The Changing Climate and Adaptation Strategies for the Mississippi Delta

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The Changing Climate and Adaptation Strategies for the Mississippi Delta

By
John Jenks

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

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ABSTRACT

The Mississippi Delta is a unique and dynamic place in Northwest/Western Mississippi that is vital to the state’s agricultural productivity. This region of the state has long been known as some of the most productive agricultural land in the entire country once the area had been cleared of thick forests and underbrush by its original settlers. However, as seasons continue to grow warmer and precipitation patterns change across the Mississippi Delta region, farmers will be forced to adapt. Agricultural practices in the Delta will be forced to undergo changes in order to ensure its productivity stays up to adequate levels of production.

Many programs have been started already that try to unify resources and provide farmers with adequate information concerning data demonstrating how the climate is changing and what adaptation strategies will be beneficial for them in the future, even strategies that are crop specific. Additionally, farmers will need to look at adaptation strategies like better irrigation practices, more flexible sowing timetables, and a possible outright switching of crops grown in a specific area.

Overall, the time to begin thinking and possibly implementing adaptation strategies is now. By planning ahead for the future, farmers will be able to save costs and be better prepared for climate change, whatever the cause of this change may be. By planning now, agricultural productivity levels will not be as affected as those farmers who do not plan for the future climate change.
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CHAPTER 1

INTRODUCTION

The Mississippi Delta is a unique region in Northwestern Mississippi that is often what people associate with the state when first thinking about Mississippi. The area began to be settled along its rivers and waterways in the early 1800s and began to be cleared of its natural thick forests to be used for agricultural activities. It is a very flat region whose economy today is heavily dependent on the agricultural productivity that occurs in the region. The area is one of the most productive agricultural sections in not only Mississippi, but in the entire country. Agriculture is a way of life in the Mississippi Delta with the agricultural sector dependent on crops such as corn, beans, cotton, and rice and recently aquaculture products such as catfish.

However, climate is changing and these changes may impact agriculture activities in the Mississippi Delta. Changing temperature and precipitation patterns are a common thread throughout the Southeast region of the United States with the Mississippi Delta being no exception. Temperatures have steadily been increasing while precipitation has decreased and seasonal patterns have changed. Both of these factors have significant impacts on crop production, crop yields, crop development, and what crops can be grown in certain areas. As a result of this, farmers in the Mississippi Delta will need to consider
adaptation strategies to help adapt to impending changes of the climate and their effects on agricultural activities.

Strategies of adaptation vary widely and need to be flexible to facilitate adjustment to the future changes. One of these adaptation strategies includes the activities of think-tanks and new networks that have an interest in climate change and its relation to agriculture. Established within research universities, government organizations, and other groups, these services share information and adaptation strategies with farmers and the public. Other strategies include breeding and modifying existing crops to be better equipped to handle future changes, establishing better agricultural and irrigation strategies, allowing for more flexible sowing dates, and looking into changing the crops that farmers grow in a particular area. All of these strategies should be considered by farmers in the Mississippi Delta.

The purpose of this thesis is to study climate changes in the Mississippi Delta along with the impacts those changes may have on agriculture in the region, and then to explore strategies for adapting agricultural practices to those changes. Studying potential climate change and its effects on agriculture in the Mississippi Delta is important for a variety of reasons. One reason is that, as stated earlier, the region is very dependent on the success of its agricultural sector for the region’s economic well-being. Moreover, the entire state of Mississippi is dependent on the success of agriculture in the region. Additionally, farmers and other interests need to understand the implications of potential climate change in the Delta. By understanding what will possibly happen in the future, farmers can be proactively ready and equipped to adapt to changes as they occur.
Discussion and implementation of adaptation strategies for climate change will help farmers maximize yields even in the face of climate change.
CHAPTER 2

BACKGROUND ON THE MISSISSIPPI DELTA

The Mississippi Delta is a region in northwest/west central Mississippi that is bounded by the Chickasaw Bluffs (Memphis) to the North, the bluffs/hill country to the East, the Yazoo River to the South/Southeast, and the Mississippi River to the West. While it is known as the Mississippi Delta, a more proper name would be the Yazoo-Mississippi Delta.

Figure 2.1. Map of Mississippi with the Mississippi Delta region highlighted (Oil-Electric)
The Mississippi Delta region is a largely rural area of land encompassing much of the western part of the state of Mississippi. The Delta region is not only considered one of the poorest regions of Mississippi, but is often considered one of the poorest regions of the nation. However, the Mississippi Delta is known for some of the finest land in the United States for farming. Today, “The Mississippi Delta is one of the largest contiguous agricultural areas in the United States with an area of more than 4 million acres” (Snipes, et. al. 2005).

HISTORY

Ever since settlement of the Delta began in the 1830s, agriculture has been an important aspect of its economy and has heavily influenced the economic health of the region. Almost all of the Delta at the time of its settlement was thick forest with bountiful trees and underbrush full of animals, even including bears and panthers. Much of the area had to be cleared of forest to allow the land to be used for agriculture. This was mostly done with the great amount of slave labor found in the state of Mississippi, especially the Delta, and imported in from other states, whose large population greatly outnumbered those of the white population.

“Throughout the antebellum period, slaves built Mississippi. They maintained roads, constructed levees, drained swamplands, washed, cooked, cleaned, tended livestock, and worked various jobs that required skilled labor. The vast majority of slaves however, cultivated cotton and other row crops on plantations and farms” (Bond, 2003).

Before the Civil War, most plantations were located on or near rivers which had natural levies, with farmers and planters in the region relying almost solely upon cotton,
with some farming of sugar cane and rice (Cobb, 1992). Antebellum plantations were generally developed on ridges near the rivers which provided transportation of products to market. The natural process of creating banks and levees also provided protection for the plantations from spring-time flooding. Most of the acreage of the Delta was still uncultivated by the Civil War, however, and even at the end of the Civil War, most of the bottomlands behind the ridges were still covered in a heavy growth of trees, bushes and vines. In fact, following the Civil War, 90 percent of the bottomlands in Mississippi were still undeveloped, which led to the state attracting numerous people to this frontier. Tens of thousands of migrants, both black and white, were drawn to the area, and by the end of the 19th century, two-thirds of the independent farmers in the Mississippi Delta were black (Bond, 2003). The extended low price of cotton had caused many to go deeply into debt, however, and gradually they had to sell their land which brought about a dominance of white land ownership.

The biggest result of this was the development of sharecropping in the Delta. Sharecropping can be described as a farming system in which, “Arrangements [are made] wherein laborers farmed a specified acreage in exchange for a share of the crop from which the costs of carrying levels of support in the form of food, clothing, and supplies had been deducted” (Cobb, 1992). Blacks in the Delta had hoped for this system to be a springboard, of sorts, towards economic freedom in order for them to gain their own land. However, due to the Jim Crow laws and the various economic constraints placed on blacks during this time, the system was merely a way to control and suppress the black population in the Delta while allowing the mainly white landowners to exploit and control their fellow black population.
During the early 20th century in the Mississippi Delta, a series of very important events occurred. These series of events are known as the Great Migrations from the Mississippi Delta. This is a period of time in which a large number of the black population left the Delta to move to other places in the North such as Chicago, St. Louis, and other large cities. There were a variety of causes for this Great Migration. One reason can be attributed to the deterioration of economic conditions in parts of the Delta due to infestation of the boll weevil pest which destroys entire fields of cotton. Another reason can be attributed to the growing racial tensions in the Delta. As noted by the NAACP:

“During the first decades of the twentieth century, the seventeen counties lying wholly or partly in the Delta witnessed a total of sixty-six lynchings. This figure accounted for over 35 percent of the 188 confirmed/reported lynchings in the state. This seventeen-county area averaged a lynching every 5.5 months” (Cobb, 1992).

It is important to recognize that the Delta blacks were ‘safer’ than those in majority-white counties, but the mob-like lynching practices and public brutality that often included prolonged torture for the blacks being lynched helped lead to this exodus. Although racial tensions were an important catalyst for exodus, manufacturing prospects because of World War I also helped give many blacks an incentive to head north. Even though blacks from the other parts of the state came to the area to fill the voids left, they, too, soon learned of the false promises of sharecropping and left for the North.

To exacerbate the exodus, the Great Flood of 1927 occurred. This flood is considered one of the biggest, if not the biggest flood in United States history. The floods destroyed thousands of acres of cropland in the Mississippi Delta (And in many states, for that matter). The flood left a shallow lake from just north of Greenville, extending east to Greenwood, and south to the Yazoo River.
Great efforts were made by the influential plantation owners in the area to prevent blacks from being evacuated in fear that much of their labor supply would leave and not return. They went to great lengths including setting national guardsmen at relief camps on levees to prevent blacks from fleeing. The forced labor, forced incarceration, and poor treatment toward blacks at this time helped drive more to the north. Even during the 1930s, the Mississippi Delta lost nearly 7 percent of its black population (United States. National Park Service).
PHYSICAL CHARACTERISTICS

To better understand the history of the Delta, it is also very important to understand the topography and physical characteristics of the region. The Mississippi Delta is an alluvial plain. An alluvial plain can be described as, “A level or gently sloping flat or a slightly undulating land surface resulting from extensive deposition of alluvial materials by running water” (Alluvial plain). As a result of thousands of years of mineral deposits from the Mississippi and Yazoo rivers which occurred through river course changes and natural flooding, this region has some of the most fertile soil in the entire world. The Delta, as evidence in the definition above, is very flat with a gradual but steady drop in elevation the further South one travels in the area.

The area is approximately 200 miles long and 70 miles across with an area inside the boundaries of nearly 7,110 square miles. The region is extremely well noted for its vast expanses of rivers and waterways which contribute to its alluvial fields. Two of the more notable waterways include the Mississippi River on the western edge of the Delta and the Yazoo River which forms its eastern, southeastern, and southern boundaries. The Yazoo River forms at the confluence of the Yalobusha and Tallahatchie Rivers in Greenwood on the eastern edge of the Delta. The Sunflower River is also a major tributary of the Yazoo River.

The Delta has also been affected as a result of Federal government flood-protection policies which shortly followed the devastating Great Flood of 1927. This great flood was an impetus to build reservoirs, levees, dams, and other flood protection mechanisms not only in Mississippi, but across the country. Most of the notable
reservoirs that affect rivers that flow into the Delta and protect the land in the Delta include Arkabutla Lake in the very northern part of the state damned on the Coldwater River, Sardis Lake damned on the Tallahatchie River, Enid Lake damned on the Yocona River, and Grenada Lake damned on the Yalobusha River. Additionally, because of the avulsion of the Mississippi River (a change in river course) and other flood control policies such as creating ‘cut-offs’ in the river (unintentional or intentional breaches in a river’s levee to create a chute that ends up connecting the closest parts of the bend, oxbow, or crescent) lakes have been created near the Mississippi River in the Delta (Oxbow Lake). A great example of this is Lake Washington in Greenville which was a result of the U.S. Army Corps of Engineers cutting off a meander that occurred in the Mississippi River near Greenville.

DEMOGRAPHICS AND ECONOMICS

Traditionally, the counties that lie wholly in the Delta consist of Bolivar, Coahoma, Humphreys, Issaquena, Leflore, Quitman, Sharkey, Sunflower, Tunica, and Washington while the counties that partially within include Carroll, Holmes, Panola, Tallahatchie, Warren, and Yazoo. Some of the major towns in the Delta included, Greenville, which had historically been the cultural and trading hub in the Delta (Washington), Clarksdale (Coahoma), Cleveland (Leflore), Greenwood (Leflore), Indianola (Sunflower), Tunica (Tunica), and Yazoo City (Yazoo). Vicksburg (Warren), while not actually located in the alluvial plain but on bluffs that overlook the Mississippi and Yazoo Rivers, is also associated with the Delta. The region has 364,616 people according to the latest Census figures published in 2010 (U.S. Census Bureau, 2010).
Additionally, the Delta is home to a high concentration of a black population. Counties that rank nationally in percentage of black population include Holmes (78.66 percent), Humphreys (71.51 percent), and Tunica (70.51 percent), although many of these historical percentages have been higher (US Census Bureau, 2010). This region of the state also happens to be not only the poorest region in the state, but one of the poorest
regions in the entire nation. At the time of the last Census, Holmes recorded the lowest per capita income at $11,585 with Issaquena being a close second recording a per capita income at $11,810, and Sunflower ranking third in the state with a per capita income at $11,993 (US Census Bureau, 2010). There have also been some very disturbing population trends in the Delta. “Between 2000 and 2010 16 Delta counties lost between 10% and 38% of their population. Since 1940, 12 of those counties have lost between 50% of 75% of their people” (J.F., 2013). For example, the least populated county in the Delta, Issaquena, with a population of 1,406, had a population in 1860 of 7,224 slaves and 587 whites while, now, it only has 10 private farm businesses that employ a total of 99 people (J.F., 2013).

As discussed before, there were a number of reasons for the earlier Great Migration and the current exodus: A population built with a majority of slaves who lost work, worsening economic conditions, further mechanization of agriculture, and increasingly hostile economic tensions. But there must be additional reasons for people continuing to leave this region. The ongoing mechanization of agricultural practices explains some reduction in agricultural jobs in the region. A lack of economic diversity also explains it, while the manufacturing jobs that did exist in the region, like the Schwinn Bicycle plant in Greenville, left the area like this plant did in the early 1990s (Schwinn, 1991). Furthermore, the low education levels in the region leave many entrepreneurs and large businesses weary of moving skilled jobs to the area. Thus, many cities in the region, like Greenville, which has experienced a 17.4 percent drop in population since the 2000 Census, have continued to see their populations spiral downward.
Despite these negatives of the region’s economy, many influential local and state leaders have sought ways to revitalize the area by introducing new industries. For example, in 1990, the Mississippi State Legislature legalized dockside gambling with the 1990 Gambling Control Act (Mississippi Gaming Control Act, 1990). With this, Delta area cities began introducing casinos to the state and many cities, with Tunica being the most notable followed by Vicksburg and Greenville, saw some economic influx to the area to the point where Tunica became one of the biggest casino attractions in the nation behind Las Vegas and Atlantic City. Additionally, the area is home to two institutions for higher education in the state. They are Delta State University and Mississippi Valley State University.

Another new development in the Delta is the installment of the Mississippi Blues Trail by former Governor Haley Barbour. The blues, specifically Delta Blues, is a genre of music that was born in the Mississippi Delta by sharecroppers in the early 1900s. The blues was born from the sharecropper’s suffering and poverty, as many of the lyrics suggest. Many of the most famous blues musicians were born in Mississippi including Robert Johnson, Muddy Waters, B.B. King, and Albert King. Highway 61, the Mississippi River, flooding, farming, poverty, and Mississippi State Penitentiary (Parchman) located in Sunflower County, all are major themes in the blues that originated in the area. In addition to these stops of notable interest, many blues museums have been set up in the Delta like the Delta Blues Museum in Clarksdale (Blues). This has become a major tourist destination in the area.
Other than the blues, the Delta is home to many other notable people that were born and/or lived in the area including actors Jim Henson, Morgan Freeman, and James Earl Jones. Athletes such as Archie Manning, and Jerry Rice, who played at Mississippi Valley State, hail from the Delta. Writers such as Walker Percy, William Alexander Percy, and Shelby Foote once called the Delta home. The great Civil Rights activist Fannie Lou Hamer once called for social justice throughout the towns in the Mississippi Delta. Besides the aforementioned great blues musicians from the Delta, country musicians Charley Pride and Conway Twitty once lived in the Delta.

The Delta has been an iconic place for the state of Mississippi in that many of the images that people invoke on first thought of Mississippi, is that of something out of the Delta: a hot, steamy day, with rows and rows of cotton fields on sprawling plantations, small towns dotting the area with a main street where people congregate to do all their
shopping and socializing. But it also invokes the negative stereotypes of the racism which legally abounded everywhere and the extreme poverty that still exists in much of the Delta. This is why many consider it to be the most, “Southern Place on Earth” (Cobb, 1992).
CHAPTER 3
HISTORICAL PRACTICES AND CROPS

FLOODING

The Mississippi Delta has a long history of issues related to the growing practices employed by its farmers. One of these was mentioned previously is the ever persistent threat of floods that has been a major fear of farmers because of the potential ability to destroy an entire season’s crop. Prior to the Flood Protection Acts in the 1930s, which was mainly brought about because of the aforementioned 1927 Flood, seasonal flooding was a major concern. Although beneficial for farmers to replace soil nutrients lost, these floods also were often large and destructive.

There have also been very recent floods which proved to be devastatingly destructive to farmland in the Delta region. The 1973 flooding of the Mississippi was especially severe. “In 1973 that the strain of record high volume flow nearly caused failure of the Old River Control Structure, which would have allowed the Atchafalaya system to capture the main flow of the Mississippi River,” and would have come at a cost of over $600 Million in today’s dollars (Trotter, et. al., 1998). Another more recent example of devastation as a result from the Mississippi flooding is the 2011 flooding of the river in which, according to the NOAA, nearly $3-$4 Billion in damages were caused
and many of the flood records reached in 1927 were broken (NOAA, 2014). When considering flooding on the Mississippi, it is also important to consider how this affects its tributaries. As, river levels rise and the volume of the river is considerably greater, it causes a backup of the tributaries. For example, Yazoo and Sharkey Counties experienced significant flooding even though they do not lie on the Mississippi River.

**PESTS AND INSECTS**

Pests and insects have also posed many issues for farmers and crops in the Mississippi Delta. The boll weevil is perhaps the most historically notorious pest that has plagued Mississippi farmers since the early 1900s. The boll weevil is a beetle that infects cotton plants by eating the cotton boll before it matures. The pest was first found in Mississippi in 1907 and by 1915 had covered the entire state, and since then, it has caused over $13 Billion in damages nationally (Mississippi Boll Weevil Management Corporation). However, the United States Department of Agriculture (USDA) instituted the Boll Weevil Eradication Program (BWEP) in most areas and has almost completely eradicated the boll weevil.

Many other diseases and insects that are common in the Delta including: (1) a variety of corn diseases like southern corn rust, which is the development of lesions and spots on the stalk, husk, and/or leaf of corn; (2) a variety of soybean diseases and insects like stinkbugs, worms, and beetles; and (3) a variety of diseases that affect cotton (Disease Monitoring, 2014). Today, however, there are a variety of seed options that are genetically modified to combat a variety of the diseases that are common to a particular area, and there are a wide variety of chemicals that are capable to eradicating or
preventing diseases and insects in a particular area. Both of these techniques, along with crop rotation techniques, have been instrumental in raising and improving crop production in the Mississippi Delta region and has allowed for more consistent crop yields.

A recent problem that has been plaguing Mississippi farmers has been the rapid rise of damage caused by wild hogs. According to Mississippi State University Professor Bronson Strickland, “They’re eating machines — they’ll eat anything they can get their mouth on, whether it’s soybeans, peanuts, corn, watermelons, rabbits, snakes, stuff in your garbage can, you name it” (Brandon, 2014). He continues, “One pregnant sow can multiply to 40 hogs in five years, in 10 years 605, and in 20 years, 122,000,” although this is obviously not sustainable (Brandon, 2014). Even though the Delta is not as affected due to the lack of natural cover for the hogs due to the extensive clearing of land for the agriculture, there is fear that the hogs will become an even greater problem and has resulted in legislative action in Mississippi.

CROPS GROWN

As noted by MSU Cares (MSU Cares is Mississippi State University’s coordinated program between its Mississippi Agriculture and Forestry Experiment Station and Mississippi State University Extension Service):

“With deep, alluvial soils, 220 to 260 frost-free days per year, average annual soil temperatures greater than 59°F at a 20-inch depth, and annual precipitation ranging from about 45 inches in the northern Delta to 60 inches in the southern Delta, this region is agronomically very productive under proper management. In addition, its near level topography is well suited for large-scale mechanized agriculture. Major agricultural enterprises of the Mississippi Delta include cotton, soybean, rice, corn, small grain, forage, vegetables, and catfish” (Snipes, et. al. 2005).
Agriculture continues to be the major contributor to the economy of Mississippi, and the Delta is the vital core to the state’s agriculture economy, as well as the nation’s agricultural output. In fact as a percent of total harvested acres in the state of Mississippi, the Delta accounted for between 97-100% of the rice, 78-81% of the cotton, 79-85% of the soybean, 67-79% of the corn, and 77-88% of the acres of water surface used for catfish production (Snipes, et. al. 2005; Annual Report, 2008).

It is very interesting to observe trends concerning acres planted for various crops in Mississippi keeping in mind the high percentage of these crops that are planted in the state’s Delta. In 1978, corn for grain accounted for just over 100,000 acres planted in the entire state with a net production of just under 5,000,000 bushels, but by 2007, corn for grain was over 800,000 acres planted and over 127,000,000 bushels harvested (US Ag Census, 2007). In 1978, there were approximately 1.2 million acres of cotton planted with about 1.4 million bales harvested, but by 2007, there were only around 656,000 acres planted but still a net harvest of about 1.2 million bales. Soybeans have seen a steady drop, as well, dropping from about 3.6 million acres in 1978 to about 1.4 million acres planted in 2007. This drop included a drop in harvest from about 73.5 million bushels to about 54.3 million bushels (U.S. Ag Census, 2007).

Current yields vary for each crop in the Mississippi Delta: Cotton ranges from 599 lb/A to 823 lb/A, Soybean ranges from 2,096 lb/A to 2,359 lb/A, Rice is at 5,838 lb/A, and Corn ranges from 3,493 lb/A to 8,033 lb/A (Snipes, et. al., 2005). Additionally, in 2008, the Delta alone produced over $1 Billion in agricultural production mostly between the commodities of catfish, corn, cotton, rice, soybean, and wheat (Delta
AGRICULTURAL PRACTICES

There have been some recent changes in the way in which agriculture has been carried out throughout the state. Considering the irregularity and vast differences in rain distribution throughout the Delta and the entire state, irrigation has become to be more relied upon. This can also be attributed to the creation of flood control devices like the aforementioned dams, levies, and flood-control reservoirs on that have prevented the state’s rivers from providing nutrients and natural saturation to the state’s farmlands. Today, approximately 25% of the cotton, 30% of the soybean, and 64% of the corn acres in Mississippi are irrigated while all of the rice acreage in the state is irrigated, since rice is grown under a flood culture system (Snipes, et. al., 2005).

There have been some organized groups that have sought out new agricultural practices to be employed and experimented in the Delta. A great example of this is the Delta F.A.R.M. (Delta Farmers Advocating Resource Management) initiative.

They are an organization, “Of growers and landowners that strive to implement recognized agricultural practices which will conserve, restore, and enhance the environment of the Northwest Mississippi. In joining this association, growers and landowners agree to use the environmental program to access their farms and to guide them in attaining the highest possible level of land and water resource stewardship in order to ensure a more sustainable and profitable future for agriculture (Delta F.A.R.M.).”

One of their major initiatives has been a buffer initiative to help restore and maintain healthy habitats for the native species of wildlife and plants. Another important program is their program for pesticide reduction to reduce risk of environmental harm. “The additions focus on pesticide stewardship specific to the production of three
commodities, corn, rice, and soybeans,” which happen to be three of the largest commodities in the Delta (Major Projects, Delta F.A.R.M.). These are just two of the many projects this organization is working on with their millions-plus acres of cropland in the Delta.
CHAPTER 4
CLIMATE CHANGE AND AGRICULTURE

The United State Environmental Protection Agency (Climate Change, EPA) defines climate change as any change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer (EPA). Unlike many other papers that have been written in the past concerning climate change and its relations with agriculture and future agricultural practices, this paper will not discuss causation of climate change, nor will it debate the mitigation strategies agriculture can use to decrease climate change. Additionally, when in discussing climate change, this paper will aim at discerning what climate change has looked like, first on a global and national perspective, then on a regional perspective in the Delta. It is vital to understand what climate change truly means, what it has looked like, what it could look like in the future, and to understand how agricultural systems can adapt to climate changes in order to retain productive crop yields.
MEANING OF CLIMATE CHANGE

First, let’s look at the actual term ‘climate change.’ Oftentimes, climate and weather are referred interchangeably, but, although the two are related, they are in fact separate terms that have quite different and important meanings. Climate refers to, “The average course or condition of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, precipitation,” and other meteorological factors that compose of the weather (Merriam-Webster, 2014).” Weather is the actual state of what is occurring, for example, it is raining is the actual weather. Thus, climate change refers to the change of the averages of experienced temperature, wind, and precipitation, among other factors. Although not being studied and discussed until more recent history, climate change has occurred throughout Earth’s history and encompasses Earth’s periods of cooling, warming, drought, and excessive precipitation. It includes the times of vast expanses of glaciers, large, barren swaths of dry land, and the expansion of jungle and savannah even to areas that are in the Sahara Desert today. Since the first papers had been published, there have been further inquiries and studies concerning climate change and the history thereof. There have also been a number of international groups and organizations that have taken keen interest in better understanding this and they include the Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

INDICATORS OF CLIMATE CHANGE

To provide a starting point for better understanding of climate change, it is important to understand how climate change as already affected our globe. The EPA has
put out a list of 26 indicators that it feels helps to explain climate changes already occurring in the United States and across the globe. Some of these indicators, however, deal with causation of climate change and will not be discussed in this thesis.

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Table 4.1. List of 26 indicators that help to explain climate change already occurring (EPA)

One indicator that the EPA uses, and I will use in a later section concerning climate change specifically in the Mississippi Delta, is annual temperature changes. Worldwide, 2001-2010 was the warmest decade on record since thermometer-based
observations began. Global average surface temperature has risen at an average rate of 0.15°F per decade since 1901, similar to the rate of warming within the contiguous 48 states, and since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.14°F per decade (1.4°F per century) (EPA indicators, 2014).

![Figure 1. Temperatures in the Contiguous 48 States, 1901–2012](image1)

![Figure 2. Temperatures Worldwide, 1901–2012](image2)

**Figure 4.1** Temperature change since 1900 in the contiguous United States and in the world (Climate Change Indicators in the United States, Weather and Climate).

Average temperatures have risen more quickly since the late 1970s (0.36 to 0.55°F per decade) and seven of the top 10 warmest years on record for the contiguous 48
states have occurred since 1998, and 2012 was the warmest year on record (EPA Indicators, 2014). Another interesting statistic that is raised in the study of climate change is the number of record setting days and nights that have been recorded in recent decades. “Unusually hot summer days (highs) have become more common over the last few decades. The occurrence of unusually hot summer nights (lows) has increased at an even faster rate” (EPA Indicators, 2014). This trend indicates less "cooling off" at night.

Figure 4.2. Record of daily high and low temperatures in the contiguous forty eight states 1950-2000 (Climate Change Indicators, Weather and Climate).

Even though the 2000s witnessed a solar output decline resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continue to increase (EPA Indicators, 2014). What has engendered alarm among climatologists in recent years is the finding that the globe and nation have seen an increase (and somewhat rapid) increase in average temperatures in the recent few decades as demonstrated by the graph.
Climatologists warn of severe ecological, including agricultural, issues if this trend continues (Bazzaz, et. al. 2000).

When it comes to precipitation trends on both a global and national level, both the National Oceanic and Atmospheric Administration (NOAA) and the EPA report increases in average precipitation. Since 1901, global precipitation has increased at an average rate of 2.2 percent per century, while precipitation in the contiguous 48 states has increased at a rate of 5.0 percent per century (EPA indicators, 2014).

**Figure 4.3.** Precipitation record since 1900 in the contiguous United States and the world (Climate Change Indicators, Weather and Climate).
As will be noted later, the increase in precipitation has mixed results when it comes to its relation with humans, ecosystems, and even agriculture. Changes in precipitation patterns and changes in the intensity and amount of rainfall can have significant consequences when it comes to these systems.

Other factors seem to demonstrate changes to our climate. Factors like sea-temperature and sea-level change have been noted as examples that point to this change. Sea surface temperature increased over the 20th century and continues to rise. From 1901 through 2012, temperatures rose at an average rate of 0.13°F per decade and, have been higher in the past decades than at any other time reliable observations have been recorded (EPA Indicators. 2014).

![Figure 4.4. Global sea surface temperatures since 1880. The gray shaded areas indicate error ranges which have decreased substantially in later decades (Climate Change Indicators, Oceans).](image)

Scientists note that with changes in sea temperature, changes to the atmosphere, winds, and air and water circulation may affect weather patterns across the globe. This can have profound effects on agriculture as will be explained in greater detail later.
Sea level rise is especially important when looking as an indicator pointing to climate change. Specifically in the United States, “Relative sea level rose along much of the U.S. coastline between 1960 and 2012, particularly the Mid-Atlantic coast and parts of the Gulf coast, where some stations registered increases of more than 8 inches (EPA Indicators, 2014).”

**Figure 2.** Relative Sea Level Change Along U.S. Coasts, 1960–2012

**Figure 4.5.** Observed sea level changes along U.S. coasts from 1960 through 2012 (Climate Change Indicators, Oceans).

The melting of the glaciers and Arctic ice cap is a clear symptom of climate change, and the former can be related to the rise in sea levels around the globe as they melt and add water to the world’s oceans. While not contributory to sea level rise, Arctic
sea ice had its lowest extent on record in September 2012, 49 percent below the 1979-2000 average for that month, and although sea ice is usually at its lowest point in the month of September, all months have shown a general decline of ice cover (EPA Indicators, 2014).

**Figure 4.6.** Arctic sea ice extent as a sign of the warming of global average temperature (EPA Indicators, 2014).
Likewise, glaciers and snowpack around the globe have continued to see the same steady decline that the Arctic ice cap has experienced. This is a tell-tale sign for climatologists that there is no doubt some change occurring with Earth’s climate, but for different and inconclusive reasons that will not be speculated about.

**EFFECTS ON AGRICULTURE FROM CLIMATE CHANGE**

With all of these observed climate changes occurring not only in the United States, but around the globe, it is important to understand what is occurring with agriculture and agricultural practices as a result of the observed climate change to better understand climate change’s effects on agriculture in the Mississippi Delta.

Climate change has the potential to greatly influence agriculture worldwide because of agriculture’s obvious dependence on weather and climate. The fact is, there are many advantages to climate change in the terms described above, but there are also many disadvantages which could end up significantly outweighing the advantages. For example, “As temperature rises, the efficiency of photosynthesis increases to a maximum and then falls, while the rate of respiration continues to increase more or less up to the point that a plant dies. All other things being equal, the productivity of vegetation thus declines once temperature exceeds an optimum” (Turral, et. al., 2011). It appears the Northern Hemisphere will experience many advantages until it hits a maximum. According to the EPA, “The average length of the growing season in the lower 48 states has increased by about two weeks since the beginning of the 20th century. A particularly large and steady increase occurred over the last 30 years (EPA Indicators, 2014).”
Figure 4.7. Observed change in the length of the growing season averaged across the contiguous United States from 1890 to the present (Climate Change Indicators, Society and Ecosystems).

But, when it comes to positives and negatives with respect to agriculture and crop production, the results can and will be mixed and can have negative consequences outside of those consequences related to agriculture.

“Moderate warming can benefit crop and pasture yields in mid- to high-latitude regions, yet even slight warming decreases yields in seasonally dry and low-latitude regions. A longer growing season could allow farmers to diversify crops or have multiple harvests from the same plot. However, it could also limit the types of crops grown, encourage invasive species or weed growth, or increase demand for irrigation” (NOAA/EPA indicators).

Many weeds, pests and fungi thrive under warmer temperatures, wetter climates, and increased CO2 levels. Currently, farmers spend more than $11 billion per year to fight weeds in the United States and the ranges of weeds and pests are likely to expand northward. (EPA/Climate change).

Different crops will be affected in different ways. For example, this thesis looks at
the cotton crop. Cotton requires a total of 105 to 125 days of sufficient soil moisture to grow. In tropical regions, cotton requires 2 to 4 mm of water are needed daily at the beginning and the end of the growing period, while at the height of flowering 5 to 7 mm are required daily, thus 500 to 700 mm of water are sufficient for the crop to develop fully. In the subtropical climate in which Mississippi is in, cotton requires more moisture because of the drier climate conditions. The cotton plant could benefit from a moderate increase in temperatures according to most agriculturists. Much like what has been discussed, short-term effects may be positive for the cotton plant, but, “Production, particularly in the tropical regions of the world, looks set to suffer under predicted rising temperatures, decreased soil moisture and more extreme weather events and flooding (Cotton and Climate Change).” Cotton has a certain resilience to high temperatures and drought due to its vertical tap root. The crop is, however, sensitive to water availability, particularly at the height of flowering and boll formation. Rising temperatures favor plant development, unless day temperatures exceed 32°C (Ton, 2011). So, countries that are experiencing higher temperatures already could see their growing season expanded substantially, but this could also have a negative impact on the development of the cotton plant. Additionally, with increasing demand and competition for freshwater supplies, water availability may in many countries become an important factor limiting cotton production. Depending on precipitation trends in cotton producing areas, the cotton plant may be negatively, or positively, affected by the precipitation outcomes that may happen as a result of climate change.

Corn is in a similar position to cotton. “Maize yields drop significantly for every day when temperatures climb over around 32°C (90 F), and that heat stress has been as
important an influence on maize yield as variation in rainfall since the turn of the century (Marshall, 2013—Climate Change, Corn).” If this trend continues, corn could be severely negatively affected because of the days that reach above the threshold.

As noted, “One critical period in which temperatures are a major factor is the pollination stage; pollen release triggers development of fruit, grain, or fiber. Exposure to high temperatures during this period can greatly reduce crop yields and increase the risk of total crop failure. Plants exposed to high nighttime temperatures during the grain, fiber, or fruit production period experience lower productivity and reduced quality (Walthall et al. 2012).”

In other words, if the temperatures are high enough during pollination stage, overall yields of crops will be severely hampered. The same can be said for precipitation. If precipitation patterns begin to be altered so as to not come during the critical growing months, the plant’s yield and growth may be stunted.

However, another effect that could occur, and in some instances are already occurring, is that the areas in which corn (and other crops for that matter) may be expanding northward in the Northern Hemisphere.

In 2012, farmers in Kansas grew the fewest amount of acres of corn they had grown in three years, but 700 miles north in Manitoba, corn acreage had nearly doubled, part of which is a result of weather patterns becoming warmer (Bjerga, 2012—Bloomberg). According to Cargill, “They are investing in northern U.S. facilities, anticipating increased grain production in that part of the country (Bjerga, 2012—Bloomberg).” So, it is important to be reminded that although climate change impacts may be negative for one region of the country or of the world, they could likewise bring about more positive changes in terms of crop production and crop type in another part of the country or world.
Another important aspect of climate change is the effects it will have on soil content and soil’s viability for agriculture. With rising temperatures, there are a few very important effects that will happen to the soil. Increased soil respiration is one of these effects. Rising temperature increases the rate of chemical and biochemical reactions. For soil microbes and roots, that also means increasing respiration, which can release more carbon dioxide and even methane from soils. Increasing these gases from soils can contribute to existing atmospheric greenhouse gas emissions (Kleinmann, 2011). Another is the loss of carbon in the soil that the soil stores naturally. Increased decomposition means higher carbon turnover in soils, which could reduce the carbon available for growing plants. While most plants get a majority of their carbon through photosynthesis, soil carbon is important for plant growth and maintenance. Soil carbon helps soils retain water and important nutrients, as well as serves as an energy source for decomposing organisms, and increased decomposition rates can lower carbon stored as organic matter, which is an important source of carbon for biomass production (Kleinman, 2011).

Higher rates of nitrogen mineralization is another possible outcome as a result of the changing climate. Increased temperature can increase nitrogen availability through higher turnover of soil nitrogen. In many North American ecosystems, increasing N availability can help increase carbon sequestration by encouraging higher rates of plant growth (Melillo et al. 1993). However, in areas where excess nitrogen is a major concern, such as Southern California, the Rocky Mountains, or the eastern United States, this priming effect could increase N losses from ecosystems. Such losses would create other ecological problems in these ecosystems, such as eutrophication in nearby streams or lower pH in soils (Kleinman, 2011).
Changes in water availability will also be an outcome in soil’s changes as a result of climate change. Since there is little agreement on what will happen in the future regarding precipitation patterns and the results of the changing precipitation patterns. The changes may result in more rain but at shifting seasons while others argue prolonged and more periods of droughts. However, it is important to consider the changes that will happen to the soil. Increased erosion risk is a risk as a result of climate change:

Increased erosion risk stems from two potential precipitation changes. Heavier rainfall events can increase runoff and erosion due to the limited ability of soils to absorb and retain water. Prolonged droughts may decrease plant cover, making it harder to retain soils and organic materials during heavy rainfalls or windstorms. Large-scale erosion events can lead to unintentional landscape conversions and the loss of stored carbon in many areas as well as inhibiting plant productivity (Kleinman, 2011).

Nutrient loss is another risk as a result of climate change.

The topsoil and organic layer of soils contain most of the nutrients needed to help sustain plant growth. Nutrients can be lost from increased erosion or from changes in aridity. Increased aridity can inhibit surface decomposition and nutrient cycling, decreasing plant productivity. Increased erosion during heavy rainfalls can also quickly deplete soil organic material (Nearing et al. 2004).

The content of the soil is vital, obviously, for the productivity and success of growing all crops. With the changing content of soil, farmers may be forced to abandon traditional and prevailing agricultural practices. If certain crops become unproductive in a certain area, farmers may be compelled to either switch the crops they are growing to those that are more conducive to the certain kind of soil that has developed in that particular area as a result of the changing climate. Farmers may also be compelled to use more fertilizers and chemicals to offset the changes of the soil’s climate. Another option could be to modify seeds that are used to combat the changes to the soil’s content. Water consumption could also be affected as farmers may have to be more concerned with how
their consumption affects their soil’s water content. In all, climate change’s effects on the content of our agriculture land’s soil should be strongly considered and studied to better understand what will happen to the soil content.
CHAPTER 5
CLIMATE CHANGE IN THE MISSISSIPPI DELTA

In order to assess the climate change in the Delta, I utilized data compiled by The Southern Regional Climate Center (SRCC) based out of Louisiana State University (LSU) in Baton Rouge, LA. These data consist of historically observed temperature and precipitation data for areas all across the Southern Region of the United States consisting of the states of Mississippi, Tennessee, Arkansas, Oklahoma, Texas, and Louisiana. Within the state of Mississippi, the SRCC disaggregated the Delta into two distinct regions, Upper Delta and Lower Delta. The Upper Delta consists of counties north of a Washington to Sunflower County line while the Lower Delta has been identified as all Delta counties south to Vicksburg and the Yazoo River. Upper Delta reporting stations used by the SRCC are located in Charleston in Tallahatchie County, Clarksdale in Coahoma County, Cleveland in Bolivar County, Lambert in Quitman County, and Tunica in Tunica County. The Lower Delta reporting stations include Belzoni in Humphreys County, Greenville in Washington County, Minter City in Leflore County, Moorhead in Sunflower County, Rolling Fork in Sharkey County, Stoneville in Washington County, and Yazoo City in Yazoo County.
For this analysis of the data, I will keep with their divisions of the Delta. I will be examining temperature and precipitation trends for the two areas defined. By compiling the averages from all reporting stations located in the Delta regions, the researchers at the SRCC have been able to compute temperature and precipitation averages for both regions of the Delta and have developed easily readable graphs and figures that demonstrate the trends occurring in the Upper and Lower Delta regions. While the SRCC records extend back to 1900, I have chosen to look at the years 1950 to the present. The reason for this is that it allows for an ample sampling of climate changes experienced in the Delta because during this time period, there began to be a steady drop in temperatures while eventually temperatures began to rise as they are currently doing today. This time period also gives ample observation of precipitation patterns in the Delta. This allows for a better sampling for the reader to better understand what the changes in the climate of the Delta have been and for the reader to better understand that there have been many and different kinds of changes in the Delta in the past. It is important to understand that changes in the climate do not only include warming periods, but there have been time periods of a certain level of cooling in the Mississippi Delta region. Thus, looking at this other changing period of cooling, there is a lesser degree of biasness in the data sampling.

It is important to look at seasonal trends in temperature and precipitation to see changes that have developed within each season rather than just the overall annual aggregate of averages. For each season, I have divided them up into the quarterly months that follow: Winter has been defined as the month of January, Spring as the month of April, Summer as the month of July, and Fall as the month of October. I have chosen these months as they coincide with the middle month of each meteorological season. The
following will be a breakdown of each month’s temperature and precipitation trends.

UPPER DELTA

For the Upper Delta Region, from the period of 1950 to 1980, there was a steady decrease in average annual temperature. But, post 1980, there has been a steady increase in temperatures to temperatures rising nearly 3.8 degrees Fahrenheit greater than 1980 levels. Notably, since 1985, the frequency of above average months to the present in terms of temperature has grown as well. Annual precipitation patterns have fluctuated during this 1950 to the present time frame. Data indicate that there has been a growing frequency of above average precipitation years, as what will be discussed shortly, the patterns and frequency of precipitation appear to be shifting for the Upper Delta region.

For the Upper Delta region, January temperature trends generally declined from the time period 1950 to right before 1980. In 1955, the long-run average of January temperatures hovered at about 41.9 degrees Fahrenheit, but by 1975, the long run average of January temperatures had dropped to about 39.5 degrees Fahrenheit. But, by 2014, the long run average of January temperatures had risen substantially to approximately 43 degrees Fahrenheit. The month of April has been a bit more consistent for the Upper Delta region with temperatures hovering fairly constant with temperatures hitting a minimum of 62.6 degrees Fahrenheit in 1984 but rebound to 63.5 degrees Fahrenheit by the year 2013 with the frequency of warmer periods growing in the last decade. July seems to be an anomaly when it comes to temperature changes in the Upper Delta region as temperatures have seen very little fluctuation in temperatures with staying very close
to the norm of 81.6 degrees Fahrenheit. However in looking at months like August and September, there are major changes to what has been observed since 1950. The 1970s saw the coolest long run average temperatures for the months of August and September for the Upper Delta, but since then, temperatures have risen at least 2 degrees Fahrenheit with the frequency of warmer stretches being more common for this region, as well. For October, after experiencing a steady decrease in temperatures after 1950, from 1972 to 2013, long run average temperatures for the month have seen an increase of about 1.2 degrees Fahrenheit.

The results of precipitation changes for the Upper Delta since 1950 are quite interesting, as well. Generally, the trend has been for greater precipitation in the non-growing months and harvest months of the Fall and Winter with a decline in precipitation in the planting and growing months of the Spring and Summer. This is in line with what most climatologists have noticed in the Southeastern United States in that there is a general decline in precipitation when the need is most. In the Upper Delta, long run average January precipitation had a steady decrease to 4.38 inches in 1981 but has risen to nearly 5.1 inches in the present. Long run average April precipitation has been on a general decline from 1970 declining to just 5 inches of precipitation, whereas prior to this drop, however, long run average precipitation slightly, but consistently risen. July long run average precipitation patterns are on a decline as well. After reaching a maximum in the 1960s, there has been a slow, but steady decrease in observed long run average precipitation trends.

A more troubling month, however, is the month of June which is a critical month for the health and productivity of crops and which I highlight because of the anomaly it
had with the other data and trends. After hitting a maximum in 1982 of 4.49 inches of precipitation, long run average precipitation trends have fallen quickly by over an inch in the present. Long run average October precipitation patterns have shown a large increase, growing nearly 2.5 inches on the average from the 1950s. These findings are in line with what has been previously reported in that precipitation changes are affecting the seasons in the Southeast and could bring about major agricultural challenges in the future.

See Appendix 1 to see the temperature and precipitation trends for the Upper Delta region.

**LOWER DELTA**

The same information has been aggregated by the SRCC for the Lower Delta region of the Mississippi Delta. Much like that of the Upper Delta, there has been a general trend in the increase of temperatures in this sector while there has been a shifting of precipitation patterns in this sector.

For the long run average annual temperature, there had been a general decrease in long run average temperatures until the beginning of the 1980s which saw a gradual increase of temperatures for the present with the occurrence of above average years more common since the turn of the 20th century until the present. For the month of January the long run average annual temperature in the Lower Delta was 42.1 degrees Fahrenheit but saw a rapid warming period by the 1980s which warmed temperatures by about 4 degrees Fahrenheit to the present. The month of April experienced little relative change to long run average temperatures in the Lower Delta until, like January, the 1980s where from until then to the present, long run average temperatures have grown by nearly a 1.5
degrees Fahrenheit. Much like July for the Upper Delta region, the long run average temperatures for the month of July have been relatively consistent with only a slight increase, but in looking at the months of June, August, and September, the change has been much more substantial with over at least a 1.5 degree Fahrenheit change since 1980 with August experiencing the largest increase. October, too, has experienced an increase in the long run average temperature rising from a 64 degree Fahrenheit average in 1972 to just over a 65 degree Fahrenheit average in the present.

Long run average precipitation trends in January for the Lower Delta have held fairly constant since 1950 at about 5 inches of precipitation. For the month of April, however, long run average precipitation has fallen by over an inch since the mid-1970s and there has been an even steeper drop in long run average precipitation for the months of March and June. Long run average precipitation for July has held fairly constant at about 4.3 inches of precipitation while long run average precipitation for the month of October in the Lower Delta region has grown over 2 inches of precipitation since the 1950s.

See Appendix 2 to see temperature and precipitation trends shown in graphs.

EFFECTS ON AGRICULTURE IN THE DELTA FROM CLIMATE CHANGE

In light of these findings about the changes to the climate that are apparent in the Mississippi Delta, it is important to consider how this will affect the agricultural systems in the Mississippi Delta. As noted in the paper earlier, low levels of warming can have a positive impact on crop performance, however, with higher the levels of warming, crops become less receptive and become more negatively affected. Just as discussed earlier,
“Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control (Karl, et. al., 2009).” Additionally, extreme precipitation events ranging from downpours and heavy precipitation events to droughts puts added stress on crops and significantly hampers crop productivity. Likewise, the changing climate in the Mississippi Delta as evidenced above will put added stress on the region’s livestock and aquaculture.

As temperatures continue to rise in the region, especially if the rise includes nighttime temperatures, yields and crop productivity decline because of the added stress from the heat and the lack of a ‘cooling off’ period for the crops at night.

In fact, “The grain-filling period (the time when the seed grows and matures) of wheat and other small grains shortens dramatically with rising temperatures. Analysis of crop responses suggests that even moderate increases in temperature will decrease yields of corn, wheat, sorghum, bean, rice, cotton, and peanut crops (Karl, et. al., 2009).”

It should be noted that many of these crops just listed, notably corn, beans, rice, and cotton, are all major cash crops in the Mississippi Delta.

However, it is important to note that with warmer conditions, the growing season for most crops is longer so, this will give farmers more flexibility in when to plant their crops in order to optimize their use in light of the evolving precipitation patterns that are transpiring in the Mississippi Delta region.

Taking into account precipitation patterns in the Mississippi Delta and extreme weather events in the region, the apparent inconsistency of precipitation patterns in the region will drive crop yields to become more volatile than the present. Examples of this in the Mississippi Delta are the devastating floods that have occurred in the past the 2011
Mississippi Flood. Although heavy rains elsewhere helped to contribute to the flooding in the area, local heavy rains played a major part, too. At any rate, extreme flooding along the Mississippi and many of its tributaries in the Delta caused widespread devastation of crops in the area as the floods hit during the main planting months in the region for its big commodities like corn, beans, and cotton. Not only did this destroy many crops, but also left fields heavily damaged by runoff and erosion which prohibited some farmers from getting a good crop in for the year.

When looking at the trends for farmers in the Delta and precipitation patterns, it should alarm some that precipitation has generally declined in the last few decades during times in which it is needed, namely, the spring and summer months, and has increased in months in which it is not desirable, namely the harvest months. “Heavy downpours that wet conditions at harvest time result in reduced quality of many crops. Storms with heavy rainfall often are accompanied by wind gusts, and both strong winds and rain can flatten crops, causing significant damage (Karl, et. al., 2009).” As a result, if the trend was to continue, yields from crops would take a hit.

As these trends continue in the Mississippi Delta, there will be an added importance on controlling weed and pests in the region. Because weeds thrive, and can generally respond to heat better than cash crops, weeds will become more of an issue in the Mississippi Delta as average annual temperatures continue to rise. Not only this, but added fears that invasive weed species will creep north as temperatures continue to rise should be cause for concern to farmers in the Delta. Because many weeds associated with warm season crops originate in tropical or warm temperature areas, northward expansion of these weeds may accelerate with warming (Walthall, et. al., 2012). With warmer
annual temperatures in the Delta, not only in growing months, but also in the winter
months, pests and plant diseases are able to thrive even more for two reasons. One, these
pests and diseases tend to thrive under hotter conditions, and two, some of these pests and
diseases will not die off as they had traditionally done in the winter and thus will be able
to spread and multiply at rates that had not normally been seen. As is evident, the number
of freezing days in the Delta has decreased by nearly 20 days from 1976 to 2007 (Karl,
et. al. 2009). “Increased temperature decreases efficacy of plant antiviral resistance
mechanisms based on gene silencing, a process by which a plant gene is “turned off” so
that it does not respond to the presence of a virus (Walthall, et. al., 2012).” If the current
rate of temperature increase in the Delta continues to hold steady, plant diseases will
ultimately cause many issues and hardships for farmers in the Mississippi Delta. Plant
diseases will thrive as a result of warmer, more humid conditions.

The trends of precipitation and temperature in the Mississippi Delta should also
be cause for alarm to water-interests in the region. This not only includes catfish growers
in the Delta region, but also farmers who rely on irrigation systems for their crops.
Catfish interest should be concerned with the trend in temperatures and precipitation for a
couple of reasons. One reason is that rising temperatures will lead to warmer pond
temperatures which can lead to an increase in the growth of algae, but also put added
stress on the fish because of the rising temperature of the water. Additionally, as pests
and diseases begin to thrive under these new favorable conditions for them, farmers could
be even forced to spray more to combat the pests, diseases, and insects.

“Due to the increased presence of pests, spraying is already much more common
in warmer areas than in cooler areas. For example, Florida sweet corn growers
spray their fields 15 to 32 times a year to fight pests such as corn borer and corn
earworm, while New York farmers average zero to five times (Klein, et. al.,
This goes true for the Delta. With increased spraying comes the runoff and infiltration of these pesticides and insecticides into the water supply which could put the catfish in ponds at risk.
CHAPTER 6
ADAPTATION STRATEGIES

As the EPA states, “Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects has occurred for thousands of years” (EPA Adaptation Overview, 2014). The thought for the need to emphasize adaptation strategies and calls for adapting not only agriculture, but many of our daily routines and economies to the threats that climate change bring, as described above, is not something new. Farmers have been adapting to climate change in different ways in the past, for example, by changing their growing strategies and changing or rotating the crops they grow.

As noted by Joyce, et. al.:

“The overall effectiveness of adaptation to climate change rests on four major considerations (Adger and Barnett 2009; Stafford Smith et al. 2011). First is the window of opportunity available for development and implementation of adaptation strategies. In some cases, this window might be smaller than previously assumed, based on the rate of climate change and the potential occurrence of thresholds in the climate system (Lenton et al. 2008). Second, the development of adaptation strategies, regardless of their potential effectiveness, is dependent upon sufficient financial and political capital to implement them in a timely and meaningful manner. Third, many current adaptations are unsustainable or maladaptive, and their limited effectiveness can slow the development and implementation of subsequent adaptations. Fourth, metrics of adaptation success are inherently more ambiguous than those for mitigation because they do not have a specific, measurable benchmark such as GHG emissions, and will vary with values and interests of various stakeholder groups” (Joyce, 2013).

In the quest for adaptation, many states have already instituted adaptation
programs or policy makers have already recommended adaptation plans or strategies that should be explored by the state. States like Alaska, Arizona, North Carolina, South Carolina, and Iowa to name a few have enacted or developed climate change adaptation task forces and groups to examine how their respective states will need to adapt to the challenges climate change will bring about in the future.

When it comes to planning adaptation strategies for agriculture in the Mississippi Delta, there are different typologies that have been used elsewhere that could prove to be beneficial to farmers in the Delta to employ when attempting to combat some of the issues climate change will bring to the region as demonstrated above. “While some economists suggest that much adaptation will occur spontaneously through marginal adjustments in markets and individual behavior, there are good reasons for public policy intervention,” and may bring about better, more efficient results if these adaptation strategies are adapted in a more centrally-planned system (Thompkins, et. al., 2010). Although many people have cited the need for letting the markets dictate the adaptation strategies for agriculture and other industries, there is a good chance that this could bring about uneven, inefficient results and adaptations that may not do enough to positively outweigh the potential consequences of such climate change. The main adaptation strategies in the agricultural sector include crop diversification and switching, changes in planting and harvesting seasons, adoption of irrigation practices, use of soil conservation techniques, and genetic breeding (Cunha, et. al, 2014). Whatever the case may be however, adaptation plans must have, “Risk and vulnerability assessments, prioritization of projects, funding and allocation of both financial and human resources, solution development and implementation, and rapid deployment of information sharing and
decision-support tools” (Cruce, 2009).

The United States government has begun trying to adopt a more efficient, centrally-planned adaptation strategy in the establishment of seven climate “hubs” throughout the country (Spross, 2014).

“The centers will look into climate forecasting and data, risk assessment, and how to adapt farming and livestock practices to climate change and new forms of extreme weather. They’ll also serve as an information and coordination hub for their particular region, linking farmers and ranchers up with universities, government agencies, scientific research centers, and other groups in an effort to spread the best farming practices and the best climate adaptation strategies” (Spross, 2014).

Following completion of the draft Climate Change Adaptation Plan, “Each EPA National Environmental Program Office, all 10 Regional Offices, and several National Support Offices developed a Climate Adaptation Implementation Plan to provide more detail on how it will carry out the work called for in the agency-wide plan” (Draft of Plan, 2013). These regional climate hubs will be divided into the Northeast Region, the Southeast Region (Which will include Mississippi), the Midwest Region, the Southwest Region, the Northern Plains Region, and the Northwest Region and all of these regions will have hubs and sub-hubs at various major agricultural colleges located within the certain region (Webinar, 2014). For example, the Southeast’s hub will be at North Carolina State University and its sub-hub will be located in Puerto Rico (Webinar, 2013).

As stated by the Southeast Regional Climate Hub, they will work with the various meteorological and agricultural colleges in the Mississippi which include Mississippi State University, Jackson State University, and Alcorn State University (SERCH, 2014). Specifically the aim of the southeastern hub is to, “SERCH will also provide periodic regional assessments of risk and vulnerability to contribute to the National Climate
Assessment and deliver and interpret regional climate change forecasts for hazard and adaptation planning” (SERCH, 2014). This kind of central planning and consolidation of resources will prove incredibly valuable in the fight for adapting agricultural strategies to the challenges that climate change will bring in the future to our agriculture.

With this sort of policy framework established, it is important to look at actual adaptation strategies that have already been employed and tried. Increased innovation will continue to be a priority when it comes to adaptation strategies for agriculture.

“Adaptation strategies currently used by U.S. farmers to cope with weather and climate changes include changing selection of crops, the timing of field operations, and the increasing use of pesticides to control increased pressure from pests” (NCA, 2014). One ever-growing source of adaptation is in the form of diversifying, rotating, and/or out-right changing of crops and livestock grown and raised in a specific area.

The EPA identifies this source of adaptation: “Federal agencies can modify support and subsidy programs to encourage the planting of more diverse sets of crops or the adoption of innovative agricultural practices in areas where yields are threatened” (http://www.epa.gov/climatechange/impacts-adaptation/agriculture-adaptation.html). Similarly, cultivars are now being developed that tolerate excessive heat during pollination for cowpea and corn and flooding early in the growing season for soybean and rice. Maize hybrids are also being developed that show better synchronization of pollination and flowering under heat and water stress (Bijil, Fisher, 2011). This goes hand in hand with what we have already seen in that there have been adaptation strategies in this sector of genetically modifying seeds for almost all crops to become more drought resistant, heat resistant, and pest and disease resistant, not just maize, or corn as was
described in the quote above. These have proven to be very successful in fighting these issues where these problems have been very detrimental to the growth of crops and their yields. By introducing beneficial traits in existing crops and engineering better seeds, we can adapt our seeds and crops to be better equipped in fighting some of the results of climate change.

Where there are areas of expected warming trends, crops more ideal for the certain temperature thresholds that will be expected can begin to be introduced to that region. As was discussed earlier, the example of the corn belt shifting north is just one instance of farmers being forced to switch what crops are grown in a particular area. The same can be said of other areas and even of other crops. In Kenya, for example, According to the International Food Policy Research Institute (IFPRI), “Kenyan farmers and agriculture officials need to prepare for a possible geographic shift in maize production as climate change threatens to make some areas of the country much less productive for cultivation while simultaneously making others more maize-friendly” (IFPRI, 2013). The report continued on stating, “As long as we offer farmers the right services and policies now, and more options in what they grow and where they grow it, Kenya can make a major transformation in its ability to cope with the changing climate” (IFPRI, 2013).

Thus with this shifting of climate zones and different capabilities evolving for the capabilities for growing new crops, farmers, agribusiness think-tanks, and government entities should be actively educating those in the agricultural sector as to what crops may be viable in the face of climate change. Looking as to what other crops may become viable in certain areas for two different reasons. One reason is that, as stated, crops that
were once viable in a region may become less viable or completely unable to be grown all together in a particular region. If there is little preparation among those that will be affected, not only will the agricultural sectors be severely impacted, but entire economies could see a near or complete collapse, especially in areas that are heavily reliant on agriculture activities like the Mississippi Delta region.

Another reason that growing different crops should be considered as a result of the climate changing is that most agribusiness experts stress the importance of crop diversity in the face of climate change. There are many experts who believe that in order to buffer crop production from the effects of greater climate variability and extreme events, variety diversification is the most rational and cost effective method (Zivanomoyo and Mukarati). Differing crop varieties can maintain and possibly even improve crop yields in the face of climate change by them inducing a natural barrier between pests, bugs, and diseases. There are also calls to develop new crop varieties all together which often requires breeding of current annual crops with their perennial counterparts; ultimately, the hope is that this would allow for the crops to become more tolerant to the changes that are coming to the climate and to allow for pollination to occur at more optimal times (Bijil and Fisher, 2011).

Another adaptation tool for agriculture that should be further considered is the use of better irrigation and water-saving techniques. The need for more efficient and reliable irrigation strategies is vital in the fight for adaptations to climate change because in the wake of climate change, agriculture interests will need reliable irrigation systems to combat the irregularity and possible sporadic precipitation patterns that may develop as a result of the impending climate change. Thirty eight states in the United States have
passed some type of drought-combating legislation to prepare for droughts and irregularities in precipitation patterns in the future (Cruce, 2009). By adapting better irrigation practices, farmers can reduce the risk of crops being negatively affected as a result of insufficient, infrequent, or unreliable rainfall patterns. Although plants ultimately have a finite heat tolerance and thus better irrigation strategies are only part of the solution and only work given adequate heat conditions, better irrigation strategies coupled with crop breeding and other adaptive strategies can be a sufficient adaptation strategy.

There are many successful examples of newly implemented water-saving irrigation strategies that have been recently developed and studied. The least efficient irrigation strategy that has become to be implemented out is the furrow irrigation strategy. Furrows are small, parallel channels, made to carry water in order to irrigate the crop (Figure 6.2). The crop is usually grown on the ridges between the furrows and is suitable for many crops, especially crops that are sensitive to water covering their crown or stem and may subsequently develop diseases that come from the water continuing to saturate the crop (Furrow). Some crops that almost always need to be irrigated in this manner are tree crops like citrus trees, grapes, and tomatoes to name a few. However, there are crops that have historically used this irrigation method that may be just as productive using other irrigation methods.
Techniques such as sprinkler (Figure 6.3) and drip irrigation (Figure 6.4) systems are more efficient than furrow irrigation (Shock, et. al., 2013). In fact, crops that are irrigated using the furrow method often receive significantly more water than they need. The sprinkler irrigation system involves large pipes that receive water which are attached to wheels that can be slowly moved, or pivoted around a central fixture, throughout the field to irrigate the crops. This technique uses much less water than the furrow or surface irrigation (Which involves the flooding of fields to saturate the ground) techniques and is generally considered very efficient at irrigating the crops evenly and efficiently. Despite this, there are some concerns that these irrigation systems are rapidly leading to the decline of aquifers and underground water like the Ogallala Aquifer in the Great Plains of the United States.
The other efficient irrigation strategy that is being promoted as a water-saving irrigation strategy and one that efficiently saturates the ground is the drip irrigation strategy. This strategy is done by laying pipes or tubes directly on the soil or just above the soil. These pipes or tubes allow water to trickle out close to the root of the plant and is widely considered to be very efficient in uniformly applying water to the crops. Drip irrigation can save a lot of water, in many cases 30 percent to more than half of the amount used for furrow irrigation (Shock, et. al., 2013). Most notably for the Mississippi Delta, there has been great success with this type of irrigation strategy for staple crops in the Delta such as corn and cotton. With both of these systems, it is vital that the equipment and machinery be maintained and updated to ensure the optimal amount of discharge of water and the systems’ efficiency.
The Extension Office at Oregon State University identifies that irrigation strategies should also take into account scheduling of irrigation to optimize watering. The soil’s water content and evaporation of the water must be taken into account so as to not over water and to not waste the valuable commodity. Better and more soil monitoring equipment should be a priority when considering how agriculture will be affected as a result of climate change (Shock, et. al., 2013). Obviously, proper irrigation scheduling saves water and optimizes crop productivity. The Extension Office of Colorado State University identifies seven advantages of proper irrigation scheduling:

1. It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields.
2. It reduces the farmer's cost of water and labor through fewer irrigations, thereby making maximum use of soil moisture storage.
3. It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum.

Figure 6.4. Drip irrigation (Marquette).
4. It increases net returns by increasing crop yields and crop quality.

5. It minimizes water-logging problems by reducing the drainage requirements.

6. It assists in controlling root zone salinity problems through controlled leaching.

7. It results in additional returns by using the "saved" water to irrigate non-cash Crops that otherwise would not be irrigated during water-short periods.

Source: Colorado State University Extension Office

Proper irrigation strategies will be of critical importance when it comes to adapting to the changes that climate change will bring. Although the success of crops ultimately depends upon heat thresholds of the crop and thus, genetic breeding for more heat resistant crops or all out switching of crops grown in a particular area will be the only option in many cases, irrigation strategies will be of vital importance in the quest for adaptations to impending climate change. With proper strategies and the benefits that come about as described above, crops can maintain their productivity and output.
CHAPTER 7

MISSISSIPPI DELTA-SPECIFIC STRATEGIES AND RECOMMENDATIONS

Considering the strategies and actions that have been outlined above, it is time to look at what strategies should be considered for the Mississippi Delta taking into account the potential changes to the climate for the region. One of the more interesting policies that policy makers and farmers in the Mississippi Delta should study and possibly mimic is the ‘Climate Hub’ strategy that the United States government has set up on a national level. A model like this could be a beneficial step for the entire state of Mississippi. Much like that on the national level, the government of Mississippi, Mississippi State University, Alcorn State University, and Jackson State University can team up their resources to set up a climate-hub for the state, of sorts, and also have a Delta-specific region and focus as part of the program.

With this newly initiated program, farmers would have a point of access to monitor the changes that are occurring with the climate and its effects with agriculture, especially in the Mississippi Delta. The joint program can further research within the state about new agricultural techniques to adapt to climate change and pool resources to better understand the changes that are occurring. Furthering education about climate change and adaptation strategies to farmers in the Delta is of vital importance to not only the farmers themselves, but to the overall economic well-being of the state of Mississippi due to the large economic impact that farming has in the state of Mississippi.
Furthermore, with this program, farmers would be able to share observations, personal adaptation strategies, and other tips and information that may prove valuable to other farmers within the Delta.

The infrastructure for this sort of program is already in place within the state and the Delta in the form of the various extension offices in most counties throughout the Delta. These extension offices would be the contact point for farmers in the various counties and would be able to provide resources for those interested. Additionally, the various research stations, like the Stoneville research station that Mississippi State University has in Stoneville, MS (Washington County) will serve, and already do in cases, as a research station for trying out new adaptation techniques and the new breeds of crops that have been developed. All this initiative would need is cooperation among the state’s schools of higher education, minimal amount of government funding, and willing participants, namely the farmers. This program would highlight the importance to farmers in the Delta that there is a need to adapt to climate change and that resources need to be pooled together in order to have an easy transition while implementing the various adaptation strategies that have been developed and researched.

Going in hand with this initiative, the Delta F.A.R.M. initiative can be incorporated, or at the minimum work with this newly set up climate change adaptation program. The Delta F.A.R.M. program already has a goal and mission for responsible farming and concerns for the environment, so by incorporating this kind of program, the new adaptation techniques can be tried out.

Furthering the calls for what needs to be done, further research should be done on new breeds of crops that will be more heat and drought resistant. Whether via
government incentives or research dollars being granted, there is an absolute necessity to find a more resistant crop to what lies ahead for farmers in the Mississippi Delta. As noted by a state senator in North Dakota, “Biotechnology has changed all that. Just as Olympic pole vaulters soar over heights that high jumpers won’t ever reach, biotechnology lets 21st-century researchers leap over daunting challenges in ways that their predecessors barely could have imagined (CropLife).” North Dakota State also has found, “Early results indicated that drought-tolerant corn could potentially improve yields by 8 to 22 percent (15 percent average) under drought stress” (CropLife). Much of the same findings have been found with other crops that are grown in the Delta like cotton and soybean. There are constantly new and improved breeds of crops developed, but as the state senator from North Dakota alluded to, the pace at which the research has been occurring could be too slow for adequate adaptation to climate change. Genetic modification technologies must be further utilized to ensure that farmers’ crops in the Delta will have enough toleration to the climate changes.

A similar area in which programs like these and especially the national Climate Hub program will be able to offer some assistance is in the use of satellite imagery and sensory data to get a better understanding on the changes that are occurring as a result of Earth’s changing climate. Aerial and satellite imagery can be used to monitor broad-scale patterns, such as changes in plant mortality and the spread of invasive plant species. Farmers can then use this information to make decisions about adjusting agricultural practices (EPA, 2014). The USDA and their National Agricultural Statistics Service (NASS) have already been using aerial and satellite imagery along with Geographic Information Systems (GIS) to analyze farmland and crops.
Much in the same way, these pieces of information that are collected can be looked through the lens of potential changes that are occurring to the agricultural lands as a result of the changing climate. These maps and GIS that are analyzed can give farmers information regarding changes of invasive weed species, soil conditions, and crop health. Through the analyzing of these things, farmers can receive information regarding the above factors and can make decisions in the future about irrigation strategies, sowing strategies, and the decision on exactly what crops need or should be planted to ensure high and adequate yields.

Farmers in the Delta may have to be prepared to change up their dates at which they intend on sowing due to the changing climate. If the seasonal trends are shifting, as is apparent by the data provided earlier, then farmers may be forced to be more flexible with their sowing dates. By changing sowing dates farmers can, “Offset moisture stress during the warm period, to prevent pest outbreaks, and to make best use of the length of the growing season” (Cotton and Climate Change). As was evident by the shifts in temperature and precipitation patterns in the Mississippi Delta, farmers may have to switch their growing seasons to accommodate for the shifting of rainfall and temperature patterns. If the warming trend continues in the region, as discussed, then farmers may have to begin to plant their crops earlier in the year so as to ensure adequate, optimal, precipitation for their newly planted crops. Whatever this shift may be in the future, farmers in the Mississippi Delta are going to have to be flexible with the sowing times for their crops to ensure maximum productivity because it appears that volatility, unpredictability, and the shifting of seasonal precipitation patterns will be a continuing trend with climate change in the Delta.
In considering the possibility of shifting precipitation patterns, Delta farmers can employ water conservation and soil moisture control strategies that will help ease the hardships of irregular or inadequate precipitation periods. This can be done in a number of ways. One way is through the expansion and encouragement of drip irrigation for crops. Not only is this a more effective irrigation technique than sprinklers or furrows, but it also saves water by not overwater and using unnecessary water, as described earlier. Farmers in the Delta should be encouraged to get away from using the furrow and sprinkler technique and implement the drip irrigation technologies.

Another possible tool in optimizing water usage is through the collection of rainwater and run off of water. Texas A&M’s Extension Service has already been doing research on water harvesting technologies notably for livestock. As they note, “Rainwater harvesting provides an alternative water source to livestock producers, whether large or small” (Texas A&M). Likewise, Clemson University has been doing experimental technologies for harvesting rainwater for the use with irrigation systems.

Much in the same way, the Mississippi Delta would benefit tremendously from systems like this put in place to anticipate and adapt to the changes in precipitation patterns resulting from climate change. Harvesting rainwater and encouraging the implementation of these kinds of infrastructure will help conserve water for dry and unpredictable periods of precipitation. Implementing technologies and infrastructure that will help harvest rainwater and excess water will help alleviate some of the precipitation and soil moisture concerns that will be prevalent as a result of the Earth’s climate changing.

The Delta F.A.R.M. program is already emphasizing and utilizing water
conservation strategies on the farms in the Delta that are participating in the program currently. It is important this organization continues their goal in water conservation and push for further participation and perhaps even further encouragement from the government to advocate water-saving strategies, technologies, and infrastructure in the Delta.

Overall, it should be of the utmost importance for farmers, policy makers, and other interests in the Mississippi Delta to continue to explore adaptation strategies. Some locales and states, as discussed earlier, have already enacted legislation and groundwork pieces for adapting to the challenges that climate change will bring. By instituting some of these changes now, it will save implicit and explicit costs in the future and will ultimately help ensure the livelihood of the Mississippi Delta will not become severely negatively harmed.
CHAPTER 8
SUMMARY

Agriculture is a way of life in the Mississippi Delta. It is the heart and soul of the region and its economy, and that of the entire state which is wholly dependent on agricultural success in the Delta. Without this economic engine operating at maximum capacity, the economic well-being of the entire state is at risk. The changing climate in the Mississippi Delta is a very real thing and, judging by the trends that have been experienced especially in the last 40 years, appears to becoming more of a reality as the years progress.

As has been demonstrated throughout the paper, there are at first mixed effects on agriculture as a result of climate changes. If there is a low level of warming to the climate, this may actually help crop productivity in the short run, especially in areas that are not already considered warm climate or warm growing areas. However, the more significant the warming is, as has been the case since the 1980s, the more likelihood of negative effects on crop productivity. This will happen for a variety of reasons including heat sensitivity of crops, the added stress put on crops, and the increase of pests and bugs that tend to thrive better under warmer conditions. Additionally, crops that were viable in certain areas may no longer be viable to the increase in heat. Conversely, crops that were
at one time not viable in certain areas may become viable in areas as evidenced by the corn belt creeping further and further north. Precipitation changes will also have profound impacts on agriculture in the Delta as irregularity and changing of precipitation patterns will affect the growing seasons of crops in the area.

All of these changes will force farmers to adapt to the changing climate. This will have to be done through a changing of traditional agricultural practices like changing irrigation strategies or becoming more flexible with the times at which they decide to sow. Farmers in the Delta may be forced to change what crops they plant altogether to favor crops that are more suitable for the new climate they are experiencing. Farmers will also have to make choices about the amount and types of fertilizers, pesticides, insecticides, and other chemicals they will have to use that are suitable for the changing climate and precipitation patterns. Further emphasis must be placed by local, state, and the Federal government about improving infrastructure to adapt to the changes to the climate. More research should be given to genetically modify and/or to breed crops that will be better at handling the changes to the climate that will be occurring. Without this kind of research and development, crops will be slow at adjusting and yields will be severely affected for farmers.

Although the costs at adapting to climate change seem like a lot, the costs for not adapting to climate change could be significantly more. If investment and other adaptation projects are undertaken now, it will save many costs in the future. It will also help to ensure that receipts from cash crops will not be too severely affected. The economy, especially of that of the Delta, would take a very big hit.

The time to adapt is now. Any future waiting will prove to be unwise and costly.
It is vital that governments, farmers, and policy makers work together for positive, optimal, and responsible adaptation strategies that will help future generations of farmers, Mississippians, and Americans.
APPENDIX 1

Trends in the Upper Delta

Summary of quarterly trends in temperature are below, with full size graphs on the pages that follow.
Average temperatures observed in January for the Upper Delta
Average temperatures observed in April for the Upper Delta
Average temperatures observed in July for the Upper Delta
Average temperatures observed in the month of October for the Upper Delta
Summary of quarterly trends in precipitation are below, with full size graphs on the pages that follow.
Average precipitation observed in the month of January for the Upper Delta
Average precipitation observed in the month of April for the Upper Delta
Average precipitation observed in the month of July for the Upper Delta
Average precipitation observed in the month of October for the Upper Delta
APPENDIX 2

Trends in the Lower Delta

Summary of quarterly trends in temperature are below, with full size graphs on the pages that follow.

Average Temperature – January

Average Temperature – April

Average Temperature – July

Average Temperature – October
Average temperatures observed in the month of January for the Lower Delta
Average temperatures observed in the month of April for the Lower Delta
Average temperatures observed in the month of July for the Lower Delta
Average temperatures observed in the month of October for the Lower Delta
Summary of quarterly trends in precipitation are below, with full size graphs on the pages that follow.
Average precipitation observed in the month of January for the Lower Delta
Average precipitation observed in the month of April for the Lower Delta
Average precipitation observed in the month of July for the Lower Delta
Average precipitation observed in the month of October for the Lower Delta
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