OPTIMAL CROP CHOICE AND WATER ALLOCATION IN THE TEXAS HIGH PLAINS

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Abstract

The Texas High Plains is one of the most important agricultural regions in the US. Major irrigated crops in this region include cotton, corn, and grain sorghum. This region depends heavily on the Ogallala Aquifer for its irrigation water supply. Subsequently, irrigation water use efficiency is a major concern in the region due to dwindling water supplies from the aquifer. Since commodity prices vary considerably and each commodity's response to irrigation differs, simultaneously identifying the profit maximizing irrigation level for each crop and optimal land allocation to maximize farm profitability, particularly under limited water availability, is a complex task. This study used the cotton, corn, and grain sorghum production functions reported for the region and a range of price scenarios to maximize farm level profit by simultaneously optimizing irrigation level and crop choice using Excel Solver with the Generalized Reduced Gradient Non-linear Algorithm. The percentage of land allocated to each crop was estimated for low (12 inches), medium (18 inches), and high (24 inches) seasonal rainfall scenarios assuming an additional 15 acre-inches of water available from irrigation. The results provided optimal crop combinations at current prices and switching points for the crops in response to changing commodity prices.

Introduction

The Texas High Plains (THP) is one of the main agricultural regions in the US. The THP accounted for 3.25 million bales of cotton out of the 5.95 million bales produced in Texas in 2014 (USDA NASS, 2016. This region also has significant acreage planted to corn and grain sorghum. Since THP is a semi-arid region without any substantial surface water resources, agricultural production in the THP depends on water from the Ogallala Aquifer. However, the aquifer has seen consistent depletion in recent years (USGS, 2014). The possible reduction in water availability in the near future has caused many producers and policy makers to begin considering ways to optimize production and profitability under reduced water usage. Consequently, irrigation efficiency is a major concern in the THP.

Corn, cotton, and grain sorghum are the three major row crops planted on the Texas High Plains in terms of acreage (USDA NASS, 2016). These three crops are planted during the same cropping season and usually compete with each other for irrigated acreage. These crops also differ widely in water requirements. The seasonal evaporative demand for corn is 28-32 inches, cotton is 13-27 inches, and grain sorghum is 13-24 inches (Sweeten and Jordan, 1989). However, the productivity of these crops also depends on the irrigation system. Producers in the THP are well known for the use of efficient irrigation systems such as center pivots. The percentage of irrigated acreage under center pivot irrigation increased from about 11% in 1958 to about 72% in 2000 in the Texas High Plains (Colaizi et al., 2009).

From a producer's standpoint, the most important factor influencing crop choice is profitability. The profitability is driven by the productivity and price of the crops. However, crop productivity is linked to the amount of irrigation water applied. This problem becomes more complex under limited water availability because the yield maximizing amount of irrigation water for high water demand crops, such as corn, may not be available to the producer. This makes it critical for producers to identify the most profitable crop mix under limited water availability. Therefore, a model is needed that can include inputs of the producer's specific situation to maximize profitability under limited water availability.

The objectives of this study were twofold. First, create a model using the Generalize Reduced Gradient (GRG) nonlinear programming function in Microsoft Excel to identify profit maximizing crop mix for a center pivot irrigated field in the THP under limited water availability. Corn, cotton, and grain sorghum, the three major crops grown in the region were considered as the available crop choices. Second, examine adjustments to the optimal crop mix as crop prices change at various available water levels.

Materials and Methods

Texas price data for corn, cotton, and grain sorghum was collected for 2011-2015 (USDA NASS, 2016. The average commodity price for each crop was computed from this data. Corn prices were reported in \$/bu, cotton prices in \$/lb, and grain sorghum price in \$/cwt. Variable cost data was collected for each crop from Texas A&M AgriLife crop and livestock budgets (Texas A&M AgriLife, 2015). Previously estimated production functions were obtained for each crop with total water available during the growing season serving as the independent variable (Colette and Almas, 2004; Marek et al., 2013; Wanjura et al., 2002). The production functions for the three crops are provided in equations 1 to 3 where TW denotes total water.

$$Y_{Corn} = -760.36 + 61.81\,TW - 0.941\,TW^2 \quad (1)$$
$$Y_{Cotton} = 479 + 26.84\,TW - 0.18\,TW^2 \quad (2)$$
$$Y_{Sorghum} = 0.3506 + 4.153\,TW - 0.0443\,TW^2 \quad (3)$$

Returns above variable cost (RAVC) was calculated for each crop using the production levels estimated from the production function at various irrigation levels (assuming three rainfall scenarios; 12, 18, and 24 inches), average prices, and variable cost data. Excel Solver with the GRG nonlinear algorithm was used to estimate the profit (RAVC) maximizing crop mix for a 100 acre field with 15 acre inches of irrigation water availability. Additionally, optimum acreage allocated to each crop were compared at low (12 inch), medium (18 inch), and high (24 inch) rainfall levels.

Results and Discussion

The results presented here shows the profit maximizing combinations of corn, cotton, and grain sorghum at three different rainfall scenarios. However, the optimal crop combinations depends on the price of the three commodities. Figures 1, 2, and 3 show the optimal crop combinations at various corn prices under low, medium, and high rainfall scenarios, respectively.

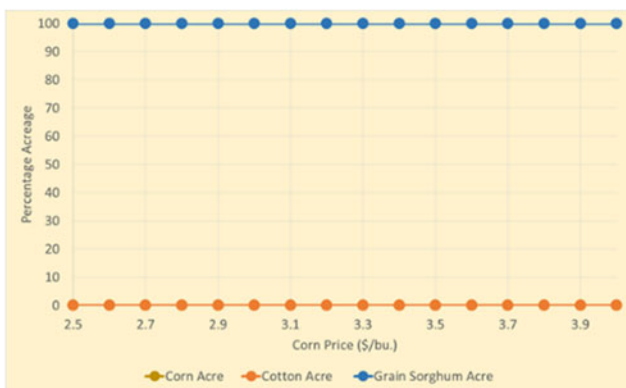

Figure 1: Optimal acreages at different corn prices at low water level.

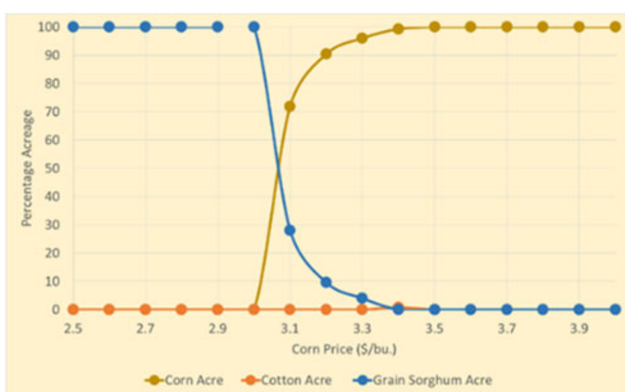

Figure 2: Optimal acreages at different corn prices at medium water level.

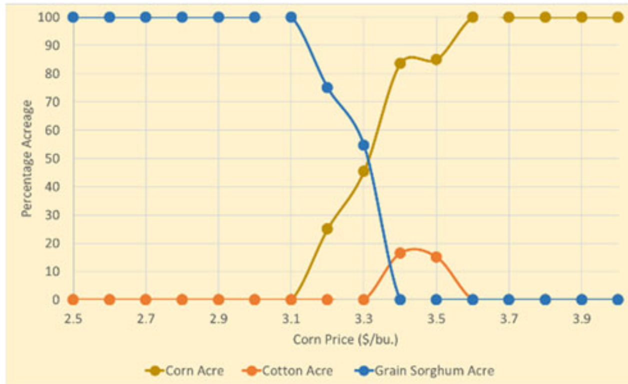

Figure 3: Optimal acreages at different corn prices at high water level.

At the low water level of 12 inches of rainfall, corn was not an ideal crop. This is due to its high water requirements. Grain sorghum remained the clear profit maximizing crop in this situation (Fig. 1). Corn entered the crop mix at $3.10/bu, at the medium water level and became the majority recommended crop at about $3.40/bu (Fig. 2). At both medium and high water levels, when corn prices reached $3.60/bu, all 100 acres was planted to corn to maximize profits. At the high water level, corn entered the crop mix at $3.20/bu, and became the majority at about $3.40/bu (Fig. 3).

The optimal crop combinations at various cotton prices under low, medium, and high rainfall scenarios are presented in Figures 4, 5, and 6, respectively.

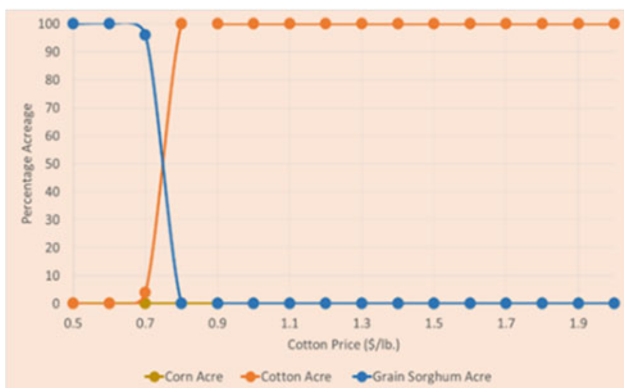

Figure 4: Optimal acreages at different cotton prices at low water level.

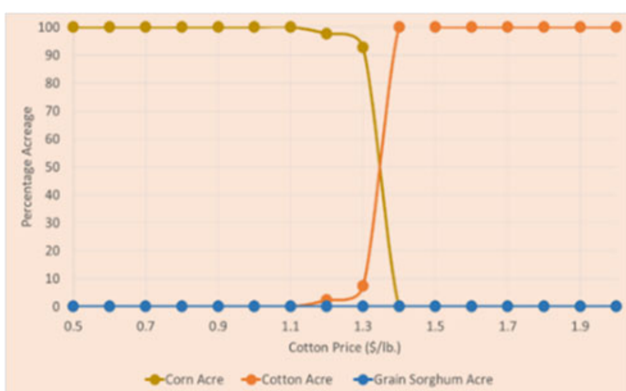

Figure 5: Optimal acreages at different cotton prices at medium water level.

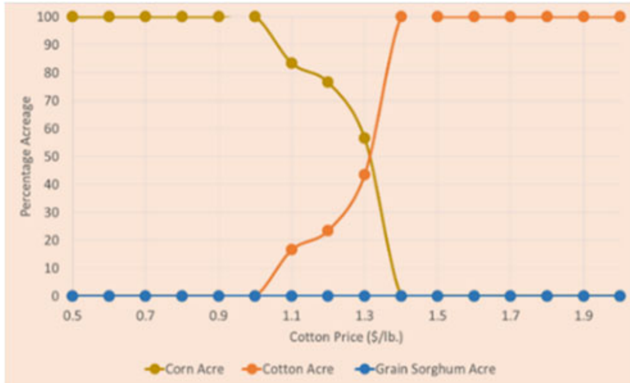

Figure 6: Optimal acreages at different cotton prices at medium water level.

Cotton became the ideal crop compared to grain sorghum at a cotton price of $0.80/lb at low water. This goes in conjunction with cotton's low water requirement (Fig. 4). At the medium water level, cotton acreage began to replace corn acreage after cotton price passed $1.10/lb (Fig. 5). When cotton price reached $1.40/lb. under both medium and high water use, it became the ideal crop overall. (Fig. 5 & 6).

Figures 7, 8, and 9 show the optimal crop combinations at various sorghum prices under low, medium, and high rainfall scenarios, respectively.

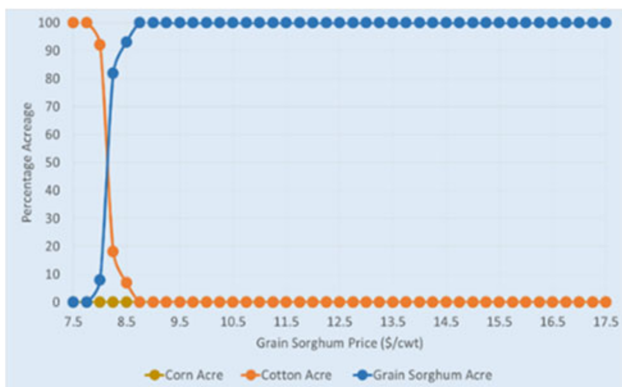

Figure 7: Optimal acreages at different sorghum prices at low water level.

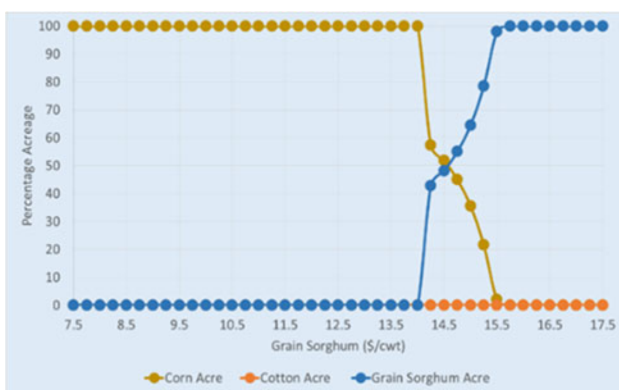

Figure 8: Optimal acreages at different sorghum prices at medium water level.

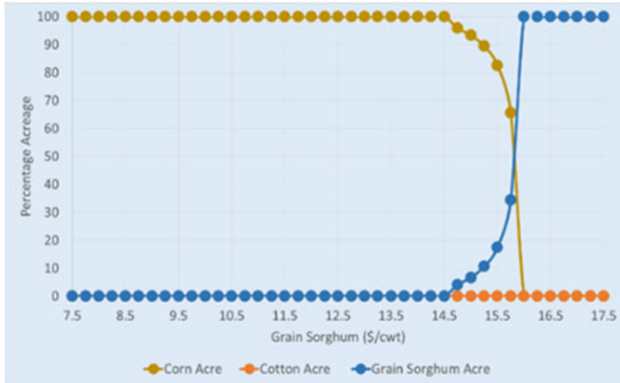

Figure 9: Optimal acreages at different sorghum prices at high water level.

At low water levels, a greater percentage of land was planted to grain sorghum compared to cotton when grain sorghum prices reached $8.25/cwt and became the ideal crop at a price of $8.75/cwt (Fig. 7). Grain sorghum rose above corn to become profit maximizing at approximately $16.00/bu at both medium and high water use (Fig. 8 and 9). The significant price increase required for grain sorghum to become the profit maximizing crop can be explained by corn's tendency to prefer higher water levels. Therefore, grain sorghum would need to have a relatively high price to overtake corn's natural productivity under high water availability.

The results reveal the functionality of the model to aid producers in providing information to enhance water and land allocation to achieve maximum profit when planning future production decisions. This will be especially significant as water becomes scarcer in the THP.

Summary

Corn, cotton, and grain sorghum are the three primary summer row-crops grown in the THP. Each crop performs differently when grown under similar water availability. Due to limited rainfall and declining groundwater levels in the THP, farmers and policy makers have seriously begun considering ways to optimize production and profitability under reduced water usage.

The study estimated a model to identify the profit maximizing crop mix (corn, cotton, and grain sorghum) for a center pivot irrigated field in the THP under limited water availability, then, examined adjustments to the optimal crop mix as crop prices changed at various rainfall levels.

When considering corn prices, grain sorghum was recommended exclusively at low water availability, but as more water was available, corn dominated planted acres above a price of $3.30/bu. This is not surprising since corn high water requirement and its productivity tends to rise with increased water availability.

Cotton and grain sorghum are generally considered to be more drought tolerant than corn. So, when cotton prices were low, grain sorghum initially dominated planted acreage until cotton prices reached $0.70/lb and by $0.80/lb, cotton was the only crop recommended by the model. Yet, as water availability increased, corn emerged as the primary competitor for crop acreage until cotton prices reached a level of about $1.30/lb., which is very uncommon.

When the prices of grain sorghum were considered at the various rainfall levels, grain sorghum at low water levels became the sole choice at a price of about $8.75/cwt. At the two higher levels of water availability, grain sorghum only became a choice when prices exceeded approximately $14.00/cwt, a price which has been approached in the marketplace, but like $1.30/lb cotton, is relatively uncommon.

Results of the study indicate that the model is a functional tool to assist THP farmers as they decide what to plant based on water availability and a series of prices available to them. Since the THP is semi-arid with dwindling groundwater resources, decision making tools of this nature will become increasingly important to help farmers make planting decisions to optimize yields and profitability.

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