PHOSECON: A Computer Economics Program to Evaluate Phosphorus Fertilization of Wheat

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Abstract. PHOSECON, an economics microcomputer software program, was developed for the northern Great Plains to allow farmers, fertilizer dealers, agricultural lenders, Cooperative Extension Service, and other agribusiness people the opportunity to evaluate potential short- and long-term profits from P_2O_5 fertilizer application. PHOSECON allows the user to input grain price, fertilizer cost, grain protein value, discount rate on money, federal income tax rate, and P_2O_5 fertilization rate and placement method. Economic results are calculated and displayed as data tables (BASIC version) and/or graphs (LOTUS version). Comparing results from different options and prices allows the user to determine the P_2O_5 rate and application method with the highest profit potential.

Introduction

Rapidly changing economic conditions due to fluctuating crop prices and/or production costs, such as fertilizer, need to be considered when making short- and long-term farm management decisions. In the northern Great Plains, P_2O_5 fertilization of soils testing "low" in plant-available P often increases crop yields. The residual value of previously applied P_2O_5 in increasing future crop yields [1, 2, 5, 12, 14] also needs to be considered when making P_2O_5 applications and evaluating P_2O_5 fertilization economics [6, 10].

Emphasis on the need for higher fertilizer rates to optimize grain yields also necessitates that the short- and long-term economic impact of fertilizer applications be evaluated. Recently, Halvorson et al. [6] evaluated the impact of N and P_2O_5 fertilization on the economics of dryland wheat production using the then current crop prices and fertilizer costs and crop yield data reported by Black [2] and Halvorson and Black [5]. PHOSECON (a microcomputer program) was developed to evaluate the economics of applying P_2O_5 fertilizer to wheat in the northern Great Plains using this same economic approach and yield database. PHOSECON evaluates the economic impact of N and P_2O_5 fertilization on dryland wheat production with user-inputed crop prices and fertilizer costs. The program addresses the cumulative change in fertilized yield minus the nonfertilized check plot yield (no N or P_2O_5 fertilizer applied) for each treatment. In addition to evaluating the economics of a one-time, broadcast P_2O_5 application, PHOSECON uses the same yield database and economic factors to simulate wheat yields and economic returns from user-inputed broadcast plus annual band P_2O_5 application rates or annual band applications of P_2O_5 fertilizer. The purpose of this paper is to describe the PHOSECON program that has potential use by Cooperative Extension Service, fertilizer dealers, agricultural money lenders, crop consultants, farmers, and other agribusiness personnel.

Program Structure

PHOSECON has two options in both BASIC and LOTUS* versions of the program. The first option, designated as "A" in this manuscript, evaluates long-term economic consequences of applying a single, one-time P_2O_5 application as influenced by user-inputed fertilizer prices and application costs while assuming crop yields and cropping sequences of the original database. Output is presented in the form of tables in the BASIC version and as tables and graphs in the LOTUS version.

The second option, designated as "B," simulates

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effects of using an initial broadcast plus annual band P_2O_5 applications or just annual band P_2O_5 applications with or without addition of 40 lb N/A each crop year. Option "B" allows the user to select and input different P_2O_5 application rates but not N rates. The user can also extrapolate the database to similar soils and climatic conditions, where the soil may have a different soil test P level. Responses to P_2O_5 fertilization are limited to yield differences between the nonfertilized check plot and the P_2O_5 treatment with maximum yield each crop year, using the yield data from option "A." Option "B" also estimates the change in soil test P level as a function of P_2O_5 application rate each crop year for a loam soil. Phosphate and N fertilizer can be applied by 1) either broadcasting or banding P_2O_5 and N the first crop year, with only a banding option available for applying N and P_2O_5 fertilizer for crop years 2 through 11 at P_2O_5 rates specified by the user, and 2) banding P_2O_5 for optimum crop yield as determined by PHOSECON starting with either crop year 1 or 2.

In both options, the first six crops (crop years 1 through 6) simulate spring wheat grown in a wheat-fallow sequence and the last five crops (crop years 7 through 11) simulate annually cropping without a fallow period between crops. In the original database, crop years 7 through 11 included spring wheat, winter wheat, barley, and safflower. Safflower and barley yields were converted to wheat equivalents to simplify economic analysis [6].

Economic Factors

The following economic factors can be changed by the program user:

1. Phosphate fertilizer cost (\$/lb P_2O_5)
2. N fertilizer cost for first crop year (\$/lb N)
3. N fertilizer cost for crop years 2 through 11 (\$/lb N)
4. Broadcast application cost for crop year 1 (\$/A)
5. N and/or P_2O_5 application cost for crop years 2 through 11 (\$/A)
6. Grain price (\$/bu)
7. Protein premium at 17% protein concentration (\$/bu)
8. Discount rate (%) on money or your cost of money above inflation rate
9. Estimated federal income tax bracket, crop year 1 (%)
10. Estimated federal income tax bracket, crop years 2 through 11 (%)

Cumulative economic benefits over time are considered by using the discounted cash flow concept [3]. A user-inputed discount rate is used to compare economic benefits for all years on a net, present value basis. This approach is necessary since a dollar today is worth more than a dollar anytime in the future because of "the time preference for money." The discount formula used is:

$$\text{Discount value} = 1/(1 + R)^n \tag{1}$$

where n is the number of years and R is the discount rate. The discount rate reflects the real interest rate that is the nominal interest rate minus the inflation rate. For example, a 10% nominal interest rate minus a 4% inflation rate equals a 6% real interest rate (discount rate). Since no inflation factor is used in fertilizer or grain prices, an interest rate excluding the inflation premium is appropriate.

Potential federal income tax savings from the application of P_2O_5 fertilizer is estimated by assuming a separate tax bracket for crop year 1 and a separate tax bracket for crop years 2 through 11. State and self-employment taxes are not included. The tax savings is calculated to illustrate the added benefit if an individual, for whatever reason, had a very high taxable income the year of P_2O_5 application. Only variable costs (P_2O_5 and N fertilizer plus application cost) are used in calculating tax savings. Additional income resulting from increased yields is also taxed.

The grain protein value with each wheat crop is also considered. Long-term history (1965 to 1984) of protein premiums actually paid by grain elevators in North Dakota [13] shows that at a concentration of 12% protein, no protein premium was paid but at a concentration of 17% protein, the premium was generally at maximum value. Therefore, no additional protein premium is considered above 17% nor is a price discount considered below 12%. A linear relationship is used to reflect an increase in grain value as grain protein increases from 12% to 17% protein.

PHOSECON analyzes the discounted economic returns over N and P_2O_5 fertilizer plus application costs. Residual or net income is what is left over to pay all other operating costs including a return to labor, capital, and management.

Assumptions for Option "A"

1. Yield, cropping sequence, and climatic conditions remain the same for another 11 crops over a 17-year period. A wheat-fallow system for crop years 1 through 6 and annual cropping for crop years 7 through 11 would be followed.
2. Protein premiums are zero at 12% grain protein and maximum at 17% with a linear relationship

in price between 12 and 17% protein concentration in grain.

3. No changes in price, production costs, discount rate, or federal income tax rate will occur between crop years 2 and 11. Users should input their best average estimate of future values since they are unknown.
4. Extra harvest costs resulting from handling increased grain yields are not considered because these costs vary considerably from farm to farm and are very small relative to other production costs.
5. Fertilizer and its application cost are tax deductible.
6. Only cumulative economic returns or losses due to the crops' response to fertilizer application are calculated. The program does not evaluate whether or not production of the wheat crop was profitable, but simply evaluates profitability of fertilizer application.

Assumptions for Option "B"

1. Assumptions for option "B" include all assumptions listed for option "A."
2. A band application of P_2O_5 fertilizer is more efficient than a broadcast application.
3. A sodium bicarbonate-extractable soil test P level of 18 ppm is needed to achieve optimum yield potential [4].
4. The soil test P level will increase linearly with an increase in broadcast P_2O_5 application rate [7].
5. The rate of change in residual soil test P level is about 6.3% each year after P_2O_5 application up to 12 years and about 1.3% each year from 12 to 17 years [unpublished data, A.D. Halvorson and A.L. Black, USDA-ARS].
6. The program calculates and keeps track of changes in residual soil test P levels and increases in soil test P level caused by annual P_2O_5 applications.
7. The check plot yields (no P_2O_5 applied) of the 0 and 40 lb N/A treatments are a function of relative yield potential, which is based on the current soil test P level and are calculated from the highest grain yield attained each crop year with the 0 or 40 lb N/A treatments plus P_2O_5. Maximum wheat yield potential is a function of relative yield potential, which is determined after the calculation of the expected soil test P level following P_2O_5 fertilization.

A linear increase in soil test P level was measured ($R^2 = 0.98$) with increasing rates of broadcast P application to the Williams loam soil used in this study. The increase in soil test P level was 0.234 ppm for each 1 lb P/A broadcast applied. The program calculates the amount of broadcast P needed to raise the soil test P level from its current level to 18 ppm, using the following relationship:

$$BFP = (18 - STP)/0.234 \qquad (2)$$

where BFP is the amount of broadcast P fertilizer (lb P/A) needed to raise the soil test P (STP) level from the user-input level to 18 ppm. Multiplying BFP by 2.29 will convert lb P/A to lb P_2O_5/A.

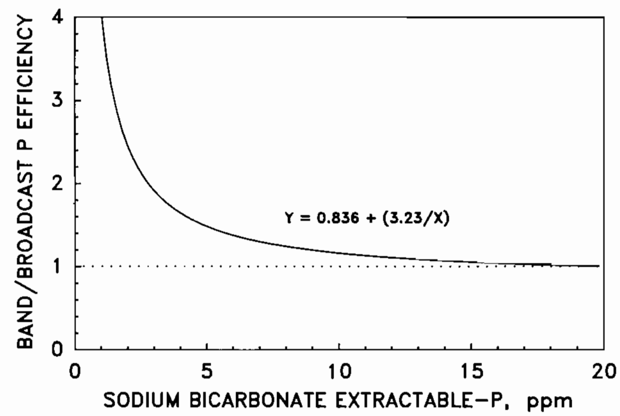

Fig. 1. Efficiency ratio of banded to broadcast P fertilizer as a function of sodium bicarbonate extractable-P soil test level.

Since band applied P_2O_5 fertilizer tends to be more efficient at low soil test levels than broadcast P_2O_5, an efficiency ratio of band to broadcast fertilizer P_2O_5 was estimated as a function of sodium bicarbonate soil test P level (Fig. 1), similar to the relationship reported by Peterson et al. [11]. Band P_2O_5 application rates are converted to broadcast equivalents using the relationship shown in Figure 1.

Based on the amount of P_2O_5 fertilizer to be applied, soil test P levels are calculated each crop year, giving credit for previous P_2O_5 applications and accounting for a decline in residual soil test P level based on the number of years since P_2O_5 application. Efficiency of the band application is assumed to last for 1 crop year. Therefore, residual activity of the band application is treated as if the P_2O_5 fertilizer had been initially broadcast for the purpose of adjusting soil test P levels for residual P_2O_5. A native soil test P level (P level of soil that has never been fertilized with P_2O_5) is used as the baseline value toward which the fertilized soil's P test will decline. The rate and application method of P_2O_5 fertilization, current soil test P level, and native soil test P level are input by the user.

Table 1. Example of an output table from option "A" of the BASIC version of PHOSECON

Cumulative gross income plus protein premium above check—fertilizer costs (discounted at 6.25% and taxed at a rate of 33% crop year 1 and 0% crop years 2 through 11).

Treat		Crop year										
N	P205	1	2	3	4	5	6	7	8	9	10	11
(lb/A)							($/A)					
0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	2	5	7	11	23	28	30	28	28	26	24
0	92	−2	13	25	29	47	52	61	59	57	54	52
0	183	−14	0	17	24	49	63	71	66	66	62	60
0	366	−35	−12	9	18	42	56	63	59	60	53	54
40	0	−10	−13	−14	−21	−10	−21	−5	−9	−5	14	19
40	46	4	13	14	8	25	17	43	48	57	75	77
40	92	5	23	34	38	70	78	99	103	112	132	142
40	183	−7	21	51	68	117	145	166	174	184	205	213
40	366	−28	4	33	52	105	139	158	169	182	207	216
80	0	−17	−23	−28	−42	−31	−43	−19	−16	−12	5	14
80	46	−3	−2	−1	−11	10	4	30	35	40	55	61
80	92	−2	12	31	29	64	68	94	101	107	127	137
80	183	−12	17	47	58	100	124	146	151	162	184	195
80	366	−37	−3	31	41	86	125	151	162	180	207	218

Note: Wheat = \$0.11/kg (\$3/bu); N = \$0.51/kg (\$0.23/lb) 1st year, N = \$0.35/kg (\$0.16/lb) crops 2–11; P_2O_5 = \$0.45/kg (\$0.205/lb); fertilizer application cost = \$6.01/ha (\$2.44/A) 1st year and \$10.34/ha (\$4.20/A) all other years
(\$/A) × 2.47 = \$/ha

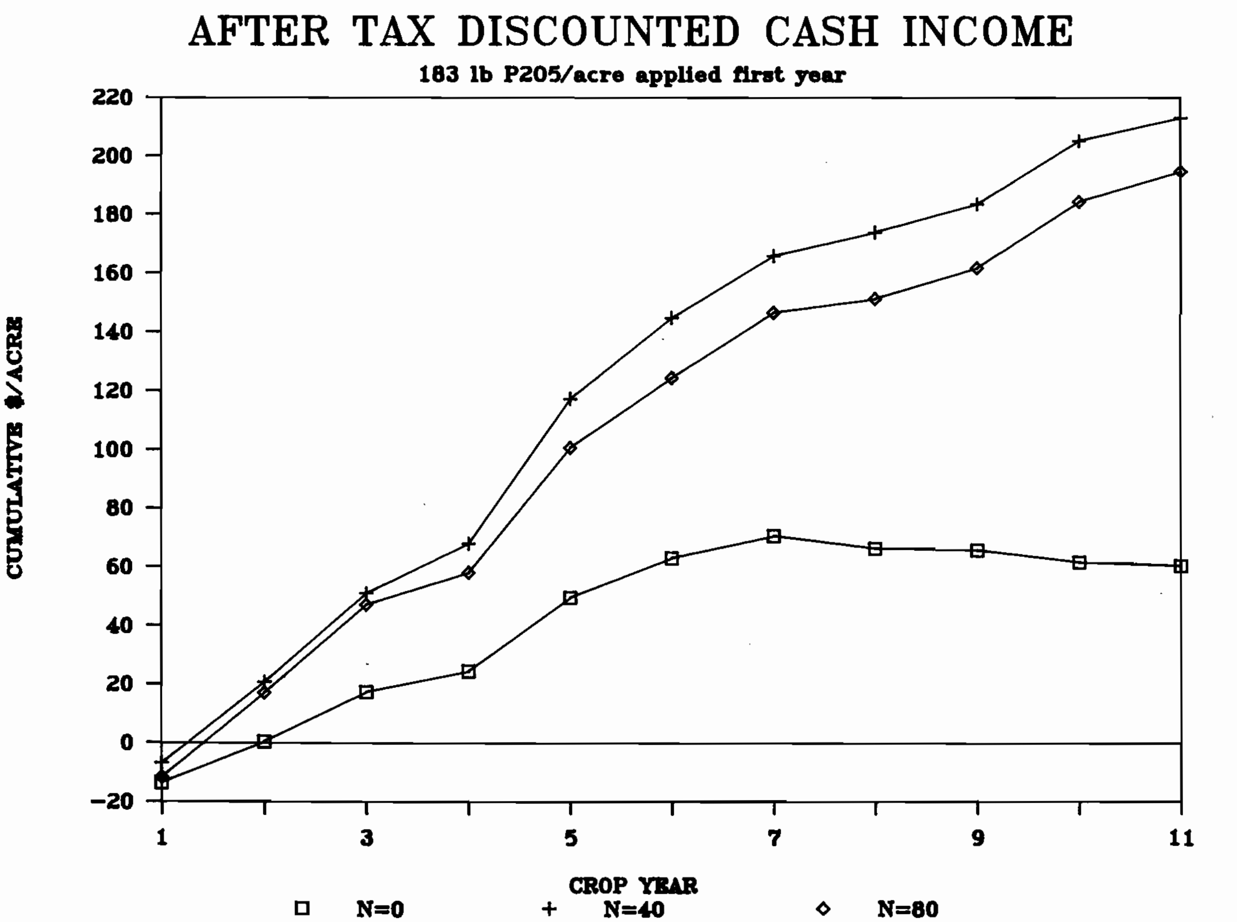

Fig. 2. LOTUS graph showing cumulative gross income plus protein premium above check minus fertilizer costs (discounted at 6.25% and taxed at a rate of 33% for crop year 1 and 0% for crop years 2 through 11) as a function of N rate plus the one-time application of 183 lb P_2O_5/A the first crop year.

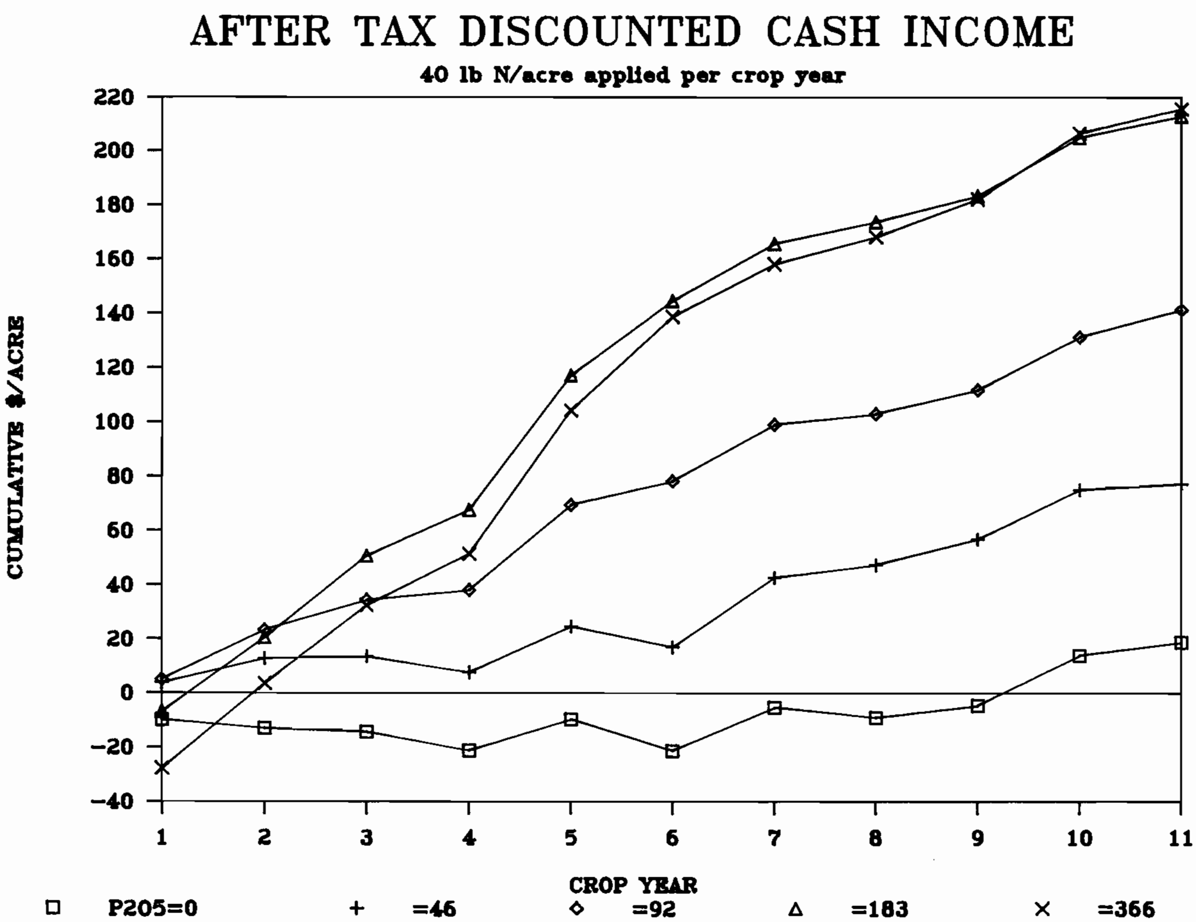

Fig. 3. LOTUS graph showing cumulative gross income plus protein premium above check minus fertilizer costs (discounted at 6.25% and taxed at a rate of 33% for crop year 1 and 0% for crop years 2 through 11) as a function of a one-time application of five rates of P_2O_5 the first crop year with 40 lb N/A applied each crop year.

Once a soil test P level is established for each year, wheat yield is calculated by multiplying the maximum wheat yield for the 0 and 40 lb N/A rates by the relative yield potential. Relative yield potential is calculated, using the relationships presented by Halvorson [4]. For the crops grown in the wheat-fallow sequence (crop years 1 through 6) and annual cropping sequence (crop years 7 through 11), the relative yield potentials are calculated using equations 3 and 4, respectively.

$$RY = 1.105 + (-2.828/STP) \quad (3)$$

$$RY = STP/(1.845 + 0.911 \times STP) \quad (4)$$

where RY is the relative yield potential and STP is the calculated sodium bicarbonate soil test P level. The program automatically sets RY to 100% yield potential if STP is $\geq$18 ppm. The nonfertilized check plot yield is then subtracted from the maximum yield to determine estimated response to P_2O_5 fertilization with or without application of 40 lb N/A. Economics are then calculated as done in option "A."

Basic Program Operations and Requirements

PHOSECON is driven by menus in the LOTUS version and by answering questions in the BASIC version. The program has preset initial default values that minimize user input to PHOSECON during an initial run of the program. Users should input new grain prices, protein values, fertilizer costs, discount rates, federal income tax rates, P_2O_5 application rates, and placement method to represent their farm situation. The program calculates potential economic returns to N and P_2O_5 fertilization based on user input. Comparing results obtained with different inputs and options allows the user to determine the P_2O_5 rate and placement method with the most profit potential. PHOSECON utilizes grain yield data from a 17-year northern Great Plains phosphorus study to evaluate potential short- and long-term profits from P_2O_5 fertilization.

The LOTUS version presents both tables and graphs of the economic results, whereas the BASIC version displays only tables. An example of an output table from the BASIC program is shown in Table 1. Graphs from the LOTUS version, which present some of the same data as Table 1, are shown in Figures 2 and 3.

Software and Hardware Requirements

PHOSECON requires an IBM PC* or compatible computer using PC.DOS* or MS.DOS* (versions 2.0 or greater) operating systems, BASICA* or GWBASIC* programming languages, and at least one 5¼″ floppy disk drive. The LOTUS worksheet version of the program requires the use of LOTUS 123* (version 1A or greater) and at least 384K of memory (RAM). The user's guide [8, 9] is intended to be used while running PHOSECON. A program diskette and user's guide are available from Office of Communications, Cooperative Extension Service, Box 5655, North Dakota State University, Fargo, ND 58105.

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