Economics of Wheat-Fallow Cropping Systems in Western North Dakota

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Income and risk aspects of wheat-fallow cropping systems are analyzed in western North Dakota. A wheat yield trend estimation model based on county yields (1950-77) is developed using independent variables of year, annual precipitation, acres of nonfallowed wheat, and a dummy variable for fallow and nonfallow practices. The year-to-year change in wheat yields on fallowed and nonfallowed land indicates that summer fallow is becoming less desirable economically. Based on 1980 costs and yields, summer fallow maximizes returns to land at low yields, low wheat prices, and high nitrogen prices. Income variability is reduced under summer fallow.

Agriculture in the western states is heavily reliant upon summer fallow [Haas, *et al,*]. In 1980 North Dakota had 6.4 million acres or about 22 percent of total cropland devoted to summer fallow [Carver and Hamlin]. Durum and other spring wheat are the major crops produced on summer-fallowed land. Eighty percent of the North Dakota land summer-fallowed in 1979 was planted to all wheat in 1980 [Carver and Hamlin].

The primary benefit of summer fallow is higher crop yield resulting from increased soil moisture, nitrogen accumulation, and weed control. Additional benefits are increased stability of production and improved seasonal distribution of work. The cost for the farmer is the income foregone by not cropping the land for a season plus tillage costs during the fallow year.

The practice of summer fallow leaves the soil without a crop cover which greatly increases soil losses through wind and water erosion and contributes to air and water pollution [Ehni, *et al.*; Haas, *et al.*; Fanning and Reff]. Also summer fallow is a contributing factor to the development of saline seeps which are making significant amounts of land less productive [Worcester, *et al.*]. Erosion of topsoil and saline seeps are long-run resource conservation problems beyond the planning horizon of most farmers. Air and water pollution are costs borne by society which are external to the farm. The economic benefits from summer fallow, on the other hand, are all short run and occur directly to farmers. Since the decision to use summer fallow is made by individual farmers, the amount of it used is greater than optimal from society's point of view.

The purpose of this paper is to analyze the factors affecting the economics of summer fallow from the perspective of the farmer. The results of the analysis are indicative of the likely use of summer fallow in the future and can aid in the formulation of policies and programs with potential to reduce the use of summer fallow.

Previous investigations of the economics of summer fallow are limited. Knight, *et al.*, using Experiment Station data from western Kansas, found wheat yields, wheat prices, and production costs influence the amount of fallow in a rotation to maximize return to land. MacKenzie examined the effects of soil productivity and fertilization practices as well as wheat prices on net returns per cultivated acre from rotations with various frequencies of fallow in Canada. Bauer compared net returns per acre from a fallow-wheat rotation with a continuous cropping

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rotation using 1967 prices and yields from farmers' field trials by area of North Dakota. He found a wheat-fallow rotation gave higher average net returns in western North Dakota where precipitation and yields are low and a continuous cropping system gave higher net returns in eastern North Dakota where precipitation and yields are higher. Burt and Stauber used data from Montana to show that a flexible strategy to crop or fallow based upon available soil moisture at planting time would give higher average returns to land than either crop-fallow or continuous cropping rotations.

This study differs from previous studies in that a projection of the relative profitability of wheat-fallow cropping systems is made based upon a statistical model of wheat yield trends on fallowed and nonfallowed land. Also the effects of changes in nitrogen prices on the economics of summer fallow are analyzed. The nitrogen analysis is topical since nitrogen prices are likely to rise faster than other prices because of deregulation of natural gas. Natural gas is a major nitrogen cost component.

The analysis is presented for wheat production in the western one-third of North Dakota. The area covers all the counties west of the Missouri River plus the four counties in the northwest corner of the state. This is an area where over one-third of the cropland is currently in summer fallow [Ali and Johnson]. In western North Dakota, wheat is planted on over 90 percent of the land fallowed the previous year. Three cropping systems are compared: fallow system (summer fallow-wheat), recropping (summer fallow-wheat-wheat), and continuous cropping. Although other small grains and, in recent years, sunflowers are also produced in addition to wheat, the analysis is made using wheat. Typical returns from competing crops are similar to wheat and, therefore, their inclusion would not have a great effect upon the economics of summer fallow.

Major factors influencing farmers' decisions on the amount of summer fallow to use in their rotation are: (1) yield of wheat produced on fallowed land compared to nonfallowed land, (2) price of wheat, (3) price of nitrogen fertilizer, and (4) differences in income variability between fallow and more intensive cropping systems.

Relative Yields

Technological developments have affected wheat yields on fallowed and nonfallowed land to a different degree. For example, the use of nitrogen fertilizer and chemical weed control has tended to increase nonfallow yields. On the other hand, the development of varieties with high-yield potential has increased yield more on fallowed land because moisture is not as limiting.

The North Dakota Crop and Livestock Reporting Service has reported county wheat yields separately for fallowed and previously cropped land since 1949. Previously cropped land planted to wheat is usually in a recropping system in western North Dakota. A multiple regression wheat yield estimation model for the area was developed using combined cross-sectional data (18 counties) and time series data (1950-1977 inclusive) for a total of 504 observations for each cropping practice. An equal weight was given to data for each county. Wheat yield per harvested acre was used as the dependent variable. Yield per harvested acre was used rather than yield per planted acre in an effort to reduce the unexplained variability in yield. Unharvested acreage is influenced by variables not included in the model, such as losses from hail, insects, disease, and flooding.

The independent variables of direct concern for the study were time, cropping practice (fallowed or cropped land), and interaction between time and cropping practice. Time was used as a proxy for technology to represent changes in yield affecting factors, such as improvement in varieties, chemical weed control, and increased use of fertilizer. Two additional variables were included to improve the estimate of the effect of time on yields for the two cropping practices. These variables were annual precipitation[1] and acres of wheat planted on nonfallowed land. Nonfallow wheat acreage was included because it was hypothesized that as acreage planted on nonfallowed land increases, the quality of the land used for wheat production declines. Precipitation data were developed for each county based upon National Weather Service data for weather stations in or near each county. A dummy variable (0-1) was used for nonfallow and fallow cropping practices.[2] Slope changes between cropping practices and year were estimated by using an interaction term in the regression model.

Several logical functional relationships and interaction terms were considered to find the best estimation model. Nonlinear functions were tested by using log and squared term transformations on the independent variables.

Selection of functional form of independent variables was based on their theoretical relationship with wheat yields, highest coefficient of multiple determination (R^2), and the lowest standard error of regression. The Hartley test (H) and the Durbin-Watson test (D-W) were used to test for heteroskedasticity and serial correlation. The Hartley test indicated heteroskedasticity was not present when counties were grouped. The Durbin-Watson test indicated a positive serial correlation which was corrected using an autoregressive process [Anthony, *et al.*]. A one-year lag between the residuals was used since it gave the best statistical reliability. The statistical results and the regression coefficients for the selected yield model are presented as follows (standard errors are in parentheses; all coefficients are significant at the 1 percent level):

$$Y = \underset{(1.7737)}{-5.8942} + \underset{(.0346)}{.3032t} + \underset{(.2339)}{3.1408D} + \underset{(.0141)}{.1526tD} + \underset{(1.4546)}{18.1242 \log P} - \underset{(.3031)}{2.2991 \log X}$$

$$R^2 = .7318$$

where:

Y = wheat yield per harvested acre (in bushels)

t = year — 1950 = 1

D = dummy variable — D = 1 if fallow, D = 0 if nonfallow

tD = interaction between year and cropping practice

P = annual precipitation in inches — September through August

X = county average acres of wheat planted on nonfallowed land (in hundreds)

The mean values of annual precipitation (15.65 inches) and 1979 county average acres of wheat planted on nonfallowed land (253 hundreds) were substituted into the yield model and wheat yields were estimated for the years 1950 through 1990 for fallow and nonfallow cropping practices. Yields per harvested acre were converted to yields per planted acre by multiplying yields by the 28-year average percent of acres harvested (1950-1977) as reported by the North Dakota Crop and Livestock Reporting Service — .95 for fallowed land and .92 for nonfallowed land. The relationship between yields per planted acre on fallow and nonfallow through time is presented in Figure 1 (wheat yield trend). The result indicates that each year wheat yields are increasing by .28 bushel on

[1]Models using separate growing season precipitation (April to August), preseason precipitation (September to March) for fallow and nonfallow yields, and a 19-month precipitation period (12 months of fallow year plus seven months during cropping year) for fallow yields gave lower statistical reliability than those using annual precipitation.

[2]An alternative would be to use separate equations for estimating yield on fallowed and nonfallowed land. If the variance in the error term is assumed to be the same for yield on fallow and nonfallow, the estimates of the regression coefficients would be essentially equivalent. The difference between the approaches would be a lower variance of the regression using pooled data because the estimate of the standard error of regression is based on the information contained in both the fallow and nonfallow data sets.

nonfallowed land [(.92)(.3032)] and .43 bushel on fallowed land [(.95)(.3032 + .1526)].

Production costs for 1980 were developed to compare returns between wheat produced on fallowed land with wheat on previously cropped land. Production practices and machinery use on fallowed and nonfallowed land were obtained from a survey of small grain producers [Schaffner, *et al.*]. The two cropping practices were compared on the basis of return to land. This assumes land to be the most limiting resource and implies a cropping practice decision criterion based on maximizing returns to land.[3] The wheat yields that give equivalent annual returns to land under a fallow system and continuous cropping were calculated. The formulas used are as follows:

$$(1.1) \qquad \pi_f = \frac{Y_F P - C_f - V_f (Y_F - Y_f)}{2}$$

$$(1.2) \qquad \pi_c = Y_C P - C_c - V_c (Y_C - Y_c)$$

where:

- π_f = return to land per acre on fallow system — one-half acre fallow and one-half acre wheat
- π_c = return to land per acre on nonfallow system — one acre wheat
- Y_F = yield on fallowed land
- Y_C = yield on nonfallowed land
- P = price of wheat
- V_f = fertilizer, grain harvesting, and handling costs associated with changes in yield on fallowed land ($1.55/bu.)
- V_c = fertilizer, grain harvesting, and handling costs associated with changes in yield on nonfallowed land ($1.54/bu.)
- Y_f = wheat yield on fallowed land for which costs were developed (26.14 bu./acre)
- Y_c = wheat yield on nonfallowed land for which costs were developed (17.91 bu./acre)
- C_f = total cost excluding land for 1980 yield on fallowed land including costs for fallowing ($70.91/acre)
- C_c = total cost excluding land for 1980 yield on nonfallowed land ($55.63/acre)

Equations (1.1) and (1.2) are solved for yields:

$$(1.3) \qquad Y_F = \frac{2\pi_f + C_f - V_f Y_f}{P - V_f}$$

$$(1.4) \qquad Y_C = \frac{\pi_c + C_c - V_c Y_c}{P - V_c}$$

Substitution of identical returns to land in equations (1.3) and (1.4) gives the combination of wheat yields on fallowed and nonfallowed land giving equivalent annual returns per acre. The results of the substitution using 1980 costs and the area target wheat price for 1980 and the target wheat price plus $1.00 are presented in Figure 1. Farmers would maximize returns to land by using the fallow system if the point of intersection of their fallow and nonfallow wheat yields lie to the left of the equivalent return line. When wheat yields lie to the right of the equivalent return line, farmers would have a higher return from wheat on nonfallowed land. Note that in 1980, returns are higher under the fallow system assuming a $3.52 price while returns are higher under continuous cropping assuming the $4.52 price. The slope of the equivalent return line indicates that for every bushel increase in nonfallow yields, yields on fallow need to increase by two bushels. Based on the yield trend line, yields on fallowed land are actually increasing only 1.54 bushels (.43 ÷ .28) for every bushel yield increased on nonfallowed land. If this yield trend continues, the fallow system will become less and less economically desirable.

[3]An analysis of returns to a fixed labor supply showed a lower return to labor for the fallow-wheat system.

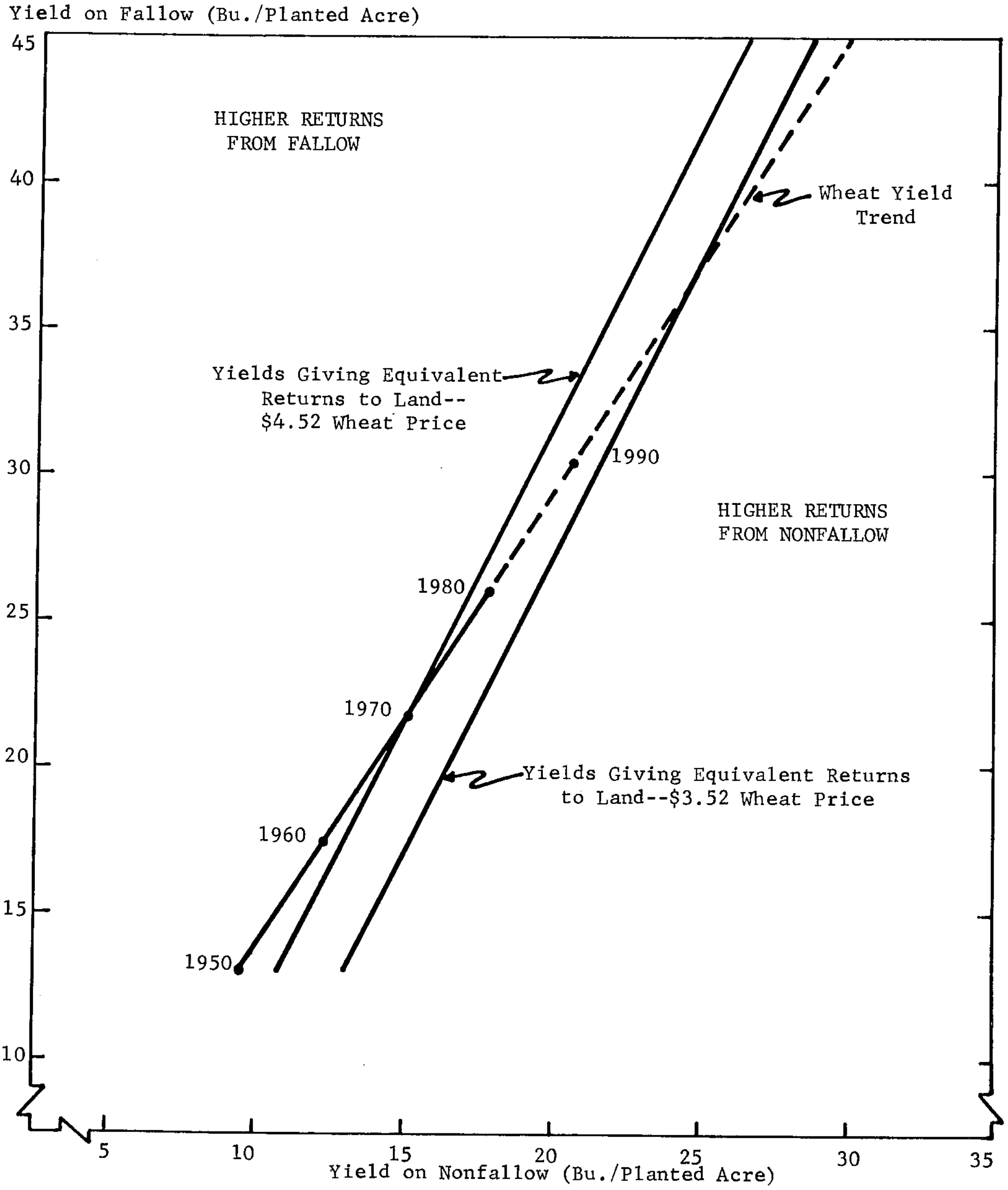

Figure 1. Trend in Wheat Yields Per Planted Acre and Yields Giving Equivalent Returns to Land at Two Wheat Prices and 1980 Costs for Fallow and Nonfallow Practices, Western North Dakota.

Wheat Price

It is evident that the price of wheat has an effect upon the economics of summer fallow (Figure 1). At the target price in 1980, a fallow-wheat system maximized return to land. The effects of wheat prices on the return to land per acre under fallow (π_f), recropping (π_r), and continuous cropping (π_c) systems are studied using the following formulas:

$$\text{(2.1)} \qquad \pi_f = \frac{Y_f P - C_f}{2}$$

$$\text{(2.2)} \qquad \pi_c = Y_c P - C_c$$

$$\text{(2.3)} \qquad \pi_r = \frac{Y_f P - C_f + Y_c P - C_c}{3}$$

Cost and yield variables on fallowed land represent two acres of land (or two crop years on acre of land). Therefore, the numerator in equation (2.1) is divided by two. For the recropping system, the cost and yield variables are divided by three to account for three acres of land (or three crop years on an acre of land).

Equations (2.1), (2.2), and (2.3) are solved for price of wheat:

$$\text{(2.4)} \qquad P = \frac{2\pi_f + C_f}{Y_f}$$

$$\text{(2.5)} \qquad P = \frac{\pi_c + C_c}{Y_c}$$

$$\text{(2.6)} \qquad P = \frac{3\pi_r + (C_f + C_c)}{Y_f + Y_c}$$

Substitution of identical returns to land into equations (2.4), (2.5), and (2.6) gives the price of wheat required for each cropping system to obtain a specified return. The relation between wheat prices and return to land for each system based on the 1980 wheat production costs and yield estimates is illustrated in Figure 2. Due to lack of information from the Crop and Livestock Reporting Service about yields per acre on recropped land versus continuously cropped land, the yield estimate for nonfallow (mostly recropped land) was used for both recropping and continuous cropping systems. In this context, it is important to mention that limited experimental results indicated slightly higher wheat yields under recropping than under continuous cropping systems [Ali and Johnson].

Returns on recropping and continuous cropping systems are more sensitive to wheat prices than for the fallow-wheat system. The steeper slopes of the continuous and recropping systems indicate this greater sensitivity to changes in wheat prices. Higher wheat prices penalize the wheat-fallow cropping system because higher wheat prices increase the opportunity cost of allowing the land to lie idle for a year.

The price of wheat at the point of intersection ($4.17) indicates equal return under the fallow, recropping, and continuous cropping systems. In other words, at this price farmers would, on average, have the same return per acre under all three cropping systems.

Nitrogen Price

A major difference in input use between production on fallowed land and nonfallowed land is in the amount of nitrogen fertilizer applied. During the fallow year, nitrogen accumulates in the soil as crop residues and soil organic matter decompose. Soil nitrogen on fallow land is high, so little or no nitrogen fertilizer is added for the subsequent wheat crop. The amount of nitrogen fertilizer used in the analysis for fallowed and nonfallowed land is based upon a survey of fertilizer use by farmers in the area [Schaffner, *et al.*].[4]

No adjustment has been made in nitrogen fertilizer use with changes in fertilizer prices. The constant fertilizer rate is based on the

[4]Based on soil test results and application rates recommended by the North Dakota State University Soils Department, area farmers are underapplying nitrogen to wheat on nonfallow and overapplying nitrogen to wheat on fallow.

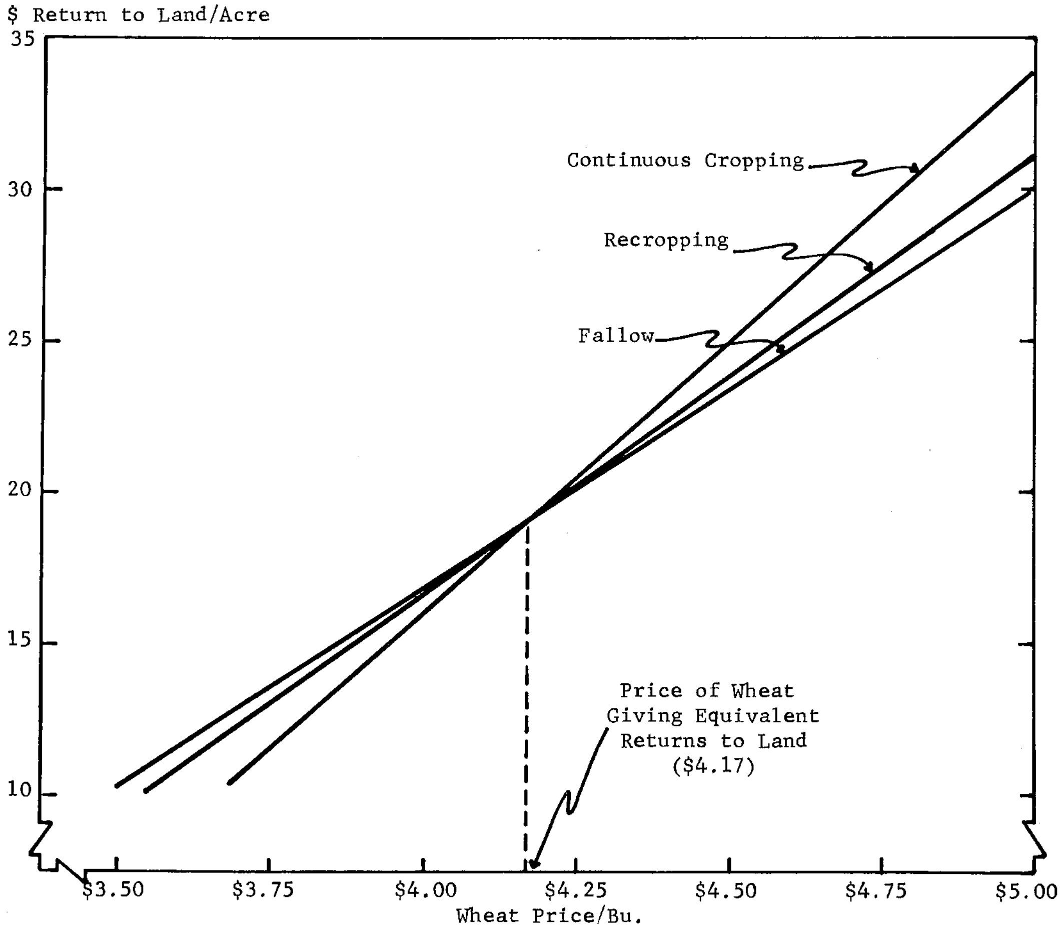

Figure 2. Effect of Wheat Prices on Returns to Land Per Acre Under Three Cropping Practices in Western North Dakota, 1980 Costs and Yields.

insensitivity of the economic optimum rate to fairly large changes in nitrogen prices [Johnson and Ali].

To evaluate the effects of changes in nitrogen prices on the returns under fallow, recropping, and continuous cropping systems, the following equations were developed:

(3.1) $$\pi_f = \frac{Y_fP - C_f^* - N_fP_n}{2}$$

(3.2) $$\pi_c = Y_cP - C_c^* - N_cP_n$$

(3.3) $$\pi_r = \frac{Y_fP - C_f^* - N_fP_n + Y_cP - C_c^* - N_cP_n}{3}$$

where:

C_f^* = total cost excluding land and nitrogen fertilizer on fallowed land ($69.57/acre)

C_c^* = total cost excluding land and nitrogen fertilizer on nonfallowed land ($52.67/acre)

N_f = amount of nitrogen fertilizer applied on fallowed land (5.83 lbs./acre)

N_c = amount of nitrogen fertilizer applied on nonfallowed land (12.89 lbs./acre)

P_n = price of nitrogen fertilizer per pound

Equations (3.1), (3.2), and (3.3) are used to determine returns to land per acre under fallow, recropping, and continuous cropping systems at various prices of nitrogen fertilizer. Results of those computations using a wheat price at $4.52 are illustrated in Figure 3.

Returns on recropping or continuous cropping systems are more sensitive to nitrogen fertilizer price than for the fallow-wheat system. This is due to the larger amount of nitrogen fertilizer applied on nonfallowed land.

The price of nitrogen fertilizer at the point of intersection equates average returns under the fallow, recropping, and continuous cropping systems. The average price paid in the area for nitrogen in 1980 was $.23 per pound. Given that cost of nitrogen and a wheat price of $4.52, the continuous cropping system would give the highest returns to land. However, at a nitrogen price above $.40 per pound, the fallow-wheat system would give higher returns per acre (holding other prices constant). Higher nitrogen prices are related to energy costs and so most other inputs (especially fuel) also increase along with increasing nitrogen prices. However, nitrogen is the major input likely to increase in price relative to other inputs in which the quantity used changes with the amount of summer fallow and its impact on the most profitable cropping practice is an important consideration.

Income Variability

One of the reasons farmers use summer fallow is to reduce yield variability. Variability in yields over time can be measured statistically by the standard deviation and the coefficient of variation. Yields per planted acre from 1950 to 1977 were used to measure wheat yield variability for each county on fallowed and nonfallowed land. The average yield variability for the counties in the study area is presented in Table 1. The data indicate that absolute variability in yields is greater on fallowed land than on nonfallowed land. However, the relative variability is less on fallowed land.

The county data even out part of the random fluctuations on individual farms. A comparison was made between wheat yield variability at five Experiment Station locations in or near the study area and the yield variability from the Statistical Reporting Service data for the counties in which the stations were located for the same time period. The county data gave about 8.5 percent lower variability in wheat yields than the Experiment Station data [Ali and Johnson]. The underestimation in yield variability using county data instead of individual farm data does not appear to be a serious problem.

The difference in yield per acre variability is magnified when looking at income variability for a farm because the acres planted each year are not constant among cropping systems. Assuming a fixed land base, a farmer would be planting twice the acreage under a continuous cropping system as he would under a fallow-wheat system. Therefore, the standard deviation in total production for continuous cropping would be twice that of a wheat-fallow rotation for the same standard deviation in yield per acre.

Income variability based only on yield variability was calculated for the three cropping systems using the following equations:

$$(4.1) \qquad D_c = d_cP - v_cd_c$$

$$(4.2) \qquad D_f = \frac{d_fP - v_fd_f}{2}$$

$$(4.3) \qquad D_r = \frac{(d_f + d_c)P - (v_fd_f + v_cd_c)}{3}$$

where:

D_c = deviation in return to land — continuous cropping system

D_f = deviation in return to land — fallow system

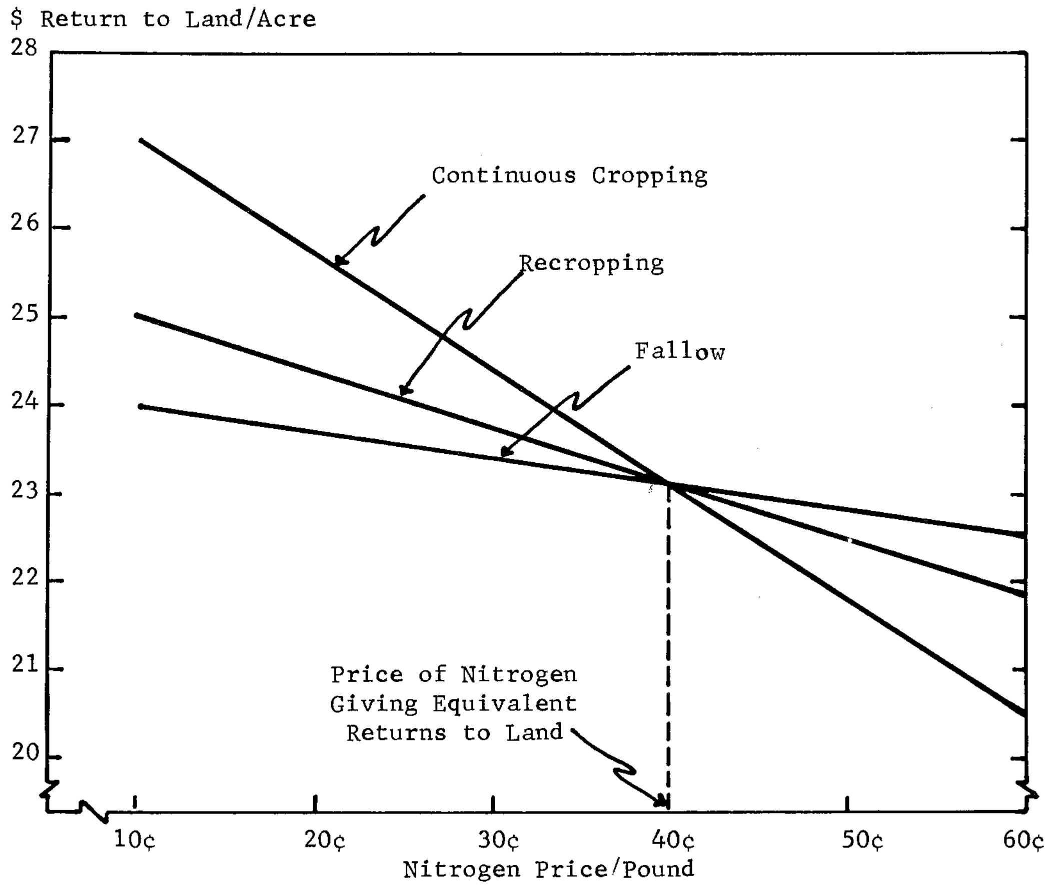

Figure 3. Effect of Nitrogen Prices on Returns to Land Per Acre Under Three Cropping Practices in Western North Dakota, 1980 Costs and Yields, Wheat Price — $4.52 Per Bushel.

TABLE 1. Mean Wheat Yield and Measures of Variability Per Planted Acre Reported by the Statistical Reporting Service (1950-1977) in Western North Dakota.

Production System	Mean Wheat Yield (Bu./Acre)	Standard Deviation (Bu./Acre)	Coefficient of Variation (%)
Fallow	19.23	6.71	34.89
Nonfallow	13.74	5.78	41.30

D_r = deviation in return to land — recropping system

d_c = standard deviation in yield per planted acre on nonfallowed land (5.68 bu./acre)

d_f = standard deviation in yield per planted acre on fallowed land (6.71 bu./acre)

v_c = cost of grain harvesting and handling associated with change in yield on nonfallowed land ($.49/bu.)

v_f = cost of grain harvesting and handling associated with change in yield on fallowed land ($.50/bu.)

P = price of wheat

The return and variability of return for the three cropping systems at 1980 target wheat price and target price plus 20 percent are presented in Table 2. It is evident that the increase in risk is substantial when going from the fallow-wheat system to the more intensive cropping systems. At the higher price level, farmers selecting the fallow system obtain a major reduction in income variability with a slight reduction in average return per acre.

Implications

This study suggests a consideration of the following economic policies if society wishes to reduce the use of summer fallow.

1. Research and education programs for farmers that accelerate the development and introduction of yield-increasing technology.
2. Policies that result in higher wheat prices. Price enhancing policies based on land diversion, however, would not help since western wheat farmers would use diverted acres for more summer fallow. Also higher wheat prices may bring rangeland into wheat production under a wheat-fallow system.
3. Policies to prevent the price of nitrogen fertilizer from increasing.
4. Risk-reducing programs, such as price stabilization and improved crop insurance.
5. Government programs which provide incentives for farmers to switch to nonfallow cropping systems.

There has been limited change in recent years toward less fallow in the study area. Western North Dakota is a high-risk production area so the increased risk involved in more intensive cropping systems is a major factor preventing much change from the fallow-wheat cropping system. Unless wheat or alternative crop prices increase considerably above the current target price levels, only a gradual reduction in summer fallow can be expected. Immediately east of the study area where precipitation and wheat yields are higher, the fallow-wheat system is in transition to a recropping and continuous cropping system. In time the transition should move west. The economic relationships developed in this study can be used both by farmers and by society in making better decisions concerning the use of summer fallow.

TABLE 2. Return to Land and Deviation in Return Per Acre Under Three Cropping Systems at Two Wheat Prices in Western North Dakota, 1980 Costs and Yields.

Production System	Wheat Price — $3.52/Bu.		Wheat Price — $4.22/Bu.	
	Return	Deviation[a]	Return	Deviation[a]
Fallow (F-W)	$10.55	$10.13	$19.70	$12.48
Recropping (F-W-W)	9.51	12.49	19.78	15.38
Continuous	7.41	17.21	19.95	21.19

[a]Deviation in net return to land per acre due to one standard deviation in yield per planted acre.

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