Irrigated Acreage Change and Groundwater Status in Eastern Arkansas

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Abstract

Arkansas rice, soybeans, cotton, and corn, which are mostly irrigated and predominantly produced in eastern Arkansas, are crucially important to the state's economy. However, increased production cost, lower commodity prices, and unsustainable groundwater withdrawals impose threats to sustainable farming. This study provides a comparative status of eastern Arkansas major crops acreage and groundwater over the past Census of Agriculture periods. Results indicate that rice acreage remained almost stable, but soybeans and corn gained more irrigated acres in 2017 than in preceding census years. Groundwater level decline seemed to be more severe during 2007 than in 2012 and 2017.

INTRODUCTION

Arkansas ranks first, fourth, and tenth in the United States in rice, cotton, and soybean production, respectively. Although corn production is not ranked as highly, corn has recently become a major commercial crop in Arkansas, overtaking cotton in sales value in 2012. Rice and soybeans are the state's high-valued commodities and top export products, accounting for thousands of jobs and contributing billions of dollars to the state's economy. Eastern Arkansas accounts for approximately 98% of rice, 96% of soybeans, 98% of cotton, and 96% of corn production in the state. Irrigation water is a crucial factor for the crops grown in the region, because frequent periods of drought during the growing season can cause large yield losses. Rice is the most intensively irrigated crop in the region, but corn, cotton, and soybean producers have become more reliant on irrigation over time as a means to reduce the yield uncertainty caused by frequent drought conditions during the summer months. As a result, more than 80% of harvested corn, cotton, and soybean farms are irrigated—and the trend is increasing.

Agriculture in eastern Arkansas accounts for 96% of the total water coming from the Mississippi River Valley alluvial aquifer (MRVAA) (Kresse et al., 2014). Excessive pumping has resulted in overexploitation of this groundwater resource, as evidenced by cones of depression[1] in key crop-producing areas of eastern Arkansas. Declining groundwater availability has two major implications. First, it imposes additional costs on groundwater withdrawal for irrigation—which tends to increase other input costs, eventually resulting in diminishing marginal farm profit. Second, excessive pumping of groundwater will likely jeopardize the sustainability of both farming and groundwater resources in the long run. For instance, in 2014, 7,255 Mgal/day[2] were pumped from the alluvial aquifer despite an estimated sustainable yield of 3,374.33 Mgal/day—leaving an unmet demand of 3,880.67 Mgal/day (Kresse et al., 2014). Many efforts have been implemented to conserve groundwater resources. However, the declining trend has not been improved significantly, as reported by the Arkansas Natural Resources Commission (ANRC) in 2018. For example, of the total 290 wells monitored in 2016 and 2017, 169 wells experienced a decline in the static water level (Battreal, 2018).

The main objective of this study is to evaluate harvested acreage statistics of four major irrigated crops grown in eastern Arkansas (corn, cotton, rice, and soybeans) over the past Census of Agriculture periods 1982–2017. Additionally, we illustrate changes in groundwater levels during the past three census periods and discuss some policy implications concerning crop production and groundwater sustainability in the region. We feel this information will be helpful for visualizing the strengths, weaknesses, and challenges of eastern Arkansas cropland management and groundwater sustainability. The remainder of this study is organized as follows. The Data and Methods section provides the data description and methodology used in the study. In the Results and Discussion section, we explain the comparative facts of harvested, irrigated, and non-irrigated acreage of corn, cotton, rice, and soybeans over the past eight census periods (from 1982 to 2017), as well as the groundwater status of the MRVAA in eastern Arkansas over the past three census periods (from 2007 to 2017). Finally, the study concludes with both a summary and potential policy implications of the findings.

DATA AND METHODS

The main focus of our study is the comparison of crop acreages for corn, cotton, rice, and soybeans, as well as comparisons of groundwater depth changes in eastern Arkansas over past census periods. For this purpose, we gathered eastern Arkansas county-specific crop acreage and groundwater information from two sources. We obtained corn, cotton, rice, and soybean acreage data from the United State Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Census of Agriculture (USDA NASS, 1982–2017) and groundwater information from the ANRC. The eastern Arkansas region consists of 26 counties, which are subdivided into NASS crop reporting districts:[3] District 3 (northeast Arkansas), District 6 (east central Arkansas), and District 9 (southeast Arkansas) for statistical reporting purposes. We aggregated the crop acreage data at the regional and district level, as shown in Table 1. Crop acreage information over the past census periods includes harvested, irrigated, and non-irrigated acres (in 1,000 acres) of corn, cotton, rice, and soybeans.

Groundwater status across the MRVAA in eastern Arkansas is based on the number of wells monitored by the United States Geological Survey (USGS) in each county as reported by the ANRC. We aggregated county-level changes in groundwater at both the regional level (representing all 26 counties) and the district level. Changes in groundwater are measured in feet and are reported in 1-year, 5-year, and 10-year monitoring periods (Table 2).

RESULTS AND DISCUSSION

Harvested, non-irrigated, and irrigated acreage of rice, soybeans, corn, and cotton during each census period is presented in tabular form (Table 1) and diagrammatically (Figures 1–6). Similarly, Table 2 displays groundwater level changes in 1-year, 5-year, and 10-year monitoring periods. Furthermore, diagrammatic illustrations of groundwater changes are shown in Figures 7 and 8.

Harvested, Irrigated, and Non-Irrigated Acreage of Four Major Crops

The total number of harvested crop acres in eastern Arkansas remained steady, hovering around six million acres over the past eight census years (Figure 1). However, irrigated acres in the region grew remarkably from 1.96 million in 1982 to 4.73 million in 2017 (Table 1). In census year 1982, harvested irrigated and non-irrigated acreage in eastern Arkansas accounted for 32% and 68%, respectively, with the majority of harvested irrigated crop acres dominated by rice. However, with the passage of time, producers have increasingly converted to irrigation to mitigate the negative yield effects of frequent drought periods occurring during the summer months (Vories and Evett, 2010). As a result of this advantage, reliance on irrigation grew over time and the number of harvested irrigated acres outpaced the number of non-irrigated acres during census year 1997, with the share of irrigated and non-irrigated acres being 58% and 42%, respectively. Proliferation of irrigated acres continued until the latest census year 2017, during which the number of harvested irrigated and non-irrigated acres in eastern Arkansas accounted for 4.73 million (83%) and 0.97 million (17%), respectively, of the total 5.7 million harvested acres (Table 1). This irrigated crop acreage expansion in the region has been driven mainly by marginal profit, water resource availability, and weather.

Harvested acres devoted to irrigation have changed over time for every major irrigated field crop except rice (Figure 2). Rice acres have remained fairly constant over the eight census years, hovering above or below approximately 1.3 million acres since 1982. However, irrigated soybean acres increased significantly over time since 1982, and irrigated corn acres increased significantly starting in 2007 (Figure 2). Irrigated cotton acres increased steadily from census years 1982–2002 but began to decline from census year 2007 onward (Figure 2).

Of the four major crops evaluated in the study, soybeans have seen the largest increase in irrigated acres since 1982. In the early 1980s, soybeans were primarily a non-irrigated crop—but since census year 1982, irrigated soybeans have increased significantly relative to non-irrigated soybeans, with the former surpassing the latter in census year 2002 (Figure 3). In addition, irrigated soybean acres have increased significantly in all three eastern Arkansas NASS reporting districts (Figure 4), indicating an upward trend in irrigated soybean acres throughout eastern Arkansas. A major factor for the upward trend in irrigated soybean acres is increased world demand for this crop since the early 1980s, particularly in China. Increased world demand for soybeans has increased the value of this crop relative to other irrigated field crops grown in the state.

As mentioned previously, the two crops that have experienced the largest increases in irrigated acres since the early 1980s are soybeans and corn. Figures 5 and 6 show where the most change occurred in eastern Arkansas for these respective crops. The change in soybean irrigated acres from census years 1982–2017 is presented by county in Figure 5. Figure 5 indicates that all counties in eastern Arkansas have experienced a positive increase in irrigated soybean acres since 1982. However, the counties experiencing the largest increases in irrigated soybean acres are those that border the Mississippi River (Chicot, Crittenden, Desha, Mississippi, Phillips, and St. Francis). The top 10 counties gaining irrigated soybean acres over the study period are shown in Figure 5A and are highlighted in yellow. These counties account for almost one million additional irrigated soybean acres since 1982. All of these counties produced predominantly non-irrigated soybeans in the early 1980s, but their close proximity to the Mississippi River means they have ample groundwater because of lateral flows from the river recharging the MRVAA. These counties have thus taken advantage of plentiful groundwater and have converted most of their non-irrigated soybean acres to irrigated acres over time. In other counties farther removed from the Mississippi River and where groundwater is more limiting, the rise in irrigated soybean acres has been the result of marketing decisions by producers when relative crop prices favored soybeans over other crops such as irrigated cotton and rice.

The change in corn irrigated acres from census years 1982–2017 is presented by county in Figure 6. Although irrigated acreage changes have not been as dramatic for corn as for soybeans, Figure 6 reveals that irrigated corn acres have increased for every county in eastern Arkansas since the early 1980s. The increase in irrigated corn acres in eastern Arkansas occurred in the mid-2000s as corn prices increased due to the U.S. Ethanol Mandate and significant drought occurring throughout the Corn Belt and southwest regions of the United States in 2012. Arkansas also has a significant poultry industry, and much of the corn grown in eastern Arkansas supplies this industry. Counties experiencing the largest increases in irrigated corn acres since 1982 tend to be rice-producing counties (Arkansas, Craighead, and Lonoke), cotton-producing counties (Lee and Phillips), or counties growing both rice and cotton (Desha and Jackson). These counties collectively account for 225,000 additional irrigated corn acres since census year 1982. The rise in irrigated corn acres within these counties has been largely due to substitution of rice or irrigated cotton area for irrigated corn area resulting from relative crop prices favoring corn over rice and cotton, particularly in the early to mid-2000s.

Groundwater Status

Groundwater use is extremely important for the state because groundwater irrigation is critical to agriculture—the keystone in the state economy (McGraw, Popp, and Miller, 2012). Irrigation accounts for the highest percentage of groundwater use in Arkansas (Holland, 2007), especially for rice production that requires large volumes of water during its growing season. Eastern Arkansas gets plenty of precipitation, ranging from 45 to 55 inches annually in a normal year (NOAA, 2017). However, most of this precipitation falls during post-harvest and pre-harvest periods such as winter and early spring. As a result, row crop producers in the region rely heavily on irrigation water for crop production during the summer months. Additionally, eastern Arkansas is an important waterfowl flyway, and flooded rice fields in the winter provide important habitat for ducks and geese. Around 28.8% of rice fields are flooded with groundwater from irrigation wells for migratory bird habitat following the rice harvest (Hardke, 2020). This event accounts for a certain amount of groundwater withdrawal during the period from the last week of November to the last week of January.

Average groundwater level changes across the MRVAA during the three census years within the eastern Arkansas region are presented in Table 2 and Figure 7.

This information shows groundwater depth changes in 1-year, 5-year, and 10-year monitoring periods.[4] Here, 1-year, 5-year, and 10-year monitoring periods for census year 2017 are 2016–2017, 2012–2017, and 2007–2017, respectively. On average, groundwater declined by 0.92, 1.35, and 2.41 feet in eastern Arkansas during the periods 2016–17, 2012–2017, and 2007–2017, respectively. These numbers clearly indicate that the groundwater pumping rate in the region exceeded the aquifer recharge rate (the rate of water that moves from the land surface to the aquifer—in other words, aquifer recharge is the process of replenishment of aquifer with the surface water) during those monitoring periods. The rate at which groundwater is being pumped cannot be sustained in the long run if that trend continues for several years. Groundwater decline rates seem to be slightly improved in 2017 compared to 2007, potentially due to continuous efforts and initiatives taken by producers toward irrigation efficiency enhancement and water conservation but also due to some movement in acres away from water-intensive rice to less water-intensive crops such as soybeans and corn. From Table 2 and Figure 7, we see that the greatest level of groundwater decline occurred in 2007. On average, groundwater declined by 0.44, 2.4, and 7.46 feet in eastern Arkansas in 1-year, 5-year, and 10-year monitoring periods ending in 2007, respectively.

Figure 8 shows district-level groundwater changes in a 5-year monitoring period (district cluster). Districts 6 and 9 had declines in groundwater level of 2.26 feet and 1.80 feet, respectively, during the 2012–2017 period. However, District 3 gained 0.21 feet during the same period. Note that District 6 and District 3 gained more irrigated corn and soybean acres from 1982 to 2017. Over the period of 2002–2007, more than 2 feet of groundwater decline occurred in all three districts. However, the rate of decline improved slightly during the 2007–2012 period, as shown in Figure 8. But a groundwater report produced by the ANRC indicated that water-level declines are persistent in areas where water use is highest, as evidenced by the presence of significant cones of depression in the MRVAA, especially in the Grand Prairie and in the Cache Study Area west of Crowley's Ridge (Battreal, 2018). In all three census years, groundwater withdrawal rates are higher than recharge rates, indicating that effective policy and proper action are needed to address this issue. Clark, Hart, and Gurdak (2011) reported that an approximately 216-mile area within the MRVAA showed declines of more than 100 feet of groundwater between 1927 and 2007. In Arkansas, there is no groundwater pumping limitation as imposed in some other states such as Texas and California.

The groundwater decline rate is significantly larger than the regional values reported in many counties, such as Jefferson, Monroe, Poinsett, St. Francis, and Woodruff. This overexploitation of groundwater might be attributed to inefficient irrigation management. For example, Watkins et al. (2019a, 2019b) found that irrigation water was overapplied on average by 37% when comparing water use efficiencies for 142 rice fields enrolled in the University of Arkansas Rice Research Verification Program (RRVP). That same study found that multiple-inlet rice irrigation (MIRI) and precision land grading (straight levees; zero-grade) significantly improved irrigation water efficiency on rice fields. A study conducted by Gautam, Paudel, and Guidry (2020) in Louisiana using farm-level survey data determined similar soybean irrigation efficiency to that found in Arkansas rice irrigation.

SUMMARY AND CONCLUDING REMARKS

This study highlighted the comparative overview of harvested and irrigated corn, cotton, rice, and soybean acreage in eastern Arkansas over the past eight census years (1982–2017). Additionally, it illustrated the information concerning groundwater level change across the alluvial aquifer within the region over the past three census years 2007, 2012, and 2017. The census data revealed a significant increase in irrigated acres since the early 1980s, and most of this increase was due to a switch from non-irritated to irrigated soybeans across the entire region. Most of the increase in irrigated soybean acres occurred in counties along the Mississippi River, where water is plentiful. Some of the increase in irrigated soybean acres was due to marketing decisions and favorable prices for soybeans, leading to substitution of soybean acres for rice and irrigated cotton. Irrigated corn acres also grew during the eight census periods, primarily starting in census year 2007. During this period, irrigated corn acres replaced rice and irrigated cotton acres as a direct result of marketing decisions made by producers.

Changes in groundwater levels during a 1-year, 5-year, and 10-year monitoring period across the eastern Arkansas region indicate that the groundwater pumping rate is beyond its sustainable range. Groundwater decline appeared to be less pronounced in 2017 and 2012 than in 2007 for the 5-year and 10-year periods. This relaxation in groundwater withdrawal might be partially attributed to continuous efforts made by producers toward irrigation efficiency enhancement and water conservation but also may be due to movement in acres away from water-intensive rice to less water-intensive crops such as soybeans and corn. Eastern Arkansas has tremendous potential for crop production, which contributes significantly to the state's economy. This region is unique mainly due to its ability to grow multiple crops to meet changing market conditions. However, overdependence on groundwater for irrigation has imposed a threat to the sustainability of invaluable groundwater resources. The major concern in the present context is to maintain groundwater sustainability in the region. More specifically, groundwater sustainability can be achieved by encouraging producers to implement efficient irrigation technology. In general, a combined effort from producers, the research community, and policy makers would be effective for achieving this goal.

Eastern Arkansas was the focus of this study. However, many of the findings—particularly with regard to groundwater availability, aquifer depletion, and water management—can be applied to the other regions bordering eastern Arkansas, such as northeastern Louisiana, northeastern Mississippi, and the Missouri Bootheel (Reba et al., 2017). A good follow-up to this study would be to determine if similar trends in irrigation area have also occurred over the same period in these regions.

FOOTNOTES

1. A cone of depression forms in an aquifer when groundwater is withdrawn excessively from a well. When the groundwater is pumped, the water level in the well is lowered. As the decline in groundwater level continues, water pressure around the well decreases, which results in the formation of a cone-shaped depression known as cone of depression. The shape of cone depends on many factors such as pumping rate, aquifer material, thickness of the aquifer, and so on.
2. The abbreviation "Mgal" stands for million gallons of water, which is equivalent to 3,785,412 liters. Alternatively, assuming 8.34 pounds per gallon, a million gallons is equivalent to 8,340,000 pounds.
3. Counties in District 3 (Clay, Craighead, Greene, Independence, Jackson, Lawrence, Mississippi, Poinsett, Randolph, and White), District 6 (Arkansas, Crittenden, Cross, Lee, Lonoke, Monroe, Phillips, Prairie, St. Francis, and Woodruff), and District 9 (Ashley, Chicot, Desha, Drew, Jefferson, and Lincoln).
4. For census year 2017, time periods 2016–2017, 2012–2017, and 2007–2017 represent 1-year, 5-year, and 10-year monitoring periods, respectively. For census years 2012 and 2007, similar patterns represent groundwater monitoring periods.

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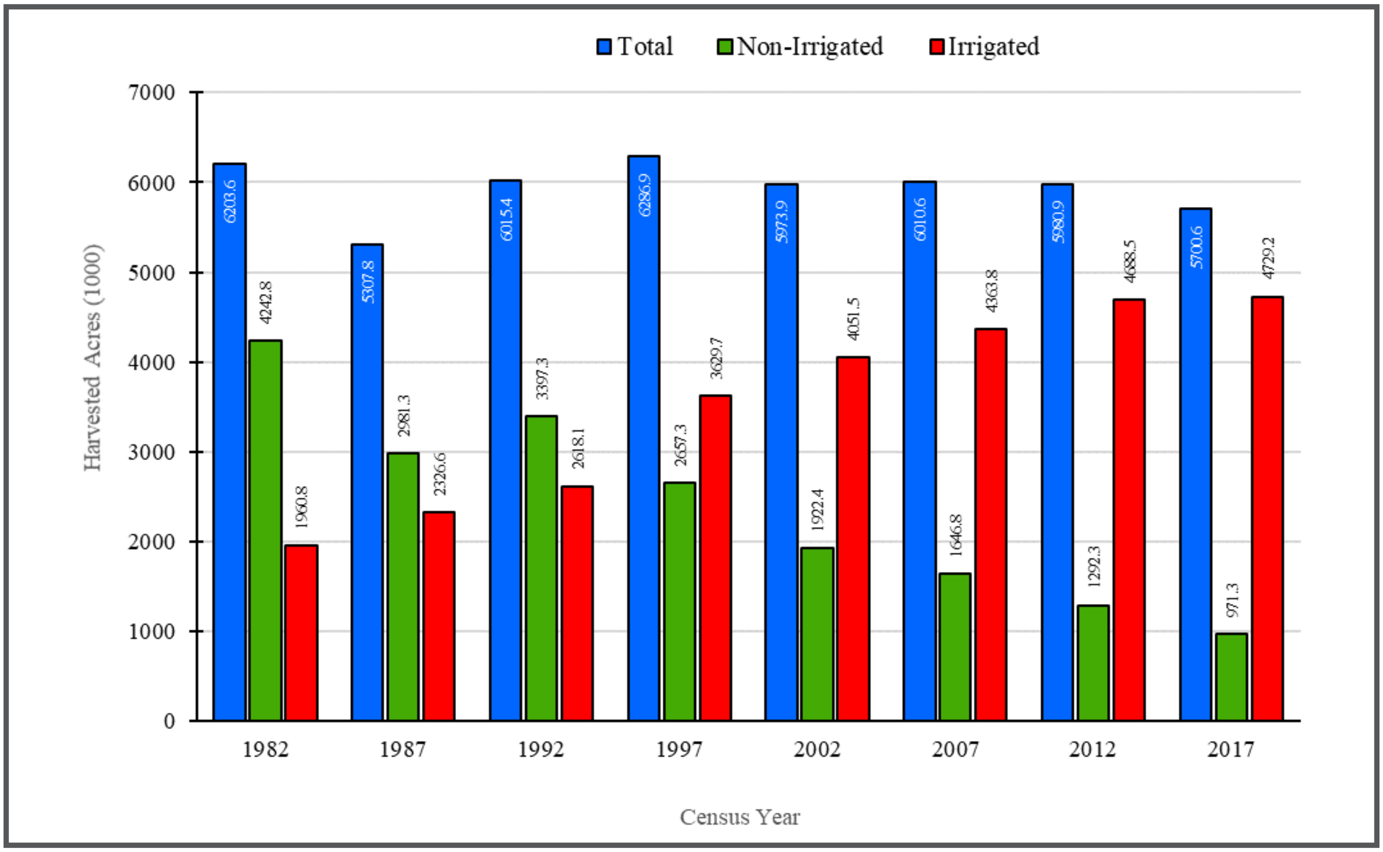

Figure 1. Total, non-irrigated, and irrigated harvested cropland by Census of Agriculture year, eastern Arkansas

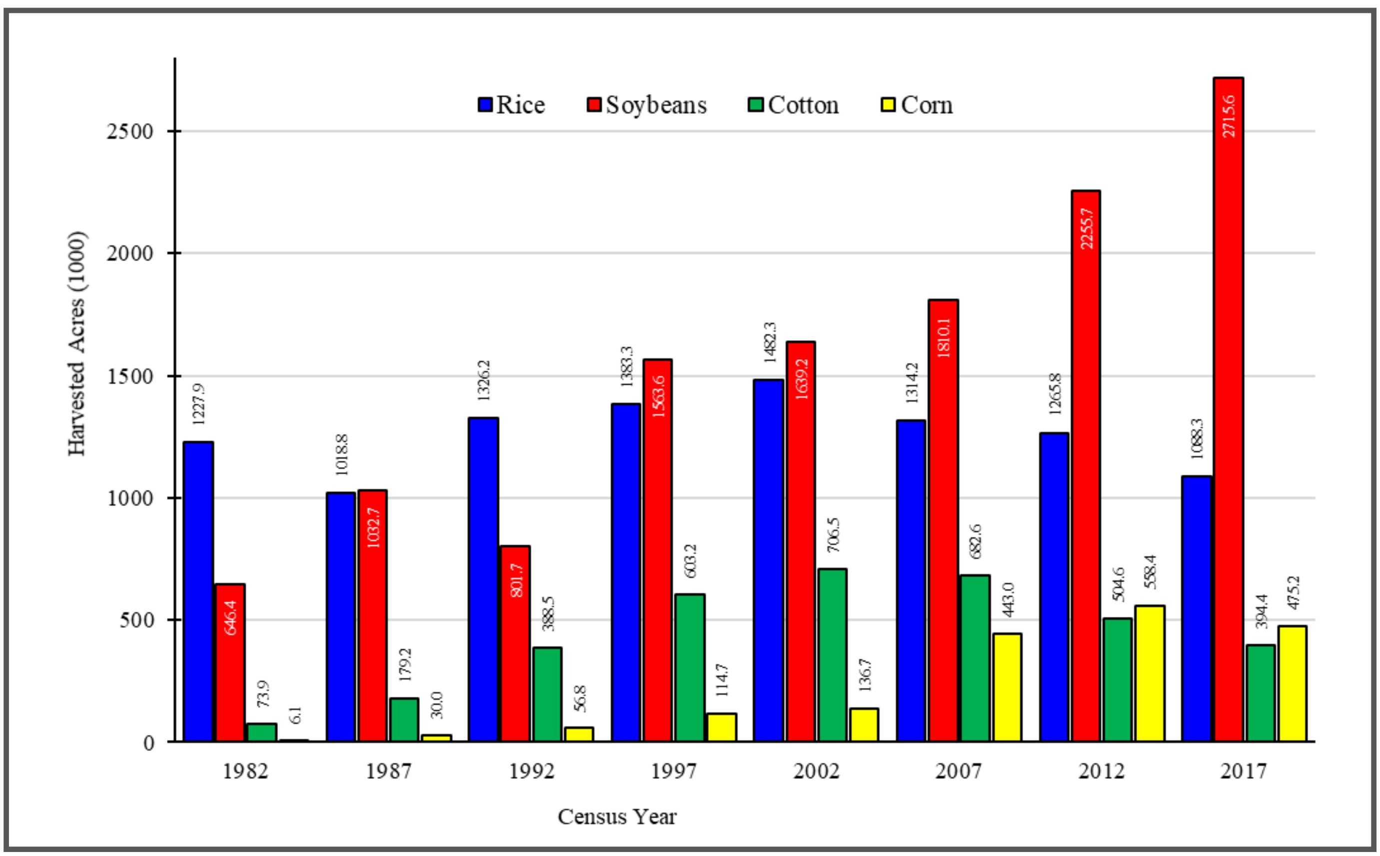

Figure 2. Irrigated harvested cropland by Census of Agriculture year and major irrigated field crop, eastern Arkansas

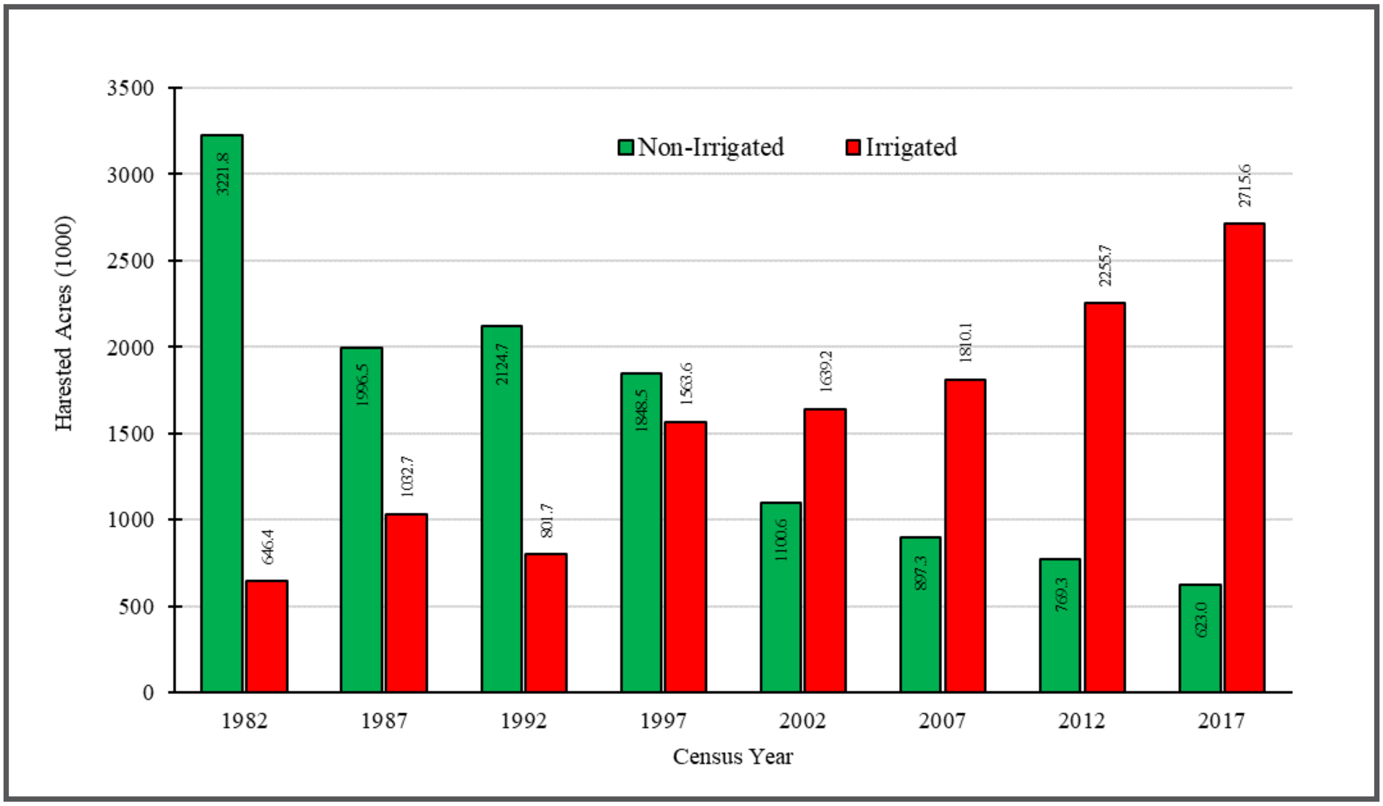

Figure 3. Non-irrigated and irrigated harvested soybean acres by Census of Agriculture year, eastern Arkansas

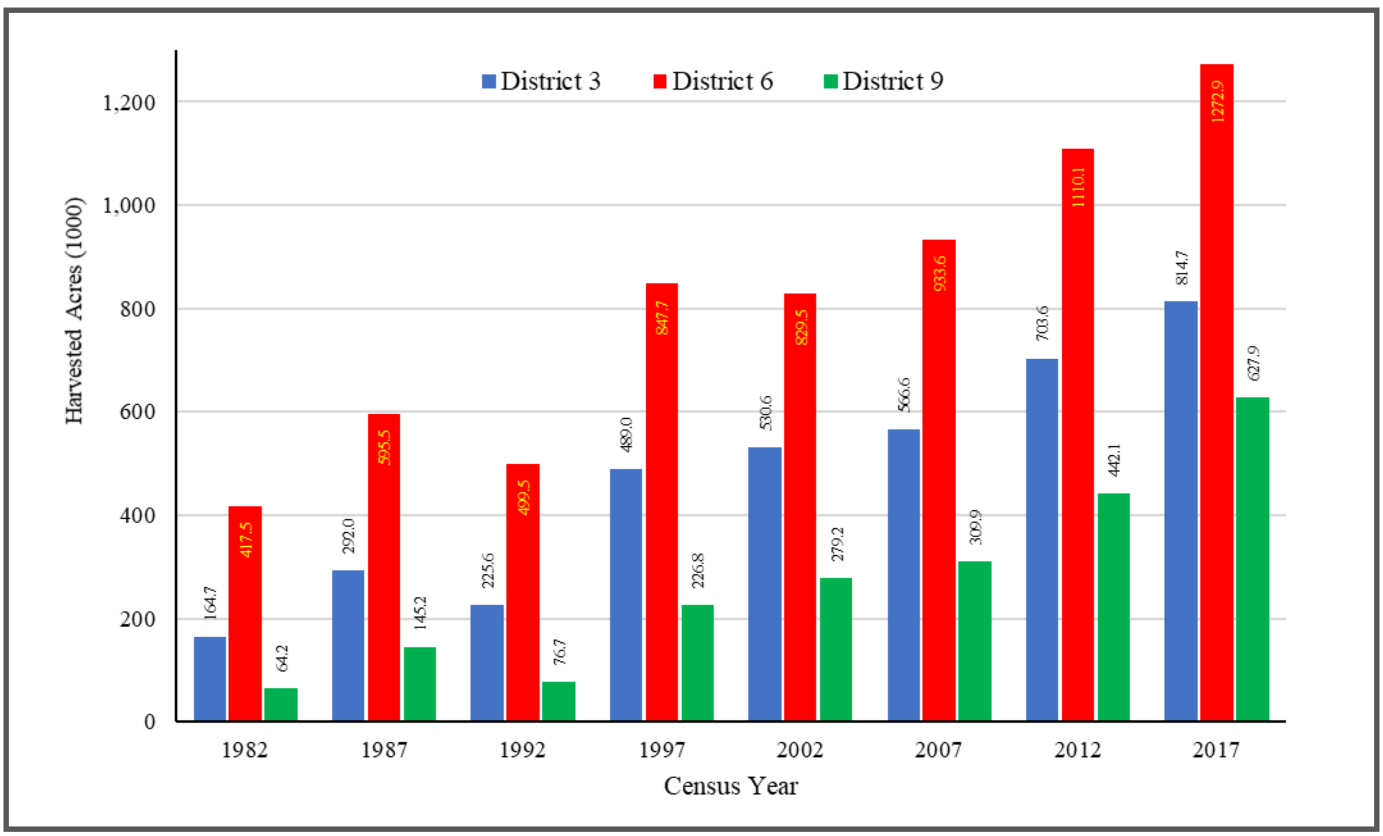

Figure 4. Irrigated harvested soybean acres by NASS Districts 3, 6, and 9 and by Census of Agriculture year, eastern Arkansas

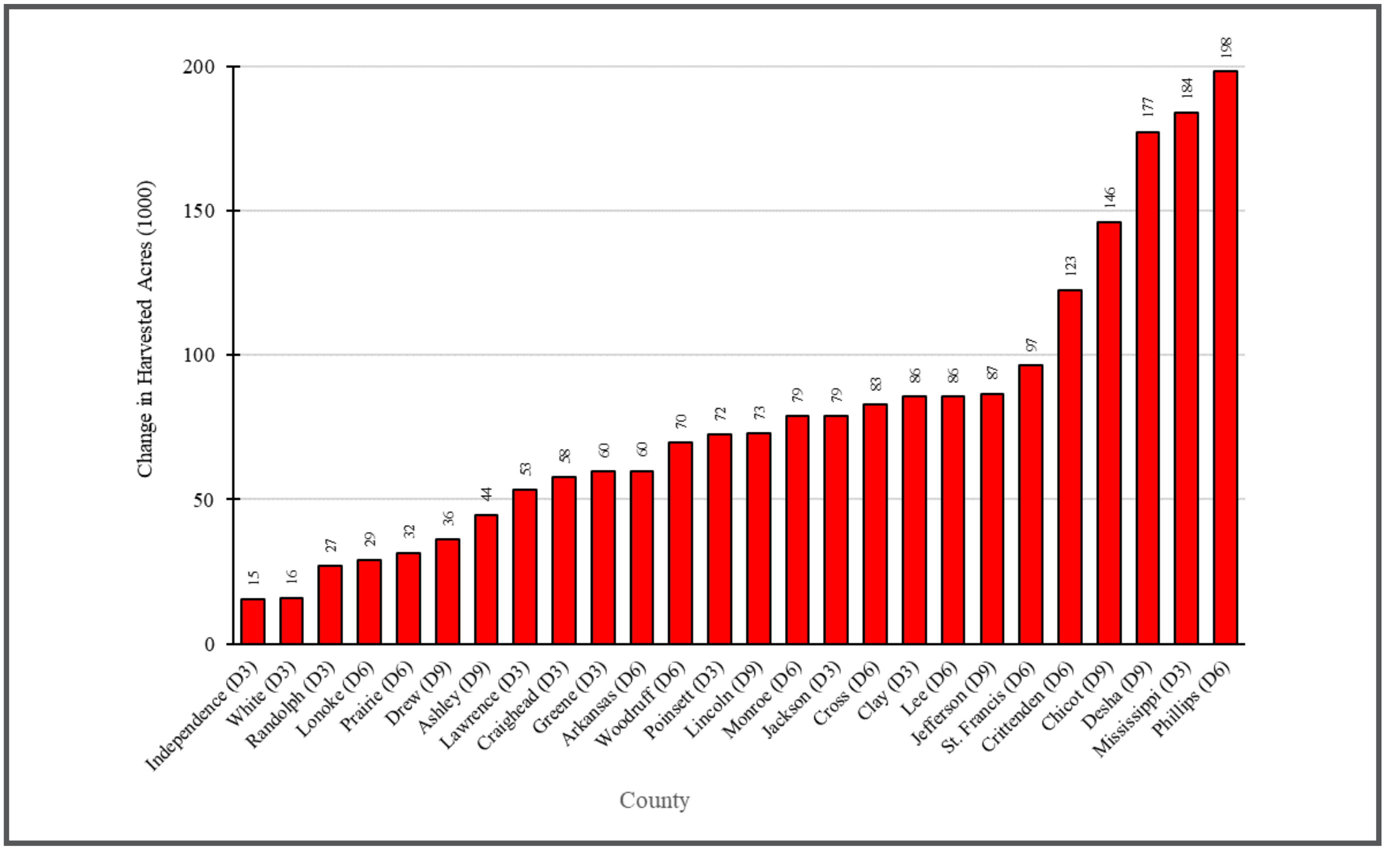

Figure 5. Change in soybean irrigated harvested acres (from census years 1982–2017) by county, eastern Arkansas. D3, D6, and D9 indicate the county is located in NASS Districts 3, 6, or 9.

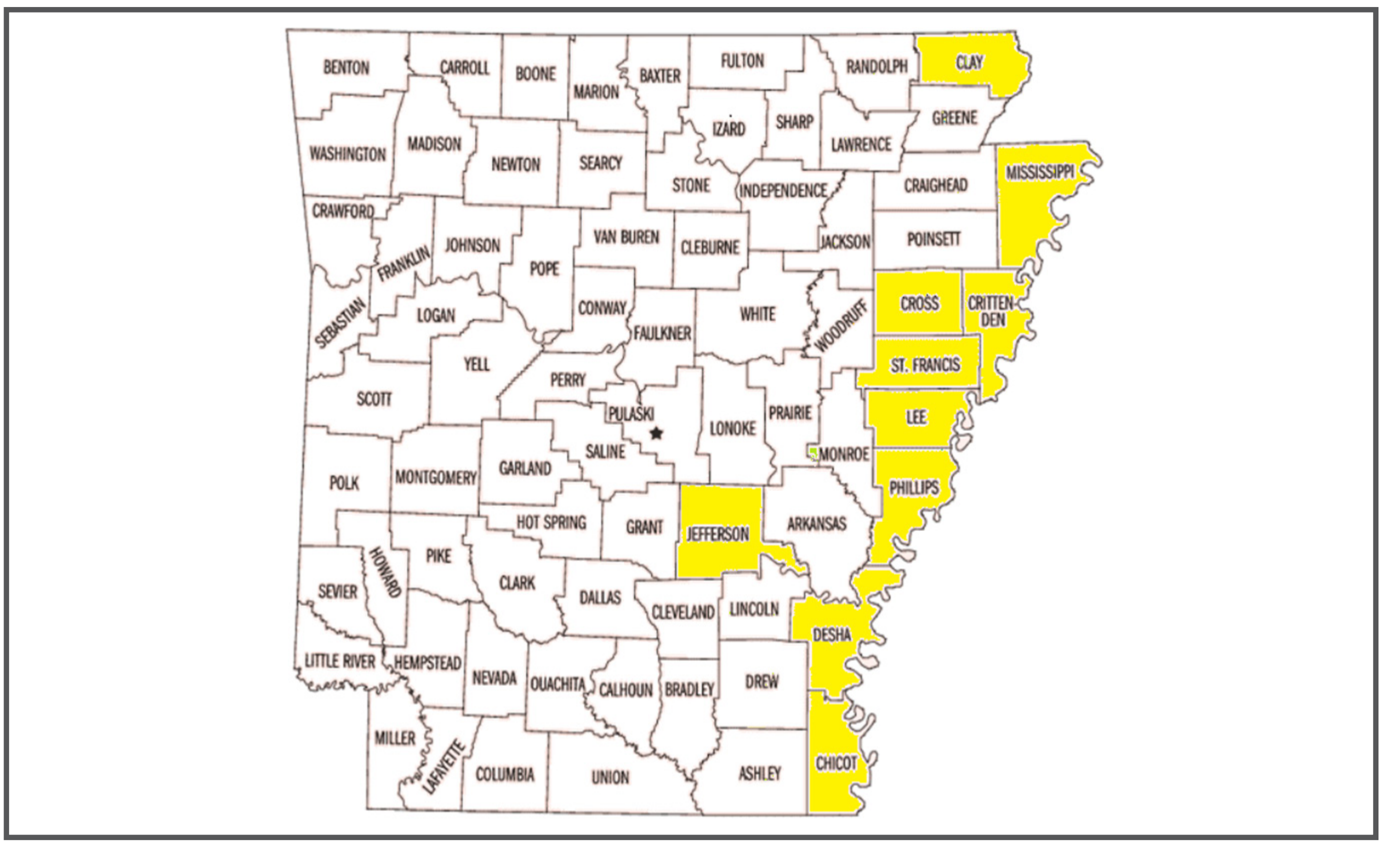

Figure 5A. Arkansas map showing top 10 counties (in yellow) that gained irrigated soybean acres over the census period since 1982

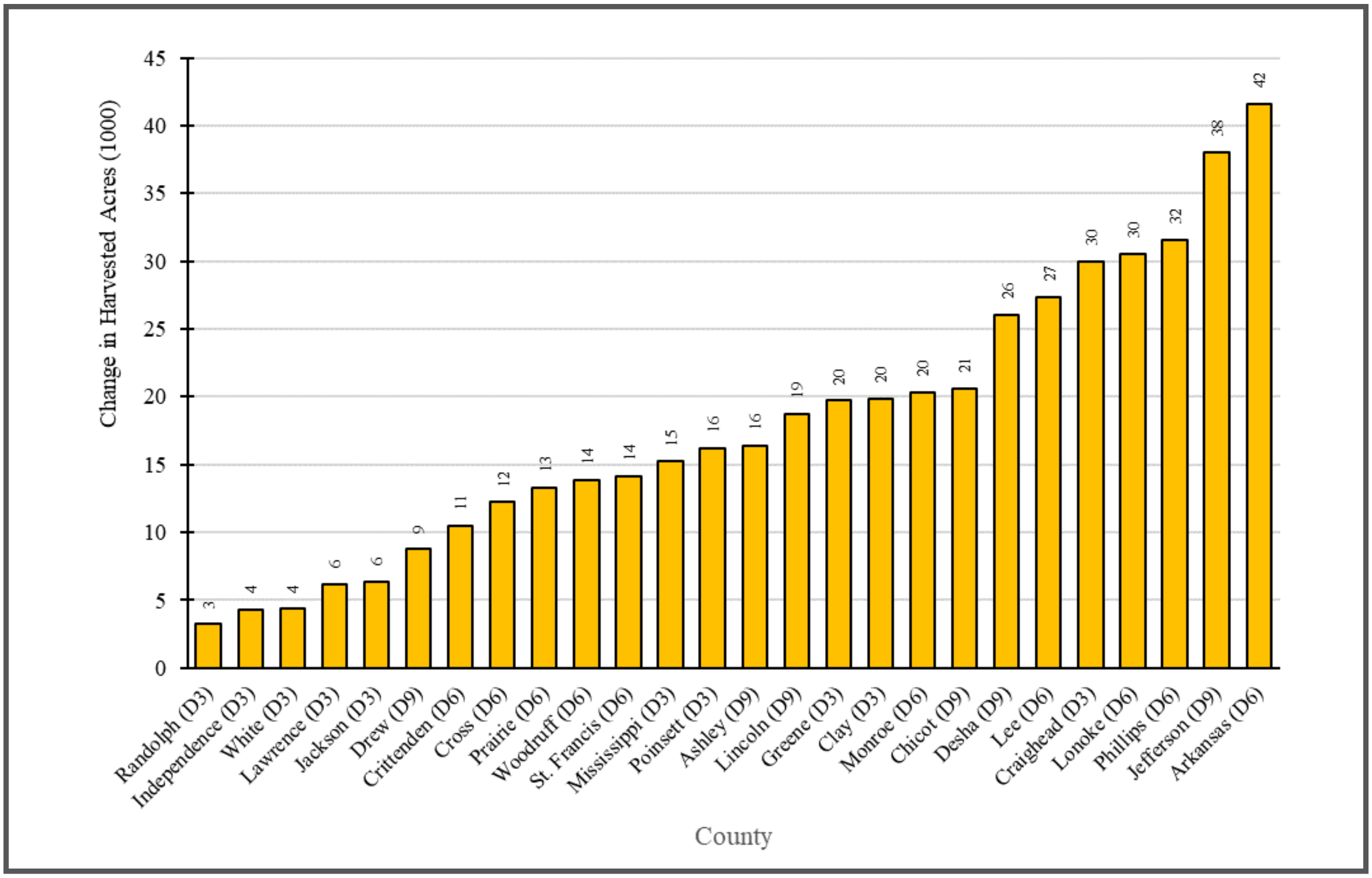

Figure 6. Change in corn irrigated harvested acres (from census years 1982–2017) by county, eastern Arkansas. D3, D6, and D9 indicate the county is located in NASS Districts 3, 6, or 9.

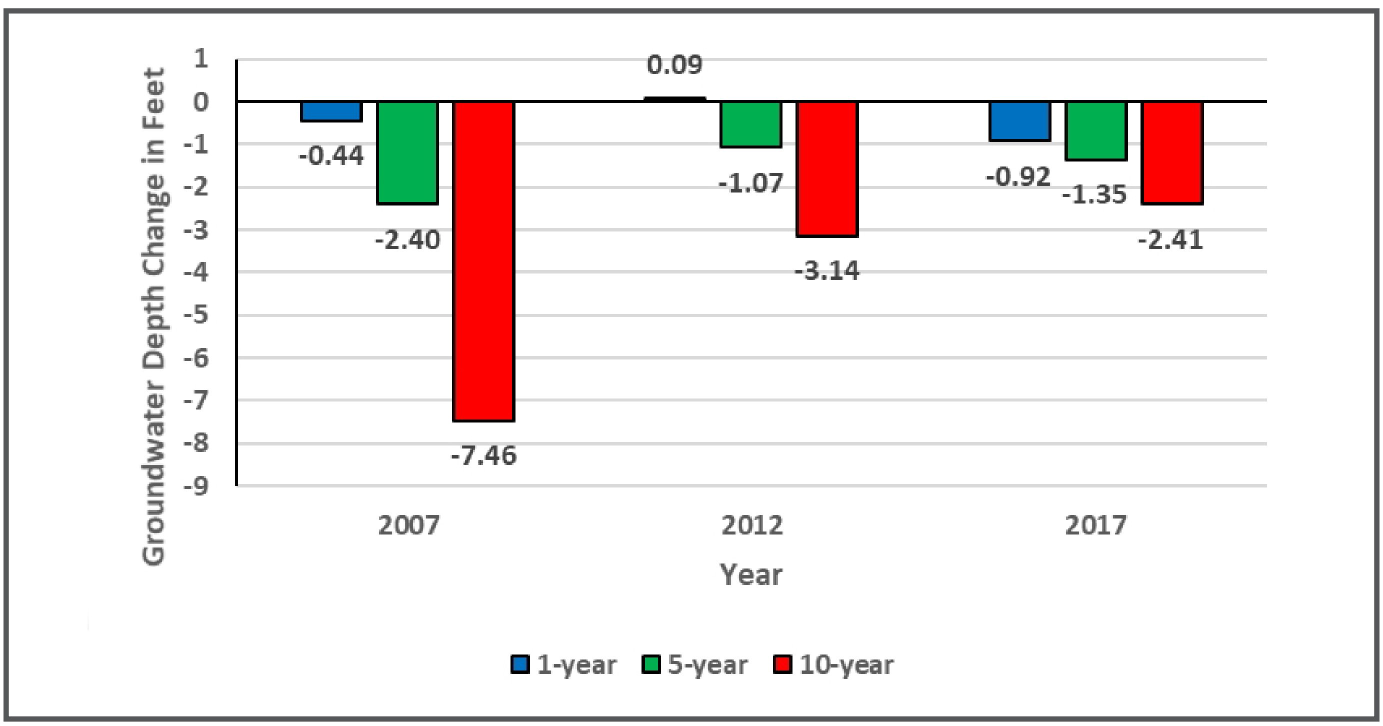

Figure 7. Groundwater depth change across MRVAA in eastern Arkansas

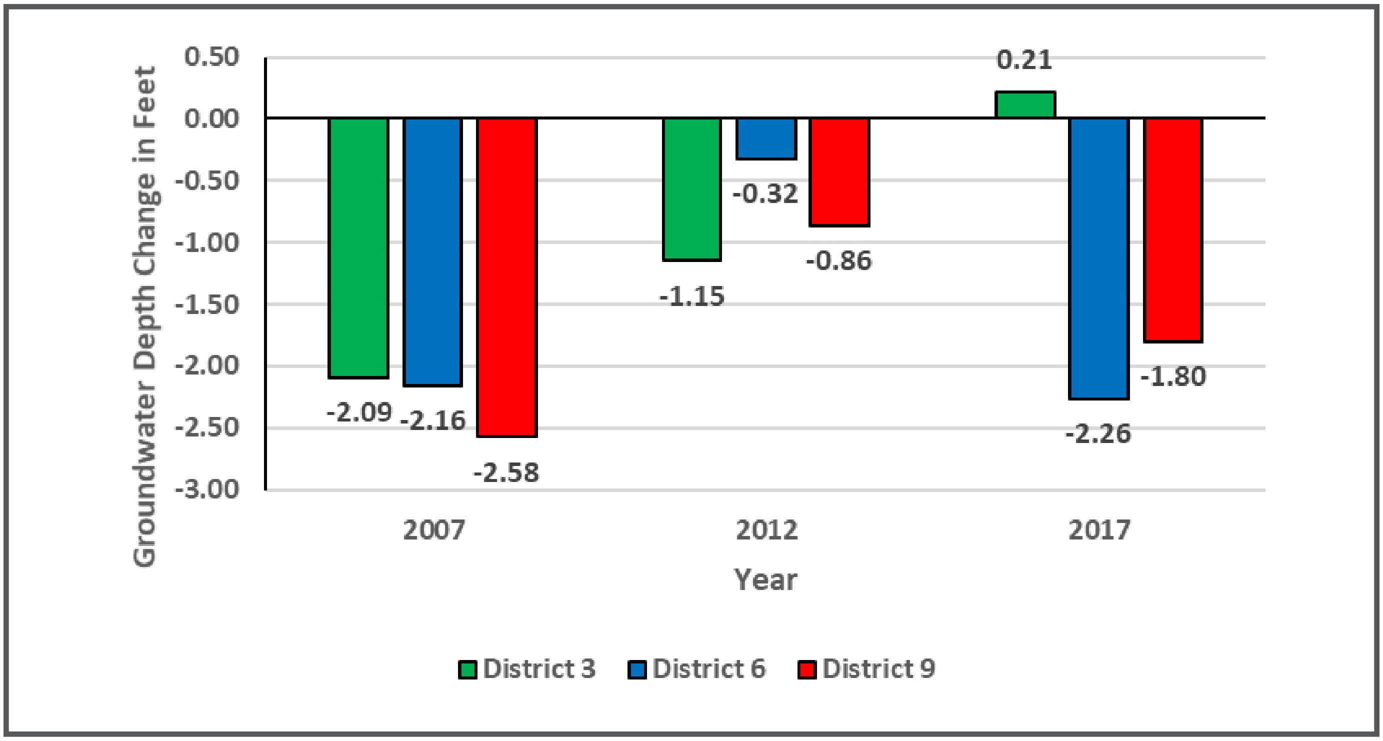

Figure 8. Groundwater depth change across MRVAA in 5-year monitoring period in eastern Arkansas (district cluster)

Table 1. Harvested Total, Non-Irrigated, and Irrigated Cropland by Census Year and Harvested Irrigated Cropland by Census Year, Crop, and NASS Districts 3, 6, and 9, Eastern Arkansas

Category	1982	1987	1992	1997	2002	2007	2012	2017
Eastern Arkansas								
Total	6203.6	5307.8	6015.4	6286.9	5973.9	6010.6	5980.9	5700.6
Non-Irrigated	4242.8	2981.3	3397.3	2657.3	1922.4	1646.8	1292.3	971.3
Irrigated	1960.8	2326.6	2618.1	3629.7	4051.5	4363.8	4688.5	4729.2
Irrigated Percent	31.6	43.8	43.5	57.7	67.8	72.6	78.4	83.0
NASS District 3								
Rice	480.5	424.3	551.8	580.6	621.7	589.3	586.9	517.6
Irrigated Soybeans	164.7	292	225.6	489.0	530.6	566.6	703.6	814.7
Non-Irrigated Soybeans	1209.8	742.1	834.7	692.5	437.6	327.2	290.9	221.0
Irrigated Corn	3.8	13.0	29.5	59.3	46.2	147	154.4	129.2
Non-Irrigated Corn	6.4	5.7	12.6	27.5	24.9	29.4	30.8	23.3
Irrigated Cotton	4.2	17.7	118.9	222.7	303.2	293.3	261.3	198.6
Non-Irrigated Cotton	137.9	177.8	247.7	227.5	136.3	117.1	56.1	18.8
NASS District 6								
Rice	544.3	434	580.5	601.9	656.1	557.3	540.8	456.1
Irrigated Soybeans	417.5	595.5	499.5	847.7	829.5	933.6	1110.1	1272.9
Non-Irrigated Soybeans	1458.8	966.3	972.3	859.3	512.5	463.2	396.5	330.1
Irrigated Corn	2.3	12.0	24.8	48.2	66.7	184.1	215.4	217.6
Non-Irrigated Corn	2.9	2.8	6.4	16.0	23.2	36.3	32.3	30.8
Irrigated Cotton	13.4	37.1	111.1	139.2	173.2	188.2	152.1	104.4
Non-Irrigated Cotton	74.5	85.8	172.2	94.5	50.6	34.9	18.2	16.7
NASS District 9								
Rice	203.2	160.5	193.8	200.8	204.6	167.6	138	114.6
Irrigated Soybeans	64.2	145.2	76.7	226.8	279.2	309.9	442.1	627.9
Non-Irrigated Soybeans	553.2	288.2	317.7	296.7	150.5	106.9	81.9	71.9
Irrigated Corn	0.0	5.1	2.5	7.2	23.8	111.9	188.6	128.4
Non-Irrigated Corn	0.8	3.8	3.7	3.7	7.0	16.6	23.3	14.4
Irrigated Cotton	56.4	124.4	158.5	241.4	230.1	201.1	91.2	91.4
Non-Irrigated Cotton	105.8	78.8	125.8	63.3	23.1	14.1	3.1	3.4
Eastern Arkansas								
Rice	1227.9	1018.8	1326.2	1383.3	1482.3	1314.2	1265.8	1088.3
Irrigated Soybeans	646.4	1032.7	801.7	1563.6	1639.2	1810.1	2255.7	2715.6
Non-Irrigated Soybeans	3221.8	1996.5	2124.7	1848.5	1100.6	897.3	769.3	623.0
Irrigated Corn	6.1	30.0	56.8	114.7	136.7	443.0	558.4	475.2
Non-Irrigated Corn	10.0	12.3	22.7	47.2	55.1	82.4	86.4	68.5
Irrigated Cotton	73.9	179.2	388.5	603.2	706.5	682.6	504.6	394.4
Non-Irrigated Cotton	318.2	342.5	545.7	385.3	210	166.1	77.3	38.9

Note: Number of acres are in 1,000.

Table 2. Groundwater Depth Change Across MRVAA Within Eastern Arkansas in 1-Year, 5-Year, and 10-Year Monitoring Periods

		Groundwater Depth Change in Feet		
Region/District	**Census Year**	**1-Yr**	**5-Yr**	**10-Yr**
Eastern Arkansas	2007	−0.44	−2.40	−7.46
	2012	0.09	−1.07	−3.14
	2017	−0.92	−1.35	−2.41
District 3 (D3)	2007	0.61	−2.09	−4.33
	2012	0.36	−1.15	0.36
	2017	−0.78	0.21	−1.41
District 6 (D6)	2007	−0.70	−2.16	−6.49
	2012	0.16	−0.32	−3.06
	2017	−0.98	−2.26	−2.15
District 9 (D9)	2007	−1.34	−2.58	−7.40
	2012	−0.51	−0.86	−3.66
	2017	−0.40	−1.80	−3.73