AN ANALYSIS OF COMPETING AGRICULTURAL LAND USES

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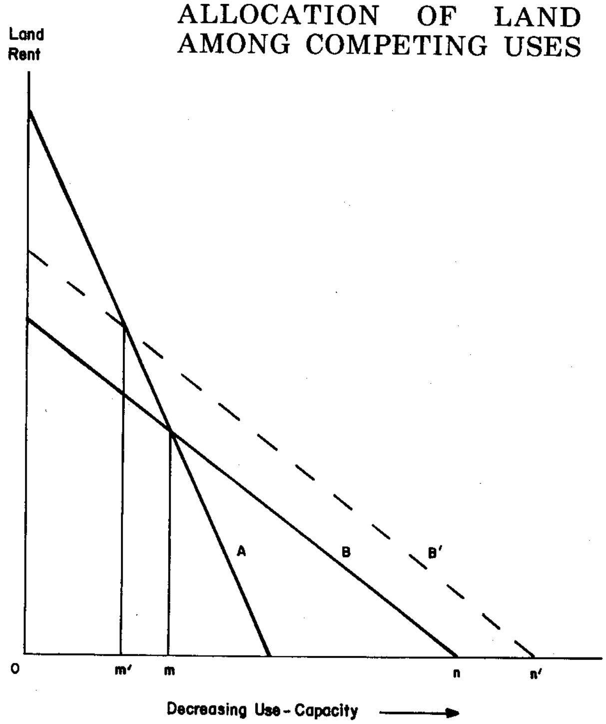
Several alternative government programs have been used in the past to achieve policy objectives related to the levels of crop acreage and net farm income. Important questions remain relating to the effectiveness of past programs in achieving selected policy objectives. In particular, what is the relative effectiveness of long-term versus short-term acreage diversion programs? One of the major impacts of government diversion programs is in the allocation of land among competing uses. Several studies (Brandow and Learn; Christensen and Aines; Hathaway) indicate that the use of acreage control on single crops rather than on all crops results in less than proportionate reduction in output from a given reduction in acreage. However, only limited information is available on the interrelationships among major competing uses of crop, pasture, and privately owned forest acreage. Studies of these interrelationships (e.g. Dideriksen et al. and Zeimetz et al.) did not consider the influence of government programs. In particular, how do government programs affect these competing uses?

The overall objective of our article is to examine the interlinkages among major agricultural land uses. Primary attention is focused on the effects of government diversion programs on land use patterns. Though diversion programs are designed to reduce crop acreage, these programs would also be expected to affect acreage in other uses, most notably pasture and privately owned forest acreage. A conceptual land use model is used to analyze empirically agricultural land uses in Georgia.

CONCEPTUAL FRAMEWORK

Variations in land rents, which influence the allocation of land among competing uses, are explained typically in terms of such factors as soil fertility and location. Barlowe measures the cumulative impacts of these factors by the concept of use-capacity (1978). The relationship between decreasing use-capacity and the amount of rent produced by a particular land use can be called the land rent profile. Land rent profiles for two alternative uses are depicted by curves A and B in Figure 1.

FIGURE 1. A FRAMEWORK FOR THE ALLOCATION OF LAND AMONG COMPETING USES



Producers can choose among alternative land uses and select the particular land use that offers the greatest opportunity for profit as measured by land rent. The two land rent profiles in Figure 1 can be used to describe the potential profit situation from competing uses such as crops and pasture. Use A, say crops, would be applied on all high use-capacity sites between O and m, because this use produces the highest land rents over this range. Though use B offers the highest rents of competing alternatives to the right of point m, the extensive margin is defined by point n because land with lower use-capacity would remain idle.

Land rent profiles can also be used to analyze the impact on competing land uses of a change in the profit situation for one of the land uses. Assume that the produce price for

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use B increases so that the land rent profile shifts from curve B to curve B′ in Figure 1. As a result, the highest and best use for those sites between m′ and m changes to use B from use A, indicating a need for resource adjustment. Actual adjustment may not occur unless benefits from adjustment exceed adjustment costs. A reduction in the efficient level of use A indicates a simultaneous relationship between the two land uses. In addition, the extensive margin is increased from n to n′ as a result of the higher profit situation for use B. Land which was formerly idle would now produce positive rents under use B. As depicted in this figure, a small increase in the produce price for use A would not have resulted in an increase in the extensive margin. Thus any increase in use A would have resulted in an equal reduction in use B.

Though the land rent profile concept is useful for determining shifts in land use, some complications should be taken into consideration. First, producers operate in an uncertain environment and generate expectations about the future in a variety of ways. Hence the impact on future rents of a change in the current price of a particular produce will be viewed differently by different producers. Second, there may be lags in adjustment from one land use to another. With recognition of these limitations, this approach provides an analytical basis for explaining interrelationships among competing land uses.

THE LAND USE MODEL

Agricultural land in Georgia is used primarily for crops, pasture, and forests. In our analysis these three uses for privately owned land are considered to be endogenously related. For example, an increase in crop acreage may result in a reduction in pasture and/or forest acreage. Furthermore, the number of acres in each of these categories depends on net returns of their respective products, government programs, and historical land use patterns. Historical patterns are mentioned here because annual changes in land use are relatively small in comparison with total agricultural acreage. Nonfarm factors may also influence agricultural land use patterns. For example, demand for land for nonfarm uses may affect the amount of land available for farm uses.[1]

Operators view decisions on the acreages to be planted in the current year in terms of adjustments from the previous year's operation (Penn and Irwin, p. 115). It can be argued that producers do not drastically alter their cropping pattern in one year but do it gradually over a period of years. Therefore, the acreage planted to crops in the previous year is included as a variable to explain the current year's acreage. Expected net income per acre from crop production is a principal determinant of the number of acres in cropland. Lagged net income per acre from crop production is used as a proxy for expected net income per acre from crop production. In addition, government programs for agriculture have often focused on reducing crop acreage in order to reduce surpluses.[2] Hence program payments are expected to be inversely related to crop acreage. Land diverted from production under long-term contracts is also expected to reduce crop acreage. Ideally, the federal government would expect to reduce crop acreage by one acre for each acre diverted under these long-term contracts. If crop acreage declines by less than the level of crop diversion, slippage is said to occur. With the possibility of slippage, the regression coefficient for the variable representing land diverted under long-term contracts is expected to be less than one. The size of this coefficient should be indicative of the relative success of the conservation reserve program.

Hence crop acreage levels are hypothesized to depend on acreage in other major agricultural uses, previous crop acreage and net income per acre from crop production, and government acreage control programs. The equation is

$$(1) \quad A_{Ct} = f(A_{Pt}, A_{Ft}; A_{Ct-1}, NI_{t-1}, LTCONT_t, G_{LT,t}, G_{ST,t})$$

where

A_C = crop acreage
A_P = pasture acreage
A_F = forest acreage
NI = net income per acre from crop production
$LTCONT$ = acreage under long-term contracts at the beginning of the year
G_{LT} = government payment rate under long-term program during enrollment period
G_{ST} = government payment rate under short-term program.

A semicolon separates the endogenous acreages on the left from the exogenous variables. Also, variables observed in the current

[1]Conversion of farmland to nonfarm uses for the years between 1958 and 1967 indicates that urban pressure is not a major factor in determining crop acreage in Georgia. Though cropland declined 1.6 million acres between 1958 and 1967, urban buildup increased only 0.3 million acres (USDA, Soil Conservation Service). Furthermore, most of the urban expansion has occurred outside the major crop-producing areas in Georgia.

[2]In this study the diversion programs for feed grains, cotton, and wheat are considered short-term programs and the Conservation Reserve and the Cropland Adjustment Programs are considered long-term programs.

year are designated by a subscript t and lagged variables are subscripted t−1. The two variables long-term contracts at the beginning of the year and payment rate for long-term contracts during the enrollment period are both included because the former term identifies acreage already under contract and the latter term identifies the amount of acreage to enter the program in year t. These two variables are not significantly correlated.

Pasture acreage is directly related to land in farms but inversely related to crop and forest acreages. As total land in farms has decreased total pasture acreage has also decreased. The competition among land uses is expected to be reflected in a negative relationship of pasture to crop and forest acreage. Both beef numbers and prices are cyclical and can be explained as a combination of endogenous and exogenous influences (McCoy, p. 54-60). A primary influence on beef numbers and consequently pasture acreage is the lag in production in response to price changes.[3] Pasture acreage also varies with the relative position of farm and nonfarm income. As farm income declines in relation to nonfarm income, pasture acreage is expected to decrease and vice versa. Therefore, pasture acreage is hypothesized to be related directly to the ratio of the previous year's average farm income to per capita personal income in the state's economy.

(2) $A_{Pt} = f(A_{Ct}, A_{Ft}; LF_{t-1}, PB_{t-1}, FIPI_{t-1})$

where

PB = price of beef
FIPI = per capita farm income divided by per capita personal income
LF = land in farms.

As forests also compete for the available agricultural land, timber acreage is expected to be inversely related to endogenous crop and pasture acreages. Increases in crop and pasture acreages would cause forest acreage to decline and vice versa if other influences were held constant. Also, forest acreage is expected to be directly related to land in farms. As total agricultural land increases or decreases, forest land, the largest component of farmland in Georgia, varies similarly. Because of the slow growth of timber stands and the possibility of harvesting at almost all stages of growth, the sale of timber can be postponed for many years. Therefore, timber harvesting is expected to be greatest when stumpage prices are high. As with pasture acreage, forest acreage is expected to vary directly with the ratio of farm to nonfarm income. These relationships are expressed as

(3) $A_{Ft} = f(A_{Ct}, A_{Pt}; LF_{t-1}, PF_{t-1}, FIPI_{t-1})$

where

PF = price of saw timber.

DATA

Acreage of land in farms for the State of Georgia has declined steadily since 1935 except for a brief surge in acreage after the end of World War II. The acreage dropped from 67 percent of total land area in 1935 to a low of 38 percent by 1974 (U.S. Department of Commerce, Bureau of the Census). This change represents an actual reduction in farmland of more than 11 million acres. During the same period both cropland and forest land decreased by 50 percent whereas pasture land doubled.

Although these data show the general trend of agricultural acreages during the past 40 years, the actual time period we analyze is from 1945 to 1975. This period was chosen to exclude the war years because of the special impact on agricultural production during that time. Also, a full complement of independent variables was not obtainable for earlier periods. Producers could enter the Soil Bank program for only 1956-1958, but some contracts ran through 1972. Principal data sources include *Georgia Agricultural Facts, Georgia ASCS Annual Report, Census of Agriculture,* and *State Farm Income Statistics.* Data on acreages and prices were principally from *Georgia Agricultural Facts* and information on the government programs was from the *Georgia ASCS Annual Reports.* As a proxy for net income from crop production, the estimate of net income from *Georgia Agricultural Facts* was apportioned to crops and other products on the basis of value of production. This estimate of net income from crop production was then converted to a per-acre basis by dividing by crop acreage. All prices and values were deflated by the Consumer Price Index to adjust for inflation.

REGRESSION RESULTS

Direct Effects

Because crop, pasture, and forest acreages are interdependent, coefficients of equations 1-3 must be estimated simultaneously. The regression results from three-stage least squares

[3]Though net farm income per acre from crop production was used in the crop acreage equation, prices were used in pasture and forest acreage. Net income for these enterprises would have been preferable, but it was not available. Also, the level of technological change was not as great in beef and forestry production as in crop production. Thus prices were used as proxies for net income from beef and forestry.

TABLE 1. REGRESSION RESULTS EXPLAINING LAND USE CHANGES IN GEORGIA[a]

Variables	Regression Equations Crop Acreage	Pasture Acreage	Forest Acreage
Intercept	3297.990 (3.403)	441.840 (1.023)	-696.311 (-0.947)
Crop Acreage		-0.391 (-6.331)	-0.633 (-11.902)
Pasture Acreage	-1.026 (-3.849)		-1.112 (-4.430)
Forest Acreage	-0.058 (-1.727)	-0.619 (-7.218)	
Lagged Crop Acreage	0.698 (9.696)		
Lagged Land in Farms		0.434 (6.024)	0.734 (30.589)
Lagged Net Income	16.892 (3.185)		
Lagged Beef Price		-7.203 (-2.106)	
Lagged Forest Price			-5.232 (-1.121)
Long-Term Contracts	-0.536 (-4.072)		
Short-Term Government Programs	-1.894 (-0.992)		
Long-Term Government Programs	-1.008 (-1.565)		
Lagged Farm Income to Personal Income (%)		4.793 (4.609)	7.224 (5.018)

[a]Student t-values are given in parentheses.

analysis are reported in Table 1. Coefficients for all of the endogenous acreage variables are significant at the 0.10 level and most are significant at the 0.001 level. The results show that a one-acre increase in crops is associated with a reduction in pasture acreage by 0.391 acre and a reduction in forst acreage by 0.633 acre (Table 1). Hence, each change in crop acreage is taken directly from pasture and forest acreage with no impact on idle acreage. This result supports the hypothesis developed in the conceptual framework that only less intensive uses such as pasture and forest production would expand the extensive margin by bringing idle land into production.

Another interesting result is the effect of government programs on crop acreage. A comparison of the government program coefficients shows that a one dollar increase in government payments per acre under short-term programs is associated with a decrease in crop acreage by 1.894 acres, and a one dollar increase in government payments under long-term programs is associated with a decrease in crop acreage by 1.008 acres. Note that the 1.008-acre decrease effected by long-term programs is for one year during the 10-year life of the program. However, this figure does not mean that the total acreage removed from production during the 10-year period is 10 times 1.008 or 10.08 acres because slippage significantly reduces the acreage actually taken out of production. The concept of slippage is evident from the regression coefficient on long-term contracts. Results show that each acre placed under contract is associated with a reduction in crop acreage by only 0.536 acre.

Direct and Indirect Effects

Although the regression coefficients show direct associations of significant variables on the dependent variable, the effect of exogenous variables on other endogenous variables can be determined only from the reduced form coefficients. From these regression results, multipliers can be calculated to explain the change in an endogenous variable from a unit change in any of the exogenous variables. To obtain these multipliers, the three structural equations must be converted to reduced forms.[4]

TABLE 2. REDUCED FORM COEFFICIENTS EXPLAINING LAND USE CHANGES IN GEORGIA

Exogenous Variables	Endogenous Variables Crop Acreage	Pasture Acreage	Forest Acreage
Lagged Crop Acreage	0.7217	0.0024	-0.4595
Lagged Land in Farms	0.0208	-0.0648	0.7926
Lagged Net Income	17.4738	0.0581	-11.1249
Lagged Beef Price	23.0295	-23.0629	11.0733
Lagged Forest Price	-10.0466	10.3746	-10.4114
Long-Term Contracts	-0.5546	-0.0018	0.3531
Short-Term Government Programs	-1.9588	-0.0065	1.2471
Long-Term Government Programs	-1.0426	-0.0035	0.6638
Lagged Farm Income to Personal Income (%)	-1.4521	1.0214	7.0069

The reduced form multipliers, reported in Table 2, can be interpreted as showing both the direct and indirect change in acreage for a particular land use resulting from a unit change in an exogenous variable. For example, each dollar increase in the previous year's net income per acre of cropland is associated with increases in crop acreage by 17.47 acres (in thousands) and decreases in forest acreage by

[4]If we postulate a set of linear structural equations

$$BY_t + LX_t = U_t$$

with reduced form

$$Y_t = -B^{-1}LX_t + B^{-1}U_t$$

the coefficients of B and L would be described as direct effects and the coefficients of $(B^{-1}L)$ would be described as including both direct and indirect effects.

11.12 acres (in thousands). Similarly, the government's acreage reduction programs tend to decrease crop acreages and increase forest acreage. Each acre under long-term contract is associated with decreases in crop acreage of 0.5546 acres and increases in forest acreage of 0.3531 acres.

SUMMARY AND CONCLUSIONS

Our study examines the effect of government land diversion programs in relieving the excess capacity problem in agriculture and the corresponding costs and effects on competing land uses for such programs. Regression techniques are used to model the land use patterns from 1945 to 1975 in Georgia agriculture. A system of equations is specified and statistically estimated to explain simultaneously changes in crop, pasture, and forest acreages. The results indicate the direct and indirect effects of government programs on major land use patterns.

For application of our method to U.S. agriculture, national land use patterns must be analyzed. Variables considered exogenous in our study may need to be specified as endogenously determined in a national model. Though the agricultural situation in Georgia is somewhat different from the situation in the nation as a whole, the method we use can be straightforwardly applied to the U.S. agricultural situation.

Though long-term land diversion programs were initially used primarily to divert excess capacity, they may be appropriate for other purposes in the future, e.g., control of soil erosion. National legislation such as the Water Pollution Control Act has focused attention recently on erosion. The possibility of future cost-sharing plans for erosion control raises the need for further analysis of historical diversion programs to increase our understanding of their effects on such factors as land use patterns, net farm income, and community development.

REFERENCES

Barlowe, Raleigh. *Land Resource Economics,* 3rd ed. Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1978.

Brandow, G. E. and E. W. Learn. *Effects of 1954 Acreage Restrictions on Crop Production in Southeastern Pennsylvania.* Pennsylvania Agr. Exp. Sta. Prog. Rep. 128, 1954.

Christensen, R. P. and R. O. Aines. *Economic Effects of Acreage Control Programs in the 1950s.* USDA, ERS, Agr. Econ. Rep. 18, 1962.

Dideriksen, Raymond I., Allen R. Hidlebaugh, and Keith O. Schmude. *Potential Cropland Study.* USDA, SCS, Stat. Bull. 578, 1977.

Georgia Crop Reporting Service. *Georgia Agricultural Facts.* USDA, SRS, Georgia Department of Agriculture, Athens, Georgia, 1900-1976.

Hathaway, D. E. "The Effects of Agriculture Production Controls in 1954 on Four Michigan Farming Areas." *Quart. Bull. Michigan Agr. Exp. Sta.* 37(1955):565-73.

McCoy, John H. *Livestock and Meat Marketing.* Westport, Connecticut: AVI Publishing Co., Inc., 1972.

Penn, J. B. and George D. Irwin. "A Simultaneous Equation Approach to Production Response: Delta Region." *S. J. Agr. Econ.* 3(1971):115-21.

U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. *Georgia ASCS Annual Report.* Athens, Georgia, 1956-1975.

______, Economic Research Service. *State Farm Income Statistics.* Suppl. to Stat. Bull. No. 557, Aug. 1976.

______, Soil Conservation Service. *Georgia Conservation Needs Inventory,* April 1970.

U.S. Department of Commerce, Bureau of the Census. *1974 Cenus of Agriculture.* Georgia State and County Data, Vol. 1, Part 10, July 1977.

Zeimetz, Kathryn A., Elizabeth Dillion, Ernest E. Hardy, and Robert C. Otte. *The Dynamics of Land Use in Fast Growth Areas.* USDA, ERS, Agr. Econ. Rep. 325, 1976.