Forecasting Irrigation Water Demand: A Structural and Time Series Analysis

Paper to be presented at AAEA 2003 meetings at
Montreal, Canada

By

Murali Adhikari
University of Georgia, Dept of Ag. & Applied Economics, Conner Hall 205
The University of Georgia
Athens, GA 30602
Email:madhikari@agecon.uga.edu

Jack Houston Dr.
University of Georgia, Dept of Ag. & Applied Economics, Conner Hall 301
The University of Georgia
Athens, GA 30602

Laxmi Paudel
University of Georgia, Dept of Ag. & Applied Economics, Conner Hall 205
The University of Georgia
Athens, GA 30602

Dipankar Bandyopadhyay
University of Georgia, Dept of Statistics, Athens, GA United States 30602

Biswo Nath Paudel,
Rice University, Dept of Economics, Houston, TX United States 77005

Nirmala Devkota
University of Georgia, Dept of Ag. & Applied Economics, Conner Hall 305
The University of Georgia
Athens, GA 30602

Forecasting Irrigation Water Demand: Structural and Time Series Analysis

An expected utility model was developed to capture the impacts of wealth, other economic, and institutional factors on irrigation acreage allocation decisions. Predicted water demand is derived from an expected utility structural model and various ARIMA models. No significant differences arise between forecasted irrigation acreage and, thereby, amount of forecasted water demand between econometric and time series models. However, estimates of water demand differ significantly from a Blaney-Criddle-based physical model.

Keywords: water forecasting, acreage response, water slippage, BC formula

Introduction

Efficient management of existing water resources has become an increasingly important aspect of water policy in the United States. The importance of efficient water use and management is supported by rapidly growing water demand and constant and/or decreasing supplies of water in the many parts of the United States. Seasonal and cyclical scarcity of water and increasing levels and variation in demand of water by municipalities, agriculture, and industries have created political conflicts leading to more scrutiny of the efficiency of water use in the United States (Frey, 1993). The problems associated with water scarcity are further exacerbated due to the requirements of water to meet minimum in-stream flow for habitat restoration, recreation, and navigation.

During most of the previous century, water management mostly focused on a search for new water supplies. As a result, large water development projects dominated water resource economics (Jordan, 1998). Now there exist limited opportunities for building additional dams because of high financial and environmental costs associated with such developments. Recent changes in water management from supply-oriented focus (i.e., water storage and distribution by developing a large-scale water project) to a more demand-oriented focus (controlling demand by efficient allocation of existing water resources) demand more economic analysis and better management of existing allocation practices (Frey, 1993). The prospect of global climate change and growing demand of water will change the trend of existing water supplies, exacerbating water supply problems. New water use needs will bolster the desirability for new water management plans to efficiently use existing water resources.

Until the last decade, very little concern or conflicts related to water supplies existed in many parts of the United States (US) east of the Mississippi River. Substantial expansion of urban areas, prolonged drought and water disputes in many parts of the US have drastically increased the public awareness and concern about potential scarcity of water, making water allocation a serious political and public issue. There is now growing concern about insufficient water supplies to sustain agriculture and simultaneously to meet all other demands during low rainfall years. Since agriculture is the largest consumer of water, that sector can play a crucial role in government efforts to efficiently utilize water in the US. Efficient allocation of water within the agricultural production sector can enhance the water conservation efforts for both future needs of agriculture and for those of competing uses.

In spite of the urgent need to efficiently allocate the existing water, policy makers and water managers are often constrained by the lack of information about present and future water demand for irrigated agriculture. This problem arises mostly due to the use of an existing water forecasting model, which comprises only engineering features and considers only physical parameters, such as temperature and daylight hours, as outlined in the Blaney-Criddle formula (BC). Indeed, the demand for irrigation water is a derived demand evolving from the several economic and institutional variables. Given the risks in agricultural production, much uncertainty also exist about the profits of agricultural businesses. Irrigation demand largely represents the risk-averting behaviors of farmers. This paper aims to evaluate the impacts of economic and institutional variables on the irrigated acreage allocation decision, and thereby the amount of water demand for crops, by developing a structural econometric model and comparing its predictive results to those of several time series forecasts.

Model Development

Consider a farmer produces ‘n’ crops where A_i is the size of irrigated acres devoted to the i^{th} irrigated crop, P_i is the market price of the i^{th} crop, and Y_i is the corresponding yield per acre, (i = 1, 2,...,n). The total revenue of a representative farmer is given by

$$R = \sum_{i=1}^{n} p_i y_i A_i \ .$$

Letting C_i be the cost of production per acre of the i^{th} crop. The total cost of agricultural production would be

$$C = \sum_{i=1}^{n} C_i A_i \ .$$

Information about output prices $P_i = (P_1, P_2,....,P_n)$ and crop yield $Y = (Y_1,Y_2,....,Y_n)$ are not obtained by farmer when the production decisions are made, so revenue (R) represents an uncertain variable. In the meantime, input prices and per acre costs (C_i) are available to produces at the time of crop acreage allocation. With the given situation, a producer faces a budget constraint which can be define as (Chavas and Holt, 1990)

$$I + R - C = qG, \text{ or}$$

$$I + \sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} C_i A_i = qG \tag{1}$$

where

I = Exogenous income (wealth)

G = Index of producer consumption of goods

q = Consumer price index

Equation 1 shows that exogenous income (I) plus farm profit (R-C) equals consumption expenditure (qG) of a household. Let the constraints on the irrigation acreage decision be represented by

$$f(A) = 0 \tag{2a}$$

where $A = (A_1, A_2,....,A_n)$. Constraints on the irrigated acreage require that all irrigation acreage is allocated to either peanut or cotton production and that irrigated acreage should not exceed the total available acreage.

$$\sum_{i=1}^{n} A_{iy} = A_Y \tag{2b}$$

Assuming that representative farmers maximize expected utility from total profit "∏" under competition, and household preferences are represented by a Von-Neuman Morgensten utility function, U(G), satisfying δU/ δG > 0, the decision model is

$$Max\ \text{A}\ \{\text{EU}\ [\frac{I}{q} + \sum_{I=1}^{n} [\frac{Pi}{q} Yi - \frac{Ci}{q} Ai]]\}\ \text{s.t. (2), or} \qquad (3a)$$

$$Max\ A\ \{\text{EU}\ [\ \text{W} + \sum_{i=1}^{n} \Pi_i A_i\ ]\}\ \text{s.t. (2)} \qquad (3b)$$

where W = I/q = Normalized initial wealth subject to acreage constraints in equation 2b. Π = Normalized profit per acre of the i^{th} crop, i = 1,2,....,n. All prices are deflated by the consumer price index. Equation (3) shows that a producer makes the irrigation acreage allocation decision 'A' under both price and production uncertainty. Here, both yield (Y) and output price (P) represent random variables with given subjective probability distributions. Consequently, the expectation E in equation (3) over the stochastic variables P and Y relies on the information available to producer at the time of planting.

Optimization problem (3) has direct economic implications for the optimal irrigation acreage decision (A). If the producer is risk averse, the optimal acreage decision depends on normalized initial wealth (W) = Expected normalized profit per acre (Π_i), and second or higher moments of distributions of normalized profits (σ) per acre Π_i, (I = 1,2,......n). In the case of normally distributed returns, expected values and variances of returns define the criterion of expected utility. Otherwise, it is a second-order Taylor series approximation to all risk-averse utility functions. In other words, the optimal irrigation acreage decision can be represented as

$$A^* = A\ (\ w, \bar{\Pi}, \sigma, z\ ) \qquad (4a)$$

where w = normalized Initial wealth,

$\bar{\Pi}$ = expected normalized profit per acre,

σ = higher moments of distributions of normalized profits (σ) per acre Π_i , and

z = Institutional variables for cotton and peanuts.

In order to analyze the producer supply behavior under risk, adaptive expectations for untruncated normalized prices are used. The final econometric model is represented as:

$$A_{it} = \alpha_i + \zeta_i w_{it} + \Sigma\beta_i\pi_{it} + \Sigma\Sigma\gamma_i\sigma_{ijt} + \theta_{it} + \Sigma\eta_i Z_{it} + \epsilon_{it} \tag{4b}$$

where

A_{it} = total irrigated acreage for i^{th} crops at time t,

w_{it} = wealth of i^{th} crop's farmers at time t,

π_{it} = mean expected profit for i^{th} crops per acre at time t,

σ_{it} = coefficient of variance of profit of i^{th} crops at time t,

σ_{ijt} = covariance of profit between the i^{th} and j^{th} crops at time t,

T = time variable,

TIA = total irrigated acres,

Z_i = matrix of institutional variables, such as deficiency payments, diversion payments, disaster payments, payments-in-kind (PIK) for cotton and quota and government support prices for peanuts, and

ϵ_{it} = errors

Data and Structural Model

Our study covers crop production in the Lower Flint River (Baker, Calhoun, Decatur, Dougherty, Early, Grady, Lee, Miller, Mitchell, Seminole, and Worth counties), Middle

Flint (Crawford, Crisp, Dooly, Macon, Marion, Randolph, Schley, Sumter, Taylor, Terrell, and Webster counties), and Upper Flint (Clayton, Coweta, Fayette, Lamar, Meriwether, Pike, Spalding, Talbot, and Upson counties) regions, representing the major cotton and peanut growing areas of Georgia. Basically, we select the study area to make our study results comparable with the findings of an Alabama-Coosa-Tallapoosa (ACT)/Apalachicola-Chattahoochee-Flint (ACF) comprehensive study, a representative physical model of the same study area. In order to carry out the objectives of the study, irrigated acreage of cotton and peanut were collected from different issues of Georgia County Guide. State irrigated acreage of cotton and peanut are available only for 1970, 1975, 1977, 1980, 1982, 1989, 1995, 1998, and 2000, reflecting a serious missing data problem. A technique called “Cubic Spline Imputation” (Brocklebank and Dickey, 1986) was employed to ameliorate the problem of missing time series data for irrigated cotton and peanut acreage. A cubic spline is a segmented function consisting of 3rd degree polynomial function where the whole curve and its first and second derivatives join to form a continuous function. Spline is globally flexible and smooth, and therefore very useful in modeling arbitrary functions. We fit a polynomial of the form:

$$Y_k(x) = a_k (X-X_i)^3 + b_k (X-X_i)^2 + C_k (X-X_i) + d_k$$

where, k = number of intervals, k =1(1)N-1, X_i = the beginning pt of each interval, and N = total number of data points.

In this cubic spline technique, a new curve passes through N data points and the polynomial passes through a set of m control points. The second derivative of each polynomial is commonly set to 0 at the end point to develop a boundary condition and thereby to make a system of complete equations. Finally, cubic spline imputation produces a so-called ‘natural’ cubic spline and solves the systems of equations to obtain the polynomial coefficients. In order to create data for our study area, a proportionate change has been made in the state irrigated acreage available after correcting for the missing data problem.

Information on seasonal average price (SAP), yield, and costs of cotton and peanut were collected from National Agriculture Statistics Service of (NASS) of United States Department of Agriculture (USDA). The market price and yield for cotton and peanut will not be known to the farmers in advance. Therefore, we assume that expected price and yield for cotton and peanut would be a linear function of lagged price and yield, and a time variable, respectively:

$$E\,(P) = \beta_0 + \beta_1 P_{i,\,t\text{-}1} + \beta_2\,T, \tag{5}$$

$$E(Y) = \alpha_0 + \alpha_1 Y_{it\text{-}1} + \alpha_2\,T \tag{6}$$

where β_0, β_1, and β_2;and α_0, α_1, and α_2 are parameters to be estimated with the price and yield using regression analysis. Using the information on expected price, expected yield and variable costs, the expected profits were calculated as

$$E_{t\text{-}1}\,(\pi_{it}) = E_{t\text{-}1}\,(P_{it} * Y_{it}) + Cov\,(P_i{*}Y_i) - C_{it} \tag{7}$$

where Cov $(P_i{*}Y_i)$ represents the covariance between price and yield of cotton and peanut. The risk averting behavior of the farmers is captured by incorporating the variance of the profits for cotton and peanut in the analysis. The variance of profits for the three-year period preceding year t is defined as the dispersion of observed profits about their mean. That is,

$$Var\,(\pi_{it}) = \sigma_{\pi_{it}} = \sum_{j=1}^{3} \gamma_j\,[\pi_{i,t\text{-}j} - E_t\,(\pi_{it})]^2,$$

where

$$E_t(\pi_{it}) = \frac{(\pi_{i,t-1} + \pi_{i,t-2} + \pi_{i,t-3})}{3},$$

represents the three-year moving average of observed profits and γ_1, γ_2 and γ_3 represent the weights from an adaptive expectations model having 0.5, 0.3 and 0.2 weightings for the first, second and third years, respectively. Covariance between the profits of cotton and peanuts was also incorporated in to model to capture the mechanism of risk-spreading by farmers via the portfolio effect in an expected value-variance (EV) setting. Covariance was calculated using the following equation

$$Cov(\pi_{it,jt}) = \sigma_{\pi_{it,jt}} = \sum_{k=1} \lambda_k [[\pi_{i,t-k} - E_t(\pi_{it})] [\pi_{j,t-k} - E_t(\pi_{jt})]],$$

where $E_t(\pi_{it}) = (\pi_{i,t-1} + \pi_{i,t-2} + \pi_{i,t-3})/3$, $E_t(\pi_{jt}) = (\pi_{j,t-1} + \pi_{j,t-2} + \pi_{j,t-3})/3$, and $i \neq j$. We standardize the covariance to eliminate the trend effect:

$$C.V.\ Cov(\pi_{it,jt}) = \frac{\sigma_{\pi_{it,jt}}}{E_t(\pi_{it}) + E_t(\pi_{jt})/2} \tag{8}$$

Wealth is calculated by adding farm assets together with total farm profits. Information on the institutional variables, such as deficiency payments, diversion payments, disaster payments, and PIK for cotton and quota and government support prices for peanuts were collected from USDA publications. Institutional variables of cotton are highly inconsistent, because of frequently changing government farm policies in the last two decades. Therefore, we created dummy variables capture these effects.

Time series forecasting model

In order to make comparative forecasting of cotton and peanut acreage response, and thereby water demand by cotton and peanut, with econometric and physical models, we also developed Autoregressive Integrated Moving Average (ARIMA) Models. ARIMA (*p,d,q)* models, where p, d, and q represent the order of the autoregressive process, the degree of differencing, and the order of the moving average process, respectively, were written in the form:

$$\Phi(B)\ \Delta^{d} y_{t} = \delta + \theta(B)\epsilon_{t}$$

where y_t represents acreage planted in time t, ϵ_t are random normal error terms with mean zero and variance σ^2_t, and Δ^d denotes differencing (i.e. $\Delta y_t = y_t - y_{t-1}$),

$$\Phi(B) = 1 - \Phi_1(B) - \Phi_2(B)^2 - \ldots - \Phi_p(B)^p, \text{ and}$$

$$\theta(B) = 1 - \theta_1(B) - \theta_2(B)^2 - \ldots - \theta_q(B)^q,$$

where B represents the backward shift operator such that $B^{n}{}_{et} = \epsilon_{t-n}$. In the ARIMA models, the acreage responses are modeled dependent on past observations of themselves. Future prices and yields of cotton and peanuts are also estimated by using Box-Jenkins (ARIMA) time series models.

Results and Discussions

In our analysis, the F statistics and p values ($p=0.0001$) strongly reject the null hypothesis that all parameters except the intercept are zero. The estimated model explains historical variations in cotton and peanut irrigated acreage well, with adjusted R^2 of 0.98 and 0.97, respectively (Tables 1 and 2). As anticipated, the expected profit of peanuts is positively related to the irrigated acres of peanuts and statistically significant at the 5% level. However, the relationship between expected profit of cotton and irrigated cotton acreage was found to be negative but not significant. Though inconsistent, Chavas and Holt (1991) also reported negative and statistically significant results between soybean acreage and expected profit of soybeans. A 0.048% increase of peanut irrigated acreage is expected for every one percent increase in the expected profits of peanuts. Own-profit elasticity was 0.00065 for cotton irrigated acreage.

Variance of profit, which captures the influence of the risk involved in the irrigation acreage allocation decision, yields the expected sign for cotton. The risk elasticities for cotton and peanut appeared to be small, although cotton irrigated acreage appears to be more risk responsive than peanut irrigated acreage. This result is consistent with the finding of Tareen (2001) and not surprising, given drastic changes in irrigated cotton acreage in the last two decades under different prices and programs. Analysis shows the positive relationship between acreage allocated for cotton and peanut and wealth of cotton and peanut farmers. In cotton, the relationship between wealth and irrigated acreage allocation was statistically significant at the 5% level. The elasticities with respect to initial wealth were 2.017 and 0.005 for cotton and peanuts, respectively, showing 2.017% and 0.005% increases in cotton and peanut irrigated acreage with the increase of 1% of initial wealth of cotton and peanut producers, respectively.

Contrary to the findings of other researchers (e.g., Duffy et al. 1987, Duffy et al. 1994, Houston et al. 1999), our analysis shows a statistically insignificant relationship between irrigated cotton acreage and different policy variables, such as deficiency payments, diversion payments, disaster payments, Target prices (TGT), and payments in kind (PIK). This might have resulted from the inconsistent government cotton support programs and conflicting goals of other governmental policies in the past. In the case of peanuts, quotas and price supports show positive and statistically significant relationship with the farmers' decision to allocate irrigated acreage for peanut production. Expecting a modification of government programs for peanuts by the 1996 farm bill, peanut farmers have been continuously receiving federal quota and price supports, making institutional variables key factors in irrigated peanut acreage allocation decisions. Analysis shows that increase of quota and peanut price supports by 1% increases the irrigated acreage for peanuts by 5.5% and 3.1%, respectively.

In our study, parameter estimates associated with the total irrigated acreage indicate the expected positive sign and are significantly different from zero at the 1% level for cotton and peanuts. This finding is consistent with the results of Tareen (2001). The elasticity coefficients of cotton and peanut show that a one percent increase in the total irrigation acreage increases the cotton and peanut acreage by 0.53% and 1.15%, respectively, *ceteris paribus.* As expected, peanut profit has an inverse relationship with cotton irrigated acreage, and the same type of statistically significant relationship exists between peanut irrigated acreage and cotton profit. Study results show that a 1% increase in the profit of peanuts decreases the cotton irrigated acreage by 0.44%. Similarly, an increase in the profit of cotton by one percent decreases the irrigated peanut acreage by 0.0013 percent. These results reflect the higher per-acre profits of peanuts compared to cotton. Parameters associated with the covariance of profit between cotton and peanut, which was hypothesized to capture the risk-spreading behavior of cotton and peanut farmers, are statistically significant only for peanut acreage. The inverse relationship demonstrates the portfolio effect between cotton and peanuts.

Box-Jenkins (ARIMA) time series model results are presented in Tables 3 and 4 for comparison purposes. As determined by Akaike's information criterion (AIC) and Schwarz's Bayesian information criterion (SBC), the ARIMA (1,1,1) model seems more effective in forecasting cotton acreage in Georgia than other ARIMA specifications. Study results show AIC and SBC values of 15.05 and 17.44, respectively, for cotton. However, in the case of peanut acreage response, AIC (66.71) and SBC (67.93) indicate ARIMA (1,1, 0) as the best model to forecast peanut acreage. With AIC (65.9) and SBC (67.16), the ARIMA (0,1,1) model also seems promising, but this model yields static values for a few forecasted years, making it unreliable for forecasting purposes. In our selected models, forecasted irrigated acreage of cotton and peanuts closely traced actual observed values between 1995 and 2000, further supporting the validity of those models for irrigated cotton and peanuts.

Water Demand Forecasting

Using the results available from the structural and time series forecasting models of cotton and peanut acres and the water demand coefficients calculated for Georgia by using the Blaney-Criddle (BC) formula, we forecast the water demand for cotton and peanut up 2010. An ACT/ACF comprehensive study carried out by the USDA Natural Resources Conservation Services (NRCS) in 1995 evaluated the water demand for cotton and peanuts, mostly based on a physical model and coefficients of the BC formula. In our analysis, the ACT/ACF comprehensive study serves as a baseline. Tables 5 through 8 show the forecasted irrigated acreage for cotton and peanuts and corresponding water demand in our study area. First, we estimated the cotton and peanut acres for coming years by using the structural and time series models. Future water demand for irrigated cotton and peanuts was next estimated by multiplying the results of forecasts by the BC coefficients available from the ACT/ACF river basin comprehensive study.

Based on the BC formula, the ACT/ACF river basin comprehensive study reports 0.00378, 0.000494, 0.000538, 0.000474, and 0.000485 million gallons per day (MGD) per acre of water use in 1992, 1995, 2000, 2005, and 2010 for cotton, respectively. Estimated values were 0.00324, 0.000446, 0.000445, 0.000465, and 0.000475 MGD per irrigated peanut acres for the corresponding years. Total irrigated cotton and peanut acres and corresponding cotton and peanut water demand to the year 2050 are available from the ACT/ACF river basin comprehensive study, which basically serves as water demand predicted by a BC formula-based physical model.

Differences in water demand between physical, structural, and time series models have been termed as "slippage" (Tareen, 2001). Our analysis estimates this slippage by comparing the reduction in estimates of water demand resulting from restrictions on total irrigated acreage available in the study area using physical model estimates versus the structural and time series estimates. Using a physical model, the NRCS forecasts 188,860, 193,472 and 200,350 irrigated acres and 86, 89.96, and 95.13 MGD of water demand for peanuts in 2000, 2005, and 2010 in the study areas of Geogia, respectively.

After considering economic and institutional variables in the peanut acreage allocation decision, our study results show 180,019 and 192,210 irrigated peanut acres and 83.70 and 86.48 MGD of water demand for peanuts in 2005 and 2010, respectively, or approximately 11% less than the physical model. Analysis of future irrigated peanut acreage by using Box-Jenkins analysis shows 171,990 and 171, 977 irrigated peanut acres and 79.97 and 81.64 MGD of water demand for peanuts in 2005 and 2010, respectively.

Similar econometric analysis shows 101,103 and 111,122 irrigated cotton acres and 47.92 and 53.98 MGD of water demand for 2005 and 2010, respectively, in the study area compared to Box-Jenkins estimates of 118,271 and 144,011 irrigated cotton acres and 56.06 and 69.90 MGD of water demand in 2005 and 2010, respectively. These results contrast with the report of the ACT/ACF river basin comprehensive study, which forecasted 132,211 and 155,850 irrigated cotton acres and 62.66 and 75.65 MGD of water demand for cotton for the comparable periods. The study results show that the BC formula-based physical model over-estimated future water demand by ignoring economic and institutional variables. The analysis also shows no substantive differences between the structural and time series forecasts.

Conclusions

We have evaluated the impacts of economic and institutional variables in the irrigated acreage allocation decisions of cotton and peanuts and, thereby, future water demand in selected counties of Georgia. Our analysis demonstrates statistically significant impacts of most economic variables that we hypothesized to influence the irrigation decision. Indeed, cotton and peanut farmers' decisions to allocate irrigated cotton and peanut acreage are based on the expected net return from the competing enterprises.

The presence of price and other institutional variables in irrigated acreage allocation decisions leads to slippage in the demand for irrigation water. The ACT/ACF river basin study appears to over-estimate water use for both cotton and peanut production by approximately 11%. However, structural and time series forecasts of water demand do not differ substantively, each appearing to contain most of the historical and economic information comprising the irrigation decision making process. While data limitations subject the study to cautious use of our forecasts, the results emerge clearly superior to solely physical forecasting techniques of irrigation water demand.

References

Brocklebank, J.C., and D.A. Dickey. “ SAS System for Forecasting Time Series.” SAS Institute Inc. SAS Campus Drive, Cary, NC, 27523, 1986

Chavas, J.P., and M.T. Holt. “Acreage Decision Under Risk: The Case of Corn and Soybeans.” *American Journal of Agricultural Economics* 72(1990):529-38.

Duffy, P.A., J.W. Richardson, and M.K. Wohlgenant. “Regional Cotton Acreage Response.” *Southern Journal of Agricultural Economics* 19(1987):99-109.

Duffy, P.A., K. Shalishali, and H.W. Kinnucan. “Acreage Response under Farm Programs for Major Southeastern Field Crops.” *Journal of Agricultural and Applied Economics* 26(1994):367-78.

Frey, F.W. “Power, Conflict, and Co-operation. “National Geographic Research and Exploration.” Water Issue 9(1993):18-37.

Houston, J.E., C.S. McIntosh, P.A. Stavriotis, and S.C. Turner. “Leading Indicators of Regional Cotton Acreage Response: Structural and Time Series Modeling Results.” *Journal of Agriculture and Applied Economics*. 31 (1999):507-17

Jordan, L.J, “An introduction to Water: Economics Concepts, Water Supply, and Water Use.” Dept. of Agricultural and Applied Economics, The University of Georgia,. Faculty Series 98-13, 1998.

Tareen, I.Y. "Forecasting Irrigation Water Demand: An Application to the Flint River Basin." Ph.D. Dissertation. Department of Agricultural and Applied Economics, The University of Georgia, 2001.

United States Department of Agriculture- Natural Resource Conservation Services "ACT/ACF River Basins Comprehensive Study: Agricultural Water Demand." 1995

Table 1. Estimated Cotton Irrigated Acreage and Elasticities at Means, 1974-2000.

Variable	Parameter	Standard Error	Elasticity
Intercept	0.0527	0.3370	
t	0.0464	0.0079	2.8458
π_1	-0.0124	0.0350	0.0007
w_1	0.305E-5	0.014E-4	2.0178
σ_{11}	-0.0040	0.0359	-6.40E-5
π_2	-0.0369	0.0281	-0.4476
σ_{22}	0.0005	0.0104	0.0048
σ_{12}	0.0153	0.0140	-0.0369
TIA	-6.3577E	1.473E-7	-0.5340
CDEFP	0.1492	0.0865	0.6174
CDIVP	-0.0051	0.0269	0.0363
CDISP	-0.0046	0.0242	0.1279
CPIK	0.0017	0.0251	0.0621
CTGT	-0.1816	0.1141	-0.5153
Durbin-Watson	1.659		
R^2	0.9886		

Table 2. Estimated Peanut Irrigated Acreage and Elasticities at Means, 1974-2000.

Variable	Parameter	Standard Error	Elasticity
Intercept	-0.0806	0.2541	
t	-0.0152	0.0043	-0.6681
π_1	0.0369	0.0147	-0.0013
w_2	-0.0437	0.0185	-0.0005
σ_{11}	0.0271	0.0171	0.2372
π_2	5.1860E-7	6.78E-7	0.0489
σ_{22}	0.0019	0.0063	0.0132
σ_{12}	-0.0158	0.0071	0.0274
TIA	2.699E-7	7.59E-8	1.1534
PQUOTA	0.0137	0.0082	5.5938
PSP	0.0136	0.0036	3.1126
Durbin-Watson	1.852		
R^2	0.9776		

.

Table 3. Structural and select ARIMA model forecasts of irrigated cotton acreage in Georgia, 1996 to 2010.

Year	Physical model	Structural model	ARIMA (1,1,1)	ARIMA (0,1,1)	ARIMA (1,1,0)	ARIMA (2,1,1)
1996		87562	216322	164834	266917	284446
1997		95211	203579	210570	231757	255064
1998		94231	168230	163915	184177	208917
1999		98428	156432	174796	154947	179004
2000	112000	96877	188258	167083	171980	179004
2001		98754	182123	238720	232724	255000
2002		99142	182411	238720	282122	352029
2003		95324	179563	238720	330023	477290
2004		93269	175322	238720	376209	636710
2005	132211	101103	171990	238720	420479	**837231**
2006		109653	172456	238720	462694	1088432
2007		99812	175891	238720	502761	1401779
2008		105896	175630	238720	540628	2278711
2009		110329	172129	238720	576278	2879156
2010	155850	111122	171977	238720	609722	2956321
AIC			15.05	20.39	17.39	21.4
SBC			21.70	21.70	18.61	25.06

Table 4. Structural and Select ARIMA Model Forecasts of Irrigated Peanut Acreage in Georgia, 1996 to 2010.

Year	Physical	Econometric model	ARIMA (0,1,1)	ARIMA (1,1,1)	ARIMA (1,1,0)	ARIMA (2,1,1)
1996		184502	200855	185316	195704	209026
1997		197439	192109	182959	187965	206857
1998		191348	190108	185065	188111	203542
1999		202511	190518	186992	190159	197662
2000	188850	160076	187530	183780	188258	187718
2001		165821	174550	170038	172410	169560
2002		170021	174550	172170	170508	184846
2003		172953	174550	173436	171110	192721
2004		179213	174550	174186	170919	186808
2005	193472	180019	174550	174629	171990	177807
2006		180021	174550	174891	170960	176052
2007		175698	174550	175046	170966	181044
2008		180035	174550	175137	170964	185522
2009		185231	174550	175200	170665	184893
2010	200350	192210	174550	175223	171977	181411
AIC			65.94	67.15	66.71	67.24
SBC			67.16	69.58	67.93	70.9

Table 5. Total irrigated peanut acreage using BC/physical, structural, and ARIMA forecasts

Year	BC/physical Model	Structural Model	ARIMA(1,1,0) model
	acres	acres	acres
1992	224,400	198,716	176,063
1995	208,200	186,298	196,715
2000	188,850	160,076	188,258
2005	193,472	180,019	171,990
2010	200,350	192,210	171,977

Table 6. Total irrigation water demand in million gallons per day by peanut production using BC/physical, structural, and ARIMA (1 , 1, 0) forecasts.

Year	BC/physical Model	Structural Model	ARIMA (1 ,1 ,0) Model
1992	72.72	64.39	62.93
1995	92.81	83.04	87.69
2000	86.00	72.89	78.97
2005	89.96	83.70	79.97
2010	95.10	86.48	81.64

Table 7. Total irrigated cotton acreage using BC/physical, structural, and ARIMA (1, 1,1) forecasts

Year	Physical Model	Structural Model	Time Series Model
1992	103,700	105,123	112,040
1995	107,800	108,642	114,542
2000	112,000	96,877	105,790
2005	132,211	101,103	118,271
2010	155,850	111,122	144,011

Table 8. Total irrigation water demand in million gallons per day by cotton production using BC/physical, structural, and ARIMA (1 ,1 , 1) forecasts

Year	Physical Model	Structural Model	ARIMA (1,1 ,1) Model
1992	39.23	39.76	42.37
1995	53.21	53.62	56.53
2000	60.20	52.07	56.86
2005	56.03	47.92	56.06
2010	75.65	53.98	69.90