GROUNDWATER WITHDRAWALS NEEDED TO MEET IRRIGATION DEMANDS DURING DROUGHT YEARS

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INTRODUCTION

Knowledge of water demands during periods of severe drought is needed to develop strategies for water management. Drought becomes hydrologically significant, lowering groundwater levels, after six or more months of below average rainfall. However, shorter drought periods can result in sharply increased water demands if crops begin to suffer on irrigated land. Agricultural development and water needs in south Georgia will grow as fruit and vegetable production shifts from highly populated southern Florida and water deficient California. At present, Georgia has little control of irrigation water withdrawals from wells installed before 1989. However, future growth and development in the state, may make regional water management necessary.

Recent droughts in the Southeast have increased awareness of limited water supplies in a region commonly considered to have abundant rainfall and inexhaustible groundwater reserves. For the first time, wells used for irrigation must be permitted in Georgia, and pumping records must be maintained. As water resource planners struggle with methods to anticipate future water use patterns, they have little historical records upon which they can draw. Yet, water withdrawals for irrigation make up the greatest total water use in the Coastal Plain region of Georgia. An inexpensive method is needed for estimating irrigation water needs, particularly for drought periods when competition and demands for water are greatest.

This study was undertaken to provide Georgia water use planners with realistic estimates of amount and timing of irrigation withdrawals which could be expected during those years when competition for water is the greatest.

BACKGROUND

Irrigation Development in Georgia

While considered to have a humid climate, agricultural drought is the norm throughout most of the state. 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 1.4 million m^3 per day as compared with industrial withdrawals of 1.5 million m^3 per day. Irrigation withdrawals, however, come in a 5-6 month period creating local drawdown problems for nearby users.

The irrigation survey conducted periodically by the Georgia Cooperative Extension Service with assistance from the Georgia Geologic Survey, now provides a county by county, and crop by crop determination of irrigated area (Harrison and Tyson, 1989.) An estimate of amount of water applied is given for the year of survey. Unfortunately, the recent survey was done for the wettest year of the 1980's.

Prediction of Irrigation Demands

Many agricultural models have been developed to evaluate irrigation requirements. Most of these efforts, however, have been used for arid and semi-arid regions where irrigation supplies all of a crop's water needs. Typically the problem is how much land can be irrigated profitably with a given water source (Hargreaves et al. 1989). Where irrigation water is self-supplied, control over individual withdrawals is difficult. Information on when individuals are likely to make withdrawals and on factors affecting that decision could improve planning for regional development of aquifer. Sanghi and Klepper (1977) used crop models to determine effects of irrigation shortfalls on net returns to farmers growing corn in the midwest. They concluded that conservation of self-supplied irrigation water could not be left to market forces. Net returns to individuals are more sensitive to yield losses when irrigation is limited, than to increased pumping and other costs.

Few attempts have been made in the humid regions of the country to determine irrigation requirements on a county or aquifer basis. Most irrigation scheduling modeling has been at the perspective of individual farm water needs. Chesness et al. (1986) determined total seasonal water use based on evaporative demand and simple crop factors. They were able to develop frequency distributions for irrigation amounts given a 40 year weather record in south Georgia. However, the water use model did not predict crop yield. Water use efficiency and economic importance of different irrigation frequencies could not be evaluated.

For corn, peanut, and soybean, the principal, irrigated row crops in the Coastal Plain region of Georgia, three crop growth models -- CERES-Maize, PNUTGRO, and SOYGRO -- have been adapted and validated for the south Georgia conditions (Hood et al., 1987; Hook, 1988.) Crop growth and water use models were used to determine drought occurrence because actual yields of these crops have varied over the past 50 years, not only because of rainfall, but also because of disease and insects infestations, variety differences, and irrigation and other cultural practice changes. Preliminary work with these validated models has shown that they can be used to evaluate yield reductions due to dry soil in normal and dry conditions, and they can provide estimates of the amounts of irrigation water needed to increase yields to economical levels. Further, the models were sensitive to date of planting, irrigation management, and other crop management practices. The models not only provide a schedule of water demands, but also suggest methods of lowering demand.

METHODS

Three crop models were chosen and validated. CERES-maize, SOYGRO, and PNUTGRO, which are structured similarly following guidelines in the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), were used for the three primary irrigated crops, corn, soybean and peanut, respectively, in the Georgia Coastal Plain. Predictions of yield and irrigation requirements were validated by comparing them with observed yields in over 180 irrigation treatments under typical field conditions in the Coastal Plain.

Years with severe agricultural drought were identified using the Tifton, Georgia, meteorological records and the three crop growth models. Tifton was chosen because it is located in the center of Georgia's Coastal Plain and because records there include 15 years with solar radiation and 52 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 soil used in this analysis was a Grossarenic Plinthic Paleudult, deep sand over heavy clay, and rooting was assumed to extend to 1.2 m allowing extraction of water from deep in the soil. Agricultural drought occurrence was determined as those growing seasons when predicted yields for non-irrigated crops fell below 50% of yields for unstressed crops.

Irrigation requirements were determined for the 15 years with the most severe drought yield losses. Maximum potential (no-stress) yields were calculated for corn, soybean, and peanut. Then, 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 the maximum yields. The upper limit prevented excessive and inefficient irrigation which occurs with maximum yields.

The timing of irrigation need and amount of potential withdrawals were calculated. Average 10-day irrigation requirements for the 15 drought years were computed for each crop. The total water withdrawals needed during this average drought year was computed from the 10-day requirements and the area of corn, peanut and soybean under irrigation in the Southwest district in Georgia, as reported in the 1986 irrigation survey (Harrison, 1986). This 18 county area includes the most irrigated farmland in Georgia, and it includes most of the Dougherty Plain region.

RESULTS

Corn and soybean were more severely affected by drought than peanut. In the 15 driest years, yield losses for corn averaged 75% and, for soybean, 73%. For peanut, an average of 64% of the yield was lost due to drought. Corn

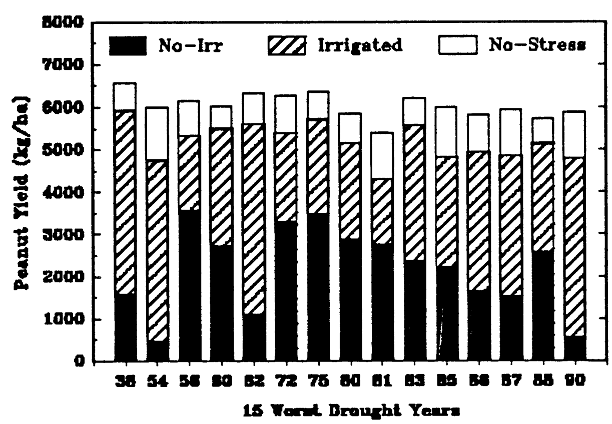

Figure 1. Optimal (No-Stress), dryland (No-Irr), and efficiently irrigated yields for peanut in the 15 years since 1938 with the worst peanut drought conditions. (Bars overlaid)

matures during late spring and early summer, a period with a high probability of low rainfall in the Coastal Plains (Sheridan et al., 1979). Likewise, soybean matures in early fall, a period with an even higher probability of low rainfall.

The effect of drought years on peanut yields are illustrated in Fig. 1. Yield loss was 90% in the two worst years; however, even 50% yield losses can mean economic losses as the investments in variable input costs alone cannot be met. Of particular interest, half of the 15 worst peanut drought years since 1938 occurred after 1979. This agrees with Sheridan et al. (1989) assessment that, in the Coastal Plain, summer rainfall has been decreasing, while winter rainfall increases have kept annual rainfall trends unchanged over the long term.

Irrigation was managed to bring yields to moderate yield goals of 80 to 90% of yields with no water stress. Above that yield goal, water is used less efficiently as increasing additions give diminishing returns. In Fig. 1, the effect of irrigation on stabilizing yields is evident. The amount of

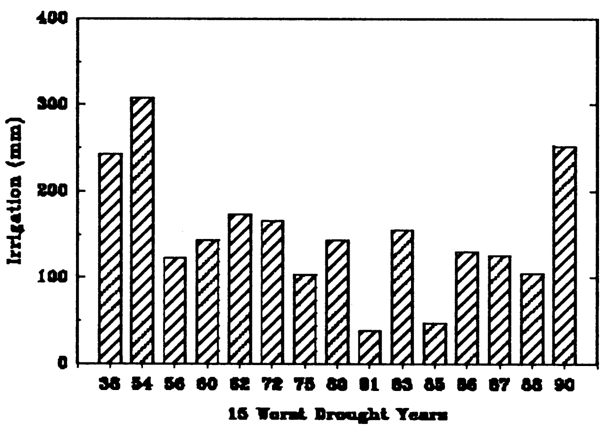

Figure 2. Seasonal irrigation amounts needed to bring peanut yields to 80 to 90% of optimal during drought years.

annual irrigation needed to achieve those stable yields varies considerably (Fig. 2). In some years two well-timed irrigations can prevent yield reducing stress at a critical stage. In the driest years, most of the water needs of the crop had to be made up by irrigation. The average irrigation needed for corn, soybean and peanut in these drought seasons were 245, 198, and 150 mm, respectively. If all 1990 Georgia growers who irrigate these crops used those irrigation levels, as much as 2.5 billion cubic meters would be withdrawn to meet moderate yields during drought years.

To examine the impact of irrigation on timing of water withdrawal from surface and groundwater sources, the average irrigation needed to meet crop water needs were computed for 10-day periods. As shown in Fig. 3, most of the irrigation needs of corn in these drought years occurs before irrigation is needed for peanut or soybean. Peanut and soybean needs coincide during late summer.

For regional water use planning, not only are timing of irrigations needed, but also land area of irrigated crops. As an example, the Southwest Georgia Extension District was

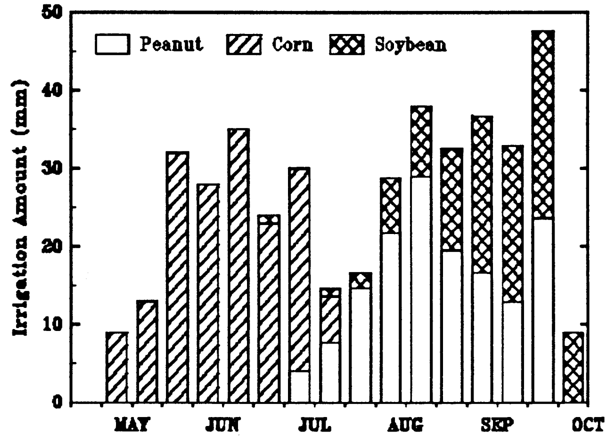

Figure 3. Average 10-day irrigation amounts needed by three crops during the 15 driest years since 1938. (Bars are stacked)

chosen. It contains almost 60% of Georgia's irrigated land. In 1986 the reported irrigated land area for corn, peanut, and soybean in that region was 98,800, 131,800 and 25,400 ha, respectively (Harrison, 1986). The combined effect of irrigation timing and land area on water withdrawals is shown in Fig. 4. For most of the 130 days between late May and late September, withdrawals could exceed 2.5 million m^3 per day, on the average, for these severe drought years.

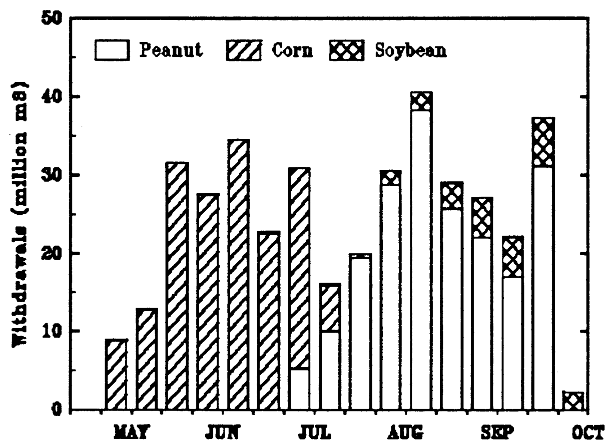

Figure 4. Average 10-day water withdrawals needed in the Southwest Georgia Extension District to meet irrigation needs for the 15 worst drought years since 1938. (Bars are stacked)

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. The amount of water used for irrigation depends upon many phenomena: crop species (and variety), planting date, level of management, soil type, irrigation equipment, operator experience, pumping costs and crop value. However the amount of water actually needed for irrigation is principally related to the rainfall and potential evapotranspiration.

Modern crop growth and water use simulation models can integrate the daily effects of changing weather patterns and predict their effects on crop yield and evapotranspiration. Analysis of long-term meteorological records with growth and water use simulation can improve our estimates of agricultural demands for groundwater withdrawals.

Examination of amount and timing of water needed during drought years should be used to help 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 irrigation water withdrawals. Arbitrary cutoff periods or restrictions which fail to account for the nature of crop production and water use may cause unnecessary adverse economic impacts. This would lead to noncompliance or low cooperation with regulations. On the other hand, farmers have a natural incentive to minimize water use. Farmers pay for pumping water throughout the growing season. Pumping costs reduce profits. By designing water use programs which minimize water withdrawals and improve water use efficiency farmers will have an economic incentive to cooperate.

SUMMARY

Irrigation demands were determined for three crops which are often irrigated in the Georgia Coastal Plains. With normal planting dates, the time of water withdrawals for corn precedes that for peanut and soybean. In the 18 county Southwest Georgia area, water demand in drought years can exceed 2.5 million m^3 per day for most of the June through September irrigation period. Further application of the techniques used here could lead to county or watershed specific estimates of maximum water needs.

ACKNOWLEDGMENTS

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