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Climate Change Adaptation Policy and Expansion of Irrigated Agriculture in Georgia, U.S.

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Abstract The expansion of irrigated agricultural production can be appropriate for the southeast region in the U.S. as a climate change adaptation strategy. This study investigated the effect of supplemental development of irrigated agriculture on the regional economy by applying the supply side Georgia multiregional input-output (MRIO) model. For the analysis, 100% conversion of non-irrigated cultivable acreage into irrigated acreage for cotton, peanuts, corn, and soybeans in 42 counties of southwest Georgia is assumed. With this assumption, the difference in total net returns of production between the non-irrigation and irrigation method is calculated as input data of the Georgia MRIO model. Based on the information of a 95% confidence interval for each crop's average price, the lower and upper bounds of estimated results are also presented. The total impact of cotton production was $60 million with the range of $35 million to $85 million: The total impact of peanuts, soybeans, corn was $10.2 million (the range of $3.28 million to $23.7 million), $6.6 million (the range of $3.1 million to $10.2 million), $1.2 million (the range of -$6 million to $8.5 million), respectively.

Keywords Climate change adaptation, economic impact, irrigated agriculture, supply-driven MRIO model, total net returns

I. Introduction

Irrigated agriculture has played an essential role in water allocation and the market value of agricultural production in the U.S. According to the U.S. Geological Survey's (USGS) water use estimates for primary water demand sectors in the U.S., water withdrawals for irrigated agriculture were estimated at 144 million acre-feet per year and accounted for 31% of the total U.S. water withdrawals (37 % of the total U.S. freshwater withdrawals) in 2005. The market value of agricultural products sold for all U.S. farms was $394.6 billion in 2012, an increase of 32.8% from 2007 ($297.2 billion). Irrigated farms, including any

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irrigated cropland, accounted for about 38.6% of the agricultural production value ($152.4 billion) for all U.S. farms in 2012 (USDA/NASS, 2014).

Irrigation is an especially crucial issue for agriculture in the western United States. On irrigated farms in the 17 western states, about 73% of the harvested cropland and 94% of the pastureland was irrigated in 2007. These ratios reduced to 71% and 92% in 2012, respectively. Among the 17 leading western states in irrigated agriculture (Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming), Nebraska had 22.2% of the harvested cropland on irrigated farms for this region in 2012. California ranked the second-largest harvested cropland at 19.9%, and Texas followed with 11.3% of harvested cropland (USDA/NASS, 2010).

During the last 50 years, the water demand of government, industry, and environmental organizations has increased significantly across the U. S. Demands for surface and ground water needed to maintain natural ecosystems, population and economic growth, and expansion of the U.S. energy sector will continue to increase and bring new challenges for agricultural water use and conservation in the face of substantial evidence of the changes in global climate (Schaible and Aillery, 2012; IPCC, 2007; U.S. CCSP, 2008).

Regarding climate change, Knowles et al. (2006) forecasted that annual precipitation would decline, particularly during the warmer summer months in many of the western states. More specifically, Kunkel et al. (2013a; 2013b; 2013c) simulated the U.S. future climate trend by climate models for two scenarios of the future path of greenhouse gas emissions. Washington, Oregon, and Idaho will experience a decrease in summer precipitation, even though there will be an increase in average annual rainfall. The far southern regions of the southwest U.S. (California, Nevada, Utah, Colorado, Arizona, and New Mexico) will show the most significant decrease in average annual precipitation. However, the far northern areas will increase slightly.

Although the southeast region of the U.S. has much more precipitation and available water resources for agriculture than the arid west, modest irrigation amounts are needed to overcome seasonal and intra-seasonal rainfall variability and relatively poor water-holding soils in most areas of the region. Considering its current and potential future climate conditions, future agricultural growth may be a sustainable enterprise in the southeastern region. Therefore, a possible climate change adaptation strategy is needed in the southeast, and the expansion of supplemental irrigated agriculture can be an appropriate strategy. To meet sustainable food demand at the local level and at the national level, crop production moving from the west to the southeast will be a possible option to address climate change vulnerability and sustain irrigated agriculture in the southeast region.

If the production of some crops is moved to Georgia (the southeast state in the U.S.) due to expected climate change, policymakers and stakeholders of irrigated agriculture will be interested in estimating the benefit of future water allocation in agriculture. Based on the possibility of the production change of certain crops, this research explores the economic impacts of shifting irrigated agricultural production from the west to the southeast of the U.S. to estimate the added value of water allocation in the southeast's agriculture. It will be difficult for future considerations regarding climate change and agricultural water allocations in the southeast of the U.S.

The countries (especially in the developing and transition process) preparing adaptation strategies in the agricultural sector for climate change will interest in water-saving agricultural production methods and want to know the benefit of water allocations. Therefore, this research provides guidelines for examining the value of water allocation with a regional input-output (IO) model and evaluating the effect and sustainability of expanding irrigated agriculture.

II. The economic impact of water allocation

Water transfer and reallocation issues have been of much interest in the southwestern region of the United States over several decades. Numerous studies focused on the evaluation of various water policies and water development projects and have been conducted on the regional economic impact analysis of water management at the state level (Seung et al., 1997; Seckler, 1971; Kelso et al., 1973; Hamilton et al., 1982; Hamilton and Pongtanakorn, 1983). Relating to the economic impact analysis of water-involved issues, two main approaches have been broadly adopted in the field: input-output (IO) and computable general equilibrium (CGE) approaches.

Among studies applying the CGE approach, Seung et al. (1997) estimated the economic impact of transferring water use from irrigated agriculture to recreational purposes at the Stillwater National Wildlife Refuge in Churchill County, Nevada. The study employed two alternative regional economic models and compared the results. The authors concluded that a regional CGE model provided a more conservative result than a supply-determined social accounting matrix (SDSAM) model. The SDSAM model employed overly restrictive assumptions, such as no factor substitution in production or commodity substitution in consumption and fixed prices including factor price. Considering water rights compensation, the agricultural production decrease, and the increase in recreation-related expenditure effects, Seung et al. (1998) analyzed the water reallocation effects in the Walker River Basin using a regional CGE model. They specified three different model variants depending on the assumptions about interregional factor mobility to test model sensitivity. The authors found that the decreasing agricultural production effect surpassed the combined impact of water rights compensation and increased recreation-related expenditures. The policy effect of each sector was also sensitive to alternative assumptions about the interregional factor mobility.

To evaluate the economic impacts of increasing irrigation in the Canterbury and Hawkes Bay regions, Kaye-Blake et al. (2010) measured the increased irrigation effects with the MONASH-NZ dynamic CGE model: an off-farm capital infrastructure costs increase, an on-farm capital costs increase, and the agricultural production increase. Using the newly developed version of the GTAP-W model, Calzadilla et al. (2008) analyzed the global effect of enhanced irrigation efficiency on crop production, water use, and welfare.

In the case of the IO approach, Kirsten and van Zyl (1990) compared several methodological alternatives for determining the impact of irrigation development, and they applied the IO model to calculate total output, income, and total employment multipliers for estimating the economic benefits of irrigation development as an empirical application. Based on the 1963 IO model of the Nebraska economy, Roesler et al. (1968) estimated the economic impact of a net increase in irrigated agriculture production with two separate impacts: the short-run impact of the additional crop production and the long-run impact due to investment activity in all sectors. With the estimated irrigated acreage in the Texas High Plains, Osborn (1973) estimated the total economic benefit using income and employment multipliers calculated from the IO model of the Texas High Plains region.

Moreover, Howe et al. (1990) analyzed the temporal pattern of water transfer from irrigated agriculture to urban areas with the Colorado Forecasting and Simulation Model (COFS). They found that the statewide negative impacts of historical agriculture-to-urban water transfer have been minor relative to the costs of alternative ways of getting water for the urban areas. Similarly, Lee et al. (1987) and Whited (2010) estimated the economic impact of irrigation water transfer on Uvalde County, Texas, adopting the IO model with different measurement methods. While Lee et al. (1987) estimated the effect of projected future groundwater withdrawal rates by San Antonio on irrigated agriculture in Uvalde County, Whited (2010) focused on intermediate input changes specific to the actual crops production rather than a change in agricultural output.

III. Data and method

For a supply-driven input-output (IO) model, the 2009 Georgia multiregional input-output (MRIO) model at the county level was constructed using the 2009 IMPLAN data. A supply-driven MRIO model for Georgia was then applied to analyze the economic impact of the crop production change induced by the conversion of non-irrigated cropland to irrigated cropland in Georgia.

The study area is 42 counties in the southwestern region of Georgia in the U.S., and the subject crops for the analysis were cotton, peanuts, corn, and soybeans. For a basic analysis scenario, all non-irrigated cultivable acreage of each subject crop in study area counties is assumed converted to irrigated acreage of cropland.

As input data for the supply-driven Georgia MRIO model, the difference in total net returns of each crop between non-irrigated and irrigated production methods was calculated. For this purpose, this study collected the relevant data in the '2012 Census of Agriculture: Georgia State and County Data', 'Agricultural Prices', and '2012 Census of Agriculture: Georgia State and County Data' from the U.S. Department of Agriculture, National Agriculture Statistics Service. The difference between harvested acreage and irrigation acreage is cultivable acreage by converting from non-irrigated production to irrigated methods.

Average price data on each crop for deriving the standard deviation of average price was calculated based on Agricultural Prices monthly reports from January 2000 through February 2014, which contain prices received by farmers for principal crops, livestock, and livestock products. The standard deviation of average price for each crop was used to calculate a 95% confidence interval of the difference in total net returns of each crop between both production methods.

Also compiled were the expected average price of each crop, the expected average yield per acre of each crop, and the total production cost of each crop, excluding land and management costs in South Georgia, for the conventional tillage from the Summary of South Georgia Crop Enterprise Estimates, 2014, provided by the UGA Extension Agricultural and Applied Economics. In Table 1, the expected average yield per acre of each crop and the total production cost of each crop, excluding land and management costs in South Georgia, are presented by both production methods.

Table 1 Expected average yield and Total production cost of each crop by the production method

	Non-Irrigated				Irrigated			
	Cotton	Peanuts	Corn	Soybeans	Cotton	Peanuts	Corn	Soybeans
Expected Yield	750	3400	85	30	1200	4700	200	60
Unit	lb/acre	lb/acre	bushel/ acre	bushel/ acre	lb/acre	lb/acre	bushel/ acre	bushel/ acre
Total Cost ($/acre)	559	712	357	283	809	957	869	501

Source: Summary of South Georgia Crop Enterprise Estimates, 2014

The procedure calculating the total net returns difference of each crop between non-irrigated production and irrigated production with the assumption of 100% conversion of non-irrigated cultivable acreage to irrigated acreage is shown in Equation 1:

$$\begin{aligned} IR_{ij} &= (IY_i \times AP_i \times NA_{ij}) - (IC_i \times NA_{ij}) \\ NR_{ij} &= (NY_i \times AP_i \times NA_{ij}) - (NC_i \times NA_{ij}) \\ DR_{ij} &= IR_{ij} - NR_{ij} \end{aligned} \tag{1}$$

where, IR = Total net return of irrigated production by each crop and county,
NR = Total net return of non-irrigated production by each crop and county,
DR = Difference in Total net returns by each crop and county,
IY = Expected average yield per acre of each crop by irrigated production,
AP = Expected average price of each crop,
IC = Total production cost of each crop by irrigated production,
NY = Expected average yield per acre of each crop by non-irrigated production,
NA = Non-irrigated acreage of each crop by each county (the difference between total harvested acreage and irrigated acreage),
NC = Total production cost of each crop by non-irrigated production,
i = cotton, peanuts, corn, soybeans, and
j = 42 counties in the southwest region of Georgia.

To indicate the reliability of an estimate, a 95% confidence interval was generated for the impact of increasing each crop's production. Based on the average crop price received by farmers from 2000 through 2014, the standard deviation of average crop price and a 95% confidence interval for average crop price were calculated. The upper and lower bounds for the difference in total net returns for both production methods were calculated using this 95% confidence interval for average crop price. The expected average price of each crop and its 95% confidence interval are shown in Table 2. Based on this information, each crop's calculated difference in total net returns and its 95% confidence interval are presented by each county in Table 3.

Table 2 Expected average price and a 95% confidence interval for the average price of each crop

	Cotton	Peanuts	Corn	Soybeans
Expected Average price	0.78	0.22	4.6	10.8
Lower bound of Average price	0.69	0.20	3.73	8.90
Upper bound of Average price	0.87	0.24	5.47	12.70
Unit	$/lb	$/lb	$/bu	$/bu

Source: 1. Summary of South Georgia Crop Enterprise Estimates, 2014
2. Agricultural Prices from January 2000 through February 2014

Table 3 A 95% of confidence interval for the difference in total net returns of each crop, by county, 2014

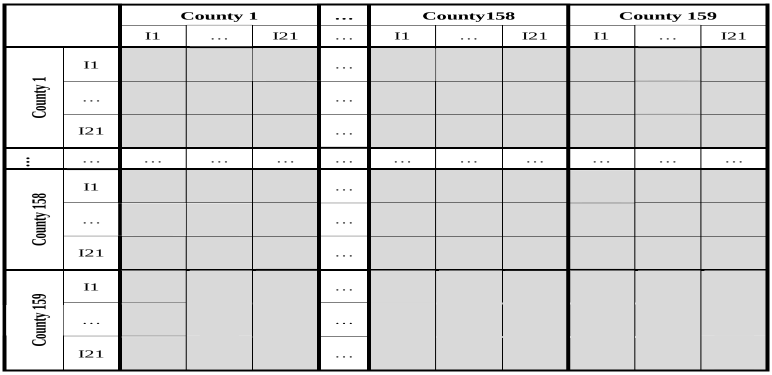
Counties	Cotton			Peanuts		
	Lower	Mean	Upper	Lower	Mean	Upper
Baker	0.31	0.54	0.77	0.10	0.32	0.75
Ben Hill	0.28	0.49	0.70	0.08	0.24	0.57
Berrien	1.35	2.33	3.31	0.18	0.55	1.27
Bleckley	0.13	0.23	0.32	0.02	0.06	0.14
Brooks	1.70	2.93	4.16	0.06	0.19	0.44
Calhoun	0.68	1.18	1.67	0.11	0.35	0.81
Clay	0.15	0.25	0.36	0.04	0.14	0.32
Colquitt	1.83	3.16	4.48	0.10	0.31	0.72
Cook	1.04	1.79	2.54	0.07	0.22	0.50
Crisp	1.81	3.12	4.42	0.11	0.36	0.83
Decatur	0.92	1.58	2.25	0.19	0.58	1.36
Dodge	0.36	0.63	0.89	0.01	0.03	0.07
Dooly	1.63	2.81	3.99	0.08	0.25	0.59
Dougherty	0.00	0.00	0.00	0.00	0.00	0.01
Early	1.18	2.03	2.89	0.16	0.50	1.16
Grady	1.10	1.90	2.69	0.06	0.20	0.47
Houston	0.15	0.25	0.36	0.02	0.07	0.16
Irwin	1.67	2.88	4.08	0.22	0.68	1.57
Lanier	0.44	0.76	1.08	0.02	0.06	0.15
Lee	0.46	0.79	1.12	0.07	0.21	0.49
Lowndes	0.22	0.39	0.55	0.03	0.08	0.19
Macon	0.25	0.44	0.62	0.01	0.03	0.06

Marion	0.01	0.01	0.02	0.00	0.01	0.03
Miller	0.72	1.24	1.75	0.07	0.22	0.51
Mitchell	1.22	2.10	2.98	0.09	0.28	0.66
Peach	0.04	0.07	0.10	0.00	0.00	0.01
Pulaski	0.58	1.01	1.43	0.02	0.08	0.18
Randolph	0.38	0.65	0.93	0.10	0.31	0.72
Schley	0.04	0.06	0.09	0.00	0.00	0.01
Seminole	0.57	0.98	1.39	0.07	0.21	0.49
Stewart	0.16	0.27	0.39	0.04	0.11	0.26
Sumter	0.77	1.32	1.88	0.05	0.16	0.37
Talbot	0.00	0.00	0.00	0.00	0.00	0.00
Taylor	0.02	0.04	0.06	0.00	0.00	0.00
Terrell	0.81	1.40	1.99	0.11	0.33	0.78
Thomas	2.08	3.58	5.08	0.09	0.29	0.66
Tift	0.86	1.49	2.11	0.06	0.19	0.45
Turner	0.81	1.40	1.99	0.07	0.22	0.52
Twiggs	0.29	0.50	0.72	0.00	0.00	0.00
Webster	0.47	0.82	1.16	0.03	0.09	0.22
Wilcox	1.53	2.63	3.74	0.09	0.29	0.67
Worth	2.81	4.84	6.87	0.27	0.84	1.94
Total	31.87	54.89	77.92	2.91	9.07	21.09

Counties	**Corn**			**Soybeans**		
	Lower	**Mean**	**Upper**	**Lower**	**Mean**	**Upper**
Baker	-0.18	0.04	0.26	0.01	0.03	0.05
Ben Hill	-0.09	0.02	0.13	0.00	0.01	0.01
Berrien	-0.23	0.05	0.32	0.03	0.07	0.11
Bleckley	-0.05	0.01	0.07	0.14	0.30	0.47
Brooks	-0.14	0.03	0.20	0.24	0.51	0.79
Calhoun	-0.29	0.06	0.41	0.02	0.03	0.05
Clay	-0.03	0.01	0.04	0.02	0.04	0.06
Colquitt	-0.08	0.02	0.11	0.03	0.05	0.08
Cook	-0.04	0.01	0.06	0.01	0.03	0.04
Crisp	-0.03	0.01	0.04	0.06	0.14	0.21

Decatur	-0.63	0.13	0.89	0.21	0.45	0.69
Dodge	-0.02	0.00	0.02	0.06	0.14	0.21
Dooly	-0.08	0.02	0.11	0.17	0.36	0.55
Dougherty	0.00	0.00	0.00	0.01	0.01	0.02
Early	-0.24	0.05	0.34	0.08	0.17	0.26
Grady	-0.34	0.07	0.49	0.08	0.18	0.28
Houston	-0.05	0.01	0.07	0.10	0.21	0.33
Irwin	-0.30	0.06	0.42	0.05	0.10	0.16
Lanier	-0.02	0.00	0.02	0.00	0.01	0.01
Lee	-0.22	0.04	0.31	0.12	0.25	0.39
Lowndes	-0.05	0.01	0.07	0.05	0.10	0.16
Macon	-0.11	0.02	0.16	0.22	0.48	0.74
Marion	-0.03	0.01	0.05	0.07	0.16	0.24
Miller	-0.14	0.03	0.19	0.07	0.16	0.24
Mitchell	-0.31	0.06	0.44	0.02	0.04	0.06
Peach	0.00	0.00	0.01	0.23	0.49	0.76
Pulaski	-0.05	0.01	0.07	0.06	0.13	0.20
Randolph	-0.16	0.03	0.22	0.13	0.28	0.43
Schley	-0.01	0.00	0.01	0.04	0.09	0.14
Seminole	-0.15	0.03	0.21	0.04	0.08	0.13
Stewart	0.00	0.00	0.01	0.02	0.05	0.08
Sumter	-0.34	0.07	0.48	0.14	0.31	0.48
Talbot	0.00	0.00	0.00	0.00	0.00	0.00
Taylor	-0.04	0.01	0.06	0.12	0.26	0.40
Terrell	-0.44	0.09	0.62	0.18	0.38	0.59
Thomas	-0.32	0.07	0.45	0.10	0.23	0.35
Tift	-0.05	0.01	0.07	0.00	0.01	0.01
Turner	-0.09	0.02	0.12	0.04	0.10	0.15
Twiggs	0.00	0.00	0.00	0.00	0.00	0.00
Webster	-0.03	0.01	0.04	0.03	0.07	0.10
Wilcox	-0.01	0.00	0.02	0.05	0.10	0.15
Worth	-0.17	0.04	0.25	0.02	0.04	0.06
Total	-5.58	1.14	7.86	3.09	6.66	10.23

Applying the methodology that Chenery (1953) and Moses (1955) suggested for the MRIO model, the supply-driven Georgia MRIO model was formulated based on the procedure that Park et al. (2009b) used to construct an operational MRIO model at the U.S. state level. The final inverse coefficient matrix structure of the supply-driven Georgia MRIO model would be expected to have the matrix form seen in Figure 1. The inverse matrix has a (21 x 159) x (21 x 159) matrix form. The description of industry sectors of the Georgia MRIO model can be found in Table 4.



		County 1			...	County158			County 159		
		I1	...	I21	...	I1	...	I21	I1	...	I21
County 1	I1				...						
	...				...						
	I21				...						
...	...	...	...	...	...	...	...	...	...	...	...
County 158	I1				...						
	...				...						
	I21				...						
County 159	I1				...						
	...				...						
	I21				...						

Figure 1 The structure of inversed Georgia supply-driven MRIO Coefficients Matrix

Table 4 The industry sector system of the Georgia supply-driven MRIO model

MRIO sectors	Two digit NAICS Code System	Sector Description
1	11	Total Farm
2	21	Natural Resources and Mining
3	22	Utilities
4	23	Construction
5	31	Manufacturing
6	42	Wholesale Trade
7	44	Retail Trade
8	48	Transportation and Warehousing
9	51	Information
10	52	Finance and Insurance
11	53	Real Estate and Rental and Leasing
12	54	Professional, Scientific and Technical Services

13	55	Management of Companies and Enterprises
14	56	Administrative and Support and Waste Services
15	61	Educational Services
16	62	Health Care and Social Assistance
17	71	Arts, Entertainment, and Recreation
18	72	Accommodation and Food Service
19	81	Other Services
20	92	Public Administration
21	93	Not an industry

Park (2007; 2008) and Park et al. (2008) elaborated a supply-driven MRIO model at the national level, including empirical tests. Equation 2 shows the inverse supply-driven Georgia MRIO matrix as $(\mathrm{I} - \mathrm{GC})^{-1}$. Since Q is defined as a row vector of regional specific value added, the difference in total net returns of each crop will have an impact on other counties and industry sectors via Equation 2:

$$\mathrm{T}^{\mathrm{I}} = \mathrm{QC}(\mathrm{I} - \mathrm{GC})^{-1} \qquad (2)$$

where, TI = the total input row vector,
Q = a row vector of regional specific value added factors,
G = $(\hat{\mathrm{T}}^{\mathrm{I}})^{-1}\mathrm{Z}$ stands for IO matrices and $\hat{\mathrm{T}}^{\mathrm{I}}$ is the block diagonal matrix of vector T^{I},
Z = the block diagonal matrix of interindustry transactions, and
C = the block diagonal matrix of interregional trade flows coefficients.

IV. Results

This study estimated the economic impact of increasing agricultural production due to the 100% conversion of non-irrigated cultivable acreage of cotton, peanuts, corn, and soybeans in 42 counties of southwest Georgia into irrigated acreage. For this purpose, the total net returns difference of each crop between the irrigated production method and the non-irrigated production method was calculated.

Applying each county's total net returns difference by each crop to Equation 2 as an exogenous change of value added vector Q, the economic impact of increasing agricultural production is estimated by 159 counties and 21 industry sectors. Based on the information of a 95% confidence interval for each crop’s average price, the economic impact of each crop is also presented with the lower and upper bounds in the results tables. The estimated results of all crops are summarized by the top ten impacted counties and the top three affected industry sectors; Table 5 shows the results for cotton, Table 6 the results for peanuts, Table 7 the results for corn, and Table 8 the results for soybeans.

In the results tables, “Direct impact” refers to the initial economic impact experienced in each sector in each county relating to the crop’s production increase. “Indirect impact” indicates the economic impact arising due to inter-industry linkages and is estimated via the inversed coefficients matrix in the supply-driven Georgia MRIO model. A Type I multiplier describes the ratio of the sum of direct and indirect impacts relative to direct impact.

Table 5 Impact of increasing cotton production for selected counties and industry sectors

Counties	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
TH	1.07	0.05	1.12	1.85	0.08	1.92 (3.2)	2.62	0.11	2.73
IR	1.03	0.06	1.09	1.78	0.10	1.88 (3.1)	2.53	0.14	2.67
WO	1.01	0.04	1.05	1.74	0.06	1.81 (3.0)	2.47	0.09	2.57
ER	0.92	0.11	1.03	1.58	0.19	1.77 (2.9)	2.24	0.27	2.51
WI	0.96	0.06	1.02	1.66	0.11	1.76 (2.9)	2.35	0.15	2.50
GR	0.90	0.05	0.95	1.55	0.08	1.63 (2.7)	2.20	0.11	2.31
BO	0.89	0.04	0.93	1.54	0.07	1.60 (2.7)	2.18	0.09	2.27
CP	0.86	0.04	0.90	1.49	0.06	1.55 (2.6)	2.11	0.09	2.20
DR	0.84	0.06	0.90	1.44	0.10	1.54 (2.6)	2.04	0.15	2.19
CQ	0.84	0.04	0.89	1.45	0.08	1.53 (2.5)	2.06	0.11	2.17
Others	21.55	3.44	24.99	37.12	5.93	43.05 (71.7)	52.69	8.42	61.11
Total	30.87	3.98	34.85	53.19	6.85	60.04	75.50	9.73	85.23

Sector	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
1	30.87	1.87	32.75	53.19	3.22	56.41 (94.0)	75.50	4.58	80.08
5	0	2.03	2.03	0	3.50	3.50 (5.8)	0	4.97	4.97
4	0	0.02	0.02	0	0.03	0.03 (0.0)	0	0.04	0.04
Total	30.87	3.98	34.85	53.19	6.85	60.04	75.50	9.73	85.23
Type I multiplier						1.129			

Note: 1. DI: Direct Impact, II: Indirect Impact, TI: Total Impact

2.The value in parenthesis is the percentage of total impacts.

3. Others: 149 counties, excluding the top ten counties

4. Unit: million dollars

As the difference in total net returns of cotton between both production methods is calculated as $53 million due to the 100% conversion of non-irrigated acreage in selected counties of Georgia, the ten most affected counties were Thomas ($1.92 million, 3.2%), Irwin ($1.88 million, 3.1%), Worth ($1.81 million, 3%), Early ($1.77 million, 2.9%), Wilcox ($1.76 million, 2.9%), Grady ($1.63 million, 2.7%), Brooks ($1.6 million, 2.7%), Crisp ($1.55 million, 2.6%), Decatur ($1.54 million, 2.6%), and Colquitt ($1.53 million, 2.5%). Almost 30% of the total impact happened in the top ten counties. The total impact of the difference in total net returns of cotton production was $60 million and in the range of $35 million to $85 million.

In Table 5, the impact of the top three industry sectors for cotton production are shown together with the results of selected counties. The total economic gain of Sector 1 (Total Farm) was the greatest at $56 million and in the range of $33 million to $80 million and accounted for 94% of the total impact; Sectors 5 (Manufacturing) and 4 (Construction) followed with $3.5 million (5.8%) and $0.03 million (0.05%), respectively. The Type I multiplier of the production change for cotton was 1.13.

Due to the conversion of non-irrigated acreage for peanuts production in 42 counties of Georgia, the difference in total net returns of peanuts between both production methods is estimated at $9 million. The most affected county for the change of peanuts production was Early ($0.4 million, 3.9%), and its impact was between $0.13 million and $0.93 million; Irwin ($0.395 million, 3.9%), Decatur ($0.37 million, 3.7%), Worth ($0.3 million, 3%), Seminole ($0.25 million, 2.5%), Thomas ($0.248 million, 2.4%), Miller ($0.247 million, 2.4%), Berrien ($0.246 million, 2.4%), Grady ($0.242 million, 2.4%), and Baker ($0.24 million, 2.4%) followed. The other 149 counties (excluding the top ten impacted counties) accounted for 71% of the total impact of peanuts production change ($10.2 million), and the total impact was in the range of $3.28 million to $23.71 million (see Table 6).

Table 6 Impact of increasing peanuts production for selected counties and industry sectors

Counties	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
ER	0.12	0.01	0.13	0.36	0.04	0.40 (3.9)	0.84	0.10	0.93
IR	0.12	0.01	0.13	0.38	0.02	0.40 (3.9)	0.87	0.04	0.92
DR	0.11	0.01	0.12	0.35	0.02	0.37 (3.7)	0.81	0.05	0.87
WO	0.09	0.00	0.10	0.29	0.01	0.30 (3.0)	0.67	0.03	0.70
SE	0.07	0.01	0.08	0.22	0.04	0.25 (2.5)	0.50	0.08	0.59
TH	0.08	0.00	0.08	0.24	0.01	0.25 (2.4)	0.55	0.03	0.58
MI	0.07	0.00	0.08	0.23	0.02	0.25 (2.4)	0.54	0.04	0.57
BE	0.08	0.00	0.08	0.24	0.01	0.25 (2.4)	0.55	0.02	0.57
GR	0.07	0.00	0.08	0.23	0.01	0.24 (2.4)	0.53	0.03	0.56
BX	0.07	0.00	0.08	0.23	0.01	0.24 (2.4)	0.53	0.03	0.56
Others	2.00	0.33	2.33	6.24	1.02	7.26 (71.1)	14.50	2.36	16.86
Total	2.89	0.39	3.28	8.99	1.21	10.20	20.89	2.82	23.71

Sector	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
1	2.89	0.19	3.08	8.99	0.59	9.58 (93.9)	20.89	1.37	22.26
5	0.00	0.19	0.19	0.00	0.60	0.60 (5.9)	0.00	1.40	1.40
4	0.00	0.00	0.00	0.00	0.01	0.01 (0.1)	0.00	0.01	0.01
Total	2.89	0.39	3.28	8.99	1.21	10.20	20.89	2.82	23.71
Type I multiplier						1.135			

Note: 1. DI: Direct Impact, II: Indirect Impact, TI: Total Impact
2.The value in parenthesis is the percentage of total impacts.
3. Others: 149 counties, excluding the top ten counties
4. Unit: million dollars

As shown in Table 6, the economic impact of the production change for peanuts was highest in the following industry sectors: Sector 1 ($9.6 million, 93.9%), Sector 5 ($0.6 million, 5.9%), and Sector 4 ($0.006 million, 0.1%). The range of these sectors' impact was between $3.08 million and $22.26 million, $0.19 million and $1.4 million, and $0.002 million and $0.013 million, respectively. The ratio of the sum of direct and indirect impacts relative to direct impact was 1.14 in the impact analysis for the peanuts production change.

In corn production change, $1.1 million of the difference in total net returns between both production methods has the greatest effect on Decatur ($0.07 million) and represents 3.9% of the total impact of corn production change. A 95% confidence interval for the impact on Decatur was estimated to be between -$0.33 million and $0.47 million. Grady ($0.05 million, 3.7%) and Early ($0.046 million, 3.7%) were ranked second and third, respectively; Thomas ($0.04 million, 3.1%), Irwin ($0.037 million, 3%), Seminole ($0.036 million, 3%), Sumter ($0.036 million, 2.9%), Miller ($0.035 million, 2.9%), Calhoun ($0.03 million, 2.8%), and Baker ($0.033 million, 2.7%) followed. The impact of the top ten counties took up almost 33% of the total impact of corn production change ($1.23 million), and the impact of the top ten counties was in the range of -$2 million to $2.82 million (see Table 7).

The individual economic gain from the corn production change was most significant in Sector 1 at $1.16 million with 93.9% of the total impact; Sector 5 ($0.07 million, 5.6%) and Sector 4 ($0.001 million, 0.05%) were ranked second and third impacted industry sectors. A 95% confidence interval for the impact of these sectors was in the range of -$5.65 million to $7.97 million, -$0.34 million to $0.47 million, and -$0.003 million to $0.004 million, respectively. The Type I multiplier for the case of the corn production change was 1.13.

Table 7 Impact of increasing corn production for selected counties and industry sectors

Counties	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
DR	-0.32	-0.02	-0.33	0.06	0.00	0.07 (5.5)	0.44	0.02	0.47
GR	-0.21	-0.01	-0.22	0.04	0.00	0.05 (3.7)	0.30	0.01	0.32
ER	-0.20	-0.02	-0.22	0.04	0.00	0.05 (3.7)	0.28	0.03	0.32
TH	-0.18	-0.01	-0.19	0.04	0.00	0.04 (3.1)	0.25	0.01	0.27
IR	-0.17	-0.01	-0.18	0.04	0.00	0.04 (3.0)	0.24	0.01	0.26
SE	-0.15	-0.02	-0.18	0.03	0.01	0.04 (3.0)	0.21	0.03	0.25
SU	-0.17	-0.01	-0.18	0.03	0.00	0.04 (2.9)	0.24	0.01	0.25
MI	-0.16	-0.01	-0.17	0.03	0.00	0.04 (2.9)	0.23	0.01	0.24
CU	-0.16	-0.01	-0.17	0.03	0.00	0.03 (2.8)	0.22	0.01	0.23
BX	-0.15	-0.01	-0.16	0.03	0.00	0.03 (2.7)	0.21	0.01	0.22
Others	-3.45	-0.56	-4.00	0.71	0.11	0.82 (66.7)	4.86	0.78	5.64
Total	-5.32	-0.68	-6.00	1.09	0.14	1.23	7.50	0.96	8.46

Sector	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
1	-5.32	-0.33	-5.65	1.09	0.07	1.16 (94.2)	7.50	0.47	7.97
5	0.00	-0.34	-0.34	0.00	0.07	0.07 (5.6)	0.00	0.47	0.47
4	0.00	0.00	0.00	0.00	0.00	0.00 (0.0)	0.00	0.00	0.00
Total	-5.32	-0.68	-6.00	1.09	0.14	1.23	7.50	0.96	8.46
Type I multiplier						1.128			

Note: 1. DI: Direct Impact, II: Indirect Impact, TI: Total Impact

2.The value in parenthesis is the percentage of total impacts.

3. Others: 149 counties, excluding the top ten counties

4. Unit: million dollars

5. Negative sign stands for the economic losses.

When all of the non-irrigated cultivable acreages for soybeans production are assumed to be converted to irrigation acreage in 42 counties of Georgia, the total net benefit is estimated at $5.9 million. The total economic impact of the benefit induced by the soybeans production change was $7 million, and the lower and upper bounds of the total impact were $3 million and $10 million, respectively. Besides, 27.1% of the total impact arose in the top ten counties with a range of $0.83 million to $2.77 million. The estimated results of these top ten impacted counties are shown in Table 8. The most affected county for the change of soybeans production was Decatur at $0.24 million, which accounted for 3.7% of the total impact, with $0.11 million as the lower bound and $0.37 million as the upper bound. Peach was the second most affected county at $0.21 million (3.1%) with a range of $0.1 million to $0.32 million. Bleckley ($0.19 million, 2.9%), Sumter ($0.18 million, 2.7%), Randolph ($0.179 million, 2.7%), Macon ($0.17 million, 2.6%), Brooks ($0.169 million, 2.5%), Early ($0.16 million, 2.5%), Grady ($0.15 million, 2.2%), and Thomas ($0.14 million, 2.1%) followed.

In the case of the economic impact of the soybeans production change upon industry sectors as shown in Table 8, the economic benefit was sizable, with the following three industry sectors experiencing the most significant gains: Sector 1 ($6.26 million, 94.2%), Sector 5 ($ 0.37 million, 5.6%), and Sector 4 ($0.003 million, 0.05%). A 95% confidence interval for the impact of these three sectors was estimated at the range of $2.9 million to $9.61 million, $0.17 million to $0.57 million, and $0.002 million to $0.005 million, respectively. The ratio of the sum of direct and indirect impacts relative to direct impact was 1.13 in the impact analysis for the soybeans production change.

Table 8 Impact of increasing soybeans production for selected counties and industry sectors

Counties	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
DR	0.11	0.01	0.11	0.23	0.01	0.24 (3.7)	0.35	0.02	0.37
PE	0.09	0.00	0.10	0.20	0.01	0.21 (3.1)	0.30	0.02	0.32
BY	0.08	0.01	0.09	0.18	0.01	0.19 (2.9)	0.28	0.02	0.30
SU	0.08	0.00	0.08	0.17	0.01	0.18 (2.7)	0.26	0.01	0.28
RH	0.08	0.01	0.08	0.17	0.01	0.18 (2.7)	0.26	0.02	0.28
MA	0.08	0.00	0.08	0.16	0.01	0.17 (2.6)	0.25	0.01	0.26
BO	0.08	0.00	0.08	0.16	0.01	0.17 (2.5)	0.25	0.01	0.26
ER	0.07	0.01	0.08	0.15	0.02	0.16 (2.5)	0.22	0.03	0.25
GR	0.06	0.00	0.07	0.14	0.01	0.15 (2.2)	0.21	0.01	0.23
TH	0.06	0.00	0.07	0.14	0.01	0.14 (2.1)	0.21	0.01	0.22
Others	1.95	0.29	2.25	4.21	0.64	4.84 (72.9)	6.47	0.98	7.44
Total	2.74	0.34	3.08	5.90	0.74	6.64	9.07	1.14	10.21

Sector	Low			Mean			Upper		
	DI	I I	T I	DI	I I	T I	DI	I I	T I
1	2.74	0.16	2.90	5.90	0.35	6.26 (94.2)	9.07	0.55	9.61
5	0.00	0.17	0.17	0.00	0.37	0.37 (5.6)	0.00	0.57	0.57
4	0.00	0.00	0.00	0.00	0.00	0.00 (0.0)	0.00	0.00	0.00
Total	2.74	0.34	3.08	5.90	0.74	6.64	9.07	1.14	10.21
Type I multiplier					1.126				

Note: 1. DI: Direct Impact, II: Indirect Impact, TI: Total Impact

2.The value in parenthesis is the percentage of total impacts.

3. Others: 149 counties, excluding the top ten counties

4. Unit: million dollars

V. Discussions and conclusions

Climate change is a crucial issue globally, and an immediate adaptation strategy at the national and local levels to cope with the climate change effect is necessary for all stakeholders of diverse interests in society. Since agriculture is susceptible to climate variability and its change, climate factors, including CO2 concentration in the atmosphere and changes in precipitation and temperatures, have affected the agricultural sector through various production mechanisms. The net effect of climate change on agricultural production will depend on the interaction of these climatic factors (Ingram et al., 2013). According to the study of Boote et al. (2011), sufficient understanding of the structure of natural systems and their operating processes in regards to climatic factors is a crucial issue to developing climate change adaptation strategies for the agricultural sector.

Through the interactions of climatic factors, such as increasing temperature and decreasing rainfall during crop growing seasons, which are expected in the western states, the timing and amount of water supply will negatively affect irrigated agriculture in the region. Reduced water supplies caused by the interaction of climate factors could further restrain the allocation of water resources in the western U.S. region. Moreover, increased water demand from competitive user groups in the region is expected to intensify, an additional constraint on water allocation.

In the southeast U.S. region, modest irrigation amounts are needed to overcome seasonal and inter-annual rainfall variability and relatively poor water-holding soils in most areas. Considering expected climate change in the western and southeastern regions and its impact on irrigated agriculture, a possible climate change adaptation strategy is needed in the southeast area. Several possible strategies, such as adaptation of variable-rate irrigation and micro-irrigation, have been suggested to optimize crop production in the southeast region (Ingram et al., 2013). In addition to these options, the expansion of irrigated agriculture can be an appropriate strategy for sustainable agriculture in the region. For the sustainability of U.S. food demand and local demand, a shift of several crop production from the west to the southeast will likely be a foreseeable option concerning climate change vulnerability and sustainability of irrigated agriculture in the southeast region. Based on the assumption of specific crop production changes, this research explores the economic impacts of shifting irrigated agricultural production from the west (e.g., peanuts and corn in the west) to the southeast to estimate the value of water allocation in the southeast's agriculture with a regional input-output (IO) model.

The impact of increasing crop production due to the conversion of non-irrigated cultivable acreage in 42 counties of Georgia positively affected the Georgia State economy. Among 159 counties of Georgia, Decatur, Early, Grady, and Thomas were in the group of the significantly affected counties for the economic impact of all crops production change; Irwin was one of the most affected counties for the economic impact of cotton, peanuts, and corn production change. Baker, Brooks, Miller, Seminole, and Sumter were among the most affected counties for the economic impact of crop production change. The economic benefit was the greatest in the total farm, manufacturing, and construction sectors. The total impact of cotton production was $60 million with the range of $35 million to $85 million: The total impact of peanuts, soybeans, corn was $10.2 million (the range of $3.28 million to $23.7 million), $6.6

million (the range of \$3.1 million to \$10.2 million), \$1.2 million (the range of -\$6 million to \$8.5 million), respectively.

As a possible adaptation strategy for climate change in Georgia, we can consider the expansion of irrigated agriculture for selected crops. Through the supply-driven Georgia multiregional input-output model, this study provides a meaningful outline to all relevant stakeholders for that option in the context of the regional economy.

With several advantages, this study also has a few limitations. First, using an expected average yield of each crop could not reflect the yield difference between counties. Therefore, the possibility of generating biased estimates could exist in the estimation process. Instead of an average yield of each crop, using a crop production simulation model could reduce such uncertainty in yield. Adopting diverse conditions of future climate factors and regional specific soil and growing conditions, the crop production simulation model will generate more realistic and regional detailed yield information than just average yield. Second, farmers could be more interested in the issue relating to a risk-reduction yield of irrigated agriculture than a 95% confidence interval of the impact. Finally, if water allocation and management plans with water scarcity issues are included in the analysis, we can get more practical implications. If these limitations are reflected in future studies, it could generate valuable research.

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