Former Agricultural Education student Bill Ferris determines phosphorus level in a soil sample using a colorimeter at the NDSU Soil Testing Laboratory.

NUTRIENT ADDITIONS AND REMOVALS FROM NORTH DAKOTA SOILS

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Increasing concern has been directed toward the general effect on soils and the environment of using chemical fertilizers. In this context, two questions often arise: "How much commercial fertilizer is added to North Dakota soils each year?" and "What amounts of plant nutrients are removed or extracted by crops from North Dakota soils each year?" Data which attempt to provide answers to these questions have been collected, tabulated and are presented below.

Nutrient removal by crops versus fertilizer additions

The major nutrients applied in commercial fertilizer are nitrogen (N), phosphorus (P) and potassium (K). Amounts of these nutrients removed in the harvested portions of the major crops grown in North Dakota are shown in Table 1. North Dakota fertilizer consumption data are provided annually by the State Laboratories Department in Bismarck. Furthermore, annual fertilizer consumption data for each state in the United States are available from the Statistical Reporting Service of the U. S. Department of Agriculture. The assumption in this paper is that soybeans and alfalfa hay do not remove any N from the soil, because these crops are legumes and fix most of their own nitrogen.

The total amount of N, in thousands of tons, removed by all crops in North Dakota for each year of the period 1945 to 1971 is presented in Figure 1. Nitrogen removed in the harvested crops was calculated using the data in Table 1 combined with crop acreage and average yield data obtained from the Crop and Livestock Division of the Statistical Reporting Service.[1] Also shown in Figure 1 is the amount of N added in commercial fertilizer over this same time period. Both N removed from the soil and commercial fertilizer N added to the soil show a general upward trend; each year removal

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Table 1. N, P, and K in the harvested portion of some North Dakota crops.

	Nutrients removed (lb/unit)			
Crop	N	P	K	Reference
Wheat, bu.	1.8	0.3	0.4	Bulletin 378
Barley, bu.	1.2	0.2	0.4	Bulletin 378
Timothy hay, T	25	5	16	Bulletin 378
Corn silage, T	6.67	1.16	5.4[2]	Tisdale & Nelson
Corn grain, bu.	0.9	0.15	0.2	Tisdale & Nelson
Soybeans, bu.	[1]	0.36	1.16	Tisdale & Nelson
Alfalfa hay, T	[1]	5.8	37.5[2]	Tisdale & Nelson
Oats, bu.	0.8	0.15	0.24	Bulletin 378
Rye, bu.	1.09	0.22	0.31	Tisdale & Nelson
Potatoes, cwt	0.27	0.04	0.4	Tisdale & Nelson
Sugar beets	5	0.8	5	Morrison
Millet, bu.	1.1	0.16	0.24	Morrison
Sunflowers, cwt	27	5.2	6.6	Morrison
Flax, bu.	2.5	0.29	0.64	Bulletin 378

[1]Legumes fix their nitrogen.

[2]The amounts of K taken from North Dakota soils are probably higher than the average amounts reported.

of N by crops greatly exceeds the addition of fertilizer N. In other words, on the average, our soils are being "mined" of N.

As early as 1950, research studies at NDSU had shown that use of supplemental N on small grain crops was very often a profitable venture, especially on non-fallowed fields. However, as shown in Figure 1, N fertilization was not widely accepted by the crop producer until the mid-1960's. Acceptance of N fertilizer increased when the continuous removal of N from the soil (Figure 1) had reduced the N reserve to a level where responses were much more pronounced and the need for additional N became more obvious.

Figure 2 presents tons of P added in commercial fertilizer and P removed in harvested crops. The data show a general decrease in the difference between that P removed in harvested crops and that added in commercial fertilizers until the late 1960's.

In general, North Dakota soils are rich in potassium. Figure 3 shows K removed in harvested crops and K added in commercial fertilizers. Both curves show an upward trend, but K removal is much greater than K additions.

The data from Figures 1, 2 and 3 are presented in a different manner in Figure 4. Each primary nutrient (N, P or K) added in commercial fertilizer is expressed as a percentage of that nutrient re-

[1]Courtesy of John Price, S.R.S.

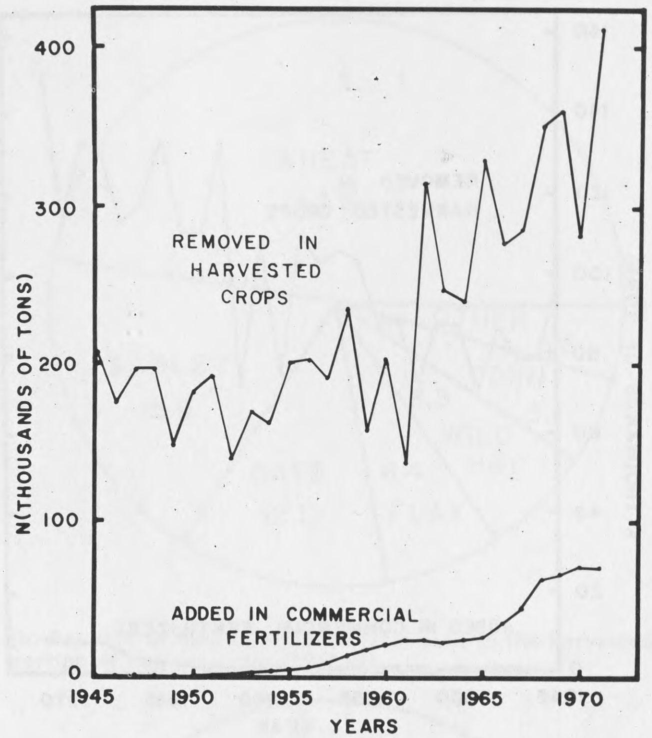


Figure 1. Nitrogen, in thousands of tons, removed in harvested crops and N in commercial fertilizers added to North Dakota soils.

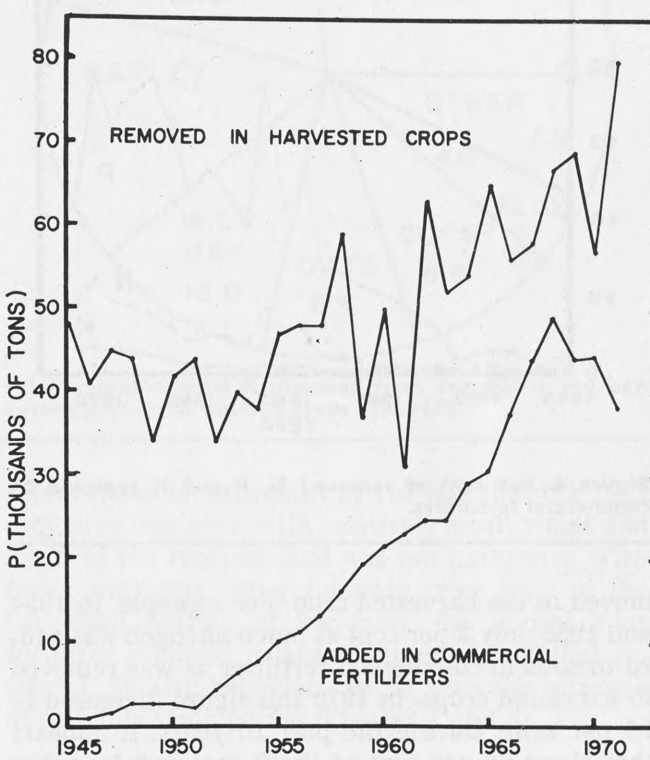


Figure 2. Phosphorous, in thousands of tons, removed in harvested crops and K in commercial fertilizers added to North Dakota soils. Note change in scale.

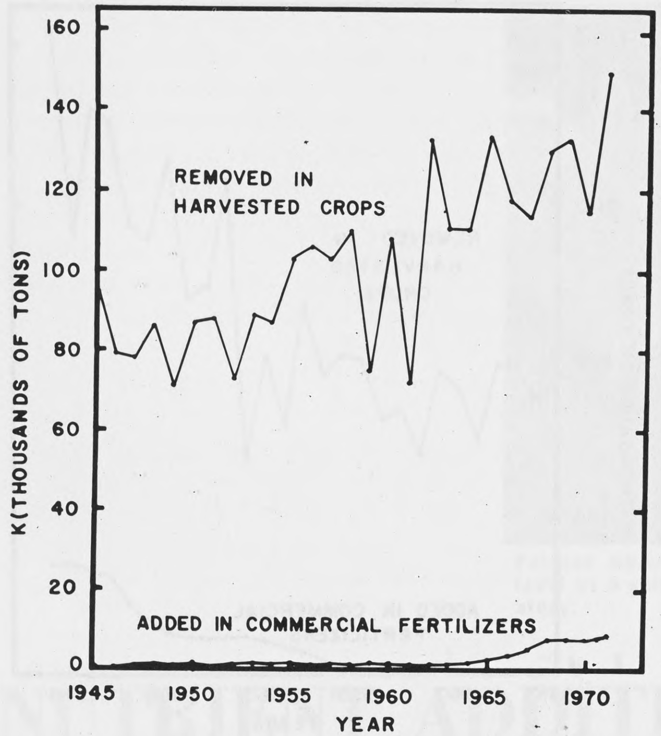


Figure 3. Potassium, in thousands of tons, removed in harvested crops and K in commercial fertilizers added to North Dakota soils. Note the change in scale.

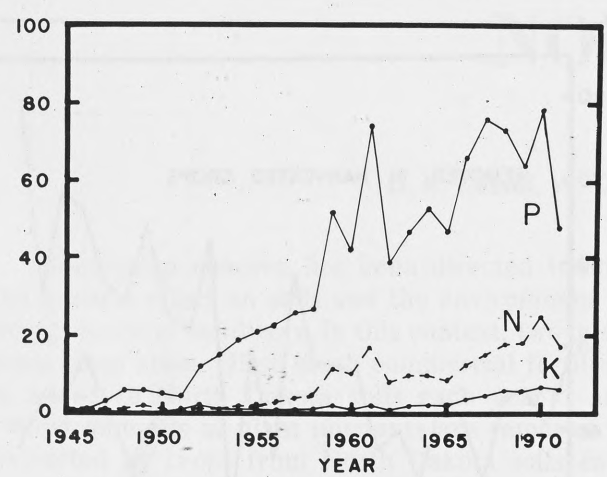


Figure 4. Per cent of removed N, P and K replaced by commercial fertilizers.

moved in the harvested crop. For example, in 1954 and 1955 only 2 per cent as much nitrogen was added to soils in commercial fertilizer as was removed in harvested crops. In 1970 this figure increased to 25 per cent. During the past 10 years, it appears that about 60 per cent of the P removed from the soil was replaced with commercial fertilizer P. In 1970 and 1971, only 6 per cent of the potassium removed was returned in commercial fertilizer.

Nutrient balance during 1960-69 decade

Adding more detail on the decade 1960-69, Figure 5 shows a diagram of land-use distribution of harvested acreage in North Dakota for that period. Total acreage represented is 24.7 million acres, but nearly 27 per cent of this land was fallowed during any one year. Since we are considering only nutrients removed in harvested crops (no attempt was made to estimate plant nutrients lost by soil erosion), it is useful to present this land-use information in a different manner. By eliminating fallow land, each crop can be expressed as a per cent of total acres harvested (18.1 million acres). Such a diagram is shown in Figure 6a. Small grains (wheat, barley and oats) are planted on 62 per cent of this acreage, all hay on 20 per cent, etc.

Figures 6b, 6c and 6d show that, although 62 per cent of the harvested acreage was planted to small grains (wheat, barley, oats), 78 per cent of the total N, 69 per cent of total P, and 51 per cent of total K, respectively, were removed in the harvested grain. It is assumed that straw remained on the field. Since some straw was removed, however, the estimate of total nutrient removal is somewhat underestimated.

Tame hay (64 per cent of tame hay during this period was alfalfa), for example, which represents less than 12 per cent of the harvested acreage, accounts for zero per cent N (it was assumed tame hay fixed all its N), 12 per cent of the P and 19 per cent of the K removed. Similar information can be taken from the graphs in Figure 6 for wild hay, flax and corn as well as for the small grains (wheat, barley and oats).

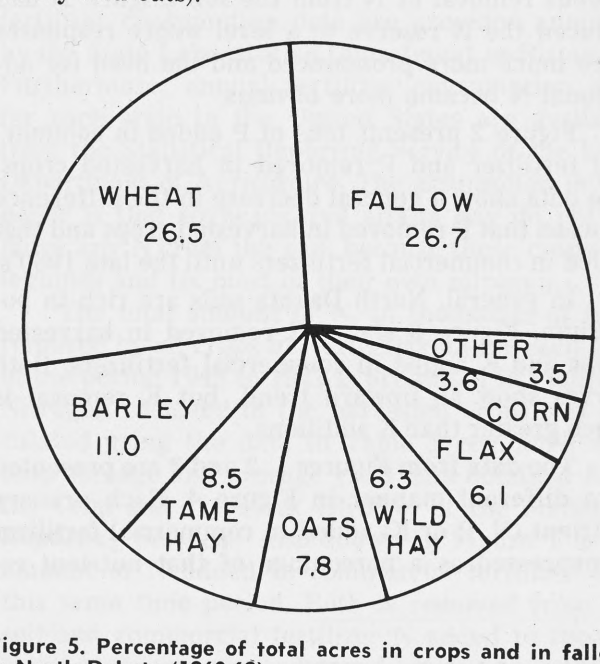


Figure 5. Percentage of total acres in crops and in fallow in North Dakota (1960-69).

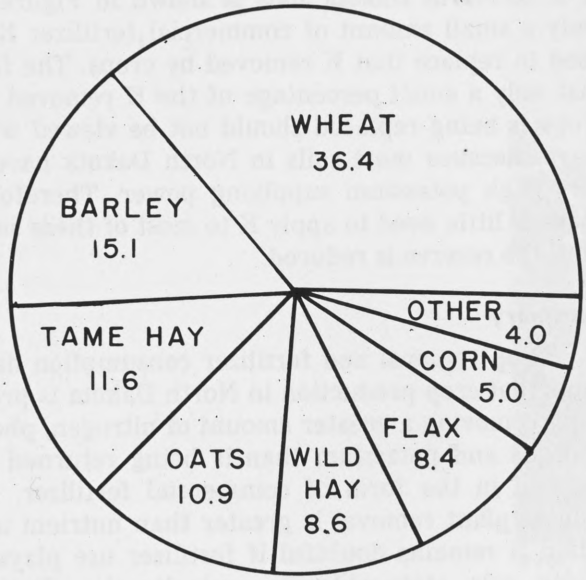
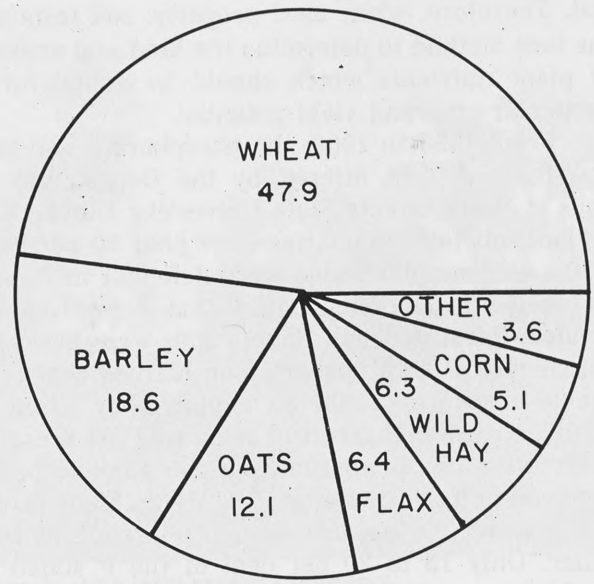
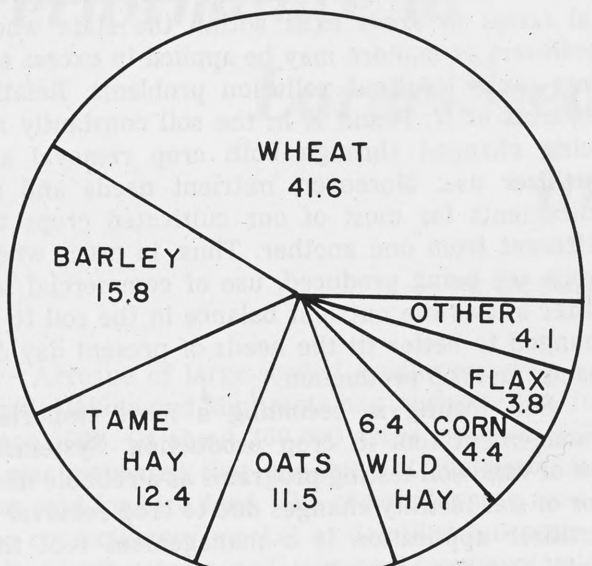


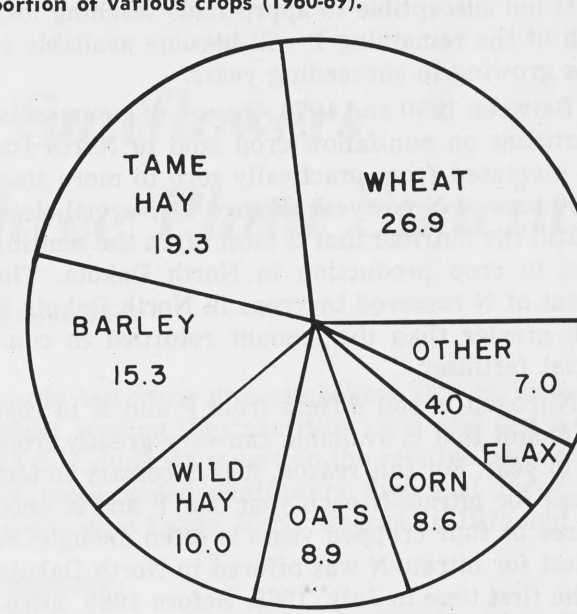
Figure 6. (a) Per cent of total acres harvested in North Dakota (1960-69).



(b) Per cent of total N removed from soils in the harvested portion of various crops (1960-69).



(c) Per cent of total P removed from soils in the harvested portion of various crops (1960-69).



(d) Per cent of total K removed from the soil in the harvested portion of various crops (1960-69).

Variation in per cent of removed nutrients replaced by commercial fertilizer

Figure 4 shows that, in 1961, 74 per cent of the P removed by crops was replaced by commercial fertilizer P, while in 1960 and 1962 only about 40 per cent of the P removed was replaced. Why was such a difference observed?

Close examination of Figure 2 shows that P fertilizer consumption increased each year during the 1960 to 1962 period. On the same graph, the amount of P removed by crops decreased nearly 20 per cent from 1960 to 1961. This large decrease in removal can be explained by the fact that the 1961 crop year was poor, with relatively small yields and much of the cropped land was not harvested. With fewer nutrients being removed from soils in the harvested portion of the crop, the phosphorous fertilizer replaced a larger percentage of that removed. Similar behavior can be seen for nitrogen during this same period (Figures 1 and 4).

How is soil testing related to nutrient removal and addition?

Soil testing is the only practical method at present to quickly determine the fertility status of soil. Therefore, when used properly, soil tests are the best method to determine the kind and amount of plant nutrients which should be added for a particular crop and yield potential.

From 1953 to 1968, the phosphorous soil test was the only test offered by the Department of Soils at North Dakota State University. During this period, soil test summaries show that 90 per cent of the soil samples tested were deficient in P, and so received a recommendation that P fertilizer be applied. Because North Dakota soils were basically deficient in P, and farmers soon learned that profitable responses could be expected by using P fertilizer, use of P fertilizer increased. At present, P fertilizer use is approaching the amount being removed in harvested crops (Figure 2). Many farmers, however, do not use enough phosphorous fertilizer. Only 15 to 20 per cent of the P added is used by crops during the year of application. The remaining 80 to 85 per cent is rendered immobile and is not susceptible to appreciable leaching loss. Much of the remaining P will become available to crops growing in succeeding years.

Between 1950 and 1970, the use of commercial N fertilizer on non-fallow crop land in North Dakota increased from practically zero to more than 70,000 tons of N per year (Figure 1). Nevertheless, N is still the nutrient that is most often the limiting factor in crop production in North Dakota. The amount of N removed by crops in North Dakota is much greater than the amount returned in commercial fertilizer.

Nitrogen in soil differs from P and K in that the amount that is available can vary greatly from year to year. For this reason, it is necessary to test the soil for nitrate-N each year (for P and K once in three or four cropped years is often enough). A soil test for nitrate-N was offered in North Dakota for the first time in July, 1968. Before 1968, nitrogen fertilizer recommendations were based on the assumption that non-fallowed fields were low in plant available N and that summerfallowed fields were high. Soil test summaries since 1968 show that about 25 per cent of the non-fallowed fields had adequate amounts of N, while about 35 per cent of the summerfallowed fields did not have adequate N. Because of the variability from field to field, it is very difficult to make general fertilizer recommendations.

Soil testing for potassium also began in 1968. A summary of the K soil test data indicates that about 95 per cent of the samples tested have adequate K. The 5 per cent that are low in K are mainly the sandy soils in eastern North Dakota. The situation with respect to removal versus addition of K to North Dakota soils is shown in Figure 3. Only a small amount of commercial fertilizer K is used to replace that K removed by crops. The fact that only a small percentage of the K removed by crops is being replaced should not be viewed with alarm because most soils in North Dakota have a very high potassium supplying power. Therefore, there is little need to apply K to most of these soils until the reserve is reduced.

Summary

Crop removal and fertilizer consumption data show that crop production in North Dakota is presently removing a greater amount of nitrogen, phosphorous and potassium than is being returned to the soil in the form of commercial fertilizer. So long as plant removal is greater than nutrient addition it remains doubtful if fertilizer use plays a major role state-wide in agricultural pollution problems in North Dakota. The above statement does not preclude the possibility that some individual farms or areas exist within the state where fertilizers or manure may be applied in excess and thus cause localized pollution problems. Relative amounts of N, P and K in the soil constantly are being changed through both crop removal and fertilizer use. Moreover, nutrient needs and requirements for most of our cultivated crops are different from one another. Thus, in areas where crops are being produced, use of commercial fertilizer allows the nutrient balance in the soil to be changed to better fit the needs of present day demands on crop production.

Soil testing is becoming a more important management tool in crop production. Systematic use of valid soil testing programs as a reliable monitor of soil fertility changes due to crop removal or fertilizer application is a management tool that many crop producers have overlooked. When good soil testing programs are used as guides to apply fertilizer, excess fertilizer use will be held to a minimum while yields are being maintained or improved.

References

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