Going, Going, Almost Gone: How the Depletion of the Alluvial Aquifer Will Affect Cropping Decisions in the Arkansas Delta

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Abstract

The U.S. Geological Survey (USGS) has determined that agricultural irrigation in Arkansas' Delta is unsustainable with significant negative economic repercussions on producers net returns affected by the Alluvial aquifer. This study examines how irrigation restrictions in that region would affect county net returns to crop production. It also considers the effect of planting less water-intensive bioenergy crops in the event biofuel markets become a reality.

A constrained optimization model determines acreage allocations and net returns under three irrigation scenarios: i) no irrigation restrictions, ii) irrigation restrictions that lead to a sustainable Alluvial aquifer, and iii) irrigation restrictions that would lengthen the life of the Alluvial aquifer. Hypothetical switchgrass and forage sorghum crops were then added to model the effect of a biofuel market.

If crop production were conducting using irrigation levels that are sustainable, as defined by the USGS, producer net returns would decrease by 28% in the Alluvial region. Estimates show that the introduction of dedicated bioenergy crops could alleviate this downturn. If the price of switchgrass reached $46.40 per dry ton at the farmgate, it is possible to restore net returns to crop production across the state to pre-irrigation restriction levels, while Alluvial region producers now would suffer only a 9.5% reduction. Significant income redistribution to crop production thus exists with depleting ground water irrigation resources even with the introduction of an alternative markets.

Key Words: ground water irrigation, sustainability, biomass crops

Introduction

In 2004, the Arkansas Natural Resources Commission (ANRC) estimated groundwater withdrawals at 6.5 billion gallons per day, a 70% increase from the amount used in 1985 and over twelve times that of 1945 (ANRC, 2007). Today's irrigation level is unsustainable in the sense that water use exceeds recharge. To reach sustainable pumping levels, the United States Geological Survey's 2006 estimates indicated that certain Arkansas Delta counties will need to reduce irrigation pumping rates by as much as 67% (USGS, 2008). This is significant since approximately 63% of the state's total water supply is sourced from groundwater, and further, 95% of that comes from the Alluvial aquifer in the Delta region of Arkansas (USGS, 2008).

With water supplies declining in parts of the Alluvial aquifer, water-intensive agricultural production and associated processing industries are at risk. Other potential adverse effects are land subsidence, saline water encroachment, increased cost to well users and reduced base flow to streams and wetlands. Exacerbating this issue is the drilling of over 10,000 new wells since 1997 (ANRC, 2007), which is likely a result of enhanced profitability with irrigation practices as well as agricultural lending preferences for irrigated production.

This study examines how Arkansas' farm crop allocation might change if i) irrigation in the Alluvial aquifer was constrained to more sustainable levels; and ii) a hypothetical market existed for less water-intensive bioenergy crops. Further, the study examines how these changes would affect agricultural net returns in the state. The effect of the introduction of biomass crops for renewable fuels production is modeled by evaluating the effects of introducing two potential alternative crops, switchgrass and forage sorghum. These alternative crops are non-irrigated and, in the case of forage sorghum, irrigation to enhance yields, is an option at irrigation rates significantly below those required for rice (1/6th) and half the rates required for corn, cotton or soybean.

County specific irrigation data and sustainable pumping rates were obtained from the USGS (USGS, 2008). Using a constrained optimization model, the most profitable crop allocations under various irrigation and price scenarios can be determined (Popp, Nalley and Vickery, 2008). The model considers historical minimum and maximum non-irrigated and irrigated harvested acres and yields (USDA, 2008), University of Arkansas Cooperative Extension Service (UACES) estimated cost of production for crops (UACES, 2008) on a county-specific level when possible. The use of county data is essential for analysis of spatial implications of irrigation water use restrictions as well as biomass production effects. Results should i) aid the development of irrigation policies such as irrigation taxes or permits; ii) provide information about investments in irrigation projects to enhance irrigation efficiency and/or supplies; and iii) inform about changes in cropping decisions or land use in the case of scarce water resources.

The Study Region

The Mississippi River Valley alluvial aquifer touches parts of Arkansas, Missouri, Louisiana and Tennessee. For purposes of this study, the Alluvial aquifer refers to the portion of the Mississippi River Valley aquifer within Arkansas. Long-term water-level data collected over a 25-year period indicate an average water level decline of 3.8 inches per year in the Alluvial aquifer over a 24 year period (USGS, 2008). In some Delta counties such as Cross, Lonoke and Jackson, the water level decline is as much as 11.3, 9.6 and 8.2 inches per year, respectively. Thus, some of the state's largest agricultural crop-producing counties are experiencing unsustainable long-term ground-water withdrawals.

Simulated studies (Ackerman, 1989; Mahon and Poynter, 1993) estimate the recharge rate for the Alluvial aquifer to be between 0.8 to 1.4 inches a year. Therefore specific areas within the state of Arkansas are currently experiencing ground-water withdrawals of such magnitude that they are deemed unsustainable with consistently falling ground-water levels.

Figure 1 illustrates the percentage of irrigation water use that is sustainable in counties located in the Alluvial aquifer region. These estimates are based on 2007 pumping rates. Arkansas, Lonoke, Lee, Poinsett and St. Francis counties would all need to reduce their pumping rates by over 40% to maintain ground-water levels. As an example, these counties alone consisted of 28% of Arkansas' total rice acreage, the state's most valuable crop, in 2007. This presents a problem for sustainability given the profitability of rice combined with the required water needed for its production. Nearly all of Arkansas' corn, rice and irrigated cotton acres withdraw from the Alluvial aquifer, which again is problematic given the recent rise in both corn and rice prices. Several options present themselves to limit irrigation use to a sustainable rate; cap-and-trade, taxation, irrigation permits, subsidization of less-irrigation intensive crops or man-made irrigation alternatives such as combinations of on-farm reservoirs and river water diversion such as proposed in the Grand Praire Area Demonstration Project (Hill et al., 2003).

Data and Methods

A state model that tracks crop profitability and resource use was necessary to model producer behavior on a county by county basis. This required cost of production information, fuel, labor, fertilizer and irrigation water use as reported by UACES, both in terms of quantity and cost to allow for sensitivity analyses. Further, crop specific extension experts were consulted to determine which of the reported production methods were most prevalent in each of the nine crop reporting districts (CRD) as defined by the Arkansas Agricultural Statistics

Service. That is, cotton extension experts were asked to determine which of the 28 possible cotton production methods in Arkansas were most frequently used within each CRD. This effort resulted in CRD-specific cost of production and resource use estimates. County level average 2004-2007 yields (USDA NASS, 2008) helped determine returns above total specified expenses that in turn were necessary to model producer decisions for the 75 counties in Arkansas. Note that spatial differentiation on the basis of cost and yield was not possible for the dedicated energy crops – forage sorghum and switchgrass – as production methods are still somewhat new and county-specific yield data were not available.

It was also necessary to constrain the model based on historical land use decisions to reflect technological, socioeconomic and capital investment barriers. Hence, historical harvested crop land information (including all crops, fruits, vegetables, hay land and hay yield), pasture and irrigated acres were collected from agricultural census data for 1987, 1992, 1997 and 2002 (USDA Census of Agriculture). Conservation Reserve Program (CRP) acreage, as well as average county specific CRP payments for 2007, were obtained from the USDA's Farm Service Agency (FSA, 2008). Annual harvested acres for the traditional crops were available electronically by county from the Arkansas Agricultural Statistics Service from 1975 to 2007 (NASS). Variation in pasture and hay land nutrient management (e.g. use of poultry litter, commercial fertilizer or nitrogen fixing companion crops), number and method of harvests, grazing differences and operator rental arrangement proved too cumbersome to model. Hence hay land returns and pasture rental rates were set to $35/acre for productive land that can be harvested with hay equipment and $25/acre – the average of surrounding states' cash rental returns to pasture (USDA, 2008 Pasture Cash Rent). This assumption is limiting but not for the case of irrigation analyses as pasture and hay land are non-irrigated.

The net return (*NR*) of Arkansas crop, hay and pasture land could then be maximized by choosing crop acres (*x*) on the basis of expected commodity prices (*p*), county relevant yield (*y*) and cost of production information (*c*) as follows:

$$\text{Maximize } NR = \sum_{i=1}^{75}\sum_{j=1}^{18}\left(p_j \cdot y_{ij} - c_{ij}\right)\cdot x_{ij} \tag{1}$$

Subject to:

$xmin_{ij} \le x_{ij} \le xmax_{ij}$	
$iacresmin_i \le \sum x_{ij} \le iacresmax_i$	for irrigated crops only
$\sum irr_{ij} \le irrmax_i$	$irrmax_i$ was set after the initial model run
$acresmin_i \le \sum x_{ij} \le acresmax_i$	for all crops except pasture and CRP

where *i* denotes each of the 75 counties of production and *j* denotes the 18 land management choices. *Xmin* and *xmax* are historically reported county acreage minima and maxima over the harvest years 2000 through 2007 for each crop (USDA NASS, 2008)[1]. Energy crops had zero minima. Switchgrass on crop land was limited to a maximum of 10% of total harvested land to reflect an expected farmer adoption lag for a new, perennial crop. Switchgrass on hay and pasture land was limited to a maximum of 10% of the sum of hay and pasture land so as not to encroach on current livestock production[2]. Because forage sorghum is similar in production technology to grain sorghum, it was not curtailed, except to historically reported maximum irrigated county crop acres (*iacresmax*) and harvested county crop land (*acresmax*) for irrigated and non-irrigated production, respectively. *Iacresmin* and *iacresmax* are the 1987 to 2002 census based reported irrigated acres that reflect technological, socioeconomic and capital barriers to irrigation, again at the county level. *Irrmax* represents the amount of water used in

1 The model was also run using historical minima and maxima reaching back to 1975 when cotton acreage was limited in Arkansas. The model predicted large acreage shifts from cotton to biomass. This was considered unrealistic given Arkansas' investment in cotton gins and specialized harvesting equipment.

2 Cattle and calf numbers for the census years corresponding to hay and pasture land numbers were used to determine average acreage per head of livestock. The January 1, 2008 inventory numbers were subsequently multiplied by the average acreage per head to determine how much hay and pasture land was required to maintain the current herd of cattle. In the most restricted county, Faulkner, the minimum was 90% of the maximum.

the 2007 base model run without water restrictions and is the constraint that was used to enforce eventual water use restrictions on a county basis by tracking acre-inch use across crops, irr_{ij}. *Acresmin* and *acresmax* are total harvested acres at the county level, as collected by the Census, and were amended by adding 10% of county CRP enrollments to the maximum harvested acre totals to reflect the potential for added acres from land coming out of CRP and the typical ten year enrollment horizon of CRP acreage. Note that winter wheat was considered part of harvested acres even though this crop can be entertained in double crop rotations with soybean, corn or sorghum crops.

Crop price information (p_j) was based on the July futures prices as of December of the previous year and no commodity price program support (Great Pacific Trading Company, 2008).[3] Basis expectations[4] were set to zero for all crops and prices were adjusted for hauling, drying and commodity board check off charges as appropriate. (See Table 1 for commodity price, yield and input information.) Switchgrass and forage sorghum prices were then modified over a range of $25 to $55 per dry ton (dt) to estimate to what degree these crops enter land allocations. A discount of $5/dt relative to baled switchgrass stored at the side of the field was applied to forage sorghum as it was assumed to be sold standing in the field. It is expected that this crop would be harvested using a forage chopper and hauled directly to a processing facility where it would be artificially dried. The $5 discount is an estimate given a lack of accurate available cost information on relative harvest, storage, packaging, drying, transport and processing costs for forage sorghum relative to switchgrass. Switchgrass is considered moderately storable at the side of the field, but it is relatively more costly to process to a desired particle size for biorefinery use, compared to forage sorghum.

[3] Wheat prices were based on the May futures prices as of September of the previous year (Great Pacific Trading Company).
[4] Local cash price less futures price to account for time, location and quality differences.

Per acre yields (y_{ij}) are county averages for most crops. Minor modifications as described by Popp, Nalley and Vickery (2008) were made to double crop soybean maximum and minimum acreage restrictions and grain sorghum yield differences between irrigated and non-irrigated production. Per acre cost of production estimates (c_{ij}) were developed as reported above.

The initial 2007 baseline results were also used to provide an estimate of per acre opportunity costs that would be incurred in the year of establishment for switchgrass, a crop that does not yield its full potential until year three with zero salable product in year one. This opportunity cost (o_i) was added to the prorated net returns above total specified expenses for switchgrass (nr) as follows:

$$nr_{i,switchgrass} = \left(\sum_{n=1}^{k^t} [((p \cdot y_n^t) - c_n^t)/(1+r)^n] \right) - o_i / k^t \qquad (2)$$

where n is the production year in the useful life (k^t) of switchgrass with useful life varying by land type (t – crop, hay or pasture land), p is the price per dt of switchgrass, y_n^t and c_n^t are the production year-dependent yield and cost of production by land type, r is the capital recovery rate (6%) and o_i are the average county net return estimates to pasture, hay or conventional crops observed in the base run with switchgrass and forage sorghum prices set to zero.

<u>Sensitivity Analyses</u>

First, a 2007 baseline scenario was estimated using the linear programming software Premium Solver Plus, an add-in to Excel (Frontline, 2008). The model had several thousand constraints and thousands of crop acreage allocation possibilities (1 of 18 land uses in each county) to maximize NR as described in equation 1. The 2007 baseline was developed using zero prices for alternative energy crops to see how accurately the model would predict observed total harvested land allocations in 2007 on the basis of cooperative extension input cost estimates and

2007 commodity price expectations.[5] This baseline estimate was unconstrained in the sense that farmers could pump as much water as needed to maximize profit per acre while staying within historical irrigated acre limits. That is, they could choose to grow as much rice, the most irrigation intensive crop, for example, without consideration of the amount of water applied per acre.

In subsequent model runs, each county was constrained to sustainable water use based off the information from Figure 1. This was done to determine changes in crop allocation and overall profitability implications of irrigation restrictions. A second set of model runs was performed to also determine what might happen if the sustainability constraint was loosened half way between the unrestricted and sustainable water use rates. For example, to meet sustainable water use, Arkansas County needed to cut current water use by 43%. The less restrictive assumption cut that reduction in half to 21.5% of current pumping rates. Essentially, the second iteration provides a scenario of doubling the current life expectancy of the aquifer.[6] Practically speaking, this may be a more realistic assumption for farmers to implement since it requires a lesser reduction in pumping, half the full amount required for sustainability, an amount that is substantial for some counties. Profitability and acreage distribution among crops were compared to the baseline to see how/if they diverge. When the fully sustainable iterations were run, the model in equation (1) was rerun with the modification of the $irrmax_i$ constraint to:

$$\sum irr_{ij} \leq iacreinchsustain_i \qquad (3)$$

[5] The model's predictive power was within 10% for corn, cotton, grain sorghum, hay land, pasture land, rice and soybean, and within 15% of the actual 2007 wheat acreage (Popp, Nalley, and Vickery 2008).
[6] This is a rough approximation, due to the non linearity of pumping rates and cones of depressions within the aquifer. Therefore this "doubling" term is simply an estimate.

where $iacreinchsustain_i$ were county specific sustainable water use rates. For the second iteration where the target is to double the life of the aquifer the constraint in equation (3) was relaxed as follows:

$$\sum irr_{ij} \leq iacreinchedoubl_i = irrmax_i - \tfrac{1}{2}\,(irrmax_i - iacreinchsustain_i) \qquad (4)$$

A final set of model runs was performed to introduce the impact of the two alternative crops (switchgrass and forage sorghum) at varying prices to see how/if they entered production in Arkansas under the full sustainability and doubling of aquifer life scenarios. Since both of the alternative crops are less water intensive than most traditional crops they should become more attractive to farmers given water use restrictions. One of the goals of this study was to see what market price levels for switchgrass and forage sorghum would be needed to restore profits to state levels observed under the unrestricted irrigation assumption. Alternatively, what would the market price of switchgrass have to be so that the state would be indifferent when forced to cut irrigation to varying degrees of sustainability?

Results

Table 2 highlights the results from each of the model iterations. The unrestricted baseline scenario indicated total net returns to land and management of $526 million for the 24 counties in Arkansas who have access to the Alluvial aquifer. These returns are gross revenue net of total specified expenses of seed, fertilizer, chemicals, fuel, custom work, repair and maintenance, operating interest and equipment ownership charges excluding property taxes and insurance. These counties represented 80% of the Arkansas' agricultural net returns as modeled in this analysis. The unrestricted base model also represented 91% of Arkansas' irrigated production and showed 1.682, 1.381, 0.509 and 0.441 million acres of irrigated soybean, rice, cotton and corn, respectively. By constraining the model to sustainable pumping levels the Alluvial region's net returns declined to $377 million (a 28% reduction) with significant reductions in irrigated crops and slight increases in hay and non-irrigated crops (especially winter wheat production, Table 2). Large rice producing counties like Poinsett, Arkansas, and Cross would experience rice acreage reductions of 57%, 42%, and 35%, respectively. Figure 2 shows the reduction of rice, irrigated soybean, irrigated cotton and corn acreage on a county level basis when the aquifer is constrained to sustainable pumping levels. These numbers represent significant acreage reductions that affect not only the producers but also the rice, soybean and cotton processing industries located in the region. The model estimates suggest that ensuring the survival of the Alluvial aquifer would result in an approximate 32% reduction in annual acre-inches pumped for the Alluvial region at a cost of $149 million in net returns to producers, *ceteris paribus*.

Table 2 also illustrates the results when the irrigation is only restricted to "double" the life of the Aquifer. As mentioned earlier this constraint may be more realistic given expected resistance to major irrigation restrictions. Under this scenario the Alluvial region's net returns decline to $448 million (a 15% decrease). This represent a $71 million dollar increase in net returns compared to the sustainable pumping constraint for the Alluvial region. Figure 3 shows the changes in acreage for rice, irrigated soybean, irrigated cotton and corn. This constraint would result in an approximate 15% reduction in acre-inches pumped for the Alluvial region at a cost of $78 million in net returns to producers, *ceteris paribus*.

By introducing the alternative crops which are much less water intensive, the hypothetical biomass price required to return the state's net returns to "pre-irrigation restriction" levels can be determined. At the same time, this requires that demand for alternative crops would establish at those price levels. The bottom half of Table 2 shows what happens to land use as switchgrass rises from $25/dry ton to $55/dry ton. At a switchgrass price of $35 a dry ton under the full sustainability scenario, the model indicates that there would be 903,000 acres of non-irrigated biomass crops. At $45 a ton under the same scenario those numbers increase to 2,046,000 and 127,000 acres for non-irrigated biomass and irrigated forage sorghum, respectively. As a reference point actual rice acreage in 2007 was 1.4 million acres. Surprisingly, acreage of non-irrigated biomass crops under the $45 a ton and full sustainability scenario would make it the second largest crop behind soybean in the state when compared to actual acres harvested in 2007. Under the full sustainability level and at the $45 a ton for biomass, the Alluvial region's net returns to producers has now decreased by only 9.5% from its original unconstrained level. That is, with the introduction of alternative crops, the Alluvial region can sustain the Alluvial aquifer and only reduce net returns by 9.5%.

Producers in counties outside the Alluvial region, however, would gain net returns as $45 switchgrass is quite profitable. In fact, to achieve the level of initial, unconstrained *state* agricultural net returns as specified in this model, switchgrass market prices would need to be $46.40 and $44.96 for the full and 50% sustainability levels, respectively (Table 3). At $46.40 per dry ton, using Wallace et al.'s (2005) assumptions of 78.3 gallons of ethanol per dry ton of biomass and non-feedstock conversion costs of $1.46 per gallon of ethanol, the breakeven cost per gallon without co-product credit and transportation charges would be $2.05 per gallon of ethanol from biomass.

While the above indicates that state net returns can be hypothetically returned to pre-irrigation restriction levels as long as biofuel markets develop to the extent shown above, there are significant spatial income redistribution effects as portrayed in Table 3. As expected, irrigation restrictions do not affect returns in counties with sustainable pumping practices. The income ramifications of the restrictions in the Alluvial aquifer counties, however, range from 0 to as much as a 57% decrease in net returns. However, these Alluvial aquifer counties, on average, are 12 and 32% better off with biomass markets than without, under the double aquifer life and full sustainability scenarios, respectively, *after* irrigation restrictions have been imposed *and* switchgrass prices rise to the levels needed to return state net returns to pre-irrigation restriction levels.

This indicates that the introduction of these crops can mitigate some of the adverse effects of irrigation water use restrictions on producer returns. There are, however, return gaining and losing counties with these scenarios, as indicated in Table 3.

Conclusion

Recent concerns over the decreasing water level in the Alluvial aquifer in Arkansas have led many to question the future of the water-intensive rice industry in the Arkansas Delta. This study set out to examine how profit maximizing cropping decisions would change at a county level if producers were constrained to irrigation levels that would sustain the Alluvial aquifer indefinitely. While there are several approaches to ensuring a sustainable water source this study examined income and crop allocation effects of the introduction of biomass crops given the recent emphasis of national policy on energy independence. Both switchgrass and forage sorghum can be grown successfully under non-irrigated conditions.

Model runs examined two irrigation restriction scenarios for the Alluvial aquifer: i) sustainable water use and ii) approximate doubling of groundwater irrigation resources. Results indicated that the hypothetical introduction of alternative, less-water intensive crops can meet policy objectives of securing a more energy independent and sustainable future. The region analyzed represents approximately 80% of crop returns to land use of Arkansas. Estimates suggested that if producers are constrained to sustainable levels without the introduction of alternative crops, the Alluvial region's producer net returns would decrease by 28% ($149 million) not counting ancillary effects on rice processing and cotton ginning industries. If producers are constrained to levels that double the life of the aquifer, producer net returns would decrease by 15% ($78 million).

When switchgrass was introduced at $25 dollars per dry ton, only a small amount of acreage enters the production mix. However under the sustainable aquifer scenario, when the hypothetical market price for switchgrass is $45 a ton, nearly 2.6 million acres of biomass crops are grown using non-irrigated production. At these production levels, the Alluvial region's producer net returns were $476 million, a 9.5% reduction compared to the 2007 baseline. This indicates that if market prices for these alternative crops were sufficiently high, irrigation sustainability could be achieved at smaller losses to state returns than without the existence of these biomass markets. If the goal is to double the life of the aquifer based on the 2007 pumping rates and alternative crops entered at the same $45 per dry ton, regional net returns would decline by only 4%.

A hypothetical scenario of returning state producer net returns to levels prior to irrigation restrictions suggested significant wealth redistribution effects – Alluvial region producers lose net returns to groundwater irrigation and non-Alluvial region counties gain as biomass production is a relatively profitable land use choice. Nonetheless, biomass markets would soften the blow for Alluvial region producers facing eventual declines in irrigation water supply. This study suggests that the examination of less water-intensive crops that could provide the biomass for the second generation of biofuels, a processing industry that could also potentially absorb losses associated with reduced rice milling or cotton ginning, needs further investigation.

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Figure 1. Sustainable Irrigation Water Use as a Percentage of Estimated 2007 Water Use for Crop Producing Counties Affected by Alluvial Aquifer Depletion in Arkansas.

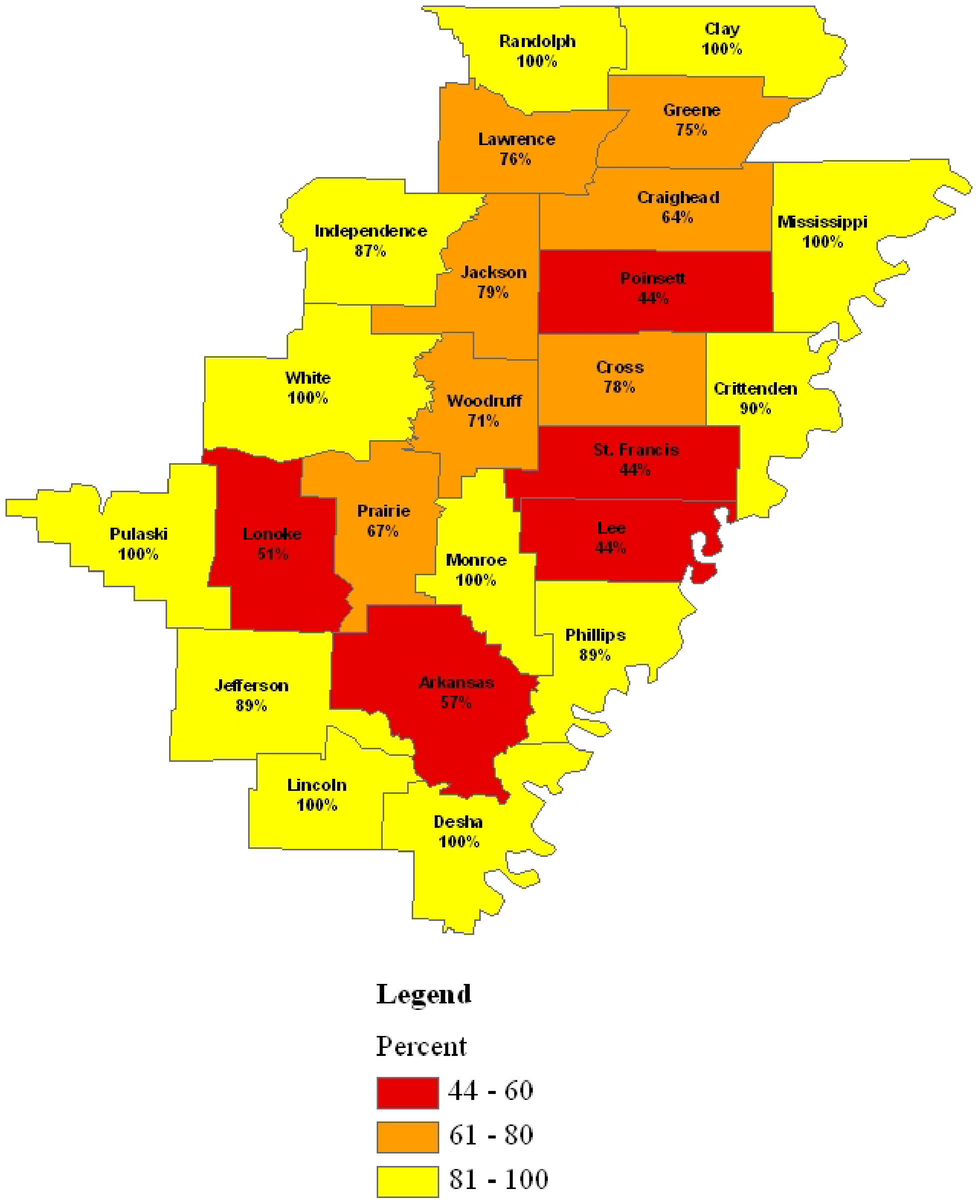

Figure 2. Estimated Reduction in Rice (top left), Irrigated Soybean (top right), Irrigated Cotton (bottom left) and Corn (bottom right) Acreage with Full Sustainable Water Use Restrictions under 2007 Crop Producing Conditions.

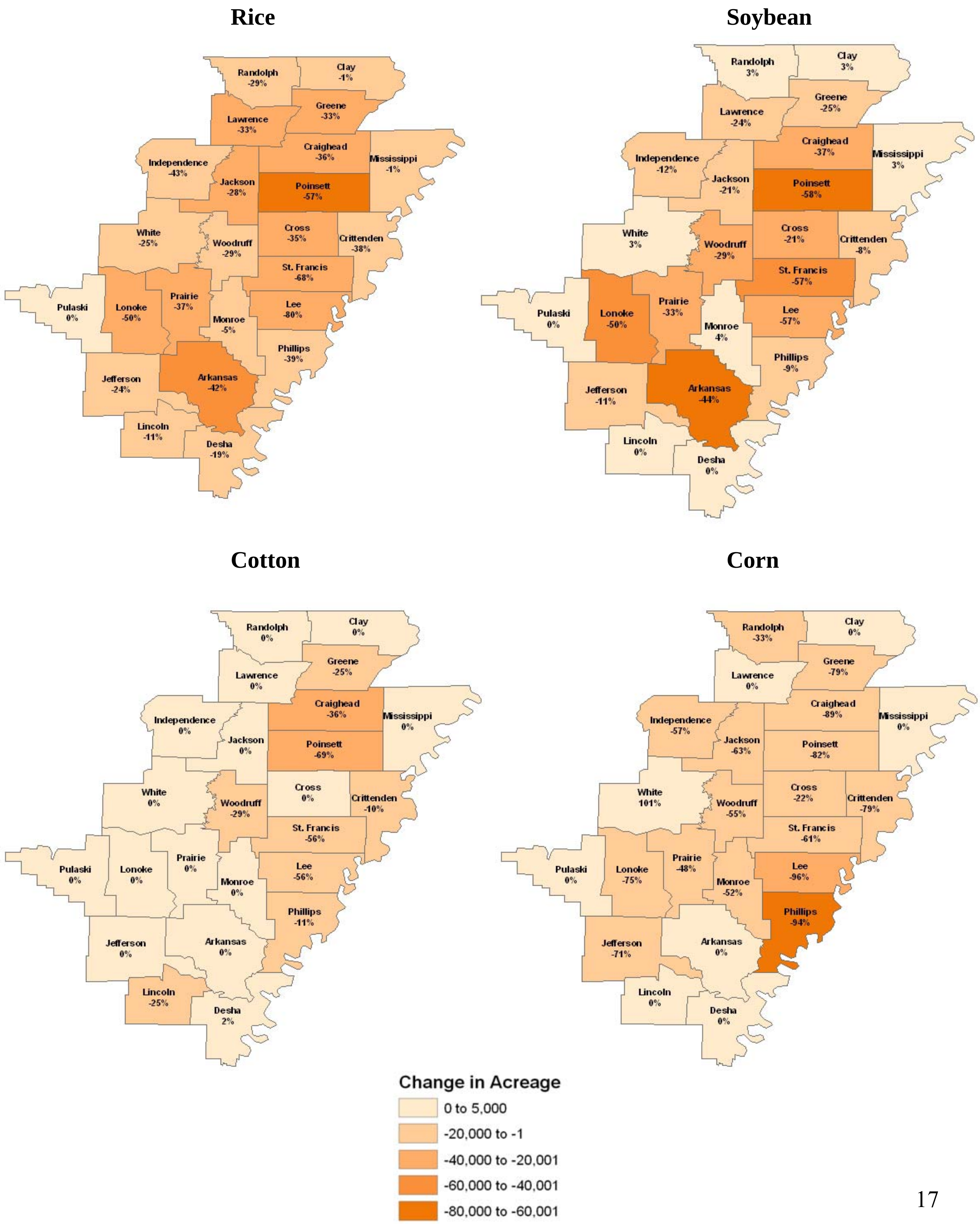

Figure 3. Estimated Reduction in Rice (top left), Irrigated Soybean (top right), Irrigated Cotton (bottom left) and Corn (bottom right) Acreage with Water Use Restrictions Implemented to Double the Life of the Alluvial Aquifer under 2007 Crop Producing Conditions.

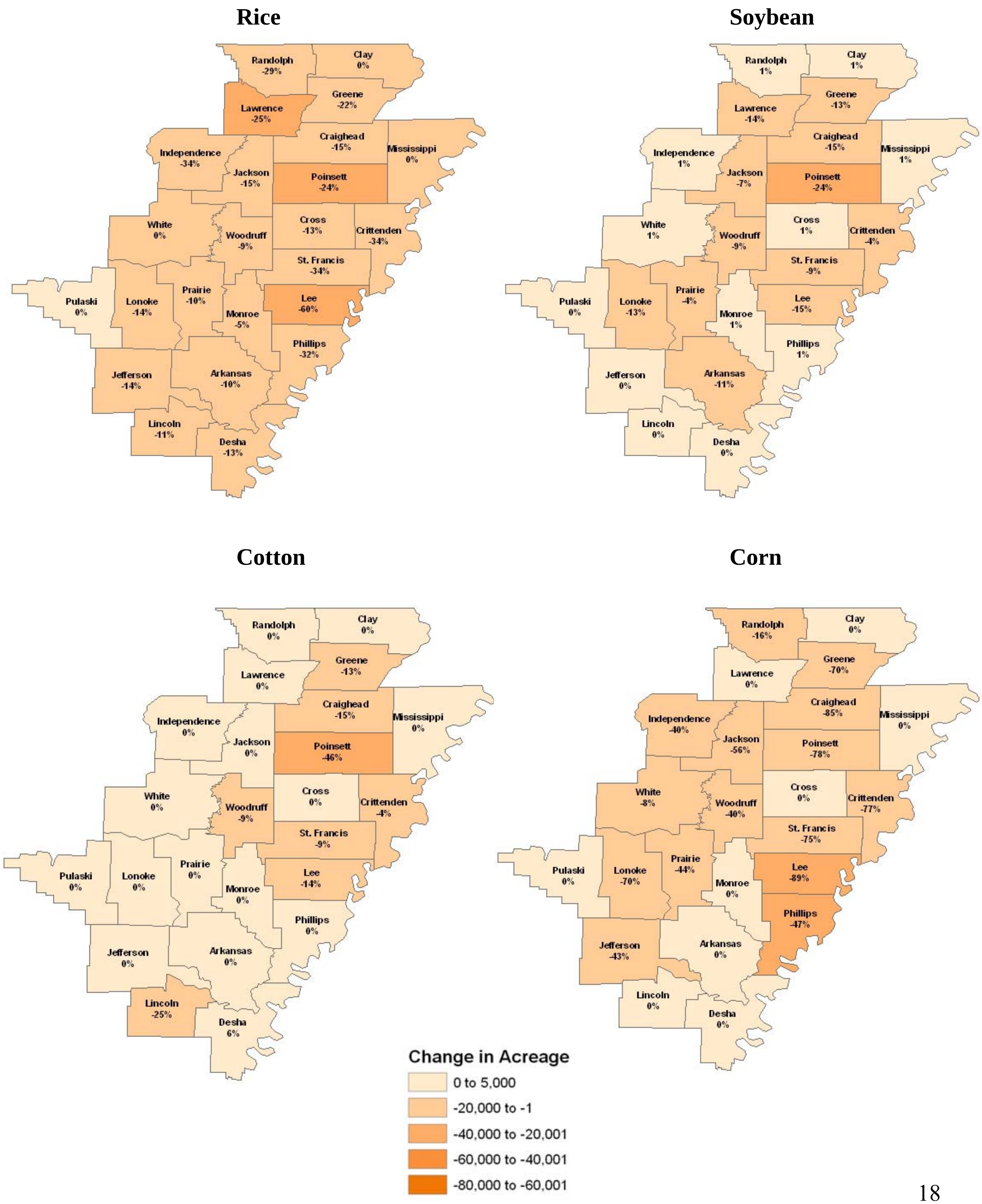

Table 1. Summary of 2007 Commodity Price, Yield and Input Cost Information.

Commodity Prices and Yields

Commodity	Unit	Futures Prices[1]	Custom Hauling[2] / Drying[3] and Checkoff / Other[4]	2007 baseline average yield[5] (2004-2007)	Production Method / Region
Corn	bu	$4.00	$0.35	151.5	Irrigated
Wheat	bu	$4.60	$0.16	51.9	Irrigated
Beans	bu	$7.10	$0.186	40.6	Irrigated
				26.8	Non-irrigated
				32.7	Double cropped
Rice	lb	$0.11	$0.01	6,896.3	Irrigated
Cotton	lb	$0.58	-$0.04	1,099.7	Irrigated
				888.8	Non-irrigated
Grain Sorghum	bu	$3.80	$0.16	105.2	Irrigated
				70.0	Non-irrigated
CRP	acre	$52.00			State average
Forage Sorghum	dt			9.75	Irrigated
				6.50	Non-irrigated
Switchgrass	dt			5.20	Cropland
				4.56	Hay
				4.13	Pasture

Input Prices

Description	Units	2007
Fertilizer (N - P - K - S)		
Urea (46-0-0)	lb	0.18
Liquid Nitrogen (32-0-0)	lb	0.12
Ammonium Nitrate (34-0-0)	lb	0.12
Diammonium Phosphate (18-46-0)	lb	0.14
Phosphate (0-45-0)	lb	0.14
Potash (0-0-60)	lb	0.13
Sulfur (0-0-0-90)	lb	0.23
Boron (0-0-0-0-15)	lb	0.53
Lime	ton	33.00
Labor		
Operator	hrs	9.45
Hired	hrs	8.19
Fuel	gal	2.20
Operating Interest	%	7.75

Notes:

1 Futures prices were for the July contract month as of December of the previous year except for wheat where May futures prices as of September were used to reflect a different planting period (GPTC, 2008).

2 Custom hauling charges amounted to $0.15 per bushel for all commodities except cotton.

3 Drying charges were $0.19 per bushel on corn and $0.30 per bushel on rice.

4 Commodity check off was ½% of price on soybean, $0.01 per bushel on grain sorghum, corn, cotton and wheat and $0.0135 per bushel on rice. Cotton ginning returns of $0.05 per lb were added for cotton.

5 Average yields are for the 2007 baseline scenario without alternative energy crops using per acre county average yields reported by NASS for 2004 through 2007. Forage sorghum yields did not vary by county due to lack of information. Switchgrass yields are prorated and a result of 0, 4 and 6 dt/acre in years 1, 2 and 3 through 10 on crop land, 0, 3.5 and 5.5 dt/acre in years 1, 2 and 3 through 8 on hay land, and 0, 3 and 5 dt/acre in years 1, 2 and 3 through 8 on pasture land.

Table 2. Crop Acreage Reallocations Under Varying Sustainability Scenarios and Alternative Biomass Prices, 2007, Alluvial Aquifer Counties of Arkansas.

		Crops															
		Corn	Cotton		Soybean		Rice	Wheat	Grain Sorghum		Switchgrass & Forage Sorghum				**Total Irr. Acres**	**Total Acre-Inches Used**	**Total Net Returns[2]**
Scenario		Irr.	Non-Irr.	Irr.	Non-Irr.	Irr.[1]	Irr.	Non-Irr.	Non-Irr.	Irr.	Non-Irr.	Irr.	**Hay**	**Pasture**			
2007 Base (**P_S[3] = 0**)		441	280	509	614	1,682	1,381	688	105	100	-	-	218	359	4,114	78	526
% of State[4]		*81*	*99*	*87*	*84*	*93*	*94*	*86*	*96*	*93*	-	-	*15*	*18*	*91*	*93*	*80*
50% Sustain		267	280	458	781	1,565	1,146	880	129	63	-	-	231	359	3,499	66	448
100% Sustain		198	284	397	884	1,248	908	897	129	61	-	-	232	359	2,812	53	377
P_S	**Sustain**	Thousands of Acres														MM of acre-inch	$ MM
25	50%	267	280	458	780	1,565	1,146	880	129	63	1	-	231	359	3,499	66	448
	100%	199	284	397	859	1,248	908	897	129	57	28	-	232	359	2,810	53	377
35	50%	269	280	458	722	1,565	1,146	871	128	58	350	-	231	359	3,496	66	452
	100%	201	284	397	835	1,248	908	889	128	54	903	-	232	359	2,809	53	384
45	50%	262	187	447	593	1,565	1,131	200	74	28	1,340	148	140	323	3,581	66	503
	100%	189	187	389	593	1,248	898	200	74	24	2,046	127	140	323	2,876	53	476
55	50%	163	135	447	593	1,565	1,115	139	24	25	1,429	341	140	323	3,655	65	620
	100%	150	135	389	593	1,248	890	139	24	21	2,169	215	140	323	2,914	52	631

Notes:

1 Includes full season and double cropped soybean

2 Returns to land and management after total specified expenses of seed, fertilizer, chemicals, fuel, custom work, repair and maintenance, operating interest and equipment ownership charges excluding property taxes and insurance. Counties affected by the Alluvial aquifer include Arkansas, Clay, Craighead, Crittenden, Cross, Desha, Greene, Independence, Jackson, Jefferson, Lawrence, Lee, Lincoln, Lonoke, Monroe, Mississippi, Poinsett, Phillips, Prairie, Pulaski, St. Francis, Randolph, White and Woodruff.

3 Price of Switchgrass per dry ton. Forage sorghum price is discounted by $5 per dry ton to reflect difference in processing and harvest costs.

4 Percentages in italics are 2007 Base information for the 24 counties affected by the aquifer relative to information for the entire state of Arkansas.

Table 3. Summary of Income Effects by Irrigation Restriction and Biomass Price Effects.

	Net Returns in Millions of $					Irrigation Restriction Effects		Biomass Compensation Effect	
Biomass Price	$0.00			$44.96	$46.40				
Scenarios[1] Counties / CRD[2]	Base Line (1)	50% Sustain (2)	100% Sustain (3)	50% Sustain (4)	100% Sustain (5)	(2) vs (1)	(3) vs (1)	(4) vs (2)	(5) vs (3)
CRD 1	21	21	21	25	26	0%	0%	17%	22%
CRD 2	17	17	17	20	21	0%	0%	16%	21%
Clay	30	30	30	30	30	0%	-1%	2%	2%
Craighead	34	27	22	30	29	-21%	-36%	12%	36%
Greene	20	14	13	18	18	-27%	-37%	26%	45%
Independence	5	5	4	6	6	-16%	-21%	27%	39%
Jackson	18	14	11	19	19	-23%	-38%	35%	73%
Lawrence	20	16	14	19	19	-22%	-30%	23%	38%
Mississippi	38	38	38	39	39	0%	-1%	1%	3%
Poinsett	38	28	18	34	32	-25%	-52%	19%	74%
Randolph	13	11	10	12	12	-19%	-22%	13%	18%
White	8	8	7	12	12	0%	-7%	49%	67%
CRD 3	225	191	168	220	218	-15%	-25%	15%	30%
CRD 4	22	22	22	26	28	0%	0%	19%	25%
CRD 5	13	13	13	17	18	0%	0%	28%	34%
Arkansas	43	41	30	42	37	-5%	-31%	2%	27%
Crittenden	17	14	13	15	16	-20%	-22%	11%	17%
Cross	26	23	18	26	25	-10%	-29%	12%	37%
Lee	21	12	9	15	16	-44%	-57%	25%	80%
Lonoke	26	21	15	24	24	-18%	-41%	13%	58%
Monroe	16	16	13	17	16	-3%	-21%	7%	23%
Phillips	28	22	16	25	23	-22%	-42%	12%	37%
Prairie	26	23	18	25	24	-11%	-31%	6%	30%
Saint Francis	18	14	11	16	17	-23%	-43%	12%	62%
Woodruff	12	10	8	12	13	-13%	-31%	20%	63%
CRD 6	234	197	152	217	211	-16%	-35%	10%	39%
CRD 7	18	18	18	23	24	0%	0%	23%	31%
CRD 8	5	5	5	7	8	0%	0%	46%	55%
Desha	28	27	27	28	29	-1%	-3%	3%	6%
Jefferson	23	18	15	21	21	-21%	-34%	17%	36%
Lincoln	13	12	12	13	14	-7%	-8%	7%	10%
CRD 9	100	94	90	102	103	-6%	-10%	8%	14%
Alluvial Counties	526	448	377	503	496	-15%	-28%	12%	32%
State Total	656	579	507	656	656	-12%	-23%	13%	29%

Notes:

[1] Scenarios are the baseline without biomass crops and no irrigation restrictions (1), irrigation restrictions to double/sustain the life of the aquifer (2)/(3). Scenarios (4) and (5) remove irrigation restriction impacts on state returns with biomass price.

[2] CRD stands for crop reporting district as reported by National Agricultural Statistics Service for Arkansas. County detail for CRDs 1, 2, 4, 5, 7, 8 and part of 9 are excluded as the irrigation restriction effects were zero.