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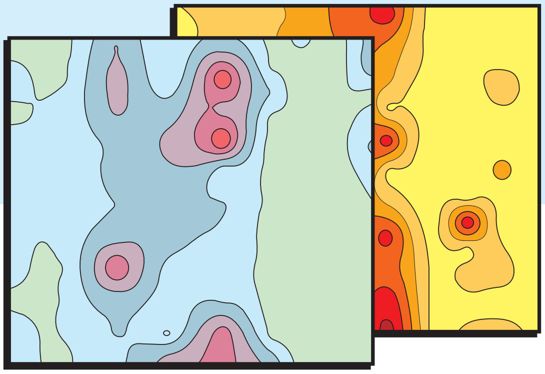

Site-specific
Farming and Soil Sampling in Western North Dakota

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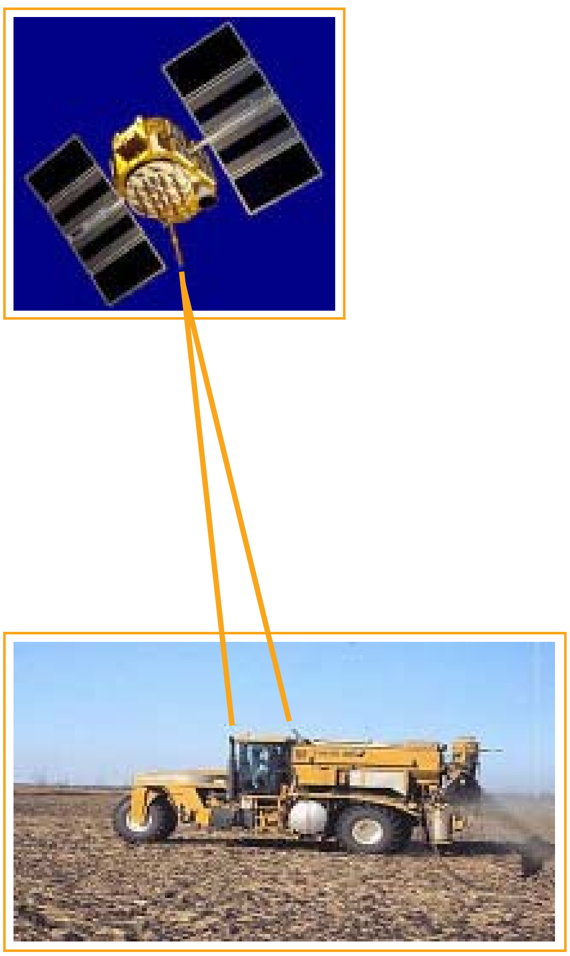

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Site-specific farming means directing soil and crop management inputs to fit the different conditions found at various locations in fields. Site-specific farming sometimes is called "prescription farming," "precision farming" or "variable-rate technology." It uses four technologies:

- Global positioning systems (GPS)
- Gather information
- Geographic information systems (GIS)
- Variable application of field inputs

The value of knowing a precise location within inches is important for the following reasons:

1. Location of soil samples so the laboratory results can be converted into a soil fertility map
2. Fertilizer and pesticides can be applied to fit soil properties (such as clay and organic matter content, along with relief and drainage) and soil conditions
3. Crop yield data can be monitored and recorded as the combine moves across the field

Producers are aware of variations in fields. Many farmers are merging fields to facilitate larger machinery, and larger fields will increase variability. Site-specific farming is capable of directing crop inputs to small, localized areas of a field with large equipment. An input prescription map is produced from topographical maps, satellite images, soil sampling information, aerial photographs and yield maps. Some of these methods (soil sampling) have proven to be very successful, whereas other methods may need more refinement to become useful.

Economic benefits of precision agriculture depend on identifying places in a field where additional inputs will increase returns by an amount greater than the added costs, or where reduced inputs will reduce costs by more than reduced returns. Producers can take advantage of the residual nutrient levels that often occur across a field to realize economic benefits.

Economic returns to site-specific technology are essential for adopting the practice, but are difficult to quantify. The economic value of spatial information is mainly unknown due to the relatively short time it has been available and the lack of basic economic research. Making maximum use of crop inputs at each location in a field can result in a significant profit potential from site-specific management practices.

Site-specific farming can have a positive effect on the environment. Crop inputs, such as fertilizer and pesticides, are applied based upon a projected yield in the field. If a part of the field has a soil type with lower production potential, producers can apply less fertilizer. In areas of the field that have higher production potential, producers can apply more fertilizer based on the prescription map created for the field.

The same can apply to pesticides. If an area of weeds or insects shows up in a field, only that part needs to be sprayed. Applying fertilizer and pesticides based on a prescription map has the potential to reduce nutrients or pesticides moving off the field in runoff water or down through the soil profile and contaminating underground water supplies.

The site-specific farming project in western North Dakota was conducted in cooperation with the Area IV Soil Conservation District; U.S. Department of Agriculture-Agricultural Research Service, Mandan; and North Dakota State University. Researchers on the project have conducted intensive soil sampling, variable-rate fertilizer application, yield monitoring and map interpretation on about 47 acres split into three fields of nearly equal size.

This project was designed to demonstrate site-specific farming techniques and gather data to support soil sampling techniques, profitability and changes in nitrogen (N) soil test levels at varying soil depths as influenced by a crop rotation. Another objective was to monitor nitrogen movement through the soil profile to determine if N leeching may present a hazard to underground water supplies.

Results of the Demonstration Project on the Area IV SCD Research Farm

They include:

1. Soil sampling based on topographic zones provides soil fertility accuracies similar to intensive grid sampling. Zone sampling requires fewer samples, which is more economical and identifies variability almost as well as grid sampling.

2. Profitability of variable fertilizer application was inconsistent. In selected years, variable fertilizer application has shown a profitable return, while in other years it was less profitable or produced a loss. For profitable variable-rate fertilizer application, residual soil N needs to vary by more than 30 pounds/acre across large areas of a field. Site-specific application is able to take advantage of the variability with the use of a prescription map for the field that includes a projected crop yield, along with the soil type variability and the residual soil N.

3. In years with good crop yields, residual soil N is reduced to very low levels (20 to 30 pounds of N/acre). This project has demonstrated that measuring and accounting for residual soil N across a field for the following year's crop will result in less nitrogen left in the soil at the end of the growing season. Less residual soil N after harvest reduces the potential for leaching or runoff contamination of water supplies.

4. Variable-rate fertilizer application can help protect the environment. Previous work has shown less residual soil N from variable application, compared with uniform application (Area IV research report). Less N in the soil will reduce the potential for polluting ground water supplies. Variable-rate application allows a producer to apply fertilizer based on the crop production capabilities of the soil while utilizing plant nutrients already in the soil.

5. Sunflowers' deep root system uses soil N from soil profile depths down to 6 feet. A rotation with a deep-rooted crop retrieves N from the 2- to 6-foot soil depths very well.

6. Yield monitoring identifies crop yield variability in a field. It gives the producer a chance to see how production practices affect crop yield. Yield monitoring with a GPS receiver is the first step a producer should take when starting site-specific farming. This will show the variability in a field.

Demonstration Project Fields on the Area IV SCD Research Farm

During the past six growing seasons, a three-year crop rotation was used on three fields. The crops were hard red spring wheat (SW), hard red winter wheat (WW) and sunflowers (SF). Sunflowers are a deep-rooted crop. These crops were selected because they commonly are grown in western North Dakota. This project was conducted during six years to obtain a variety of growing conditions, including years with good rainfall, as well as dry years. Soil samples were taken each fall after the crops were harvested.

Table 1 summarizes the average N fertilizer applied to each field and the average crop yield. Fertilizer rates are the average of the variable-rate application, as well as some fields that had N fertilizer applied uniformly. Uniform application was used in certain cases where measurements of residual fertilizer amounts in the field showed little variation. Average crop yield was determined with a combine equipped with a yield monitor.

Table 2 and 3 present the residual soil N after the crop was harvested. Column one also indicates the nitrogen sampling depths in 2-foot increments down to 6 feet. The next six columns present the average pounds of N left in the soil at the various depths for the six years of the demonstration. The average crop yield for the year also is included. These values are listed in the table with the soil-test values.

During the first three years, rainfall at Mandan was normal or above normal. But rainfall for the last three years was below normal. Annual precipitation at Mandan is 16.1 inches, while growing-season rainfall during May through August is slightly more than 10 inches. During 2002, rainfall occurred too late for the cereal crops, but helped produce a sunflower crop that was at targeted yield. During the last two years, rainfall was below normal and all crops produced below-average yields.

The crops were fertilized at a rate higher than most producers would use. The crops were fertilized for target yields at between 50 and 60 bushels/acre for the wheat crops, and more than 2,000 pounds/acre for sunflowers. This was done to determine if residual soil N would remain or leach through the soil profile and potentially cause groundwater pollution. Usually, residual soil N amounts are considered low if they are between 20 and 30 pounds per acre.

Some sample residual soil fertility contour maps are shown in Figures 1 through 8. They include maps from the top 48 inches of the soil profile. The 48- to 72-inch level showed little variation. Most of the mobile nutrients (N) remain in the top 48 inches of the soil profile.

During the first two years (1999 and 2000), residual fertilizer amounts were low except for a few instances. In 2000, a significant amount of N remained in the top 24 inches of the soil profile (Figure 1). The winter wheat yield was 57 bushels/acre, but the high amount of residual soil N

Table 1. Crop Yields and Average Pounds of N Applied to the I Fields on the Area IV SCD Farm*

Field	1999	2000	2001	2002	2003	2004
I-4						
N Fertilizer Applied	120 lb/ac	125 lb/ac	125 lb/ac	45 lb/ac	87 lb/ac	77 lb/ac
Crop Yield	SF 2,230 lb/ac	SW 56 bu/ac	WW 16.5 bu/ac (winterkill)	SF 2,112 lb/ac	SW 26.2 bu/ac	WW 30 bu/ac
I-5						
N Fertilizer Applied	120 lb/ac	170 lb/ac	60 lb/ac	120 lb/ac	58 lb/ac	50 lb/ac
Crop Yield	SW 52 bu/ac	WW 57 bu/ac	SF 1,768 lb/ac	SW 6.7 bu/ac	WW 36 bu/ac	SF 1,958 lb/ac
I-6						
N Fertilizer Applied	120 lb/ac	125 lb/ac	125 lb/ac	125 lb/ac	50 lb/ac	63 lb/ac
Crop Yield	WW 46 bu/ac	SF 2,217 lb/ac	SW 50.5 bu/ac	WW 14.8 bu/ac	SF 1,493 lb/ac	SW 29 bu/ac

*SF = sunflowers; SW = spring wheat; WW = winter wheat left in the top 24 inches of the I-5 field was due to the high application rate of N (170 pounds/acre). The 57 bushels/acre winter wheat yield did not use all the N, so the excess remained in the top 2 feet and was used for the next year's crop. Variable application was used on this field the next spring. Areas in red received little fertilizer. Figure 2 indicates the residual soil N in the 24- to 48-inch soil profile. Small variations occured across the field except for one small area in the north end of field I-6.

In 2001, the winter wheat (Field I-4) had severe winterkill, yielded poorly and the amount of N left in the top 2 feet was low (Figure 3), but a considerable amount of N was left in the 24- to 48-inch level (Figure 4). This was due to the poor winter wheat stand and the inability of the winter wheat crop to use the moisture and the 125 pounds of N/acre, resulting in N movement below 24 inches. Variable-rate application was used the next spring at planting time to adjust N rates on the I-4 field for the 2002 sunflower crop.

Table 2. Residual Soil Nitrogen (N) in the I Fields At the End of the Cropping Season (lb/ac)*

Field	Soil Depth (inches)	1999	2000	2001	2002 (Dry Year Early)	2003	2004	Average
I-4	0-24	26	27	37 (WW =	13	9	18	22
	24-48	14 (SF =	14 (SW =	93 16.5 bu/ac)	41 (SF =	49 (SW =	24 (WW =	39
	48-72	26 2,230 lb/ac)	21 56 bu/ac)	30 (winterkill)	27 2,112 lb/ac)	31 26.2 bu/ac)	21 30 bu/ac)	26
I-5	0-24	26	66	24	112	47	19	49
	24-48	17 (SW =	17 (WW =	26 (SF =	29 (SW =	59 (WN =	26 (SF =	29
	48-72	17 52 bu/ac)	22 57 bu/ac)	27 1,768 lb/ac)	29 6.7 bu/ac)	31 36 bu/ac)	13 1,958 lb/ac)	23
I-6	0-24	30	20	40	74	51	38	42
	24-48	18 (WW =	12 (SF =	15 (SW =	19 (WW =	40 (SF =	35 (SW =	23
	48-72	25 46 bu/ac)	13 2,217 lb/ac)	15 50.5 bu/ac)	15 14.8 bu/ac)	31 1,493 lb/ac)	23 29 bu/ac)	20
All Fields	0-24	27	38	34	66	36	25	38
	24-48	16	14	45	30	49	28	30
	48-72	22	19	24	24	31	19	23

Table 3. Residual Soil N After Harvest of Spring Wheat, Winter Wheat and Sunflowers (lb/ac)*

Field	Soil Depth (inches)	1999	2000	2001	2002 (Dry Spring)	2003	2004	Average
Spring Wheat	0-24	26	27	40	112	9	38	42
	24-48	17 (52 bu/ac)	14 (56 bu/ac)	15 (50.5 bu/ac)	29 (6.7 bu/ac)	49 (26.2 bu/ac)	25 (29 bu/ac)	26
	48-72	17	21	15	29	31	23	23
Winter Wheat	0-24	30	66	37	74	47	18	45
	24-48	18 (46 bu/ac)	17 (57 bu/ac)	93 (16.5 bu/ac)	19 (14.8 bu/ac)	59 (36 bu/ac)	24 (30 bu/ac)	38
	48-72	25	22	30 winter kill	15	31	21	24
Sun-flowers	0-24	26	20	24	13	51	19	26
	24-48	14 (2,230 lb/ac)	12 (2,217 lb/ac)	26 (1,768 lb/ac)	41 (2,112 lb/ac)	40 (1,493 lb/ac)	26 (1,958 lb/ac)	27
	48-72	26	13	27	27	31	13	23

* Note: SF=sunflowers, SW=hard red spring wheat, WW=winter wheat
Yields: wheat=bu/ac, sunflowers=lb/ac

In 2002, the high N fertilizer rates left in the soil in the I-5 and I-6 fields (wheat) were due to an extremely dry year, especially during May and June (Figure 5). But the sunflower crop yield (Field I-4) was very good due to timely rains in July. As a result, the residual soil N amounts were low in both the 0 to 24-inch and 24- to 48-inch soil levels. In 2002, the residual soil N amounts went up because fertilizer was applied for 50-plus bushels/acre wheat yields, and more than 2,000 pounds/acre SF yield. Fields I-5 and I-6 (Figures 5 and 6) resulted in a high residual soil N in the top 24 inches, with less in the 24- to 48-inch level after harvest. This was due to the poor wheat yields that dry weather early in the growing season caused.

In 2003, fertilizer rates were reduced on all three fields from what had been applied in previous years, and yields were below previous goals due to below-normal rainfall. Residual soil N was similar to residual soil N found in 2002. Fields I-5 and I-6 were found to have considerable N left in the top 24 inches (Figure 7), and all three fields were found to have slightly higher than desirable rates of N left in the 24- to 48-inch soil depth (Figure 8).

In 2004, N application was reduced based upon the dry soil conditions and the low probability that rainfall plus dry soil could produce a 50-plus bushel/acre wheat crop or a 2,000 pounds/acre sunflower crop. The residual soil N decreased on the three fields and most of the soil tests were near the 20 to 30 pounds/acre desired for each of the 24- inch soil levels. If significant amounts of snow were to fall during the winter and replenish soil moisture levels, more fertilizer could be applied so better yields would be possible. If extremely dry soils exist into the spring, normal growing season rainfall will not be adequate to produce 50 bushels/acre wheat or 2,000 pounds/acre sunflower yields, and producers should apply less N fertilizer for the next crop.

Table 3 indicates the variability of residual soil N and crop yield across the six years of the trial while growing the same crop. The listed information is from Table 2 and is arranged based upon crops grown. During dry years, residual soil N increased, but at the end of the study after several dry years, applied soil N and residual soil N amounts were reduced. Rainfall in 2004 was below normal, but with reduced applied N, soil residual amounts decreased.

Variable-rate fertilizer application is an excellent method to make use of residual soil N. This allows feeding a crop for a yield goal without applying excessive amounts to low-producing areas and allowing producers to apply more fertilizer to higher-producing areas. Variable-rate fertilizer application allows producers to make efficient use of the total amount of applied N fertilizer without causing a hazard to water supplies.

Summary

Site-specific farming has potential to reduce production costs by applying fertilizer to a field based upon production capacity and proven yields, and reduce the pollution potential in lower-value crops with dryland farming in western North Dakota. This demonstration has shown that producers can apply high fertilizer rates to increase yields in good rainfall years. If weather conditions reduce crop yields, the fertilizer still is available in the soil profile to be utilized for the next crop year. If some residual N moves to lower levels, sunflowers in the following year will retrieve those nutrients. Variable-rate application also can reduce potential environmental contamination. If high levels of fertilizer are found in certain areas, variable-rate application for the next year's crop can take that into consideration and reduce the rate so the total amount of fertilizer is based upon a yield goal for soil type and moisture availability.

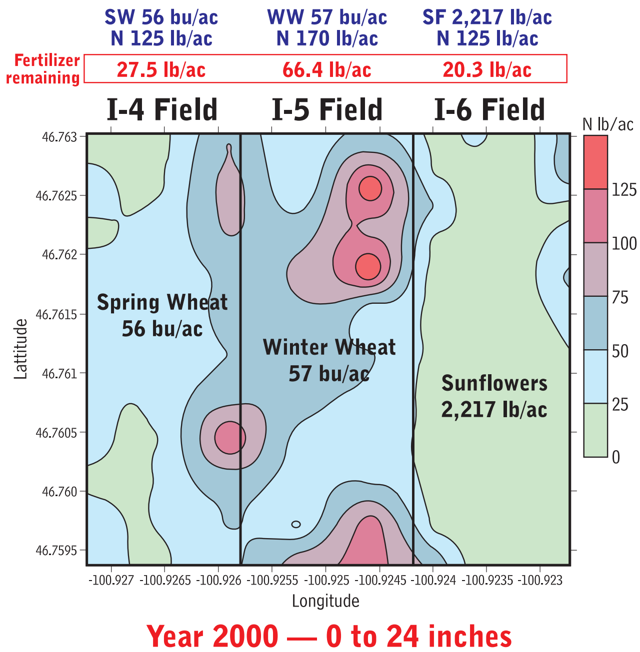


Figure 1. Soil Nitrogen I-4, I-5 and I-6 Fields

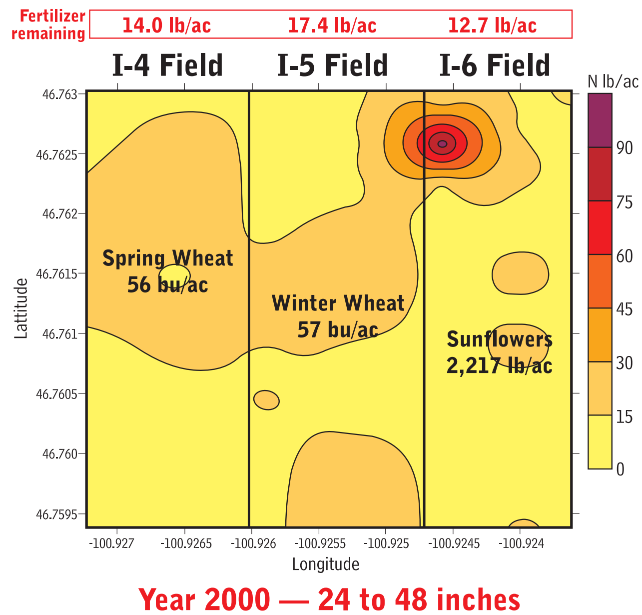


Figure 2. Soil Nitrogen I-4, I-5 and I-6 Fields

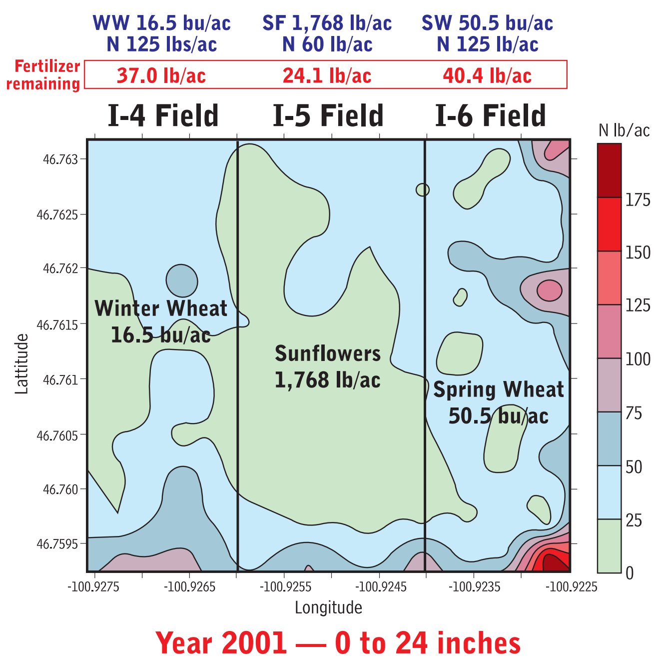


Figure 3. Soil Nitrogen I-4, I-5 and I-6 Fields (winter kill in winter wheat)

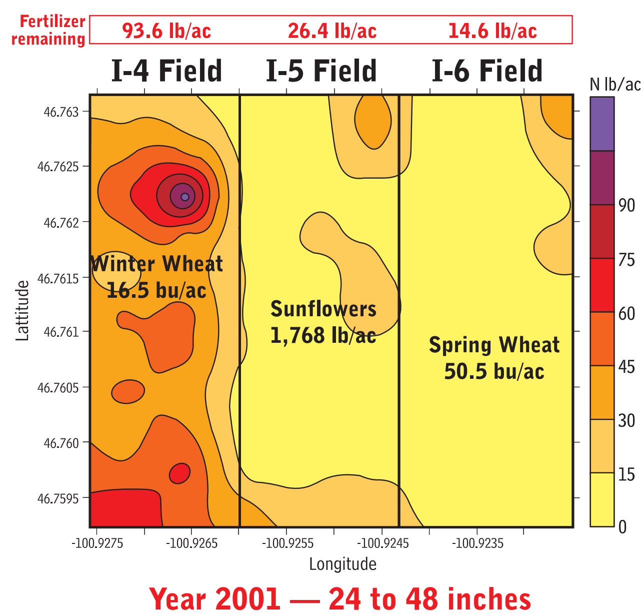


Figure 4. Soil Nitrogen I-4, I-5 and I-6 Fields

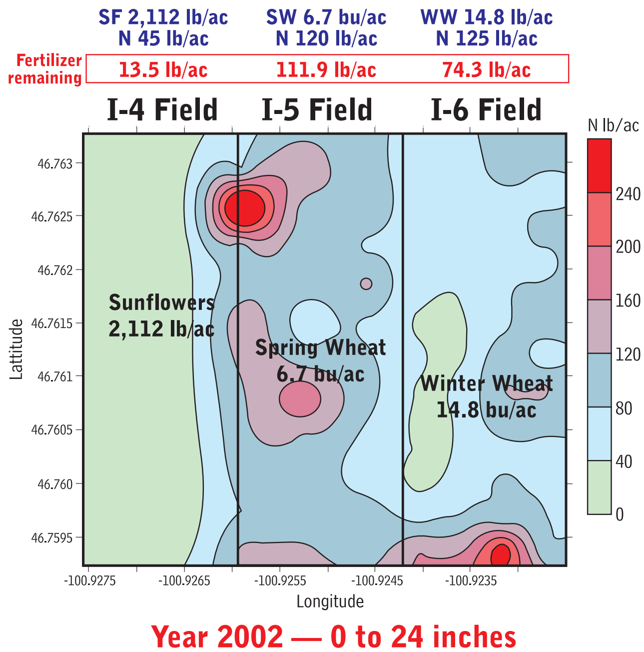


Figure 5. Soil Nitrogen I-4, I-5 and I-6 Fields (dry weather in spring wheat)

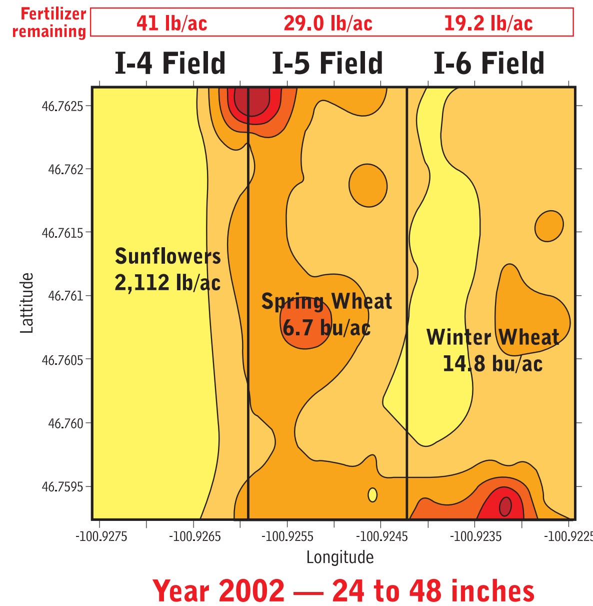


Figure 6. Soil Nitrogen I-4, I-5 and I-6 Fields

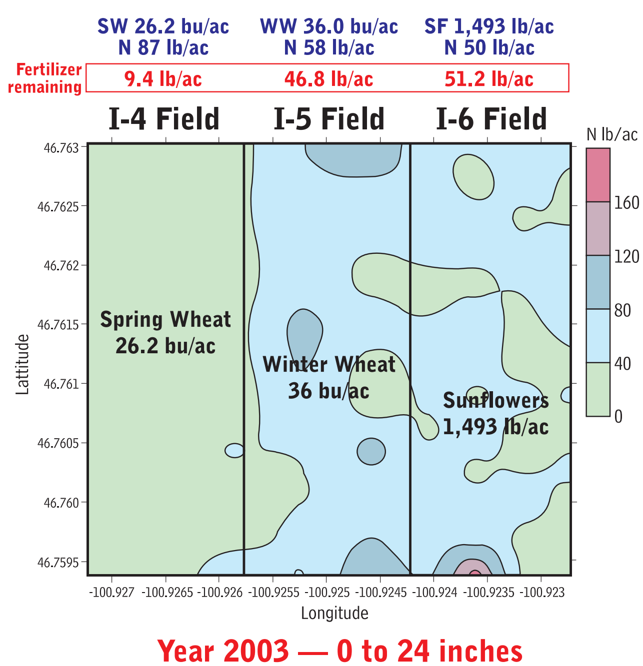


Figure 7. Soil Nitrogen I-4, I-5 and I-6 Fields (winter kill in winter wheat)

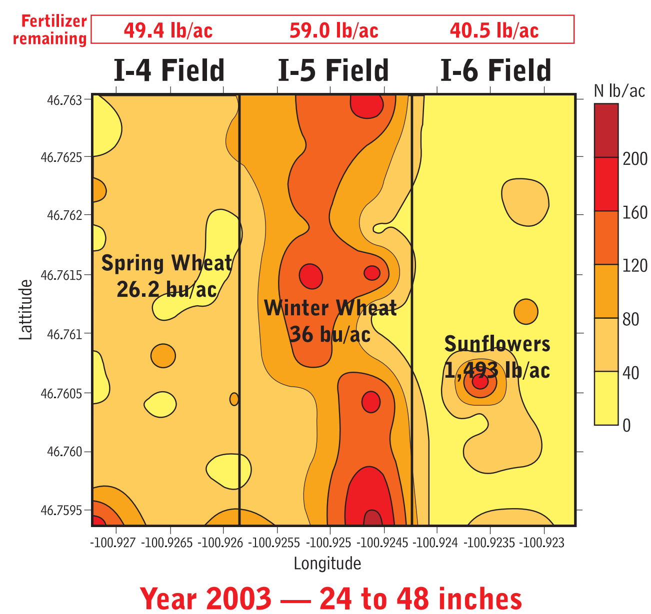
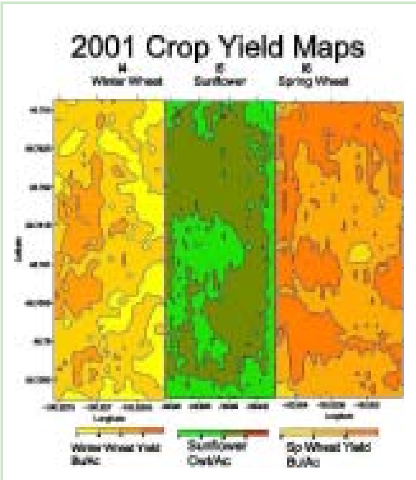
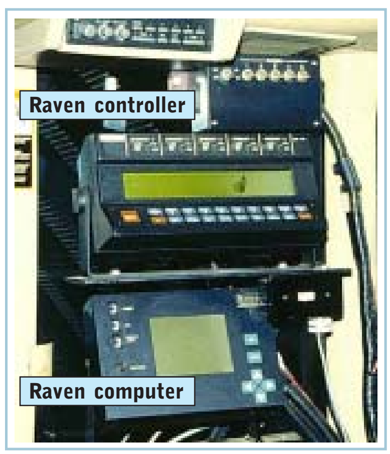


Figure 8. Soil Nitrogen I-4, I-5 and I-6 Fields



Crop yield map and yield monitor

Aerial photography helps show variation in fields



Air seeder and variable rate fertilizer applicator

Soil sampling to the six foot depth

For more information on this and other topics, see: www.ag.ndsu.edu

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