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Shifts in Cropland Use in the North Central Region*

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An empirical model accurately estimates row crop and extensive crop acreage in the North Central region. It shows (a) for each 1-acre increase in diversion, row crops decrease 0.62 acre and extensive crops decrease 0.12 acre, and (b) the annual shift to row crops is diminishing.

Key words: Soybeans, corn, acreage, North Central region, regression analysis, time series.

What's the future for corn and soybeans in the Midwest? Have both crops reached their acreage limit? In 1954 farmers planted 57 million acres to corn and soybeans combined. By 1973 they planted 80 million acres to the two crops, with soybeans accounting for most of the increase. The additional acres came out of hay land and small grains. Can we expect this shift to continue? The answer is vital to predictions of future corn and soybean acreage.

This paper reports an empirical examination of shifts in cropland use in the North Central region.[1] The model can be used to make short-run predictions of row crop acres (corn and soybeans combined)[2] and combined extensive crop acres (wheat, oats, barley, rye, flax, and tame hay). The remaining sections of the paper contain a description and evaluation of the model.

Conceptual Model

The conceptual model attempts to account for the impact of two major factors on planted acreage: (1) the change in crop rotations over time, and (2) cropland diversion. The purpose of the model is to make short-run predictions of planted acreage of row crops and extensive crops in the North Central region, given various levels of annually diverted acreage.

Changes in crop rotations

During the 1960's substantial acreage in the North Central States shifted out of the extensive crops into corn and soybeans. The higher profit incentive from corn and soybeans plus changes in technology encouraged farmers to change traditional farming practices to increase their income. Hieronymus noted this shift toward corn and soybeans in 1969 but he speculated that the shift was about over (*4*). He thought that hay, oat, and wheat acreage remaining in the late 1960's was primarily on the poorer quality land—land not suited for continuous row crops. Finke and Swanson also noted the increase in soybean and corn acreages over time and characterized the trend as being primarily due to the "decline in the practice of rotations containing standover legumes" and the increasing profitability of corn and soybeans relative to oats, wheat, hay, and other crops (*2*).

New technology was available and being used by some farmers in 1961—the beginning of the period of analysis. Agronomic practices being used by innovators allowed continuous row crops on good land and increased row crops on the poorer land. The economic incentive to shift to row crops existed throughout the period. The net returns per acre of corn and soybeans greatly exceeded net returns on the extensive crops. Given the technology and the economic incentive, farmers shifted land use to row crops at a rapid rate during the early 1960's, but in recent years approached the limit of land suitable for row crops with present technology.

To model this process, a Spillman-type functional relationship was hypothesized to describe farmers' shift of land to row crops over time. The Spillman function had the desirable characteristics of (a) having an upper (or lower) limit, and (b) approaching that limit asymptotically, that is, row crops increase rapidly at first and increase more slowly as some upper limit (land suitable for row crops) is

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[1] Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

[2] Since row crops such as grain sorghum, popcorn, sugarbeets, potatoes, and vegetables account for less than 4 percent of all row crops, they were not included in the analysis.

approached. Conversely, cropland inextensive crops decreases rapidly at first but then more slowly as a lower limit is approached. For a more complete explanation of the Spillman function see Heady and Dillon (*3*).

Diversion

A second factor that is hypothesized to have an impact on the acreage of row crops and extensive crops is the acreage diverted from crop production by the wheat and feed grain programs. From 1961 (first year of the feed grain program) to 1972, farmers in the North Central region diverted between 4 and 18 million acres annually under the two programs. Most of the diversion was due to the feed grain program. Wheat diversion never exceeded 2 million acres.[3]

The Agricultural Act of 1970 (effective during 1971-73) changed the rules for diverting cropland. No longer did a farmer with a corn base have to restrict his corn acreage to the base acreage less the diverted acreage to comply. Thus, it was hypothesized that in 1971 there would be an upward shift in the trend of row crop acreage because farmers could plant corn in excess of previous plantings and still comply with the feed grain program. The increased corn acreage would not all come at the expense of soybean acreage and the acreage in extensive crops was hypothesized to be below trend for 1971 and 1972.

Economic variables

Preliminary testing indicated that over the period of analysis, economic variables were of little value in explaining shifts in cropland use. This is not very surprising since cost, price, and profit relationships among competing crops were fairly stable during 1961-72. For example, net returns per acre of corn and soybeans greatly exceeded net returns of extensive crops in most of the North Central Region throughout the period of analysis. Relative to this profit gap, year-to-year changes in relative profits were small. Thus economic variables were not included in the final model. Data from 1973 and later years, however, should provide considerable fluctuation in the economic variables and should be added to the analysis when available.

The Empirical Model

Utilizing the above conceptual model, a statistical model was specified as shown below.

$$(1)\quad Y_R = a_0 + \beta_1 [a_1 + \beta_2(\beta_3)^T] + \beta_4\,(DVRN) + \beta_5\,(CFP) + \epsilon$$

$$(2)\quad Y_E = a_0 + \beta_1 [a_1 + \beta_2(\beta_3)^T] + \beta_4\,(DVRN) + \beta_5\,(CFP) + \epsilon$$

where

Y_R = planted acres (in thousands) of row crops,

Y_E = planted acres (in thousands) of extensive crops including wheat, oats, barley, rye and flax, and harvested hay.

T = time expressed as 1961=1, 1962=2, . . ., 1972=12,

$DVRN$ = wheat, feed grain, and cotton diverted acres (in thousands),

CFP = a zero-one variable representing change of farm programs in 1971 eliminating planting restrictions on individual crops (1961-70 = 0, 1971-72 = 1),

$a_0,\ a_1,\ \beta_1,\ \beta_2, \ldots \beta_5$ = coefficients to be estimated,

ϵ = random disturbance terms.

The term $a_1 + \beta_2(\beta_3)^T$ represents the Spillman-type asymptotic shift of land into (out of) row crops (extensive crops). In equation (1), a_1 represents the upper limit of cropland suited for row crops. Over time this limit will be approached asymptotically. The coefficient β_3 should lie between 0 and 1 and β_2 should be negative. In equation (2), a_1 represents a lower limit of acreage suitable for extensive crops. Over time this lower limit will also be approached asymptotically. The coefficient β_3 in this equation should also lie between 0 and 1

[3] The cotton program required diversion in 5 of the years in the sample period, but the diversion never exceeded 100,000 acres in the North Central States—virtually all in southeast Missouri.

and the coefficient β_2 should be positive.

The coefficient (β_4) on the diversion variable (*DVRN*) should be between -1 and 0 in both equations, indicating that an increase in diversion of 1 acre will reduce crop acreage by some fraction of an acre. The coefficient on the zero-one variable (*CFP*) should be positive in equation (1) and negative in equation (2) to indicate a one-time acreage shift out of extensive crops (into row crops) for 1971 and beyond.

Equations (1) and (2) can be viewed as two estimates of the same phenomenon—the shift of land from extensive crops to row crops. The decrease in extensive crops (Y_E) is expected to approximate the increase in row crops (Y_R) over time except for the land diverted out of crops by Government programs. Less than 2 percent of the cropland harvested in the North Central States is in crops other than the eight included in this study, so changes in other crops' acreage would have little influence on the major crops.

A simultaneous system of equations has intuitive appeal in this case because of the competition among crops for a limited quantity of cropland. The complexity of the estimation procedures, however, eliminated this possibility and forced us to use the simpler single-equation techniques.

Since equations (1) and (2) are nonlinear in the parameters, the impact of the three exogenous variables (*T, DVRN*, and *CFP*) could not be estimated using traditional linear estimating techniques. Nonlinear techniques were tried but the algorithms were unsatisfactory for our needs. Consequently, a two-step estimating procedure was utilized. For both type crops, the dependent variables (Y_R, Y_E) were first regressed on time using the following equations:

$$(3)\quad Y_R = a_1 + \beta_2(\beta_3)^T + \epsilon$$

$$(4)\quad Y_E = a_1 + \beta_2(\beta_3)^T + \epsilon$$

The actual dependent variables (Y_R and Y_E) were then regressed on the predicted values ($\hat{Y}_R$ and $\hat{Y}_E$) obtained from equations (3) and (4), diversion, and the zero-one variable as follows:

$$(5)\quad Y_R = a_0 + \beta_1 \hat{Y}_R + \beta_4 (DVRN) + \beta_5 (CFP) + \epsilon$$

$$(6)\quad Y_E = a_0 + \beta_1 \hat{Y}_E + \beta_4 (DVRN) + \beta_5 (CFP) + \epsilon$$

Consequently, values of β_1 in equations (5) and (6) are not expected to differ significantly from 1.0.[4]

An asymptotic regression algorithm was used to estimate the parameters for equations (3) and (4).[5] The estimated equations are:

$$(7)\quad Y_R = 75{,}404 - 21{,}197(0.8748)^T \qquad R^2 = 0.86$$

$$(8)\quad Y_E = 22{,}996 + 27{,}601(0.9276)^T \qquad R^2 = 0.98$$

In equation (7), the estimate of β_2 has the expected sign. The estimate of β_3 is less than 1.0, indicating that row crop acreage (Y_R) will increase at a decreasing rate over time and approach a maximum. The estimate of β_2 in equation (8) has the expected sign and the coefficient of β_3 indicates that acreage will decrease at a decreasing rate toward a minimum.

The predicted values obtained from equations (7) and (8) were used as independent variables (along with *DVRN* and *CFP*) and estimated by ordinary least squares to obtain an ordinary least squares estimate of the parameters for equations (5) and (6). The resulting equations are:

$$(9)\quad Y_R = 2141 + \underset{(0.086)}{1.094}(\hat{Y}_R) - \underset{(0.101)}{0.621}(DVRN) + \underset{(855.5)}{718.74}(CFP) \qquad R^2 = 0.97$$

$$(10)\quad Y_E = 2432 + \underset{(0.061)}{0.980}(\hat{Y}_E) - \underset{(0.082)}{0.120}(DVRN) + \underset{(691)}{137}(CFP) \qquad R^2 = 0.98$$

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[4] From the method of estimation used for equation (3), $\hat{Y}_R$, the predicted values from equation (3), are unbiased estimates of Y_R. If $\hat{Y}_R$ is not correlated over time with *DVRN* or *CFP*, then in equation (5), β_1 will equal 1.0. The higher the correlation between $\hat{Y}_R$ and the other independent variables, the more β_1 will deviate from 1.0.

[5] See (*1*, p. 297).

Numbers in parentheses are the standard errors of the estimated coefficients. Because of the insignificant size of the coefficient for (*CFP*) in relation to its standard error in equation (10), that variable was omitted and the equation reestimated to give:

$$(11)\quad Y_E = 2815 + \underset{(0.046)}{0.972}\,(\hat{Y}_E) - \underset{(0.075)}{0.124}\,(DVRN) \qquad R^2 = 0.98$$

Substituting (7) into (9) and (8) into (11) for the $\hat{Y}_R$ and $\hat{Y}_E$ terms, respectively, and simplifying, yields:[6]

$$(12)\quad Y_R = 84{,}184 - 22{,}746\,(0.8748)^T - 0.621\,(DVRN) + 1260\,(CFP)$$

$$(13)\quad Y_E = 25{,}167 + 26{,}828\,(0.9276)^T - 0.124\,(DVRN)$$

Equations (12) and (13) are the equations used for predictive purposes.

Implications

Several implications may be drawn from equations (12) and (13). First, the R^2 values and predicted versus actual values shown in figure 1 indicate that the equations accurately fit the sample data. The largest deviation in the estimate of row crop acreage was 2 percent (1.2 million acres) in 1965 and in only 2 years, 1963 and 1965, was the deviation in excess of 1 million acres. For extensive crops the largest deviation was 3 percent (1 million acres) in 1968.

Second, the addition of the diverted acres and zero-one variables accounted for most of the deviation of the annual row crop acreages from the asymptotic trend line, and raised the R^2 from 0.86 in equation (7) to 0.97 in equation (9). The addition of the diverted acres variable to the extensive crops equation had little impact. Equation (9) indicates that after

[6] This two-step estimating procedure would give misleading estimates of the coefficients for the time variable and the set-aside variable if set-aside were correlated with time. The simple correlation coefficient between time and set-aside was 0.38; low enough to indicate that this was not a problem.

ACTUAL AND ESTIMATED INTENSIVE AND EXTENSIVE CROP ACREAGES, NORTH CENTRAL REGION

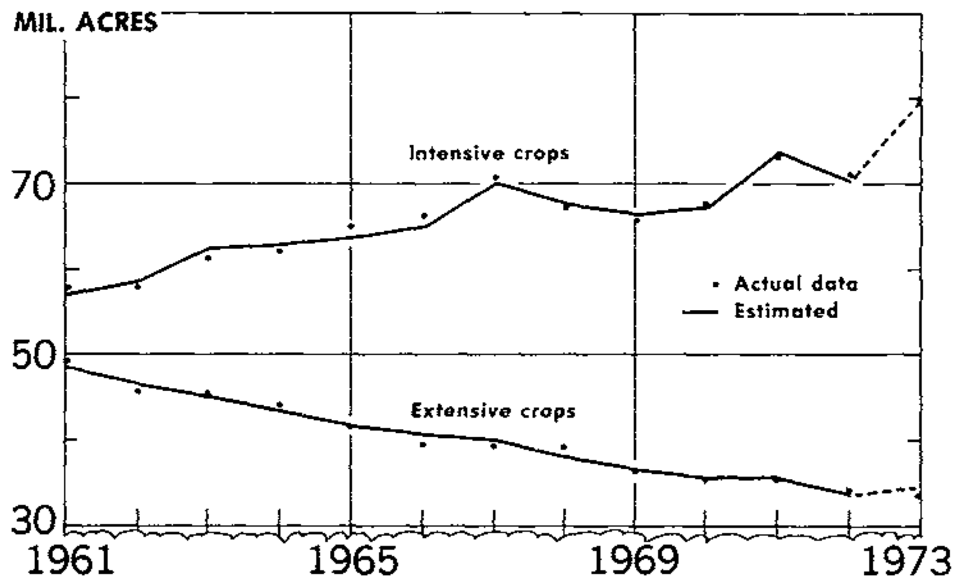

Figure 1

accounting for trend, there was a decrease of 0.621 acre of row crops for each acre increase in diversion. During the 1960's most of the impact of an increase in diversion was on the corn portion of the row crops, but with the set-aside programs of 1971 and 1972, the diversion acreage could be taken from any crop.

In 1973 the Agricultural Stabilization and Conservation Service made a survey of 982 farms across the country. One question asked was, "How do you plan to use the 1973 set-aside land in 1974?" All 1973 set-aside acreage is available for use in 1974. In the North Central region the survey showed that farmers planned to plant 67 percent of the 1973 set-aside land to corn or soybeans in 1974—57 percent to corn and 10 percent to soybeans. This survey estimate is equivalent in definition to the coefficient on the diversion variable in the row crop equation and lends credence to the estimated value (0.621) of that coefficient.

Third, equations (12) and (13) can be used to estimate the trend in cropland shifted from extensive crops to row crops. This is done by holding (*DVRN*) and (*CFP*) constant and evaluating with sequential values from time (*T*). The shift between selected years is shown in table 1. The estimated equations show that during the early 1960's the shift to row crops was large and decreased over time. The opposite occurs for extensive crops. However, the two time trends are not mirror images of each other, that is, the incfease in row crops has not been equal to the decrease in extensive crops.

Table 1. Estimated trend change in row crops and extensive crops, selected years, North Central region

Period of change	Row crops[a]	Extensive crops[a]
	1,000 acres	*1,000 acres*
1961 to 1962	2,492	−1,803
1971 to 1972	652	−850
1972 to 1973	574	−789
1981 to 1982	172	−401

[a]The tabular numbers were obtained assigning values of $DVRN = 0$ in equations (12) and (13) and $CFP = 1$ in equation (13).

Estimates of the upper limit on intensive acreage and the lower limit on extensive acreage may be obtained by setting time (*T*) to infinity. This results in an upper bound on corn and soybean acreage of 85.4 million acres (5.4 million acres above the 1973 acreage) and a lower bound on extensive crop acreage of 25.2 million acres (8.7 million acres below 1973). These estimates indicate that a relatively small shift in cropland can be expected in future years.

These upper and lower bound estimates are critical to the usefulness of equations (12) and (13) for making longer run predictions. An analysis of the Conservation Needs Inventory data by Martin and Van Arsdall indicates that about 100 million acres would be a reasonable upper bound on corn and soybean acres, assuming present technology and accepted conservation practices (*5*). Compared with this estimate, the 85.4-million-acre estimate is low and suggests that predictions from equation (12) may be low. The converse would be true for equation (13).

Equations (12) and (13) are useful for estimating expected response to various levels of feed grain and wheat set-aside acreage in 1973. The change in row crop acreage can be divided into two parts: (1) that which is not responsive to annual changes in the programs (the trend component), and (2) that which is responsive to the programs (the diversion component). For 1973 the trend component adds 574,000 acres to row crops over 1972 and each acre reduction of set-aside below 1972 acreage adds 0.621 acr.

Predictions for 1973 are ...de using the two equations (see figure 1). Diverted acreage under the wheat, cotton and feed grain programs was 3.8 million acres. Equation (12) underestimated row crops by 1,080,000 acres or 1.3 percent. Equation (13) overestimated extensive crops by 596,000 acres or 1.7 percent. These small deviations are probably due to farmers' response to commodity price levels for 1973, which were substantially above those of previous years. The accuracy of these estimates is especially significant because of the major change in 1973 farm programs. Eighty percent (13 million acres) of the 1972 set-aside in the North Central States was released in 1973 and the model accurately predicted the row crop response.

The estimation of individual crop acreages is more difficult. It requires detailed knowledge of the wheat and feed grain programs and their cross-effects on other crops. Other factors

Table 2. Data used in acreage analysis, North Central States, 1961-73

Year	Time (T)	Zero-one variable (CFP)[a]	All diversion ($DVRN$)[b]	Row crops (Y_R)[c]	Extensive crops (Y_E)[d]	Estimates of (Y_R)[e]	Estimates of (Y_E)[f]
			1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
1961	1	0	11,742	57,623	49,074	56,994	48,596
1962	2	0	13,803	58,011	45,602	58,205	46,539
1963	3	0	10,830	61,218	45,369	62,230	45,236
1964	4	0	13,200	62,229	44,236	62,665	43,392
1965	5	0	14,454	65,005	41,840	63,554	41,799
1966	6	0	14,461	66,178	39,686	65,009	40,464
1967	7	0	8,487	70,798	39,610	69,995	39,967
1968	8	0	14,260	67,247	39,156	67,527	38,104
1969	9	0	17,615	65,904	36,412	66,420	36,623
1970	10	0	16,860	67,942	35,425	67,743	35,729
1971	11	1	10,347	73,310	35,447	73,795	35,620
1972	12	1	17,207	71,307	34,328	70,189	33,920
1973[g]	13	1	3,865	80,126	34,190	79,046	34,786

[a]Farm programs changed to remove restraints on planted acres of individual crops.
[b]Feed grain, wheat and cotton diversion.
[c]Corn and soybean acreas planted.
[d]Planted acres of oats, wheat, barley, rye and flax, and harvested acres of tame hay.
[e]Estimated values for corn and soybean acreas planted.
[f]Estimated values for planted acres of oats, wheat, barley, rye and flax, and harvested acres of tame hay.
[g]Not used for estimating.

affecting the acreage response of individual crops must also be identified and assessed. But the problem of individual crop estimation is aided by having a reliable estimate of the acreage in row crops and extensive crops.

Conclusions

Four main conclusions are derived from this analysis:

(a) Since 1961, considerable acreage has shifted from extensive crops, such as wheat, oats, and barley, to corn and soybeans in the North Central States. Even though the annual shift is estimated to be much smaller now than during the early 1960's, it should be considered when predictions of future crop production are made.

(b) For each acre increase in diversion or set-aside, row crop acreage decreases about 0.62 acre and extensive crops decrease about 0.12 acre. The remaining 0.26 acre comes from other land uses.

(c) The model demonstrates the ability to predict accurately cropland planted to two crop categories—row crops and extensive crops. Prediction of planted acreage of individual crops can be made more accurately once a reliable prediction of these two groups of crops is obtained.

(d) In the future, economic variables could play a more direct and important role in explaining crop acres while the impact of the shift of cropland should be diminished. However, this paper indicates that future models of crop production in the North Central Region should incorporate a measure of cropland shifting to the row crops during the 1960's.

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