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ANALYSIS OF SOIL FERTILITY TESTING PROCEDURES USING UNIFORM, TOPOGRAPHICAL AND OTHER SITE-SPECIFIC METHODS

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Abstract

This study summarizes an analysis of uniform, topographical and other site-specific soil fertility testing procedures based on observations of various crops at various locations in North Dakota and one location in Minnesota for 2001 through 2004. Results showed little difference in economic returns among the soil fertility testing methods by crop or location.

Key Words: fertility, topography, soil testing, site-specific, North Dakota

ANALYSIS OF SOIL FERTILITY TESTING PROCEDURES USING UNIFORM, TOPOGRAPHICAL AND OTHER SITE-SPECIFIC METHODS

Ronald H. Haugen and Dwight G. Aakre[1]

Introduction

Accurate soil tests are important to help producers identify proper fertilizer rates. Farmers are concerned about accurate soil testing procedures so they may apply the proper amount of fertilizers. Underapplication would lead to reduced yield. Overapplication would lead to increased input cost. Both under and overapplication would lead to reduced economic returns. Also, farmers are concerned about environmental impacts of overapplying fertilizer, especially nitrogen, which would have a tendency to leach into ground water. This comparison of soil fertility testing methods evaluates the economic efficiency of different soil testing procedures. This study had two main objectives:

1. To calculate the differences in returns for each soil testing procedure.

2. To use statistical methods to determine if differences are significant for each soil testing procedure.

Analysis of environmental impact is beyond the scope of this study.

Background

Other studies have been conducted comparing uniform to site-specific soil testing procedures. In a study by Swinton, et al., the testing procedures show no gain in site-specific management. Lowenberg-DeBoer and Swinton developed a flow chart for farm-level economic analysis on the decision to adopt site-specific management technology. This flow chart is shown in Figure 1.

Definitions for the Figure 1 flow chart are as follows:

SSM is site-specific management.

PB is partial budget.

GM is gross margin.

ACC is added capital cost.

NRR is net revenue risk.

EB is environmental benefits.

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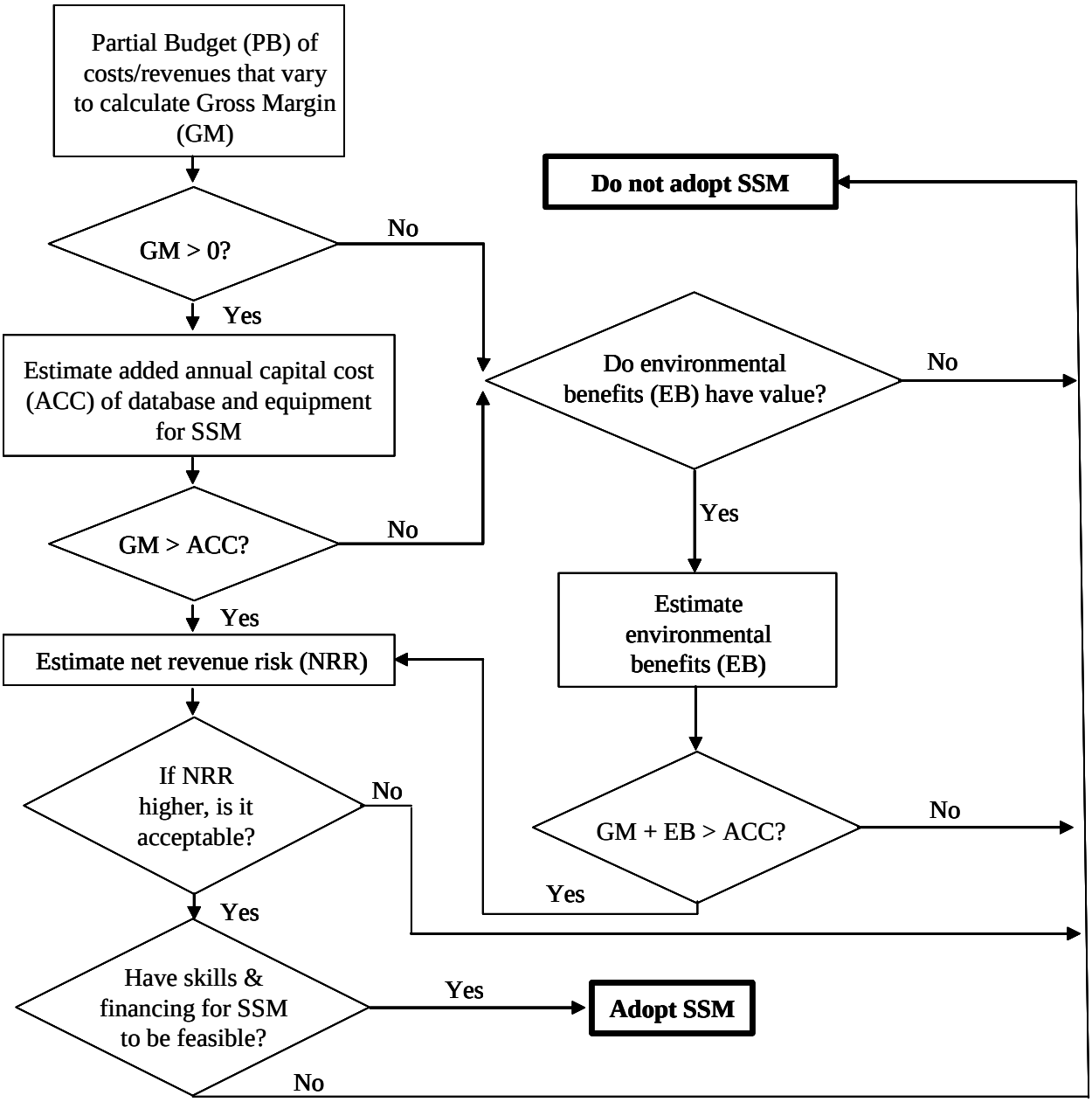

SOURCE: Lowenberg-DeBoer and Swinton.

Figure 1. Flow Chart of Economic Decision.

Overview of Soil Testing Procedures

This study analyzed five soil testing procedures, which are listed below:

1. Uniform
2. Topography
3. Topography with electro-conductivity
4. Topography with satellite imagery and electro-conductivity
5. Topography with yield map and electro-conductivity

The uniform treatment method was the check for the experiment. This is the conventional method for soil testing, using uniform fertilizer application rates for each grid sample.

The topography treatment method uses soil elevations to determine sample locations within a field.

The topography with electro-conductivity method uses soil elevations and electro-conductivity. Electro-conductivity measures soil conductivity of salts. Information from both of these items is used to determine soil sample zone locations.

The topography with satellite imagery and electro-conductivity method adds satellite imagery. This image shows field residue and wet areas by color. Information from all three of these items is used to determine soil sample zone locations.

The topography with yield map and electro-conductivity method adds a yield map of the field. The yield map overlays a yield history of the field. Information from all three of these items is used to determine soil sample zone locations.

Uniform sampling typically involves taking 20 to 30 core samples in a 160-acre field. These core samples are combined into a composite sample that is analyzed in a soil-testing laboratory. The site-specific soil testing methods typically involve taking 12 to 15 core samples in each topography zone. A 160-acre field usually has four to five zones. A soil-testing laboratory analyzes the composite sample for each zone.

Overview of Experiments

Experiments were completed in various locations with various crops in various years. Figure 2 shows the locations, crops and years for each of the experiments.

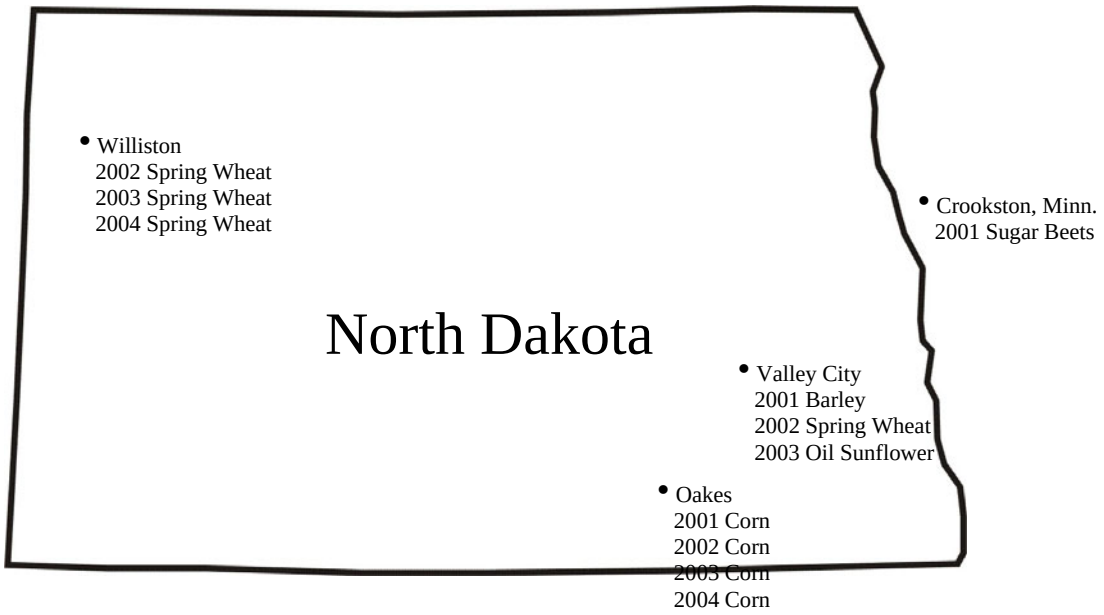

Figure 2. Map of Experiment Locations.

Tables 1 through 11 show the data collected from each experiment. The three treatments on sugar beets at Crookston were uniform, topography and topography with electro-conductivity. They are listed as treatments 1, 2 and 3, respectively. Only 2001 data was collected.

At the Oakes location, trials were conducted on corn in 2001, 2002, 2003 and 2004. Uniform, topography and topography with electro-conductivity treatments were used each year. They are listed as treatments 1, 2 and 3, respectively.

The Valley City location used barley in 2001, spring wheat in 2002 and oil sunflowers in 2003. Uniform, topography and topography with electro-conductivity were the treatments used in all three years. They are listed as treatments 1, 2 and 3, respectively.

The Williston location had spring wheat data for 2002, 2003 and 2004. Uniform, topography and topography with yield map and electro-conductivity treatments were used in each of the four years. They are listed as treatments 1, 2 and 3, respectively.

Definitions for Tables 1 though 11:

N Rate is the applied nitrogen rate in pounds.

Total Rev is yield times price.

N Cost is pounds of nitrogen applied times the nitrogen price.

Table 1. Crookston 2001 Sugar Beet Data.

Block	Treatment	Yield	Sugar %	N Rate	Total Rev	N Cost	Difference
3	1	11.2	14.9	54.0	308.92	11.88	297.04
3	2	11.8	15.5	65.0	356.98	14.30	342.68
3	3	6.6	14.2	41.0	161.49	9.02	152.47
4	1	17.3	16.5	54.0	600.35	11.88	588.47
4	2	22.6	16.2	98.0	754.11	21.56	732.55
4	3	22.6	17.1	86.0	844.62	18.92	825.70
5	1	15.1	16.6	54.0	530.73	11.88	518.85
5	2	15.0	16.1	98.0	493.84	21.56	472.28
5	3	22.0	16.8	86.0	792.83	18.92	773.91
6	1	13.0	15.0	54.0	364.36	11.88	352.48
6	2	10.8	15.3	65.0	317.12	14.30	302.82
6	3	11.8	14.7	98.0	314.97	21.56	293.41
7	1	11.8	14.8	54.0	320.22	11.88	308.34
7	2	16.7	15.4	65.0	497.79	14.30	483.49
7	3	19.5	15.8	56.0	615.96	12.32	603.64
8	1	18.4	15.8	54.0	581.21	11.88	569.33
8	2	18.4	16.2	68.0	613.96	14.96	599.00
8	3	18.7	15.3	56.0	549.08	12.32	536.76
9	1	18.6	16.5	54.0	645.47	11.88	633.59
9	2	16.5	16.6	98.0	579.93	21.56	558.37
9	3	22.6	16.2	86.0	754.11	18.92	735.19
10	1	17.1	16.0	54.0	555.37	11.88	543.49
10	2	20.7	16.5	68.0	718.34	14.96	703.38
10	3	21.5	16.1	63.0	707.83	13.86	693.97
11	1	14.5	15.9	54.0	464.47	11.88	452.59
11	2	15.8	16.1	65.0	520.18	14.30	505.88
11	3	17.7	16.4	90.0	606.36	19.80	586.56
12	1	15.8	15.1	54.0	449.87	11.88	437.99
12	2	10.7	15.1	68.0	304.66	14.96	289.70
12	3	14.4	13.6	86.0	313.88	18.92	294.96
13	1	15.8	15.8	54.0	499.08	11.88	487.20
13	2	11.6	14.9	68.0	319.96	14.96	305.00
13	3	18.6	16.6	86.0	653.74	18.92	634.82
14	1	23.5	16.0	54.0	763.22	11.88	751.34
14	2	23.1	15.8	68.0	729.67	14.96	714.71
14	3	21.5	16.6	77.0	755.67	16.94	738.73
15	1	22.4	16.6	54.0	787.30	11.88	775.42
15	2	21.5	16.4	68.0	736.54	14.96	721.58
15	3	23.0	16.1	51.0	757.22	11.22	746.00
16	1	18.1	16.0	54.0	587.84	11.88	575.96
16	2	22.0	16.3	46.0	743.88	10.12	733.76
16	3	23.7	16.2	86.0	790.81	18.92	771.89
17	1	22.9	14.0	54.0	539.92	11.88	528.04
17	2	21.8	15.8	68.0	688.61	14.96	673.65
17	3	24.5	15.8	58.0	773.89	12.76	761.13
18	1	22.5	15.5	54.0	680.68	11.88	668.80
18	2	21.0	15.3	68.0	616.61	14.96	601.65
18	3	22.6	15.9	58.0	723.93	12.76	711.17
19	1	21.0	16.2	54.0	700.72	11.88	688.84
19	2	21.6	15.7	46.0	672.68	10.12	662.56
19	3	22.4	16.0	56.0	727.50	12.32	715.18
20	1	21.4	15.5	54.0	647.40	11.88	635.52
20	2	19.7	16.4	46.0	674.87	10.12	664.75
20	3	21.3	16.6	54.0	748.64	11.88	736.76

Table 2. Oakes 2001 Corn Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	181.3	149.0	326.34	32.78	293.56
1	2	170.2	150.0	306.36	33.00	273.36
1	3	192.9	149.9	347.22	32.98	314.24
2	2	195.2	149.0	351.36	32.78	318.58
2	2	205.6	149.0	370.08	32.78	337.30
2	3	170.3	149.0	306.54	32.78	273.76
3	1	186.3	149.0	335.34	32.78	302.56
3	2	211.3	149.0	380.34	32.78	347.56
3	3	169.5	153.5	305.10	33.77	271.33
4	2	174.3	143.4	313.74	31.55	282.19
4	2	197.1	144.4	354.78	31.77	323.01
4	3	216.3	149.0	389.34	32.78	356.56
5	1	178.0	137.8	320.40	30.32	290.08
5	2	193.9	134.1	349.02	29.50	319.52
5	3	210.7	149.0	379.26	32.78	346.48
6	1	175.8	148.6	316.44	32.69	283.75
6	2	195.8	140.4	352.44	30.89	321.55
6	3	161.1	146.8	289.98	32.30	257.68
7	1	185.8	149.0	334.44	32.78	301.66
7	1	208.8	149.0	375.84	32.78	343.06
7	2	185.4	149.0	333.72	32.78	300.94
8	1	175.7	149.5	316.26	32.89	283.37
8	1	201.2	149.5	362.16	32.89	329.27
8	3	184.8	157.8	332.64	34.72	297.92
9	1	178.8	159.0	321.84	34.98	286.86
9	2	175.0	161.3	315.00	35.49	279.51
9	3	183.7	159.5	330.66	35.09	295.57
10	1	189.0	149.0	340.20	32.78	307.42
10	3	172.6	165.0	310.68	36.30	274.38
10	3	178.8	157.7	321.84	34.69	287.15
11	1	187.0	148.6	336.60	32.69	303.91
11	2	177.3	140.2	319.14	30.84	288.30
11	3	189.1	137.8	340.38	30.32	310.06
12	1	162.4	148.0	292.32	32.56	259.76
12	2	159.5	139.9	287.10	30.78	256.32
12	3	181.5	140.0	326.70	30.80	295.90
13	1	165.7	149.8	298.26	32.96	265.30
13	2	169.2	153.7	304.56	33.81	270.75
13	2	181.9	149.0	327.42	32.78	294.64
14	2	156.5	160.4	281.70	35.29	246.41
14	2	172.0	162.6	309.60	35.77	273.83
14	3	172.0	159.3	309.60	35.05	274.55
15	2	158.0	160.2	284.40	35.24	249.16
15	2	178.0	162.0	320.40	35.64	284.76
15	2	179.6	149.0	323.28	32.78	290.50
16	1	155.0	154.5	279.00	33.99	245.01
16	1	172.8	159.6	311.04	35.11	275.93
16	2	189.4	149.0	340.92	32.78	308.14
17	1	158.5	151.6	285.30	33.35	251.95
17	1	181.6	139.5	326.88	30.69	296.19
17	3	174.4	149.4	313.92	32.87	281.05
18	2	166.3	140.0	299.34	30.80	268.54
18	2	175.5	139.0	315.90	30.58	285.32
18	3	154.8	139.0	278.64	30.58	248.06

Table 3. Oakes 2002 Corn Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	151.5	167.8	272.70	36.92	235.78
1	2	148.0	167.0	266.40	36.74	229.66
1	3	176.5	164.6	317.70	36.21	281.49
2	1	174.0	167.8	313.20	36.92	276.28
2	2	177.9	167.8	320.22	36.92	283.30
2	3	153.6	159.5	276.48	35.09	241.39
3	1	120.6	167.8	217.08	36.92	180.16
3	2	145.5	167.8	261.90	36.92	224.98
3	3	163.9	167.9	295.02	36.94	258.08
4	1	174.4	167.8	313.92	36.92	277.00
4	2	176.2	166.9	317.16	36.72	280.44
4	3	180.5	188.4	324.90	41.45	283.45
5	1	167.4	167.8	301.32	36.92	264.40
5	2	169.0	163.5	304.20	35.97	268.23
5	3	175.7	192.8	316.26	42.42	273.84
6	1	158.8	167.8	285.84	36.92	248.92
6	2	162.2	166.0	291.96	36.52	255.44
6	3	158.0	176.6	284.40	38.85	245.55
7	1	167.8	167.8	302.04	36.92	265.12
7	2	177.2	167.8	318.96	36.92	282.04
7	3	158.3	192.2	284.94	42.28	242.66
8	1	152.5	167.8	274.50	36.92	237.58
8	2	168.2	167.8	302.76	36.92	265.84
8	3	178.9	155.5	322.02	34.21	287.81
9	1	162.8	167.8	293.04	36.92	256.12
9	2	156.2	167.0	281.16	36.74	244.42
9	3	157.8	167.7	284.04	36.89	247.15
10	1	161.6	167.8	290.88	36.92	253.96
10	2	176.0	167.1	316.80	36.76	280.04
10	3	171.2	164.0	308.16	36.08	272.08
11	1	171.1	167.8	307.98	36.92	271.06
11	2	166.0	164.9	298.80	36.28	262.52
11	3	157.6	192.8	283.68	42.42	241.26
12	1	157.1	167.8	282.78	36.92	245.86
12	2	159.4	167.8	286.92	36.92	250.00
12	3	158.2	179.8	284.76	39.56	245.20
13	1	164.6	167.8	296.28	36.92	259.36
13	2	173.5	167.8	312.30	36.92	275.38
13	3	161.8	167.7	291.24	36.89	254.35
14	1	164.6	167.8	296.28	36.92	259.36
14	2	157.0	166.8	282.60	36.70	245.90
14	3	152.8	152.4	275.04	33.53	241.51
15	1	160.2	167.8	288.36	36.92	251.44
15	2	158.6	167.0	285.48	36.74	248.74
15	3	156.0	159.4	280.80	35.07	245.73
16	1	149.6	167.8	269.28	36.92	232.36
16	2	139.7	167.0	251.46	36.74	214.72
16	3	168.6	154.3	303.48	33.95	269.53
17	1	146.7	167.8	264.06	36.92	227.14
17	2	174.4	167.8	313.92	36.92	277.00
17	3	164.6	176.5	296.28	38.83	257.45
18	1	169.8	167.8	305.64	36.92	268.72
18	2	150.0	167.8	270.00	36.92	233.08
18	3	133.0	179.8	239.40	39.56	199.84

Table 4. Oakes 2003 Corn Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	135.0	200.8	242.97	44.18	198.79
1	2	143.7	206.7	258.70	45.47	213.23
1	3	129.3	213.6	232.80	46.99	185.81
2	1	152.1	193.8	273.84	42.64	231.20
2	2	151.5	201.9	272.66	44.42	228.24
2	3	147.0	194.5	264.57	42.79	221.78
3	1	151.7	200.8	272.99	44.18	228.81
3	2	152.1	199.3	273.72	43.85	229.87
3	3	153.5	204.9	276.36	45.08	231.28
4	1	149.3	200.8	268.71	44.18	224.53
4	2	152.1	206.6	273.78	45.45	228.33
4	3	146.4	236.8	263.56	52.10	211.46
5	1	148.7	200.8	267.67	44.18	223.49
5	2	153.2	210.3	275.81	46.27	229.54
5	3	149.6	230.9	269.32	50.80	218.52
6	1	145.4	200.8	261.78	44.18	217.60
6	2	155.8	209.7	280.40	46.13	234.27
6	3	142.3	236.8	256.06	52.10	203.96
7	1	136.3	200.8	245.25	44.18	201.07
7	2	143.6	207.8	258.53	45.72	212.81
7	3	136.0	217.5	244.77	47.85	196.92
8	1	149.1	200.8	268.39	44.18	224.21
8	2	144.8	197.9	260.55	43.54	217.01
8	3	150.3	193.0	270.57	42.46	228.11
9	1	153.4	200.8	276.15	44.18	231.97
9	2	154.7	203.4	278.46	44.75	233.71
9	3	153.6	181.3	276.52	39.89	236.63
10	1	152.3	200.8	274.07	44.18	229.89
10	2	152.4	206.7	274.30	45.47	228.83
10	3	155.3	216.3	279.49	47.59	231.90
11	1	153.7	200.8	276.69	44.18	232.51
11	2	153.6	209.2	276.49	46.02	230.47
11	3	154.0	236.8	277.19	52.10	225.09
12	1	152.1	200.8	273.86	44.18	229.68
12	2	150.0	207.3	270.05	45.61	224.44
12	3	145.5	236.8	261.84	52.10	209.74
13	1	155.3	200.8	279.47	44.18	235.29
13	2	152.7	201.8	274.89	44.40	230.49
13	3	156.1	188.2	280.92	41.40	239.52
14	1	158.2	200.8	284.76	44.18	240.58
14	2	160.0	195.6	287.92	43.03	244.89
14	3	158.2	169.1	284.82	37.20	247.62
15	1	159.3	200.8	286.70	44.18	242.52
15	2	154.6	194.9	278.19	42.88	235.31
15	3	153.3	169.0	275.87	37.18	238.69
16	1	155.4	200.8	279.76	44.18	235.58
16	2	158.8	195.8	285.89	43.08	242.81
16	3	156.7	172.3	282.03	37.91	244.12
17	1	154.9	200.8	278.81	44.18	234.63
17	2	155.8	207.1	280.48	45.56	234.92
17	3	155.4	218.1	279.71	47.98	231.73
18	1	149.7	200.8	269.44	44.18	225.26
18	2	149.9	207.8	269.78	45.72	224.06
18	3	148.2	236.8	266.72	52.10	214.62
19	1	149.6	200.8	269.21	44.18	225.03
19	2	156.2	193.8	281.14	42.64	238.50
19	3	128.5	182.6	231.33	40.17	191.16
20	1	155.3	200.8	279.59	44.18	235.41
20	2	145.6	195.3	262.08	42.97	219.11
20	3	154.1	236.8	277.45	52.10	225.35

Table 5. Oakes 2004 Corn Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	139.5	190.8	251.10	41.98	209.12
1	2	144.0	209.9	259.20	46.18	213.02
1	3	150.7	204.6	271.26	45.01	226.25
2	1	139.9	190.8	251.82	41.98	209.84
2	2	146.2	197.4	263.16	43.43	219.73
2	3	136.9	203.5	246.42	44.77	201.65
3	1	134.8	190.8	242.64	41.98	200.66
3	2	143.7	191.1	258.66	42.04	216.62
3	3	139.6	210.4	251.28	46.29	204.99
4	1	139.5	190.8	251.10	41.98	209.12
4	2	146.4	209.2	263.52	46.02	217.50
4	3	152.2	227.5	273.96	50.05	223.91
5	1	134.4	190.8	241.92	41.98	199.94
5	2	145.2	211.6	261.36	46.54	214.82
5	3	142.0	220.8	255.60	48.58	207.02
6	1	123.0	190.8	221.40	41.98	179.42
6	2	128.0	212.0	230.40	46.64	183.76
6	3	117.4	228.3	211.32	50.23	161.09
7	1	149.7	190.8	269.46	41.98	227.48
7	2	144.7	212.8	260.46	46.82	213.64
7	3	148.9	208.8	268.02	45.94	222.08
8	1	133.3	190.8	239.94	41.98	197.96
8	2	134.0	187.7	241.20	41.29	199.91
8	3	147.3	196.5	265.14	43.23	221.91
9	1	138.0	190.8	248.40	41.98	206.42
9	2	135.1	199.8	243.18	43.96	199.22
9	3	132.9	188.5	239.22	41.47	197.75
10	1	136.2	190.8	245.16	41.98	203.18
10	2	145.8	209.3	262.44	46.05	216.39
10	3	137.2	203.0	246.96	44.66	202.30
11	1	131.7	190.8	237.06	41.98	195.08
11	2	139.2	209.0	250.56	45.98	204.58
11	3	132.5	228.7	238.50	50.31	188.19
12	1	113.7	190.8	204.66	41.98	162.68
12	2	120.6	211.3	217.08	46.49	170.59
12	3	133.5	232.8	240.30	51.22	189.08
13	1	140.5	190.8	252.90	41.98	210.92
13	2	140.7	199.4	253.26	43.87	209.39
13	3	134.8	193.0	242.64	42.46	200.18
14	1	136.8	190.8	246.24	41.98	204.26
14	2	133.3	181.0	239.94	39.82	200.12
14	3	128.8	176.4	231.84	38.81	193.03
15	1	128.6	190.8	231.48	41.98	189.50
15	2	118.2	179.4	212.76	39.47	173.29
15	3	127.1	180.0	228.78	39.60	189.18
16	1	132.9	190.8	239.22	41.98	197.24
16	2	129.2	181.2	232.56	39.86	192.70
16	3	134.1	185.7	241.38	40.85	200.53
17	1	125.1	190.8	225.18	41.98	183.20
17	2	133.2	210.6	239.76	46.33	193.43
17	3	121.2	200.4	218.16	44.09	174.07
18	1	129.6	190.8	233.28	41.98	191.30
18	2	115.4	212.8	207.72	46.82	160.90
18	3	114.7	208.8	206.46	45.94	160.52
19	1	130.4	190.8	234.72	41.98	192.74
19	2	127.1	176.8	228.78	38.90	189.88
19	3	150.7	193.0	271.26	42.46	228.80
20	1	125.7	190.8	226.26	41.98	184.28
20	2	132.4	180.4	238.32	39.69	198.63
20	3	119.0	226.4	214.20	49.81	164.39

Table 6. Valley City 2001 Barley Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	69.4	45.0	138.80	9.90	128.90
1	2	52.1	0.0	104.20	0.00	104.20
1	3	51.0	45.0	102.00	9.90	92.10
2	1	59.0	45.0	118.00	9.90	108.10
2	2	45.1	54.0	90.20	11.88	78.32
2	3	43.0	45.0	86.00	9.90	76.10
3	1	56.0	45.0	112.00	9.90	102.10
3	2	60.1	54.0	120.20	11.88	108.32
3	3	53.0	45.0	106.00	9.90	96.10
4	1	60.2	45.0	120.40	9.90	110.50
4	2	52.7	54.0	105.40	11.88	93.52
4	3	51.1	45.0	102.20	9.90	92.30
5	1	74.9	45.0	149.80	9.90	139.90
5	2	71.0	45.0	142.00	9.90	132.10
5	3	75.7	45.0	151.40	9.90	141.50
6	1	75.6	45.0	151.20	9.90	141.30
6	2	77.2	40.0	154.40	8.80	145.60
6	3	70.5	45.0	141.00	9.90	131.10
7	1	58.1	45.0	116.20	9.90	106.30
7	2	59.2	0.0	118.40	0.00	118.40
7	3	65.4	45.0	130.80	9.90	120.90
8	1	53.1	45.0	106.20	9.90	96.30
8	2	61.8	54.0	123.60	11.88	111.72
8	3	53.3	45.0	106.60	9.90	96.70
9	1	61.7	45.0	123.40	9.90	113.50
9	2	64.0	54.0	128.00	11.88	116.12
9	3	63.4	45.0	126.80	9.90	116.90
10	1	61.7	45.0	123.40	9.90	113.50
10	2	59.3	54.0	118.60	11.88	106.72
10	3	62.2	45.0	124.40	9.90	114.50
11	1	80.3	45.0	160.60	9.90	150.70
11	2	75.0	54.0	150.00	11.88	138.12
11	3	82.0	45.0	164.00	9.90	154.10
12	1	72.2	45.0	144.40	9.90	134.50
12	2	81.7	54.0	163.40	11.88	151.52
12	3	82.6	45.0	165.20	9.90	155.30
13	1	56.2	45.0	112.40	9.90	102.50
13	2	53.1	0.0	106.20	0.00	106.20
13	3	59.6	45.0	119.20	9.90	109.30
14	1	48.8	45.0	97.60	9.90	87.70
14	2	35.7	54.0	71.40	11.88	59.52
14	3	45.7	45.0	91.40	9.90	81.50
15	1	62.8	45.0	125.60	9.90	115.70
15	2	62.7	54.0	125.40	11.88	113.52
15	3	37.3	45.0	74.60	9.90	64.70
16	1	64.9	45.0	129.80	9.90	119.90
16	2	66.6	54.0	133.20	11.88	121.32
16	3	62.8	45.0	125.60	9.90	115.70
17	1	68.4	45.0	136.80	9.90	126.90
17	2	64.6	54.0	129.20	11.88	117.32
17	3	63.3	45.0	126.60	9.90	116.70
18	1	74.7	45.0	149.40	9.90	139.50
18	2	61.0	54.0	122.00	11.88	110.12
18	3	75.3	45.0	150.60	9.90	140.70

Table 7. Valley City 2002 Spring Wheat Data.

Block	Treatment	Yield	Protein	TW	N Rate	Total Rev	N Cost	Difference
1	1	23.2	14.2	55.3	59.0	79.95	12.98	66.97
1	2	24.6	13.9	56.3	74.0	83.79	16.28	67.51
1	3	18.6	17.8	51.8	74.0	76.19	16.28	59.91
2	1	24.8	16.2	54.4	59.0	94.93	12.98	81.95
2	2	23.4	15.6	53.3	62.0	86.25	13.64	72.61
2	3	23.5	16.4	53.9	64.0	90.66	14.08	76.58
3	1	31.5	16.5	55.0	59.0	122.85	12.98	109.87
3	2	28.1	15.7	53.9	57.0	104.48	12.54	91.94
3	3	30.0	16.2	53.8	50.0	114.48	11.00	103.48
4	1	29.8	16.2	55.7	59.0	114.85	12.98	101.87
4	2	30.0	16.8	52.9	47.0	117.54	10.34	107.20
4	3	31.3	15.5	55.0	52.0	115.81	11.44	104.37
5	1	26.7	16.2	54.6	59.0	102.31	12.98	89.33
5	2	28.2	16.0	53.3	56.0	106.20	12.32	93.88
5	3	27.0	17.0	54.4	52.0	107.68	11.44	96.24
6	1	26.2	15.1	53.6	59.0	94.11	12.98	81.13
6	2	31.3	15.8	54.5	52.0	117.38	11.44	105.94
6	3	31.9	16.1	52.7	53.0	120.39	11.66	108.73
7	1	24.7	14.7	54.2	59.0	87.04	12.98	74.06
7	2	31.2	16.2	54.2	52.0	119.31	11.44	107.87
7	3	32.0	16.4	55.0	46.0	124.16	10.12	114.04
8	1	30.0	16.1	52.1	59.0	112.86	12.98	99.88
8	2	29.4	15.9	53.3	52.0	110.13	11.44	98.69
8	3	24.0	17.0	53.8	58.0	95.42	12.76	82.66
9	1	28.6	15.9	53.6	59.0	107.31	12.98	94.33
9	2	28.5	15.3	52.7	56.0	103.00	12.32	90.68
9	3	29.6	15.8	54.5	52.0	111.00	11.44	99.56

Table 8. Valley City 2003 Oil Sunflower Data.

Block	Treatment	Yield	Oil %	N Rate	Total Rev	N Cost	Difference
1	1	1765.0	48.1	43.0	205.09	9.46	195.63
1	2	1942.0	46.1	25.0	217.89	5.50	212.39
1	3	2162.0	47.3	55.0	247.77	12.10	235.67
2	1	2226.0	49.0	45.0	262.67	9.90	252.77
2	2	2069.0	46.7	20.0	234.62	4.40	230.22
2	2	2130.0	45.3	43.0	235.58	9.46	226.12
3	1	2254.0	47.8	30.0	260.56	6.60	253.96
3	2	2045.0	47.8	50.0	236.40	11.00	225.40
3	3	1875.0	43.7	43.0	201.38	9.46	191.92
4	1	2287.0	45.5	43.0	253.86	9.46	244.40
4	2	2335.0	46.3	20.0	262.92	4.40	258.52
4	3	2437.0	45.7	50.0	271.48	11.00	260.48
5	1	2335.0	46.2	43.0	262.45	9.46	252.99
5	2	2277.0	47.5	50.0	261.86	11.00	250.86
5	3	2326.0	46.1	45.0	260.98	9.90	251.08
6	1	2210.0	44.8	43.0	242.22	9.46	232.76
6	2	2214.0	47.0	35.0	252.40	7.70	244.70
6	3	2404.0	48.0	50.0	278.86	11.00	267.86
7	1	2312.0	47.0	43.0	263.57	9.46	254.11
7	2	2374.0	46.0	50.0	265.89	11.00	254.89
7	3	2436.0	47.0	30.0	277.70	6.60	271.10
8	1	2434.0	44.2	50.0	263.85	11.00	252.85
8	3	2197.0	46.6	40.0	248.70	8.80	239.90
8	3	2603.0	46.3	43.0	293.10	9.46	283.64
9	1	2361.0	51.1	55.0	288.51	12.10	276.41
9	2	2284.0	46.3	43.0	257.18	9.46	247.72
9	3	2227.0	45.7	40.0	248.09	8.80	239.29

Table 9. Williston 2002 Spring Wheat Data.

Block	Treatment	Yield	Protein	N Rate	Total Rev	N Cost	Difference
1	1	19.8	13.8	59.0	68.51	12.98	55.53
1	2	20.2	14.4	59.0	72.32	12.98	59.34
1	3	21.9	14.4	69.0	78.40	15.18	63.22
2	1	23.1	13.9	59.0	80.39	12.98	67.41
2	2	22.6	13.8	59.0	78.20	12.98	65.22
2	3	21.9	13.8	72.0	75.77	15.84	59.93
3	1	23.5	13.6	59.0	80.37	12.98	67.39
3	2	20.6	13.6	59.0	70.45	12.98	57.47
3	3	23.0	13.8	68.0	79.58	14.96	64.62
4	1	16.3	14.4	59.0	58.35	12.98	45.37
4	2	21.6	13.1	59.0	71.71	12.98	58.73
4	3	19.1	14.0	68.0	66.85	14.96	51.89
5	1	16.9	13.4	59.0	57.12	12.98	44.14
5	2	16.8	13.3	59.0	56.45	12.98	43.47
5	3	17.1	14.4	72.0	61.22	15.84	45.38
6	1	19.9	15.1	59.0	74.03	12.98	61.05
6	2	24.0	13.8	59.0	83.04	12.98	70.06
6	3	20.8	13.6	59.0	71.14	12.98	58.16
7	1	23.7	13.4	59.0	80.11	12.98	67.13
7	2	20.2	13.4	59.0	68.28	12.98	55.30
7	3	21.4	13.8	72.0	74.04	15.84	58.20
8	1	18.4	14.5	59.0	66.24	12.98	53.26
8	2	16.4	14.4	59.0	58.71	12.98	45.73
8	3	18.9	14.6	57.0	68.42	12.54	55.88
9	1	20.1	14.0	59.0	70.35	12.98	57.37
9	2	18.8	14.4	59.0	67.30	12.98	54.32
9	3	20.9	14.6	57.0	75.66	12.54	63.12
10	1	21.9	13.8	59.0	75.77	12.98	62.79
10	2	20.7	14.0	59.0	72.45	12.98	59.47
10	3	24.4	13.6	57.0	83.45	12.54	70.91
11	1	20.0	14.1	59.0	70.40	12.98	57.42
11	2	19.1	14.1	59.0	67.23	12.98	54.25
11	3	19.3	13.8	54.0	66.78	11.88	54.90
12	1	17.5	13.7	59.0	60.20	12.98	47.22
12	2	21.4	14.0	59.0	74.90	12.98	61.92
12	3	18.1	13.9	62.0	62.99	13.64	49.35
13	1	22.8	13.7	59.0	78.43	12.98	65.45
13	2	24.1	13.5	59.0	81.94	12.98	68.96
13	3	22.6	13.3	65.0	75.94	14.30	61.64
14	1	25.5	13.4	59.0	86.19	12.98	73.21
14	2	25.3	13.5	59.0	86.02	12.98	73.04
14	3	21.0	14.0	67.0	73.50	14.74	58.76
15	1	19.8	14.0	59.0	69.30	12.98	56.32
15	2	20.8	13.7	59.0	71.55	12.98	58.57
15	3	22.8	13.6	58.0	77.98	12.76	65.22

Table 10. Williston 2003 Spring Wheat Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	28.3	45.0	99.05	9.90	89.15
1	2	23.5	45.0	82.25	9.90	72.35
1	3	26.4	40.0	92.40	8.80	83.60
2	1	28.5	45.0	99.75	9.90	89.85
2	2	29.4	45.0	102.90	9.90	93.00
2	3	29.1	35.0	101.85	7.70	94.15
3	1	27.3	45.0	95.55	9.90	85.65
3	2	28.3	45.0	99.05	9.90	89.15
3	3	28.9	40.0	101.15	8.80	92.35
4	1	26.1	45.0	91.35	9.90	81.45
4	2	25.8	45.0	90.30	9.90	80.40
4	3	25.0	40.0	87.50	8.80	78.70
5	1	26.7	45.0	93.45	9.90	83.55
5	2	26.1	30.0	91.35	6.60	84.75
5	3	26.1	50.0	91.35	11.00	80.35
6	1	24.9	45.0	87.15	9.90	77.25
6	2	26.4	45.0	92.40	9.90	82.50
6	3	27.2	35.0	95.20	7.70	87.50
7	1	28.3	45.0	99.05	9.90	89.15
7	2	29.6	41.0	103.60	9.02	94.58
7	3	29.3	35.0	102.55	7.70	94.85
8	1	27.1	45.0	94.85	9.90	84.95
8	2	23.2	33.0	81.20	7.26	73.94
8	3	23.8	35.0	83.30	7.70	75.60
9	1	26.6	45.0	93.10	9.90	83.20
9	2	24.4	36.0	85.40	7.92	77.48
9	3	23.3	35.0	81.55	7.70	73.85
10	1	27.2	45.0	95.20	9.90	85.30
10	2	28.7	45.0	100.45	9.90	90.55
10	3	28.5	40.0	99.75	8.80	90.95
11	1	25.1	45.0	87.85	9.90	77.95
11	2	26.5	37.0	92.75	8.14	84.61
11	3	25.6	50.0	89.60	11.00	78.60
12	1	26.0	45.0	91.00	9.90	81.10
12	2	30.2	41.0	105.70	9.02	96.68
12	3	26.1	35.0	91.35	7.70	83.65
13	1	31.7	45.0	110.95	9.90	101.05
13	2	32.0	60.0	112.00	13.20	98.80
13	3	30.6	35.0	107.10	7.70	99.40
14	1	31.9	45.0	111.65	9.90	101.75
14	2	30.5	60.0	106.75	13.20	93.55
14	3	27.3	35.0	95.55	7.70	87.85
15	1	27.4	45.0	95.90	9.90	86.00
15	2	27.4	60.0	95.90	13.20	82.70
15	3	27.2	50.0	95.20	11.00	84.20

Table 11. Williston 2004 Spring Wheat Data.

Block	Treatment	Yield	N Rate	Total Rev	N Cost	Difference
1	1	35.4	55.0	123.90	12.10	111.80
1	2	35.2	55.0	123.20	12.10	111.10
1	3	34.8	56.0	121.80	12.32	109.48
2	1	38.1	55.0	133.35	12.10	121.25
2	2	41.8	55.0	146.30	12.10	134.20
2	3	42.2	49.0	147.70	10.78	136.92
3	1	40.8	55.0	142.80	12.10	130.70
3	2	41.6	55.0	145.60	12.10	133.50
3	3	42.4	56.0	148.40	12.32	136.08
4	1	35.9	55.0	125.65	12.10	113.55
4	2	37.7	55.0	131.95	12.10	119.85
4	3	36.8	56.0	128.80	12.32	116.48
5	1	36.7	55.0	128.45	12.10	116.35
5	2	35.3	54.0	123.55	11.88	111.67
5	3	32.0	70.0	112.00	15.40	96.60
6	1	33.1	55.0	115.85	12.10	103.75
6	2	36.2	55.0	126.70	12.10	114.60
6	3	37.6	49.0	131.60	10.78	120.82
7	1	39.2	55.0	137.20	12.10	125.10
7	2	39.0	54.0	136.50	11.88	124.62
7	3	39.7	49.0	138.95	10.78	128.17
8	1	38.6	55.0	135.10	12.10	123.00
8	2	37.1	55.0	129.85	12.10	117.75
8	3	36.2	49.0	126.70	10.78	115.92
9	1	35.0	49.0	122.50	10.78	111.72
9	2	36.9	55.0	129.15	12.10	117.05
9	3	33.9	54.0	118.65	11.88	106.77
10	1	38.9	55.0	136.15	12.10	124.05
10	2	39.9	57.0	139.65	12.54	127.11
10	3	38.6	56.0	135.10	12.32	122.78
11	1	38.4	55.0	134.40	12.10	122.30
11	2	38.1	50.0	133.35	11.00	122.35
11	3	37.2	70.0	130.20	15.40	114.80
12	1	37.7	55.0	131.95	12.10	119.85
12	2	42.1	54.0	147.35	11.88	135.47
12	3	37.5	49.0	131.25	10.78	120.47
13	1	41.5	55.0	145.25	12.10	133.15
13	2	42.6	60.0	149.10	13.20	135.90
13	3	40.5	49.0	141.75	10.78	130.97
14	1	40.2	55.0	140.70	12.10	128.60
14	2	39.6	60.0	138.60	13.20	125.40
14	3	38.7	49.0	135.45	10.78	124.67
15	1	36.7	55.0	128.45	12.10	116.35
15	2	39.5	60.0	138.25	13.20	125.05
15	3	34.7	70.0	121.45	15.40	106.05

Methodology

The methodology estimated marginal returns for each crop and location and determined statistical significance for each. Returns above nitrogen cost equal total revenue less nitrogen cost. Total revenue is yield times price for each observation. Nitrogen cost is nitrogen applied (in pounds) times nitrogen price. Table 12 shows crop price and nitrogen cost assumptions. Only nitrogen fertilizer is analyzed in this study. The marginal returns (differences in the returns above nitrogen price) are analyzed. The additional costs associated with variable-rate application and site-specific sampling are not included in the marginal returns. Therefore, the marginal returns must increase enough to cover these additional costs.

Table 12. Crop Price and Nitrogen Cost Assumptions.

Crop	Crop Base Price (dollars)	Nitrogen Cost (dollars)
Barley	2.00 per bushel	0.22 per pound
Corn	2.00 per bushel	0.22 per pound
Oil Sunflowers	0.10 per pound	0.22 per pound
Spring Wheat	3.50 per bushel	0.22 per pound
Sugar Beets	39.82 per ton	0.22 per pound

The study assumes a malting barley price because all observations were less than 13.5 percent protein and greater than 70 percent plump, which are the minimum requirements for malting barley grade. The study calculated the spring wheat price at plus or minus 4 cents per bushel per fifth of protein percentage above or below 14 percent protein from the base price. Also, the study adjusted the spring wheat price plus or minus 2 cents per pound above or below a test weight of 60 pounds from the base price. The study adjusted the oil sunflower price plus or minus 2 percent of base price above or below 40 percent oil content. All observations were above 40 percent oil content. The sugar beet price is calculated using the sugar formula for the 2004 crop year from American Crystal Sugar Co. (Dan Bernhardson, American Crystal Sugar Co., Moorhead, Minn., Personal Communications). The base price is adjusted plus or minus $4.45 per percentage point above or below 17.65 percent sugar content.

Treatment Costs

Table 13 shows the fertilizer treatment costs. A $3-per-acre charge is included for any variable-rate fertilizer application. This would be in addition to the normal custom fertilizer application charge of $4 per acre. Table 14 shows the supplemental treatment information.

Table 14 supplemental treatment information definitions:

Veris is the brand name of electro-conductivity test equipment commonly used.

RTK is common farmer-owned topography equipment.

EC is electro-conductivity

Table 13. Treatment Costs.

Treatment	One-time Charge Per Acre	Per Acre Per Year Charges	Soil Sampling Charge (including lab fees)
Uniform	0	0	$0.75
Topography	$8.00	$3.00	$2.50
Topography with EC	$11.00	$3.00	$2.50
Topography with satellite imagery and EC	$16.00	$3.00	$2.50
Topography with yield mapping and EC	$14.00	$3.00	$2.50
Satellite imagery	$0.50 per acre per year	$3.00	$2.50

SOURCE: Dave Franzen, NDSU Soil Science Department

Table 14. Supplemental Treatment Information.

Treatment	One-time Charge Per Acre	Per Acre Per Year Charges	Soil Sampling Charge (including lab fees)
Farmer-owned RTK Topography	$4.00	$3.00	$2.50
Farmer-owned Veris for EC	$2.00	$3.00	$2.50
Veris custom charge	$4.00	$3.00	$2.50
Sugar Beet Satellite Imagery	$1.50 per acre each year	$3.00	$2.50

SOURCE: Dave Franzen, NDSU Soil Science Department

Marginal revenue (yield response times price) must be greater than the marginal cost of site-specific fertilizer application, which includes technology costs and soil sampling costs plus or minus fertilizer input costs. All these factors must be considered when making the technology investment.

Results

This study used analysis of variance (ANOVA) to determine if soil fertility testing procedures showed any significant difference in returns. The null and alternative hypothesis are shown below:

Null hypothesis: $H_o : \mu = 0$

Alternative hypothesis: $H_a : \mu \neq 0$

Where μ = the mean difference for each value

Table 15 shows the means for each experiment.

Table 15. Experiment Means.

Experiment	Means
Crookston 2001 Sugar Beets	594.0209
Oakes 2001 Corn	288.8655
Oakes 2002 Corn	255.2864
Oakes 2003 Corn	227.3872
Oakes 2004 Corn	195.7676
Valley City 2001 Barley	117.7709
Valley City 2002 Spring Wheat	96.97588
Valley City 2003 Oil Sunflowers	255.2447
Williston 2002 Spring Wheat	58.35971
Williston 2003 Spring Wheat	85.92257
Williston 2004 Spring Wheat	120.1583

The study ran the model using 2001, 2002, 2003 and 2004 data for each crop in each location. The analysis used SAS (SAS Institute Inc.) software. The study used an F-test with an alpha of 0.05. This would be at the 95 percent significance level. Table 16 shows the statistical values for each experiment. The study analyzed differences separately for each location and crop.

Table 16. Statistical Values.

Experiment	F Value	p Value	R-Square
Crookston 2001 Sugar Beets	0.98	0.3853	0.045455
Oakes 2001 Corn	0.29	0.7472	0.014117
Oakes 2002 Corn	0.44	0.6491	0.020859
Oakes 2003 Corn	1.49	0.2359	0.059616
Oakes 2004 Corn	0.02	0.9839	0000689
Valley City 2001 Barley	0.16	0.8495	0.007925
Valley City 2002 Spring Wheat	3.25	0.0691	0.317336
Valley City 2003 Oil Sunflowers	0.48	06275	0.064411
Williston 2002 Spring Wheat	0.04	0.9566	0.002771
Williston 2003 Spring Wheat	0.24	0.7845	0.015057
Williston 2004 Spring Wheat	1.48	0.2436	0.084447

The study conducted statistical analysis on the locations with the same crop in different years. The Oakes location had corn for 2001, 2002, 2003 and 2004. The Oakes analysis by treatment was not significant. The Oakes analysis by year was significant; however, this difference can not be attributed to soil fertility testing procedures. Table 17 shows the combined statistical results.

Table 17. Oakes Combined Statistical Results.

Variable	F Value	p Value
Treatment	0.11	0.8932
Year	195.14	<0.0001

The Williston location had spring wheat for 2002, 2003 and 2004. The Williston analysis by treatment was not significant. The Williston analysis by year was significant; however, this difference can not be attributed to soil testing procedures. The Williston experiment had balanced data with the same number of observations each year. Table 18 shows the combined statistical results.

Table 18. Williston Combined Statistical Results.

Variable	F Value	p Value
Treatment	1.26	0.2889
Year	503.10	<0.0001

The results indicated that no significant difference existed in marginal returns by fertilizer treatment on any crop at any location. Because of the nonsignificance, comparing marginal differences and analyzing the data in more detail would be statistically meaningless.

Conclusions

The results suggest that paying more for advanced soil testing procedures may be difficult. The statistical conclusion shows no significant differences compared with uniform sampling and application. One would speculate that a high-value crop such as sugar beets might show more benefits in adopting advanced technology than a low-value crop such as spring wheat.

The first objective of this study was accomplished. The marginal differences were calculated for each soil fertility testing procedure for each crop at each location. The second objective also was achieved. Statistical analysis determined no significant differences in fertilizer treatment methods.

The study may be limiting because of a small data set. More data would be helpful. Also, the results are dependent on the accuracy of the data. More observations for the same crop in the various locations, using consistent data collection techniques, would improve the analysis.

This analysis was based on only four years of data. Data for future years when available could be used to update the findings. The model also could be refined for technology advances in global positioning systems and satellite imaging.

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