PROJECTED SEASONAL WATER CONSUMPTION AND WATER RESTRICTIONS FOR ROW CROP IRRIGATION IN THE A.C.F. BASIN

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REFERENCE: Proceedings of the 1995 Georgia Water Resources Conference, held April 11 and 12, 1995, at The University of Georgia. Kathryn J. Hatcher, Editor, Carl Vinson Institute of Government, The University of Georgia, Athens, Georgia.

ABSTRACT

Water consumption in the Flint River Basin depends upon seasonal irrigation of the major row crops — corn, peanut, cotton, and soybean. Knowledge of each crop's water use pattern, water retention by major soil types, and probable weather patterns is essential for comprehensive water management in the basin. Crop model prediction of yield and water use under weather patterns of the past 58 years showed that irrigation water withdrawals can exceed 1200 million gal/day during peak use periods in drought years. If emergency irrigation restrictions that eliminated irrigation for 30- to 60-day periods were imposed to curtail irrigation water consumption, water savings could amount to 6 to 60 billion gallons annually in the Flint River Basin. However, in-season curtailment of irrigation for 30- to 60-days would cause direct economic losses to growers of $4 to $148 million, depending on timing and duration of restrictions. Alternative water management strategies should be developed for reducing irrigation demands in drought years.

INTRODUCTION

While considered to have a humid climate, agricultural drought is the norm throughout most of Georgia. Van Bavel and Carreker (1957) pointed out that between 50 and 100 drought days can be expected in 3 out of 10 years for the March through October growing season, depending on local soil water holding capacities. With favorable commodity prices in the 1970's, farmers responded by installing irrigation systems to reduce risks associated with drought. Development of groundwater aquifers for irrigation in the Coastal Plain of Georgia occurred with the rapid expansion of irrigation between 1970 and 1981. By 1983, competition between irrigation, industrial, and municipal users for groundwater in a 30 county area of Southwest Georgia was recognized as a major water availability issue (U.S. Geological Survey, 1984). Irrigation withdrawals in 1980 were estimated at 380 million gal/day as compared with industrial withdrawals of 400 million gal/day. Irrigation withdrawals, however, come in a 5-6 month period, creating local drawdown problems for nearby users.

In the late 1980's Alabama and Florida initiated litigation over water use, primarily by the Atlanta, Georgia, metropolitan area, in the shared river basins of the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint (ACT/ACF) systems. While water use by metro Atlanta has little connection with agricultural water use in the Georgia Coastal Plain, they both affect flow into the Apalachicola Bay. To help resolve the water rights case, the U.S. Army Corps of Engineers initiated comprehensive studies of water use in the entire ACT/ACF River Basins, including several studies on agricultural water use (Soil Conservaion Service, 1994). In that report the authors estimated that irrigation water consumption in the ACF basin will increase as much as 146% in the next 50 years. The Flint River Basin contains the greatest irrigated acreage of the ACT/ACF Basins. Hydrologically, the surface waters of the Flint Basin are directly connected with groundwater in parts of the Dougherty Plain from which much of the irrigated water is pumped. Effective regional water management will require continued refinement of the projections of irrigated acres, water consumption, and, especially for seasonal management, timing of water withdrawals for irrigation in this basin.

METHODS

The objective of this study was to determine the potential economic effects and water savings resulting from 30- to 60- day periods when no row-crop irrigation was allowed in the Flint River Basin. In this study, a portion of which was included in the Soil Conservation Service report (1994), we examined the irrigation demands for corn, soybean, peanut, and cotton and reported yield effects of arbitrary irrigation water restrictions.

Identifying Affected Acreage

Planted acreage in the Flint River Basin for major row crops were 191, 384, 217, and 114 thousand acres for corn, peanut, cotton, and soybean, respectively, averaged over the 1992 and 1993 season (Georgia Agricultural Statistics Service, 1994). Distribution of these row crops in the sub-basins of the Flint were 96, 292, and 518 thousand acres for the Upper, Middle, and Lower Flint River Basins, respectively. Total irrigated acreage for these row crops were 137, 225, 103, and 20 thousand acres for corn, peanut, cotton, and soybean, respectively. Distribution in the sub-basins of the Flint were 26, 110, and 349 thousand acres for the Upper, Middle, and Lower Flint River Basins, respectively. Irrigated acreage was taken from the ACT/ACF River Basins Study (Soil Conservation Service, 1994) for corn, peanut and cotton. Acreage of irrigated corn and peanut agreed with the 1989 irrigated acreage for these counties (Harrison and Tyson, 1989), but cotton acreage reflected a 76% increase over 1989 acreage. Both total and irrigated cotton acreage are undergoing rapid increases in the mid-1990's as cotton markets remain strong. Much of this acreage has come at the expense of soybean acreage, although some decreases in corn and peanut acreage have also occurred. Soybean acreage, which was included with other acreage in the ACT/ACF basins study, was computed by multiplying the ratio of irrigated to total soybean acreage in 1989 by the 1992-93 soybean acreage.

Predicting Potential Yield Losses

Predictions of crop yield and irrigation timing and amount were made as described by Hook (1994). Three crop models were chosen and validated. CERES-maize, SOYGRO, and PNUTGRO were used for corn, soybean and peanut, respectively. No validated cotton model was available for predicting irrigation amounts and yields. Cotton yield versus irrigation was taken from the ACT/ACF River Basins Study (Soil Conservation Service, 1994, pg. 110), while distribution of cotton water use was assumed proportional to soybean water use.

Years with severe agricultural drought were identified using the Tifton, Georgia, meteorological records. Tifton is located 20 miles from the eastern edge of the middle Flint River Basin and was chosen because records there include 20 years with solar radiation and 57 years with rainfall, temperature, soil and air temperature, and pan evaporation. For the period 1938 to 1974, daily solar radiation estimates were made to complete the records for use in crop growth models (Hook and McClendon, 1991). The soils used in this analysis included the major agricultural soils of the Middle and Lower Flint Basins where 95% of the irrigation is located: Troup/Lakeland deep sand, Tifton/Dothan loamy sand, and Orangeburg sandy loam. Rooting was assumed to be unimpeded, so most of the 4 to 5 ft deep soil profiles were able to supply water and water storage.

Agricultural drought occurrence was determined by ranking years by ratio of non-irrigated yield to no-stress yields. The quartile of years with lowest ratios were considered drought years. Subsequent reference to "drought years" indicates these 14 driest years. Since a year may have severe drought for a spring crop but not a fall crop, the drought years differed for each crop.

Soil water depletion limits were chosen to trigger irrigation at a time when average yield losses would be no less than 80%, but no more than 90%, of maximum yields. The upper limit prevented excessive and inefficient irrigation which occurs with maximum yields. The models were next run for each year with full irrigation to determine normal irrigated yields and irrigation timing and amount. Then, to determine effects of in-season water restrictions on yield and irrigation amounts, each model was repeated for each year using several 30- and 60-day no-irrigation periods. These would be similar to regulatory restrictions initiated at the height of a drought emergency stipulating that water withdrawals stop for a period of time.

Economic Impacts

With yields and irrigation amounts resulting from the water restrictions available, direct economic impacts to growers were calculated for each restriction option. Direct loss for any crop was the value of full irrigation yield minus the restricted irrigation yield minus savings from applying less water times the irrigated acreage of the crop. Values for crops were average prices received by growers for the 1993 marketing seasons (Georgia Agricultural Facts, 1994). The 1993 crop season had moderate drought periods, and prices reflected that fact. Costs for applying irrigation were $4.25 acre-inch, the variable application costs. All other costs to growers including fixed costs for irrigation were assumed to be unchanged, since the irrigation restrictions were assumed to be initiated after the crop was established and most costs incurred. No economic multipliers were used for this calculation. Water savings from the irrigation restriction were calculated as the difference between irrigation amounts with full and with restricted irrigation times the total irrigated acreage for that crop. Two additional figures were computed. The cost to the region per million gallons saved was the direct economic impact divided by the water savings. The value of the irrigation water to the grower was the value of the crop lost minus cost of water application saved divided by the amount of water saved. This latter figure can be considered the incremental value of the irrigation expenditure for the farmer, after he has absorbed the fixed costs of the irrigation system. For each of these computations the soil of the Flint River Basin was assumed to be half Tifton/Dothan and half Troup/Lakeland. The Orangeburg soil occurs in smaller areas, and less of the soil is under irrigation.

RESULTS

Water withdrawals needed to meet full irrigation demands in drought years are shown in Fig. 1. The daily values are not annualized withdrawals as usually reported for irrigation. Instead, they show the average daily withdrawals that will be made to meet irrigation demands during each 10-day period from May through October. Corn irrigation occurs primarily in spring and early summer while peanut, cotton, and soybean irrigation overlap from mid-summer through October. It is these peak seasonal demands that cause temporary drawdown in water tables and competition with other users of water in the river basin.

Use of emergency water restrictions that stop irrigation for various periods of time could shave some of the demand during peak use periods. The effects on crop growth and profitability must be understood before these restrictions are imposed. Corn matures during late spring and early summer, a period with a high probability of low rainfall in the Coastal Plain (Sheridan et al., 1979). For the Tifton/Troup soil, substantial yield losses resulted from withholding water from corn in May and June, typically periods of late vegetative growth and grainfill (Fig. 2). Restriction of irrigation for two-month periods can lower yields to no-irrigation levels. Irrigation amounts are effectively lowered by the restrictions to corn irrigation (Fig. 3). Similar results could be seen for other soils.

Peanut yield reductions were less severe than corn (Fig. 4). As a deep rooted indeterminant crop, peanut is better able to withstand drought than the determinant corn crop. Peanut can remain dormant during dry periods and regrow when suitable moisture returns. The most critical growth stages for peanut occur in July and August, typically the wettest months of the growing season. When water is lacking during that time, peanut yield is lowered, but shortages during

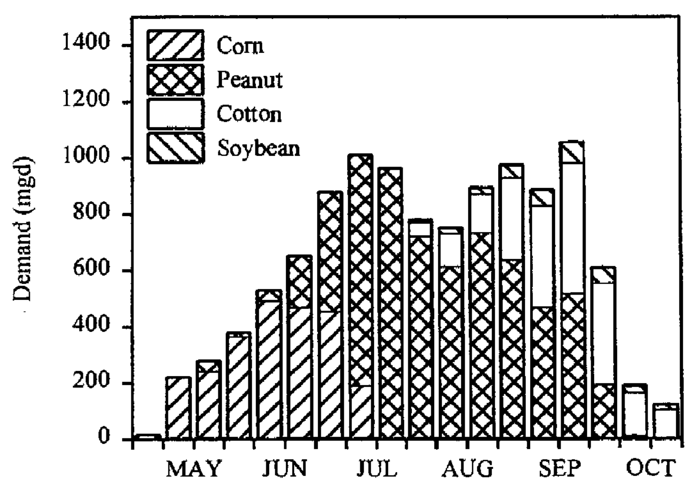

Figure 1. Mean total irrigation water demand for each 10-day period for the Flint River Basin during 14 drought years.

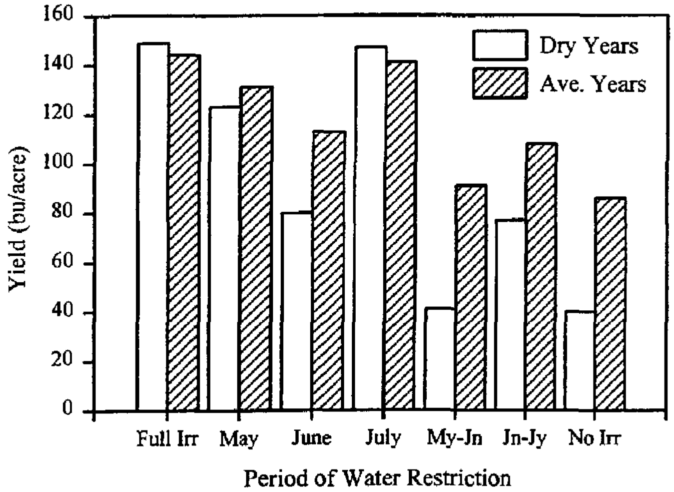

Figure 2. Average corn yields under full irrigation, no irrigation, and selected 30- and 60-day periods with no irrigation for 14 drought and 58 average years on Tifton/Dothan soil.

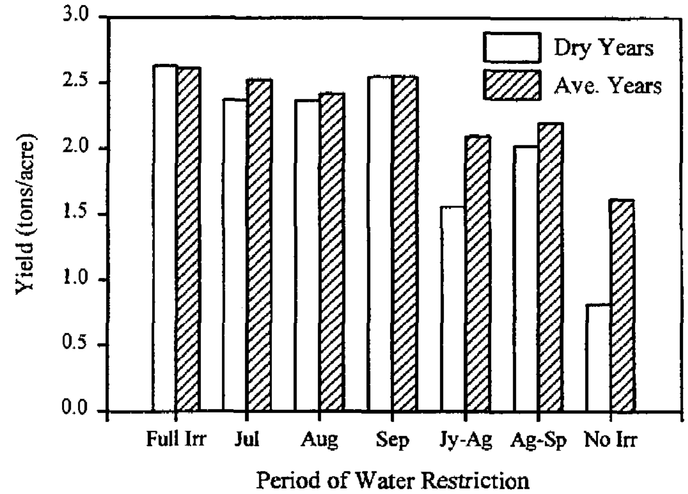

Figure 4. Average peanut yields under full irrigation, no irrigation, and selected periods with no irrigation for 14 drought and 58 average years on Tifton/Dothan soil.

other months can also affect quality and maturity. Lowered quality and delayed maturity reduce economic returns, but PNUTGRO predicts total yield only. Additional economic losses will occur when water restrictions affect quality. With the higher prices received by peanut producers, even moderate yield losses can result in severe economic losses.

Soybean yield losses were very severe (70%) when water restrictions were implemented in September (not shown). This is a critical growth period when pods are filling, and it also is a period of low rainfall even in the best years. The difficulty of producing acceptable soybean yields without this late summer and fall irrigation is part of the reason for the decline in soybean acreage in the Flint River Basin.

Soil type affects irrigation amounts, and, when irrigation is restricted, affects yield. For example, on deep sand Troup/Lakeland soil, full season irrigation of peanut required 12.1 inches in drought years. The same years required 9.6 inches of Tifton/Dothan soil but only 7.6 inches on the Orangeburg soil. Yields of fully irrigated peanuts were almost the same on the Troup and Tifton soils, but yields were reduced 42 and 37%, respectively, for July-August irrigation restriction.

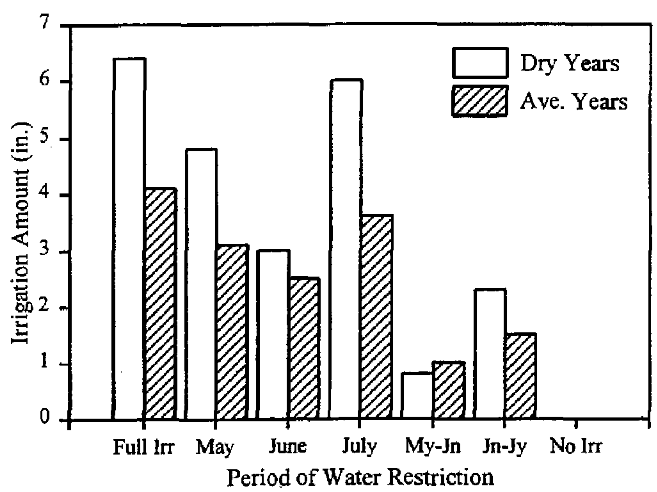

Figure 3. Average irrigation amounts used to produce corn under full irrigation and selected 30- and 60-day no-irrigation periods for 14 drought and 58 average years on Tifton/Dothan soil.

When yields are lowered by water restrictions, direct losses to growers occur because most of the production and fixed costs cannot be adjusted to the restriction. Over the Flint River Basin, from $10 to $35 million could be lost by a single months restriction (Table 1). Two-month-long restrictions could cause direct losses of $26 to $144 million.

For individual growers, losses of gross receipts amount to $180/acre for corn when June irrigation restrictions are imposed. August restrictions would lower gross receipts by $154/acre for peanut producers, and September restrictions would lower receipts by $230/acre for soybean producers and by $75/acre for cotton producers. For all of these producers the net receipts would be negative with these restrictions. With two month restrictions net losses would be greater.

Water savings brought about by different water restrictions would be significant (Table 2). Six to 28 billion gallons would be saved by 30-day restrictions; 16 to 51 billion for 60-day restrictions. These

Table 1. Loss of Revenue by Growers in the Flint River Basin from Water Restrictions that Eliminate Irrigation During Specified Periods for Four Crops.

	Corn	Peanut	Soybean	Cotton	All
	---------- Million $ ----------				
May	9.9	-	-	-	9.9
Jun	24.8	-	-	-	24.8
Jul	0.5	33.5	0.0	-	33.5
Aug	-	34.8	0.3	-	35.1
Sep	-	9.8	4.6	9.3	23.7
May-Jun	37.0	-	-	-	37.0
Jun-Jul	25.7	-	-	-	25.7
Jul-Aug	-	143.2	0.5	-	143.6
Aug-Sep	-	79.6	5.2	9.3	94.1
No Irr	37.3	241.5	5.7	26.8	311.3

Table 2. Water Savings That Could Be Realized in the Flint River Basin from Water Restrictions that Eliminate Irrigation During Specified Periods for Four Crops, and Unit Costs of Those Water Savings for Growers of Two Crops.

	Water Savings All Crops	Cost of Water Savings	
		Corn	Peanut
	Million gal	--- $/Million gal ---	
May	6,530	907	-
Jun	13,250	871	-
Jul	18,320	531	617
Aug	13,510	-	2,388
Sep	27,810	-	733
May-Jun	21,840	897	-
Jun-Jul	16,050	785	-
Jul-Aug	37,880	-	2,001
Aug-Sep	51,950	-	1,882
No Irr	130,260	832	2,118

savings can be compared with the cost of savings. These differ by value of the crop affected, as shown for corn and peanut (Table 2). For periods when yield is most sensitive to water, restricting water will have a greater effect than during less critical months. During July water savings are as great or greater than for May, June or August (Table 2), but economic impact to all crops is minimal (Table 1.) If all irrigation were terminated for these four crops in the Flint River Basin, over 130 billion gallons of water would be saved in drought years, but at a loss of $311 million in gross farm receipts.

DISCUSSION

Understanding evaporative demand and crop water use during drought periods is analogous to understanding low stream flows and municipal water use. The extremes dictate the design parameters and management guidelines for our water resources. Examination of amount and timing of water needed during drought years should be used to help regional water managers to predict the impact of irrigation on groundwater reserves. As information becomes available on location of wells, aquifers tapped, area irrigated, and crops managed, we should be able anticipate water needs for irrigation. This will help in licensing new wells, anticipating seasonal drawdown, and recommending water use optimization. A first step in this examination is water use during drought years.

Managing groundwater resources requires a more thorough understanding of impacts of irrigation water withdrawals. Mandatory emergency restrictions which fail to account for the nature of crop production and water use may cause severe adverse economic impacts. Crop water use for corn occurs primarily in spring and early summer. Peanut is most sensitive to mid-summers droughts, while cotton and soybean will be adversely affected by late summer to early fall droughts. Recent shifts in irrigated acreage from corn to cotton will further aggrevate the late summer irrigation water demand, while switching from irrigated soybean to irrigated cotton would have little impact on water use.

Economic impacts of water restriction differ by crop, soil, and month. Since distribution of soils and crops differs by county over the Flint River Basin, different counties will be affected differently by the same restriction. For example the eastern counties of the Middle Flint Basin have more cotton, while the Lower Flint Counties have more corn acreage. Economic multipliers must also be computed for complete evaluation of economic impacts from irrigation restriction. Revenue losses by cotton ginners, peanut shellers, grain handlers, and many others would be as important to the region's economy as direct farm impacts. Since many bankers make farm production loans with the stipulation that irrigation will be available, it is not clear how they would react to potential restricted access to the irrgation water.

Water savings are not as great as might first appear when one examines irrigation used during full season irrigation. For example peanut received an average of 3.0 in. of water during August with full-season irrigation. However, when irrigation was restricted during that month, seasonal water savings were only 1.7 in. When irrigation was resumed in September, more water was applied to make up part of the accumulated deficit.

The principle reason that economic losses are so difficult to manage is the nature of the restrictions assumed in these calculations. Each was imposed after the crop was planted and most fixed and production expenses had been incurred. If growers knew ahead of time how much water would be available for the whole growing season, they would have the opportunity to choose crops, production levels, acres irrigated, and irrigation scheduling techniques to optimize irrigation water use. While the region would still have the lowered economic returns, individual farmers could lower their risks to acceptable levels and probably remain profitable. In addition to preplanned amounts, reductions in water use during emergencies could be accomplished with reduced irrigation rather than no irrigation. This is difficult for farmers to manage because timing of applications becomes critical. These alternatives should be investigated by universities and agencies with responsibility for water mangement in the Flint River Basin so that emergency water management plans are readied before severe droughts force hasty decisions.

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