Determining Profitable Fertilizer Use on North Dakota Farms

Billy B. Rice, Carl E. Olson and David E. Hoff

Each year North Dakota farmers use more fertilizer than before. (In 1939, they used 1,446 tons of fertilizer; by 1968 they increased fertilizer use to 361,509 tons.) The only exceptions are reflected in the years following a particularly "short" crop in the state.

Table 1. Annual consumption (tons) of commercial fertilizer in 1951 to 1968.

Year	Tons
1951	17,017
1955	62,644
1960	142,733
1961	160,974
1962	166,795
1963	158,412
1964	183,657
1965	197,515
1966	246,356
1967	297,718
1968	361,509

Compiled by North Dakota State Laboratories.

However, much more fertilizer could profitably be employed by North Dakota farmers. For example, researchers at North Dakota State University estimate that in 1965 farmers applied only about one-fourth the nitrogen and phosphorous and less than one-half as much potassium as could have been used to economic advantage.

The Census of Agriculture reports a total of 48,836 farms in North Dakota in 1964. However, only 23,527 of these, or 48.1 per cent, reported using any fertilizer. Farmers applied fertilizer on less than one-third of the cropland harvested in 1964. In 1964, 52 per cent of all wheat grown in the state, 46 per cent of the barley, 26 per cent of the corn, 22 per cent of the oats, 3 per cent of the flax, and 2 per cent of tame hay and pasture, were fertilized, while 100 per cent of the sugarbeet and potato crops were fertilized that year.[1]

Extreme variations in weather, especially precipitation, cause fluctuations in North Dakota crop yields. Some farmers fear fertilizer will "burn" their crop, particularly during a dry year. Others say a properly fertilized crop will make more efficient use of available moisture by sending roots down deeper into the soil where more water may be found. Data gathered by soil scientists at North Dakota State University and elsewhere show that a properly fertilized crop will not burn any sooner than an unfertilized crop in the same field on the same soil type.[2]

Seventy-eight fertilizer response trials throughout North Dakota conducted by soil scientists at NDSU showed that fertilized wheat on fallow increased water use efficiency about 22 per cent over nonfertilized plots.[3] Other research has shown water use efficiency to increase over 50 per cent in some cases.[4]

The so-called "cost-price squeeze" in agriculture supports greater fertilizer use.

Table 2. Comparative price paid by farmers for various production resources.
Base 1957 - 59 = 100

Year	Fertilizer[1]	Farm Machinery[1]	Land[2]	Wage[1] Rates
1950	94	78	65	73
1960	100	107	111	109
1965	100	119	142	125
1966	100	124	150	134
1967	100	129	163	146
1968	97	137	173	158

[1]**The Farm Cost Situation,** Economic Research Service, United States Department of Agriculture, November, 1966, p. 2.
[2]**Farm Real Estate Developments,** Economic Research Service, United States Department of Agriculture, 1963 and 1966.

Table 2 indicates that prices for farm machinery, land, and wage rates have all increased substantially while fertilizer prices have remained relatively stable.

Taking into account the higher analyses of fertilizers marketed in recent years, it appears that fertilizer prices may have declined slightly. In 1951, a ton of fertilizer contained an average of

[1]Schaffner, L. W. and S. W. Voelker, **Statistics on Fertilizer Consumption in North Dakota, 1951-56,** Agricultural Economics Report No. 53, Department of Agricultural Economics, North Dakota State University, in cooperation with Economic Research Service, USDA, Fargo, North Dakota, July, 1967, p. 5.

Rice is assistant professor (Extension), Olson was associate professor, and Hoff was a former graduate assistant, Department of Agricultural Economics.

[2]Bauer, Armand and R. A. Young, "Fertilized Wheat Uses Water More efficiently," **North Dakota Farm Research,** Bimonthly Bulletin, Vol. 24, No. 3, January-February, 1966, p. 10.

[3]**Ibid.,** p. 4.

[4]Ferguson, W. S., "Effect of Intensity of Cropping on the Efficiency of Water Use," **Canadian Journal of Soil Science,** 4:156, 1963.

760 pounds of nutrients, while in 1965 the average content of nutrients had been increased to 980 pounds per ton.

Narrowing profit margins point to a more intensive cropping program. As prices for other factors of production increase, fertilizer becomes a more inviting alternative for capital investment. Price adjustments, new technology and better educational processes are some reasons for the increase in fertilizer use in North Dakota over the past years. However, North Dakota farmers are still under-using fertilizer, although it is becoming a more attractive choice for resource allocation. North Dakota farmers have a real opportunity to increase their income through proper use of commercial fertilizer.

To realize a profitable response from fertilizer, the crop must respond sufficiently in terms of quantity and/or quality to cover all costs involved. Fertilizer is generally applied in the spring, but profits or losses from its application are not realized until the crop is harvested. The basic question the farmer asks is, "How much should I use to get the best maximum returns?" Production economics says to apply fertilizer until the returns from the last unit, or pound, of fertilizer are equal to the cost of that last unit of fertilizer. That is, add units of fertilizer (the variable) until the added cost is equal to the added returns.

The decision as to how much and what kind of fertilizer to use to maximize returns is much more involved than the added cost — added returns approach. Before the crop is harvested, the farmer does not know what his returns, both economic and physical, will be. Farmers need some means of predicting crop response from fertilizer and profit maximization levels of use prior to application.

Farmers gain knowledge and experience regarding fertilizer use with each passing year. Producers must weigh their knowledge and experience against the uncertainty of factors affecting prices and crop responses in planning each year's fertilization program.

The fertilizer industry advertises large profits from the use of commercial fertilizers. High returns may be true for certain crops in a given area under optimum conditions, but farmers are the first to recognize that conditions are usually less than optimum. Returns to fertilizer vary a great deal. It means little to the individual farmer to say a **given** level of fertilizer gives a profitable response. Perhaps net profit could be increased by using more or less fertilizer. There is, therefore, a need to locate profit maximizing levels of fertilizer applications.

Risk, Uncertainty, and Fertilizer Use

Profits from fertilizer application are uncertain. Many factors affecting crop response from applied fertilizer are unpredictable. The question is, how much fertilizer should you use in a given year?

The term "risk" in everyday conversation includes both risk and uncertainty. However, there is a difference between the two. Risk can be measured, while uncertainty cannot. Fertilizer use is a subjective risk. A producer cannot foresee future happenings perfectly. But knowledge and experience with fertilizer allow him to make rational decisions regarding its use.

Individual management decisions regarding fertilizer use depend upon many things, including the degree of uncertainty and nature of expectations, and preference for risk because of his psychological makeup, thought processes, family responsibilities, age, and ethical and philosophical background. Other important factors are his capital and equity position, level of education, and the economic outlook.

Each person has different expectations for what the future might bring. That which is risk to one is uncertainty to another. The possibility of a barn burning down is uncertainty to a farmer and risk to an insurance company. No one can say a specific barn will be destroyed by fire. Yet, with a large random sample, actuaries can predict with a small degree of error how many barns out of 100,000 will burn down in a given year. By the same token, no one can say that the crop on a particular field will respond profitably to fertilizer application in a given year. However, if a large enough random sample of crop responses from applied fertilizer were available, one could apply probabilities for profitable response. When probabilities can be realistically assigned, fertilizer use will move from the category of uncertainty into the area of risk.

Probability theories can, therefore, be applied to fertilizer response statistics to help reduce the degree of uncertainty and improve decision-making on the part of the farmer regarding fertilizer use.

Probabilities of profitable response were calculated in a 1967 study from a relatively small number of observations.[5] Probabilities were calculated from response distributions on the basis of

[5]Hoff, David E., **A Method of Determining Profitable Response From Fertilization,** M. S. Thesis, North Dakota State University, 1967.

frequency of occurrence. Table 3 indicates the probability of a profitable response to various fertilizer application rates, with the price of wheat changed in \$.25 intervals from \$1.25 to \$2.25 per bushel and considering all phosphorus soil test levels. Table 4 is the same except that only soils testing very low and low are included. The price of fertilizer is held constant at \$.10 per pound of actual P_2O_5 in all cases.

Table 3. Probability of profitable response from phosphorus fertilizer at various available subsoil moisture levels for soils of all phosphorus test levels at selected wheat prices.

Price of Wheat	Subsoil Moisture	Applied P_2O_5 15	25	35	45
\$1:25	Less than 3	.71	.71	.54	.46
	3-5	.82	.79	.71	.68
	More than 5	.57	.57	.50	.57
1.50	Less than 3	.71	.75	.62	.58
	3-5	.82	.79	.79	.75
	More than 5	.57	.57	.50	.50
1.75	Less than 3	.75	.83	.67	.63
	3-5	.86	.86	.85	.82
	More than 5	.57	.57	.50	.58
2.00	Less than 3	.75	.87	.67	.62
	3-5	.86	.86	.86	.82
	More than 5	.57	.57	.57	.57
2.25	Less than 3	.75	.87	.75	.67
	3-5	.86	.89	.89	.89
	More than 5	.57	.57	.64	.64

For example, when wheat sells for \$1.25 per bushel with three to five inches of subsoil moisture available, the probability of a profitable response to 15 pounds of P_2O_5 is .82; to 25 pounds, .79; to 35 pounds, .71; and to 45 pounds, .68. When the price of wheat is increased to \$2.25, the probabilities are .86, .89, .89, and .89 of receiving profitable yield increases.

The probabilities computed for the various subsoil moisture classes and for profitable responses at various phosphorus application rates for each subsoil moisture level are presented in Tables 3 and 4.

The highest probabilities of a profitable response to phosphate were noted on soils with three to five inches of available soil moisture. It appears that profits will be recognized about 80 to 90 per cent of the time when three to five inches of soil moisture are present at seeding. The probability of a profitable return on fertilizer applied on soils with less than three inches of available soil moisture is less than that indicated for three to five inches.

Between 70 and 85 per cent of the time, applications up to 25 pounds of P_2O_5 are profitable. The probability of profitable responses from applications heavier than 25 pounds of P_2O_5 decreases sharply.

Table 4. Probability of profitable response from phosphorus fertilizer at various available subsoil moisture levels for soils testing very low and low in phosphorus, at selected wheat prices.

Price of Wheat	Subsoil Moisture	Applied P_2O_5 15	25	35	45
\$1.25	Less than 3	.83	.78	.61	.61
	3-5	.83	.83	.79	.75
	More than 5	.67	.67	.67	.67
1.50	Less than 3	.83	.83	.72	.67
	3-5	.87	.83	.87	.83
	More than 5	.67	.67	.67	.67
1.75	Less than 3	.89	.89	.78	.72
	3-5	.92	.83	.92	.92
	More than 5	.67	.67	.67	.83
2.00	Less than 3	.89	.89	.78	.72
	3-5	.92	.96	.92	.92
	More than 5	.67	.67	.67	.83
2.25	Less than 3	.89	.89	.78	.78
	3-5	.92	.96	.92	.96
	More than 5	.67	.67	.67	.83

The chance of obtaining profitable responses on soils with over five inches of available soil moisture is noticeably lower, ranging in general from .50 to .67. This is expected, due to the higher check yields and lower response from phosphate indicated when sufficient moisture is available. Results obtained in the category of over five inches of available soil moisture must be viewed with skepticism due to the severely limited number of cases available for analysis.

The above analysis was done for one type of fertilizer, one cropping practice, one crop, and had limited observation. However, we think the results have meaning. What we should do now is set up such contingency tables for all major crops in North Dakota, using several types of fertilizer and different cropping practices. If and when such data are compiled, much of the uncertainty of fertilizer use could be reduced.

Also needed are techniques that a farmer can use to determine soil moisture at planting time. Present soil tests indicating if a particular soil is very low, low, medium, and high in a particular nutrient, in P_2O_5 or K_2O_1, appear to be good enough.

What farm management economists need for economic analysis of fertilizer use are a large number of observations of many combinations of soil moisture, soil test level, type of fertilizer, amount of fertilizer, crop, cultural practices and soil type. When such data are available for economic analysis, it may be possible to predict the probability that a given level of fertilizer application will be profitable.