Wheat

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ECONOMICS OF WHEAT-FALLOW SYSTEMS

Roger G. Johnson and Mir B. Ali

Agriculture in the western states is heavily reliant upon summer fallow (Haas, et al., p. 1). In 1978 North Dakota had 6.7 million acres or about 20 percent of total cropland devoted to summer fallow (Price and Hamlin, p. 41). Wheat is the major crop produced on summer-fallowed land.

The benefits of summer fallow are higher crop yields resulting from increased soil moisture, nitrogen accumulation, and weed control. Additional benefits are increased stability of production and improved distribution of seasonal work. The cost for the farmer is the income foregone by allowing the land to remain idle for a cropping season. In addition, the practice of summer fallow leaves the soil without a crop cover. This contributes to soil losses through wind and water erosion and to increased air and water pollution (Ehni, et al., p. 14). Also, summer fallow is a contributing factor to the development of saline seeps which are making significant amounts of land unproductive (Worcester, et al., p. 16).

The economic benefits from summer fallow are short run and occur directly to farmers, whereas many of the costs are long run and occur to society. Since the decision to use the practice is made by individual farmers, the level of summer fallow is higher 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 short-run perspective of the farmer. This information not only is designed to help farmers make more rational decisions concerning the use of summer fallow, but also to aid in the formulation of policies designed to reduce the use of

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Johnson is professor and Ali is research assistant, Department of Agricultural Economics, North Dakota State University.

Presented at AAEA meetings, Urbana, July 1980 summer fallow. The present study differs from similar work (Burt, et al., Knight, and MacKenzie) in that county yields are used rather than yields based on experimental trials, and a yield model is developed which shows the yield trend on fallowed and nonfallowed land.

The analysis is presented for wheat production in the western one-third of North Dakota. This is an area where over one-third of the cropland is currently in summer fallow (Ali, p. 5). In western North Dakota wheat is planted on over 90 percent of the land summer fallowed the previous year. Three cropping systems are compared in the paper: fallow system (summer fallow-wheat), recropping (summer fallow-wheat-wheat), and continuous cropping. Although other small grains and, in recent years, sunflower 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.

The four major factors influencing the economics of summer fallow use are: (1) yield of wheat produced on summer-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 had a differential effect upon wheat yield on fallowed and nonfallowed land. For example, the use of nitrogen fertilizer and chemical weed control has tended to favor nonfallow yields. On the other hand, the development of varieties with high yield potential increases 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 summer fallow and previously cropped land since 1949. Previously cropped land planted to wheat is usually in a recropping system in western North Dakota. A wheat yield estimation model was developed using combined cross-sectional data (18 counties) and time-series data (1949-1977). An equal weight was given to data for each county when the counties were grouped. County average wheat yields per harvested acre were used as the dependent variable. The independent variables considered were time as a proxy for technology, annual precipitation (September-August),[1] and a dummy variable (0-1) for nonfallow and fallow cropping practices. Precipitation data were developed for each county based upon National Weather Service data for weather stations in or near each county.

Several logically consistent functional relationships and interaction terms were estimated using least square regression to find the best model. The model selected was based on the highest coefficient of multiple determination (R^2) and lowest standard error of regression line. The Hartley test (H) and the Durbin-Watson test (D-W) were used to test for heteroscedasticity and serial correlation. The Hartley test indicated heteroscedasticity 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_., p. 62). 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

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[1] Models using separate growing season and preseason precipitation gave lower statistical reliability than those using annual precipitation.

parentheses; all coefficients are significant at the .0001 level):

$$\underset{(1.8739)}{Y = -8.7988} + \underset{(.0355)}{.3748t} + \underset{(.2380)}{3.1451D} + \underset{(.0143)}{.1522tD} + \underset{(1.4560)}{15.2310 \log P} \qquad R^2 = .7172$$

where:

Y = wheat yield per harvested acre

t = year; 1949 = 0

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

tD = interaction between year and cropping practice

P = annual precipitation (September-August)

The average annual precipitation of 15.65 inches was substituted into the yield model, and wheat yields were determined for the years 1949 through 1987 for fallow and nonfallow cropping practices. Yields per harvested acre were converted to yields per planted acre by multiplying yields on fallow by .95 and yields on nonfallow by .92, the average percent harvested. The trend in fallow and nonfallow yields per planted acre is presented in Figure 1. The trend line indicates that each year wheat yields are increasing by .50 bushel on fallowed land and .34 bushel on nonfallowed land.

Production costs for 1977 were developed to compare returns between wheat produced on fallowed land with wheat on previously cropped land. The two cropping practices were compared on the basis of return to land. This assumes land to be the most limiting resource and a cropping practice decision criteria based on maximizing returns to land.[2] The wheat yields that give equivalent returns to land under a fallow system and continuous

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

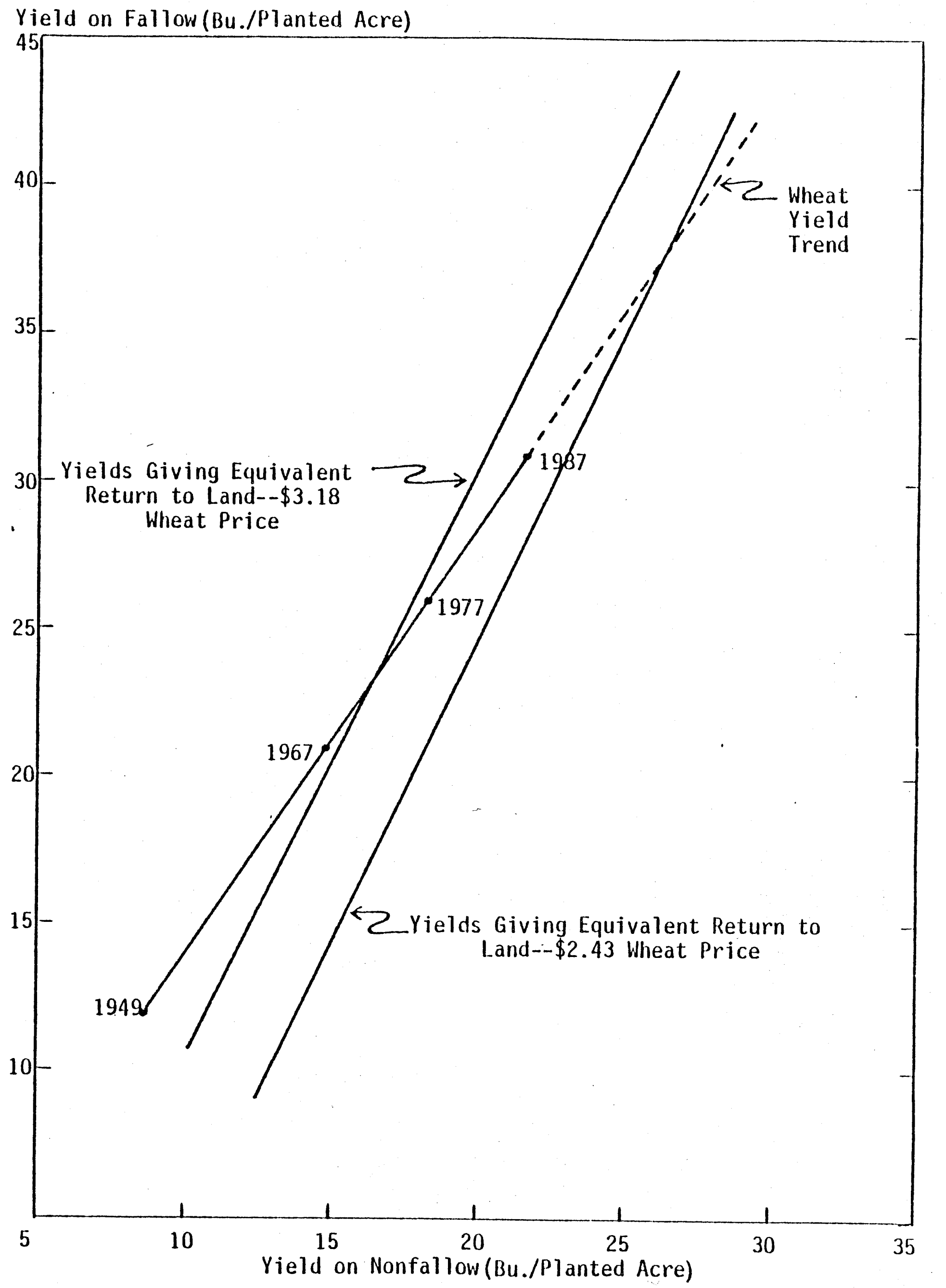

Figure 1. Trend in Wheat Yield Per Planted Acre and Yields Giving Equivalent Return to Land at Two Wheat Prices and 1977 Costs for Fallow and Nonfallow Practices, Western North Dakota

cropping were calculated. The formulas used are as follows:

$$\pi_f = \frac{Y_f P - C_f - V_f(Y_f - Y_{bf})}{2} \qquad (1)$$

$$\pi_c = Y_c P - C_c - V_c(Y_c - Y_{bc}) \qquad (2)$$

where:

π_f = return to land per acre on fallow system

π_c = return to land per acre on nonfallow system

Y_f = yield on fallow

Y_c = yield on nonfallow

P = price of wheat

V_f = cost associated with changes in yield on fallow ($1.20/bu.)

V_c = cost associated with changes in yield on nonfallow ($1.17/bu.)

Y_{bf} = wheat yield on fallow for which costs were developed (26.0 bu.)

Y_{bc} = wheat yield on nonfallow for which costs were developed (18.2 bu.)

C_f = total cost except land for 1977 yield on fallow (includes costs for the fallow year) ($53.63/acre)

C_c = total cost except land for 1977 yield on nonfallow ($42.42/acre)

Equations (1) and (2) are solved for yields:

$$Y_f = \frac{2\pi_f + C_f - V_f Y_{bf}}{P - V_f} \qquad (3)$$

$$Y_c = \frac{\pi_c + C_c - V_c Y_{bc}}{P - V_c} \qquad (4)$$

Substituting a series of returns to land in equations (3) and (4) gives the combination of wheat yields on fallowed and nonfallowed land giving equivalent returns. The results using the area average wheat price and target price for 1977 are presented in Figure 1. Farmers would maximize return to land by using the fallow system if the point of intersection of fallow and nonfallow wheat yields fall to the left of the equivalent return line. When wheat yields fall to the right of the equivalent return line, farmers would have a higher return from wheat on nonfallowed land. 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 1.47 bushels for every bushel yield increased on nonfallowed land. If this yield trend continues, the fallow system will become less and less economically desirable.

Wheat Price

It is evident that the price of wheat has an effect upon the economics of summer fallow (Figure 1). At the average wheat price in 1977, a wheat-fallow system maximized return to land, while at the target price level a recropping or continuous cropping system would be more profitable. The effect of wheat prices on return to land under the three cropping systems is shown in Figure 2.

Higher wheat prices favor the recropping and continuous cropping systems because higher wheat prices increase the opportunity cost of allowing the land to lie idle for a year. On the other hand, the cost of fallowing is not affected by the wheat price.

Nitrogen Price

A major difference in input use between production on fallowed land and nonfallowed land is in the amount of nitrogen fertilizer required. During the fallow year nitrogen accumulates in the soil from the breakdown of crop residues and soil organic matter. Depending on yield level, little or no nitrogen fertilizer is needed on fallowed land. The effects of nitrogen fertilizer prices on return to land are illustrated in Figure 3.

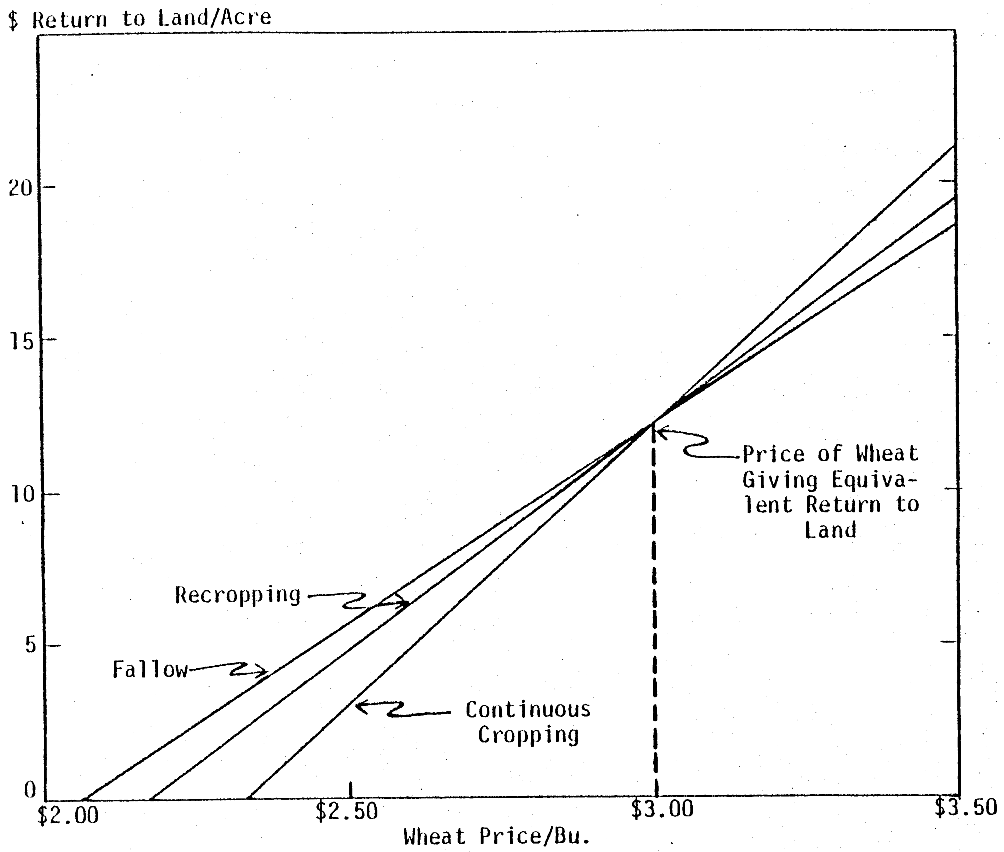

Figure 2. Effect of Wheat Prices on Return to Land Per Acre Under Three Cropping Systems in Western North Dakota, 1977 Costs and Yields

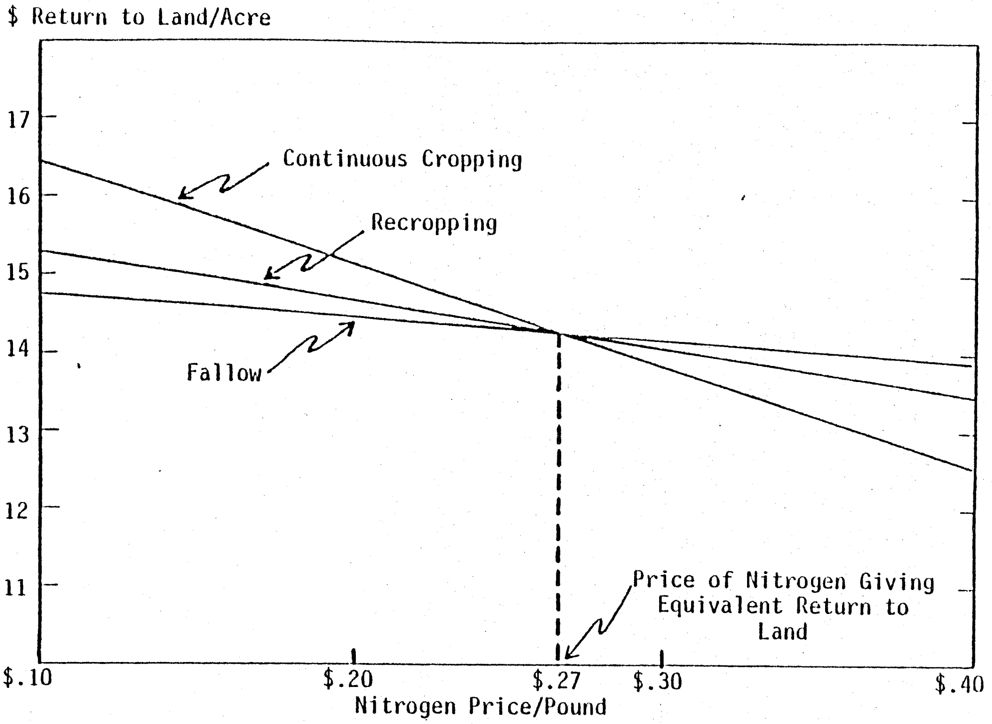

Figure 3. Effect of Nitrogen Prices on Return to Land Per Acre Under Three Cropping Practices in Western North Dakota, 1977 Costs and Yields, Wheat Price of $3.18 Per Bushel

The average price paid in the area for nitrogen in 1977 was $.18 per pound. Given that cost and a wheat price of $3.18, the continuous cropping system would give the highest returns to land. However, at a nitrogen price above $.27 per pound, the fallow systems would give higher returns (holding other prices constant). Higher nitrogen prices are related to energy costs so most other inputs, and especially fuel, also increase with increasing nitrogen prices. However, nitrogen is the major input in which the quantity used changes with the summer fallow practice.

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. The county yield data from 1950-1977 were used to measure wheat yield variability on fallowed and nonfallowed land (Table 1).

TABLE 1. MEAN WHEAT YIELD AND MEASURES OF VARIABILITY PER PLANTED ACRE FOR WESTERN NORTH DAKOTA (1950-1977)

Cropping Practice	Mean Yield (bu.)	Standard Deviation (bu.)	Coefficient of Variation
Fallow	19.23	6.71	34.89
Nonfallow	13.74	5.68	41.30

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.

Since relative variability in yields is less on fallowed land, it follows that variability in income would be lower under a fallow system.

However, the difference in yield variability is magnified when looking at income variability because the acres harvested each year are not constant among cropping systems. Assuming a fixed land situation, a farmer would be harevesting twice the acreage under a continuous cropping system than on a fallow-wheat system.

Income variability was calculated for three cropping systems using the formulas described below:

$$D_c = d_cP - V_cd_c$$

$$D_f = \frac{d_fP - V_fd_f}{2}$$

$$D_r = \frac{(d_f + d_c)P - (V_fd_f + V_cd_c)}{3}$$

where:

D_c = deviation in return to land--continuous cropping system

D_f = deviation in return to land--fallow system

D_r = deviation in return to land--recropping system

d_c = standard deviation in yield on nonfallow (5.68 bu.)

d_f = standard deviation in yield on fallow (6.71 bu.)

V_c = cost of unplanned change in yield on nonfallow ($.37/bu.)

V_f = cost of unplanned change in yield on fallow ($.40/bu.)

P = price of wheat

The income variability measures for the three cropping systems at 1977 average wheat price and target price levels are presented in Table 2. From the data presented in Table 2 it is evident that the increase in risk is substantial in going from the fallow-wheat system to the more intensive cropping systems. At the higher price level farmers selecting the fallow system would give up very little average return to obtain a major reduction in income variability.

TABLE 2. RETURN TO LAND PER ACRE AND DEVIATION IN RETURN PER ACRE UNDER THREE CROPPING SYSTEMS AT TWO WHEAT PRICES

Production System	$2.43 Wheat Price		$3.18 Wheat Price	
	Return	Deviation	Return	Deviation
Fallow (F-W)	$4.78	$6.81	$14.53	$ 9.33
Recropping (F-W-W)	3.79	8.44	14.84	11.54
Continuous	1.81	11.70	15.46	15.96

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 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, improved crop insurance, and emergency credit.

5. Government programs which pay farmers to switch to nonfallow cropping or charge penalties against the use of summer fallow.

There has been limited change in recent years toward less fallow in the study area. Western North Dakota is already a high risk production area so the increased risk involved in more intensive cropping systems is a major factor preventing much change from the wheat-fallow 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 in the next few years. Immediately east of the study area where precipitation and wheat yields are higher, the fallow-wheat system already 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.

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