WATER USE ESTIMATION FOR SOME MAJOR CROPS IN GEORGIA USING GEOSPATIAL MODELING

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Abstract. Agricultural water use estimation can contribute to finding a satisfactory solution of the water dispute among the states of Alabama, Florida, and Georgia. In this paper, the depths of irrigation for cotton, peanut, corn, and soybean are estimated for the Flint, Central, and Coastal water zones of Georgia for 2000 2001, and 2002. In addition, the volume of irrigation for these crops are estimated for 2000 and 2001. The estimation was based on the spatial interpolation of the data collected under the Agricultural Water Pumping project. The interpolation techniques included the inverse distance weighting, local polynomial, global polynomial, radial basis function, ordinary kriging, and universal kriging. The total volume of irrigation was highest for the Flint zone (578.4 Mm^3), followed by the Central zone (296.3 Mm^3) and the Coastal zone (103.0 Mm^3) for 2000. For 2001, the irrigation volume declined by 41% for the Flint zone, 31% for the Central zone, and 20% for the Coastal zone.

INTRODUCTION

The states of Alabama, Florida, and Georgia currently dispute the apportioning of water from the Alabama-Coosa-Tallapoosa (ACT) and Apalachicola-Chattahoochee-Flint (ACF) river basins. It is alleged that Georgia uses more water than its fair share. In order to find a satisfactory solution for such a dispute, an accurate estimation of water used in various economic sectors is required for each state. In Georgia, the amount of water used in the agricultural sector is about 60% of the total – more than that in any other sector (e.g., industrial, municipal, recreational etc.). In 1998, the College of Agricultural and Environmental Sciences at the University of Georgia initiated a project called Agricultural Water Pumping (AWP) project (www.AgWaterPumping.net; Thomas et. al, 1999) to estimate the amount of agricultural water use in Georgia. Under the auspices of this project, hour meters were installed and monthly data (discharge rate, duration of pumping, type of crop, acreage etc.) recorded at approximately 400 sites during 1999-2002. The AWP sites included both surface and ground water withdrawals and constituted about 2% of the total permitted sites in the state. In the present study, we applied various geospatial techniques to estimate irrigation depth and volume for different crops, at a county level.

The objective of the present study was: i) to estimate the depth of irrigation (DI) for cotton, peanut, corn, and soybean at a county level as these crops constitute approximately 75% of the total irrigated area in the state (other main crops include vegetables and fruits), ii) to average these depths for the Flint, Central, and Coastal water zones (Fig. 1), which comprise about 90% of the agricultural lands in Georgia, and finally, iii) to determine the volume of water used by these crops in different zones.

METHODOLOGY

We employed the ArcGIS software v8.2 (Environmental Systems Research Institute, Redlands, California). Using the coordinate information available for sample sites, we created a 'point coverage' for each crop to depict the sample sites for that crop. The coordinate information (latitudes and longitudes) was determined using a global positioning system (GPS). The total number of sites for different crops and years are shown in Table 1. The 'attribute tables' of the 'coverages' were updated with the DI data extracted from the AWP database. Using the 'Geostatistical Analyst' module of the ArcGIS, we applied various geospatial techniques to generate a grid of interpolated values based on the sample sites for each crop.

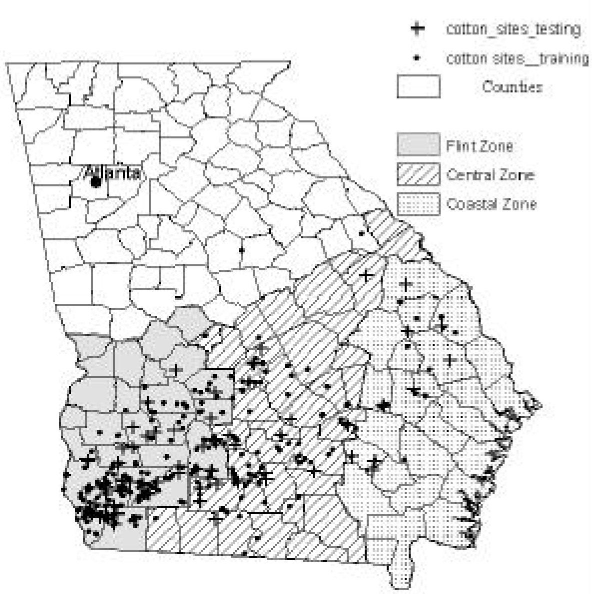


Fig. 1. A map showing water zones and cotton sites.

We applied the following techniques: i) Inverse Distance Weighting (IDW), ii) Local Polynomial (LP), iii) Global Polynomial (GP), iv) Radial Basis Function 2001). These are the common techniques that have been used for geospatial modeling by many other researchers (Fonteh, 1994; Holdaway, 1996; Sousa, 1999).

The total number of sample sites (for a selected crop and year) was divided into two sets, training and testing sets. The training set (with 80% of sites) was used for developing a geospatial model while the testing set (with the remaining 20% of sites) was used to test the performance of the model by comparing root mean squared (RMS) error (Fig. 1). Table 1 lists the techniques finally selected for geospatial modeling for different crops that led to the creation of prediction maps. The prediction map for each crop was converted to a raster form. We then used 'zonal statistics' option to compute the average DI for all crops within the counties that reported irrigated area the crops for 2000. The data on irrigated area were available only for 2000 (Harrison, 2001). We estimated irrigated area for each crop for 2001 by assuming that the ratio of the irrigated to harvested area for a crop within a county did not change from 2000 to 2001.

Table 1. The basic statistics of the irrigation data of the Agricultural Water Pumping project, and the specification of geospatial techniques evaluated in this study

Crop	Year	No. of sample sites	Observed irrigation (*cm*)			Technique selected for spatial interpolation		
			Mean	Range	Stand. Dev.	Method	Specification*	RMS-error
Cotton	2000	131	20.7	0- 61.5	12.2	Radial Basis Function*	Completely regularized spline function	9.7
	2001	314	11.2	0 - 42.2	9.5	-do-	-do-	7.3
	2002	374	16.9	0 - 50.8	10.1	-do-	-do-	9.8
Peanut	2000	93	22.2	0 - 47.2	10.3	-do-	-do-	9.6
	2001	241	12.1	0 - 82.8	10.8	-do-	-do-	8.3
	2002	215	19.8	0 - 49.8	10.9	-do-	-do-	8.9
Corn	2000	53	29.4	0 - 60.2	16.3	-do-	-do-	16.7
	2001	97	13.9	0 - 53.1	12.7	Ordinary Kriging	Order of trend removal (OTR) = first	11.4
	2002	135	25.0	0 - 95.5	15.8	Inverse Distance Weighting (IDW)	Power = 1	11.8
Soybean	2000	25	13.4	0 - 45.0	11.6	Ordinary Kriging	OTR = first	11.4
	2001	28	10.8	0 - 23.4	6.7	Ordinary Kriging	OTR = constant	3.5
	2002	30	13.4	0 - 57.2	13.9	IDW	Power = 2	12.7

* The number of neighbors to include was 5 or at least 2 for all of the techniques.

Table 2. The predicted depth and volume of irrigation for the Flint, Central, and Coastal water zones of Georgia

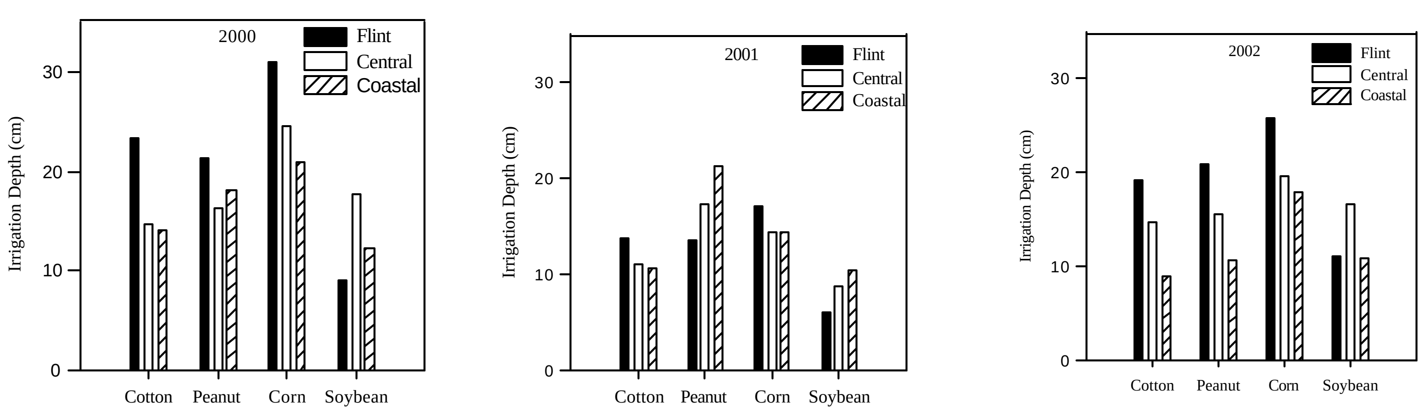
Crop	Year	Estimated depth of irrigation (*cm*)			Irrigated area (1000 ha)				Volume of water used (Mm^3)			
		Flint	Cent.	Coast.	Flint	Cent.	Coast.	Total	Flint	Cent.	Coast.	Total
Cotton	2000	23.4	14.7	14.2	130.3	103.4	25.6	259.3	307.0	148.7	38.1	493.8
	2001	13.8	11.0	10.6	150.6	109.6	28.8	289.0	197.0	114.9	37.3	349.2
	2002	19.2	14.8	9.0								
Peanut	2000	21.3	16.3	18.1	79.6	35.1	9.0	123.7	101.6	89.5	33.5	224.6
	2001	13.5	17.4	21.2	82.0	37.3	11.3	130.6	90.1	51.4	28.0	169.5
	2002	20.8	15.6	10.6								
Corn	2000	31.0	24.6	20.9	44.1	20.9	10.9	75.9	155.6	53.7	22.5	231.8
	2001	17.2	14.4	14.3	38.6	21.3	9.4	69.3	52.6	32.8	13.7	99.1
	2002	25.7	19.7	18.0								
Soybean	2000	9.0	17.7	12.2	2.1	2.4	3.8	8.3	14.2	4.4	8.9	27.5
	2001	6.1	8.8	10.4	2.1	3.5	3.7	9.3	1.7	4.6	3.8	10.1
	2002	11.1	16.6	10.9								
Total	2000				256.1	161.8	49.3	467.2	578.4	296.3	103.0	977.7
	2001				273.3	171.7	53.2	498.2	341.4	203.7	82.8	627.9
	Change				(+7%)	(+6%)	(+8%)	(+7%)	(-41%)	(-31%)	(-20%)	(-36%)

By multiplying the DI with the corresponding irrigated area, we estimated the total volume of irrigation for a crop within a county. However, due to the confidentiality assured to the farmers associated with the AWP data, we are reporting our results only on a zonal basis and not on a county basis.

RESULTS & DISCUSSION

Table 2, Fig. 2, and Fig. 3 present the predicted DI's and the volume of irrigation for different crops and water zones. In general, the DI was highest for corn followed by cotton, peanut, and soybean. In addition, the DI was higher for the Flint zone when compared to other zones, and declined significantly for 2001 and 2002. The decline in the DI could be attributed to the the restrictions imposed by the state on irrigation withdrawals due to occurrence of droughts.

For 2000, the total volume of irrigation was highest for the Flint zone (578.4 Mm^3), followed by the Central zone (296.3 Mm^3), and the Coastal zone (103.0 Mm^3). In 2001, the irrigation volume declined by about 41% for the Flint zone, 31% for the Central zone, and 20% for the Coastal zone (Table 2).



(i) (ii) (iii)

Fig. 2. Estimated depth of irrigation for different crops, water zones, and years in Georgia.

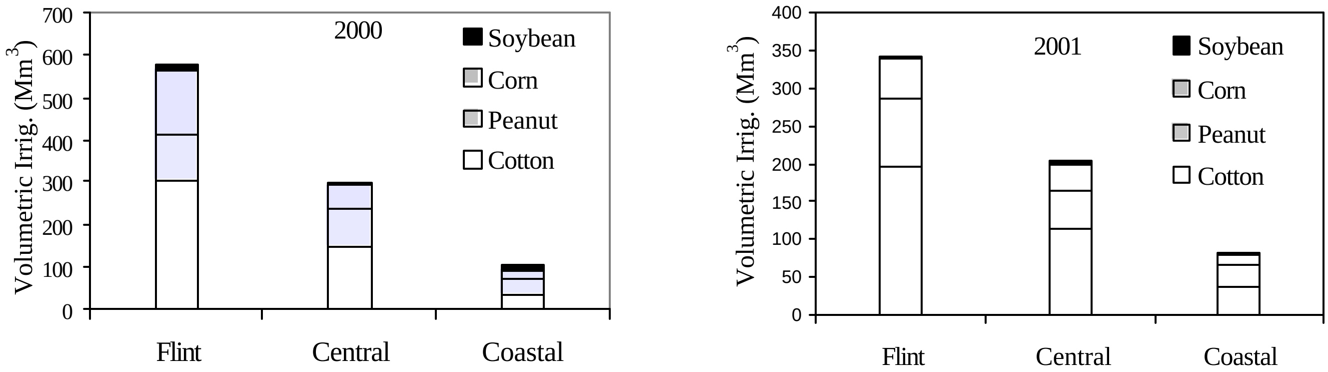


Fig. 3. The estimated volume of irrigation for the selected crops in Georgia for 2000 and 2001.

The irrigation volume could not be estimated for 2002 because of the unavailability of the harvested area.

CONCLUSION

The total volume of irrigation for cotton, peanut, corn, and soybean was highest for the Flint zone (578.4 Mm^3), followed by the Central zone (296.3 Mm^3) and the Coastal zone (103.0 Mm^3) for 2000. This volume declined by 41%, 31%, and 20%, respectively, for 2001. Such estimates of agricultural water use can help resolve the interstate water dispute among Alabama, Florida, and Georgia.

The estimates presented in this study are based on the spatial interpolation of the irrigation data collected at the sample sites selected under the AWP project. The selection of the techniques was based on the RMS error that depends on the number of sites and their spatial patterns, and variation in the data across the sites. Several factors affect variation in irrigation depths, e.g., weather conditions, soil characteristics, cost-benefit analysis, and psychological factors. A better understanding of these factors can contribute to improving the estimates.

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