LAND USE FOR COTTON IN THE CORN-DOMINATED NORTHERN HIGH PLAINS OF TEXAS: TRENDS AND DRIVERS

Shyam Nair
Foy Mills Jr.
Kelsey Powers
Benjamin Kresta
Sam Houston State University
Huntsville, TX

Abstract

Approximately 60% of the corn and 20% of all cotton produced in the state of Texas comes from the Northern High Plains. Grain sorghum is also planted on irrigated acreage in the region. Although corn dominates irrigated land use, it appears economic and environmental factors are driving changes in land use patterns. Using historical land use data, changes in acres planted to corn, cotton, and grain sorghum were examined. Irrigated acreage planted to corn, cotton, and grain sorghum, along with their respective prices, were collected from 1974 to 2014. Regression equations were developed for each crop with planted irrigated acreage serving as the dependent variable. The independent variables were lag acreage and lag price of the crop, and lag prices of the two competing crops. These regression equations were simultaneously estimated using iterative Seemingly Unrelated Regression to identify the factors influencing irrigated land use decisions in the region. Results revealed that corn and cotton acreages showed a positive trend over time in the region, while the time trend for grain sorghum acreage was negative. Lag acreage significantly and positively influenced the planted acreage for all three crops. Planted acreage of all crops were significantly and positively influenced by their lag prices, at least at the 10% alpha level.

Introduction

The Northern High Plains (NHP) agricultural statistical district is located in the northern panhandle of Texas and consists of 23 counties. The 23 counties included in this district are Armstrong, Briscoe, Carson, Castro, Dallam, Deaf Smith, Floyd, Gray, Hale, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Parmer, Potter, Randall, Roberts, Sherman, and Swisher (USDA NASS, 2015b). Corn, winter wheat, cotton, and grain sorghum are the major irrigated crops grown in the region. Corn accounts for almost 40% of the irrigated acreage and about 60% of total irrigation water used in the region (Freese and Nichols Inc., 2015). Approximately 60% of corn and 20% of cotton production in the state is from the NHP (USDA NASS, 2015a).

Land use refers to the management regime imposed by humans on a particular parcel of land (Antrop, 2005). Agricultural land use exhibits substantial changes over time because of the interaction among environment, resource availability, and agronomic factors. Land use change models analyze the causes and consequences of changes in land use. The basic premise of land use models is that the agents respond to bio-physical attributes of the land according to the socio-cultural conditions to maximize their economic and socio-cultural wellbeing and hence land use change is modeled as a function of these driving forces (Verburg et al., 2004). The socio-economic driving forces play a crucial role in agricultural land use decisions (Turner et al., 1995) along with soil productivity and water availability (Iverson, 1988). Land use change models can be used to analyze temporal trends and drivers of land use and act as an important tool in land use planning and policy making (Verburg et al., 2004).

Since corn, cotton, and grain sorghum are planted during the same season, they compete with each other for irrigated acreage. Producers make crop choices based on several factors such as profitability, suitability of soil and climatic conditions, water requirement of crops, and ownership of implements required for agronomic operations. In a low rainfall region like the NHP, water availability plays a major role in crop choice. The dwindling water supply from the Ogallala aquifer (McGuire et al., 2003) has forced some producers to choose crops with low water requirements (Colaizzi et al., 2009). Although agronomic considerations such as crop rotation may influence acreage decisions at the field scale, it may not play a major role at the regional scale because of aggregation. Since the ownership of specialized equipment can influence crop choice, lag acreage can be an important predictor of current acreage. The most important factor that influences crop choice is the relative profitability of competing crops. Since yield expectations are relatively more stable than price expectations, the expected commodity prices can be regarded as major drivers of irrigated land use. Based on the rational expectations theory (Muth, 1961), we can assume lag prices are indicators of the expected prices.

There is considerable year-to-year variability in planted acreages of cotton, corn, and grain sorghum in the NHP. Factors such as lag acreage of the crop, and lag price of the crop and competing crops can influence crop choices. It is important to analyze acreage trends of the crops and to quantify the influence of these possible driving factors on crop choices. The planted acreage of crops has important implications on commodity supply and subsequently prices. A predictive model for planted acreage in the region will provide important information for policy makers. Hence, this study was conducted with the following two objectives: 1) assess the changes in irrigated acreage of cotton, corn, and grain sorghum in the NHP of Texas and 2) identify the possible drivers of land use change in the region and quantify their influence on the irrigated acreage of cotton, corn, and grain sorghum.

Materials and Methods

The Data

Data on planted acreage and prices received for cotton, corn, and grain sorghum in the NHP from 1975 to 2014 were collected (USDA-NASS, 2015a). Corn and grain sorghum prices were reported in \$/bu. and \$/CWT, respectively. The grain sorghum price was converted to \$/bu. to enable meaningful comparison of the marginal impact of grain prices on acreage choices. The acreage data for corn and cotton were not reported for 2011. Hence, yield data for 39 years (1975 to 2014 except 2011) was used to analyze the yield trends using simple linear regression (OLS) with time as the explanatory variable. Lag acreage was an explanatory variable in our empirical model to analyze land use change. Hence, 2012 data was also excluded from the dataset used for empirical estimation (because lag acreage and prices for 2012 are data from 2011).

Empirical Model

The econometric model used in this study can be conceptualized as a two-step process. The first step was to develop multiple regression equations to explain planted acreage of each crop using its lag acreage and lag price, and the lag prices of the two competing crops as explanatory variables. This resulted in the following three regression equations.

$$Cotton\ Acreage = \beta_0 + \beta_1 LA_{cotton} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (1)$$
$$Corn\ Acreage = \beta_0 + \beta_1 LA_{corn} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (2)$$
$$Sorghum\ Acreage = \beta_0 + \beta_1 LA_{sorghum} + \beta_2 LP_{cotton} + \beta_3 LP_{corn} + \beta_4 LP_{sorghum} + \varepsilon \quad (3)$$

where LA is lag acreage, LP is lag price, $\beta' s$ are the coefficient estimates, and ε is the error term.

Even though these are three separate equations, the error terms in these equations are correlated because change in acreage of one crop will influence the acreage of the other crops. Hence, these three equations were simultaneously estimated using iterative Seemingly Unrelated Regression (SUR) procedure (Zellner, 1962) in STATA® (StataCorp, 2013) to quantify the influence of the factors driving irrigated land use in the region. Our SUR model was estimated using the Feasible Generalized Least Square (FGLS) algorithm (Cameron and Trivedi, 2009). SUR is more efficient than OLS when the errors are correlated (Greene, 2008), which is a realistic assumption in this case.

Results and Discussion

Acreage and Price Trends

Descriptive statistics of the price and acreage data for cotton, corn and grain sorghum in the NHP are provided in Table 1. The descriptive statistics show that corn occupies the largest irrigated acreage share with 715,736 acres planted to corn in the region on average. The average irrigated area planted to cotton was 550,331 acres and cotton showed the lowest year-to-year variability in planted acreage among the three crops. Grain sorghum had the lowest average planted acreage at 402,149 acres, but exhibited the highest year-to-year variability in planted acreage.

The time trend of irrigated acreage and prices of the three crops are illustrated in Figure 1. The regression lines in Figure 1 indicate that corn and cotton showed positive trends over time with average annual increases of 4,700 acres and 2,500 acres, respectively. However, grain sorghum acreage decreased by about 14,000 acres per year. Additionally, corn and grain sorghum prices closely follow one another. This happens because both have similar principle end uses. We can also observe the sharp increase in corn and grain sorghum prices starting in 2007 spurred by biofuel initiatives.

Table 1. Descriptive statistics of acreage and price data for the three crops from 1975 to 2014 (2011 not included)

Statistic	Planted acreage (acres)			Price ($/lbs. for cotton & $/bu. for grains)		
	Cotton	Corn	Sorghum	Cotton	Corn	Sorghum
Mean	550,331	715,736	402,149	$0.55	$3.06	$2.67
Minimum	340,000	368,000	138,000	$0.28	$1.87	$1.60
Maximum	810,000	1,120,000	1,114,000	$0.82	$7.12	$6.27
Standard Deviation	128,025	195,072	211,545	$0.11	$1.14	$1.01

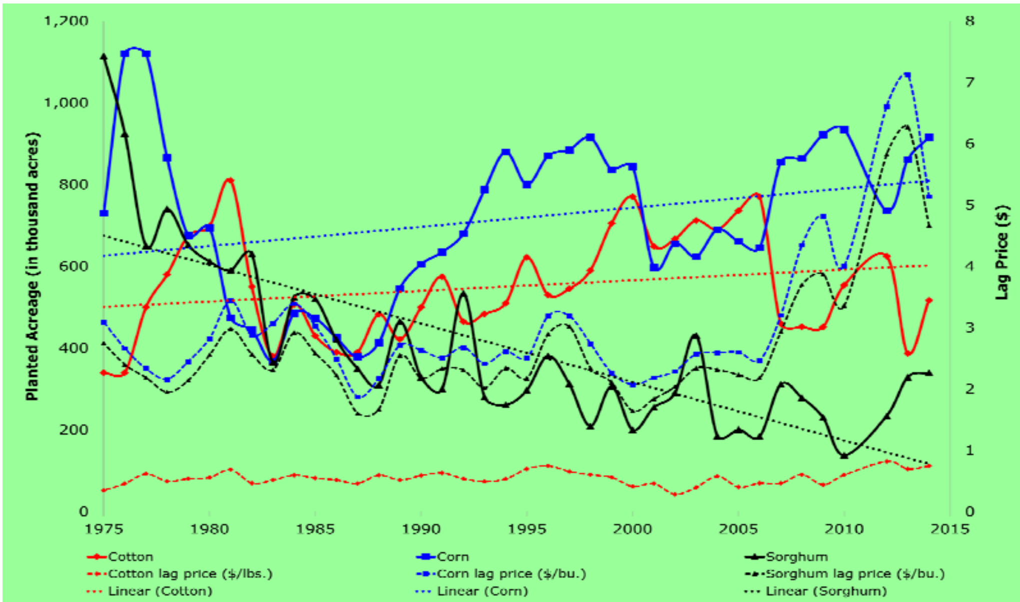

Figure 1. Planted acreage of irrigated cotton, corn, and grain sorghum with trend lines, and their prices in the Texas NHP, 1975-2015.

Drivers of Crop Choice

The overall results of the iterative SUR analysis of the crop acreage equations are shown in Table 2. The irrigated acreages of all three crops were significantly influenced by at least one of the explanatory variable. The explanatory variables accounted for most of the variability in grain sorghum and corn acreage (R^2 of 0.8019 and 0.7136), respectively. However, only 50% of the variability in cotton acreage was explained by its lag acreage and the lag prices of cotton, corn, and grain sorghum. This may have happened because of the influence of crop rotation on land use decisions.

Table 2. Results of SUR analysis for crop acreage equations

Equation	No. of obs.	No. of param.	RMSE	R square	Chi Square	P-value
Cotton acreage	38	4	90036.5	0.5008	33.67	<0.001
Corn acreage	38	4	104370.8	0.7136	116.96	<0.001
Sorghum acreage	38	4	93353.6	0.8019	169.02	<0.001

The coefficient estimates and p-values for explanatory variables in all three equations are provided in Table 3. Lag acreage was the only variable that significantly influenced cotton acreage at the 5% alpha level. Lag acreage had a strong positive impact on irrigated cotton acreage. The lag price of cotton influenced cotton acreage at the 10% alpha level (p=0.058). A one cent/lbs. increase in lag cotton price increases planted cotton acreage by 3,097 acres.

The lag acreage of corn and the lag price of grain sorghum (at 10% α level) were significant in determining the planted acreage of irrigated corn. When the lag price of grain sorghum increases by 10 cents/bu., the area planted to corn increases by 25,307 acres. It was surprising to observe that corn acreage was influenced by the lag price of grain sorghum rather than by the lag price of corn. This may be the result of the very high correlation between corn and grain sorghum prices.

Table 3. Influence of lag acreage and lag prices on planted acreage of irrigated cotton, corn, and grain sorghum

Variable	Cotton Acreage		Corn Acreage		Grain Sorghum Acreage	
	Coef.	P value	Coef.	P value	Coef.	P value
Lag acreage	0.57418	<0.001	0.83897	<0.001	0.74109	<0.001
Lag price (cotton)	309751	0.058	-266862	0.149	-255252	0.120
Lag price (corn)	-27217.1	0.786	174004	0.133	-294829	0.004
Lag price (sorghum)	-22874.1	0.844	253078	0.059	363684	0.002
Constant	205889	0.071	131663	0.191	157033	0.084

The planted acreage of grain sorghum was significantly and positively influenced by its lag acreage and lag price. The lag price of corn significantly and negatively influenced grain sorghum acreage. A 10 cent/bu. increase in the lag grain sorghum price increases sorghum acreage in the NHP by 36,368 acres, while a 10 cent/bu. increase in the lag corn price leads to a 29,482 acre decrease in the area planted to grain sorghum. We can observe from Figure 1 that although corn and grain sorghum prices tend to move together, the difference between corn and grain sorghum prices shows some variations. The difference between corn and grain sorghum prices varies from $0.15 to $0.95/bu. Therefore, high grain prices lead to more acreage planted to grains. Yet, if the price of corn is relatively higher than grain sorghum price, then acreage shifts towards corn and vice versa.

Summary

The portion of irrigated acreage planted to corn and cotton has increased over time at the expense of irrigated acreage planted to grain sorghum in the NHP of Texas. Given dwindling water supplies in the region, this seems counter-intuitive since grain sorghum has the lowest water requirements of the three crops and seems to be contrary to assertions of Colaizzi et al. (2009). Therefore, it appears that factors other than environmental concerns had greater impacts on irrigated land use decisions over the time period analyzed.

Results support Muth's (1961) rational expectations theory that market participants see lag prices as indicators of expected prices. The lag price of cotton impacted irrigated acreage planted to cotton (at 10% α level), the lag price of grain sorghum influenced the irrigated acreage planted to corn (at 10% α level), and the lag price of corn and grain sorghum significantly impacted irrigated acreage planted to grain sorghum. Therefore, farmers in the NHP of Texas are sensitive to lag commodity prices in their land use decision making, particularly irrigated acreage planted to grain sorghum. This outcome raises an associated question for subsequent investigation, do NHP farmers consider futures prices in their crop acreage allocation?

Finally, it is clearly apparent that what farmers in the Texas NHP plant this year is significantly impacted by what crops they planted previously. This could be due to the design of farm programs (e.g., allotments, base acres) or possibly to resource fixity (Nelson, Braden, and Roh, 1986), though economist differ on this subject.

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