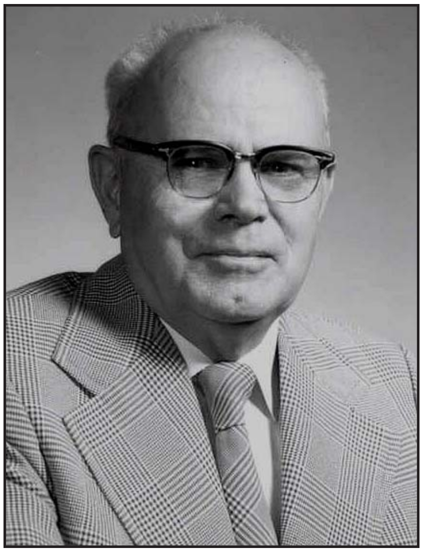


Foreword

The Illinois Grid Sampling Project began in 1961 with soil testing in a 5-rod grid in two fields. One field, the Mansfield site, continued to be sampled periodically for more than 40 years. The other site, near Urbana, was sampled only once. The initial sampling was the product of two University of Illinois scientists working together to achieve the common goal of improving the use of soil testing for soil pH (acidity), phosphorus (P) and potassium (K). The two soil scientists were Sigurd Melsted and Ted Peck.

When I entered graduate school at the University of Illinois in 1975, Melsted was still on the faculty. Ironically, Melsted was born and raised in North Dakota in a town named Gardar, about 20 miles northwest of Park River, N.D., in the southwestern corner of Pembina County. Gardar and the surrounding farms at the date of his birth in 1911 were settled by a combination of Icelandic and Norwegian immigrants, and the area remains populated by their descendents today. Melsted graduated from North Dakota State Agricultural College (now North Dakota State University) in 1938. He received his M.S. degree from Rutgers and then his Ph.D. from the University of Illinois in 1943. In 1943, he entered the U.S. Army and, with his unit in the U.S. Third Army, landed on Omaha Beach on D-Day. He remained in Europe until being sent to the Pacific in preparation for the assault on Japan, and was in the Philippines when the war ended.

Melsted entered the faculty of the University of Illinois after the war and was highly regarded for his work on establishing critical levels in plant and soil analysis, and the identification of nutrient deficiency symptoms. He was a pioneer in the use of nitrogen fertilizers for corn and used a systems approach for incorporating fertilizers into the cropping systems of the day. He was one of the first to use N-15 isotopes to follow nitrogen fate in the soil, leading to advances in our knowledge about denitrification.

He also extended his work to include the use of municipal wastes and reclamation of strip-mined farmland. He retired in 1977 and returned to North Dakota to work with strip-mine reclamation of land out of the North Dakota State University Mine Reclamation Center in Mandan, N.D. I remember him as a graduate student attending faculty and graduate student seminars. He spoke with a deep, Scandinavian accent, which commanded attention and respect.

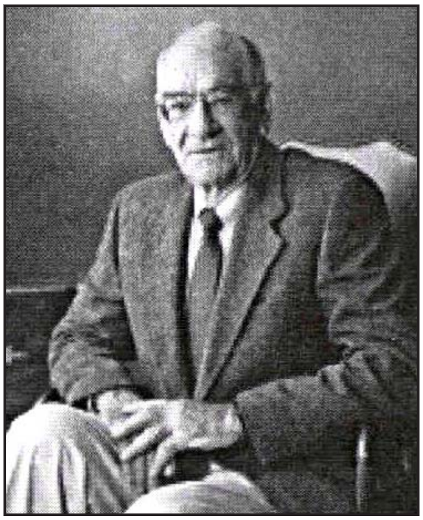
Throughout his life, he maintained close ties to his heritage. He helped finance restoration of the Gardar Pioneer Lutheran Church that his father helped build and was honored in 1989 and again in 1991 for his contributions to that community.

Melsted died Aug. 16, 1995, at the age of 83, after a prolonged battle with Parkinson's disease.

I also knew Ted Peck since graduate school in 1975. Peck was an undergraduate activities adviser and helped direct the soil judging team, an activity I participated in, and decided to pursue a degree in Soil Science. When I graduated, I began life as an industry agronomist about 20 miles north of Champaign, Ill. The business also maintained a soil-testing laboratory, which meant that I had frequent contact with Peck.

Ted was a great proponent of private soil-testing laboratories and considered the private sector to be much more able to service communities and growers than a central, state-controlled laboratory. His vision for the university was more as a watchdog, soil analysis developer and soil test verification entity than as a commercial institution. Throughout my career as a commercial agronomist, we had more than one disagreement, but I learned some important life lessons through his conversations and discussions and I always will thank him for those learnable moments concerning agronomy, soils and ethics.

I became his graduate student in 1989, when I returned to the University of Illinois to pursue



my doctoral degree, working on the Mansfield and Thomasboro fields that are the focus of this technical publication, graduating in 1993. Ted always went to the field with his technician, Marilyn Sullivan, and me, and ran rings around us every time. His vigor was astounding in the field; he always was energized, never seeming fatigued. Carrying 50-pound bags of corn ears nearly a quarter-mile across the field was no problem for him. I admit to succumbing to a few minutes of rest every once in awhile during some of those excursions, and I thought I was in pretty decent shape at the time.

Peck acquired his work ethic honestly. He was born in 1931 in the Peck family farm near Spring Green, Wis. His mother died when he was 11 and his sister helped raise Ted and his three other siblings. He served in the U.S. Army in Alaska during the Korean conflict. After discharge, he attended the University of Wisconsin and completed B.S., M.S. and Ph.D. degrees in Soil Chemistry. He joined the University of Illinois in 1962.

Through his career, he spent a great amount of time working with independent soil testing laboratories and helping them set up simple, efficient equipment that would maximize laboratory precision and accuracy and minimize costs.

Ted was also a curator of the Morrow Plots history and, after being called to the basement of Davenport Hall during a restoration project, he was appalled by the lack of care received by soil samples dating back far into the 1800s. His efforts resulted in the establishment of the Archival Soils Collection, which contains soils collected and sealed against any of our modern contaminants of pesticides or atomic fallout.

Ted loved to garden and operated a large, beautiful vegetable garden for many years across property owned by at least two different people on South Prospect Avenue in Champaign. The garden was included in the 2002 Champaign Master Gardener Garden Walk.

This love of vegetables also runs in the family, as shown in a 2007 photograph of Peck's Farm Market taken by my colleague, David Hopkins, during a trip through Spring Green, Wis., recently.

After I left graduate school, Peck was diagnosed with leiomyosarcoma, a rare soft-tissue cancer that first showed up in his prostate. The first surgery effectively relieved the problem, but in 2000, the cancer recurred in the lungs and progressively worsened. In 2003, Ted called me and asked if I would summarize the work conducted on these two Illinois fields and I said I would. He sent me all of his data and this work is the keeping of the promise I gave him. I hope, and he hoped also, that this data would be useful long after both of us are gone.

Peck died Dec. 27, 2003, leaving behind his wife, Karen, their two daughters, Lynne and Andrea, and many of us who continue to miss him.

D.W. Franzen

Introduction

The Illinois Grid Sampling Project began quietly in 1961 with a 5-rod (80-foot), 0- to 6-inch depth grid sampling of a field southwest of Mansfield, Ill. The samples were analyzed for soil pH, Bray P1 and ammonium acetate-K. The project was co-directed by Sig Melsted and Ted Peck, both of the University of Illinois Department of Agronomy in the Soils Department. The goal of the project was to determine a grid density of soil sampling that might be used to identify the "central tendency" soil pH, P and K of the field.

Grid sampling was not new to Illinois in 1961. The first known literature concerning grid soil sampling was written by Lindsley and Bauer (1929) in a University of Illinois Agricultural Experiment Station circular. In the 1920s, the value of agricultural limestone and its requirement for increasing pH already were recognized by researchers and growers. However, the logistics of limestone application was a daunting, physically exhausting task. Limestone was ordered into a station on railroad cars. The farmer then needed to drive a wagon, often horse-drawn, to the station and load the wagon by hand. The wagon then was driven to the field and, in many cases, men would scatter the limestone out the back of the wagon with their shovels.

Understandably, the men had plenty of time during this process to consider whether the whole field, or only a portion of it, needed lime. Through their publication, Lindsley and Bauer detailed a grid-sampling technique of equidistant points, approximately one sample per acre, that would characterize the field soil pH site-specifically so that the farmer would minimize the area that would need limestone, and even identify areas that required more or less than average rates.

By the Second World War, farm machinery had become more mechanized and spreading lime or fertilizer was more easily broadcast-applied at a single rate than sampling on a relatively dense grid and then trying to pick out areas within the fields that had special requirements. The goal of soil sampling then moved toward the idea of "central tendency."

Agriculturalists held a deep belief, partly due to statistical correctness of Fisher and the analysis of the variance concept of small-plot work, and partly due to the needs and desires of farmers in how they managed inputs, that sampling needed to reflect the true, practical average of the soil test levels. This concept was called "central tendency." Statistical correctness demanded that samples be taken without personal bias about the location. Extension and Experiment Station researchers in different states approached this problem differently. In North Dakota and most Great Plains states, samples were collected in a systematic, random method, avoiding unusual areas, and the collected soil was combined in a bucket. The soil was mixed as thoroughly as possible to form a sample composite, then about one-half pound of soil from the composite was used for analysis of the field.

In Illinois, the grid-sampling tradition that Lindsley and Bauer helped found dictated that at each soil sample site, usually three to eight soil cores from an area about 10 to 20 feet in radius were combined into a composite sample from a subfield area representing some defined, regularly shaped polygon of acreage, and these individual samples were analyzed. After analysis, the sample values were averaged through an arithmetic mean and the result would direct the recommended rate of fertilizer or lime. This was the strategy that Peck and Melsted began to address in their 1961 Mansfield sampling, published in 1967.

From this experiment, a strategy of 11 samples per 40-acre field was established. The density was a compromise between the need for more samples to reproduce a field mean and the combined problem of physically taking that many samples from a field, getting farmers or fertilizer dealers to pay for the samples and having enough laboratories to handle the sample load of 3.3 acres per sample every four years on 20 million acres of farm ground in Illinois (412,500 samples per year). From the beginning, the grid-sampling strategy of 11 samples per 40 acres was cumbersome and self-defeating. As indicated in Figure 1, obtaining equal representation of the field with 11 samples is not physically possible for the soil sampler, who usually is walking.

The outside column of four samples represents a wider area of land, and the interior column represents longer, narrower areas of land. The field may be equally

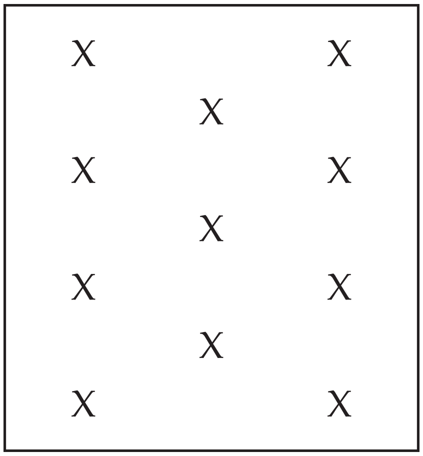


Figure 1.

partitioned by acreage, but given the systematic errors associated with field operations in east-west/north-south directions, the 11 samples per 40-acre approach was problematic to Peck for many years (personal communication).

In 1973, the second edition of Melsted and Peck was published. Due to feedback from this publication, questions that Peck continued to have about the nature of soil test pattern behavior and the changes in soil test levels through time, a second, similar sampling at Mansfield was conducted in fall 1976. The field next was sampled in 1982, along with a second field northwest of Thomasboro, Ill. The fields were sampled each fall from 1986 through 1992, then in 1994, at Thomasboro in 1995, and finally in 1999 and at Thomasboro in 2001.

These data are unique in the literature not because they include grid sampling at a relatively dense scale (0.156-acre grid), but because they have been sampled in the same grid pattern during a period of 38 years at Mansfield and 19 years at Thomasboro. These data allow the examination of changes or stability in soil pH, P and K patterns through time and the spatial buildup of soil P and K levels with added nutrients through time, as well as depletion of P and K with crop removal through time (both fields received no P and K from 1986 through 1994). They allow the comparison of less dense grid strategy pH, P and K estimates with the dense grid values. Finally, with new techniques, these data can be compared with zone delineation tools to determine relationships between field patterns and more easily obtained sampling strategies.

The publications, Peck and Melsted (1967) and Peck and Melsted (1973), were the cornerstones of site-specific nutrient management technologies. An update of these ideas was published by Peck and Soltanpour (1990). All three of these articles continue to be cited in the literature. Melsted and Peck (1967) were cited twice in official journals since 1971, Peck and Melsted (1973) were cited by 16 different authors 17 times in five journals and Peck and Soltanpour (1990) were cited by 15 different authors 15 times in three journals. In addition, most of the site-specific literature between 1990 and the present was published in conference proceedings. Reading the literature of site-specific nutrient management without seeing reference to at least one of these three papers is unusual.

The objective of this technical paper is to publicly present the data for those who follow us to use and to explore the data with tools presently available for analysis of relationships.

Methods

The fields

Mansfield: soil sampling dates – 1961, 1976, 1982, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1994, 1999

Mansfield corn yield – 1991, 1993, 1999

Mansfield soybean yield – 1992, 1994

Thomasboro: soil sampling dates – 1982, 1986, 1987, 1988, June and October 1989, 1990, 1991, 1992, 1994, 1995, 1999, 2001

Thomasboro corn yield – 1992, 1994, 1995, 1999

Thomasboro soybean yield – 1996

Soil sampling

Unless otherwise indicated, soil sampling always was conducted following crop harvest. The exception was Thomasboro in June 1989, but this was followed by an October 1989 sampling. At both sites, distances between samples were determined with a tape measure, with 80-feet distance between sampling points in the north-south and east-west direction. At Thomasboro, the southwest plot (1-16) was determined from the southwest field corner, east 40 feet, and then north 40 feet. At the far north boundary, a flag was located 40 feet east of the west boundary. The tape then was stretched from the south flag in line with this north line, and each point was marked with a flag every 80 feet. Each north-south rank of flags was marked out similarly. Mansfield always contained 256 sampling points (16 north-south, 16 east-west). Thomasboro contained three to six fewer points due to the presence of an abandoned Air Force radar station building and radar pole in the region from sample location 13-14 through 14-15 near the southeastern corner.

Five soil samples at the 0- to 6-inch depth were obtained and placed into a common kraft paper bag at each sampling location. Samples were dried at 50 degrees Celsius for several days before grinding, sieving and storage. Soil pH was determined on a thin soil paste of approximately a 1-to-1 ratio of soil to water, P was determined using the Bray P1 method and K was determined using 1-N ammonium acetate extraction.

Yield determination

Corn yield in 1991 was calculated by determining plant harvest population in each plot, then collecting 10 representative ears. In 1992, after considerable discussion about this method, a measured 20-foot of row from two interior rows in each plot was collected. Soybean yield was determined using a plot combine in 1992 using a long pole to separate the end of each plot area so that the combine did not extend farther into the next plot. From 1994, corn and soybean yields were determined using a plot combine.

Mapping for this publication was conducted using Surfer 8.0 for Windows (Golden Software Co., Golden, Colo.). Parameters for kriged contour maps were determined using GS+ 5.0 for Windows, with the maps developed using these parameters within Surfer 8.0.

Elevations for use in terrain modeling were measured October 2006 using a laser transit device with a stationary laser emitter. The readings are relative within each field independently.

Electrical conductivity (EC) measurements were conducted in November 2006 using a Geonics EM-38 magnetic electrical conductivity sensor set for shallow EC measurement.

Results

1. Mansfield

Figures 1-1 through 1-30 contain the spatial plot values of pH, P and K for all sampling years at Mansfield. The original maps were organized on paper until 1986, then were placed in an Excel spread sheet and organized by plot numbers 1-1 through 16-16, with 1-1 in the northwestern corner and 16-16 in the southeastern corner.
The original maps that were shared in publications and presentations depicted the maps as in the figures, with color-coded squares representing each value area. Utilizing interpolation to estimate values between the sample points was thought to introduce bias into the results.

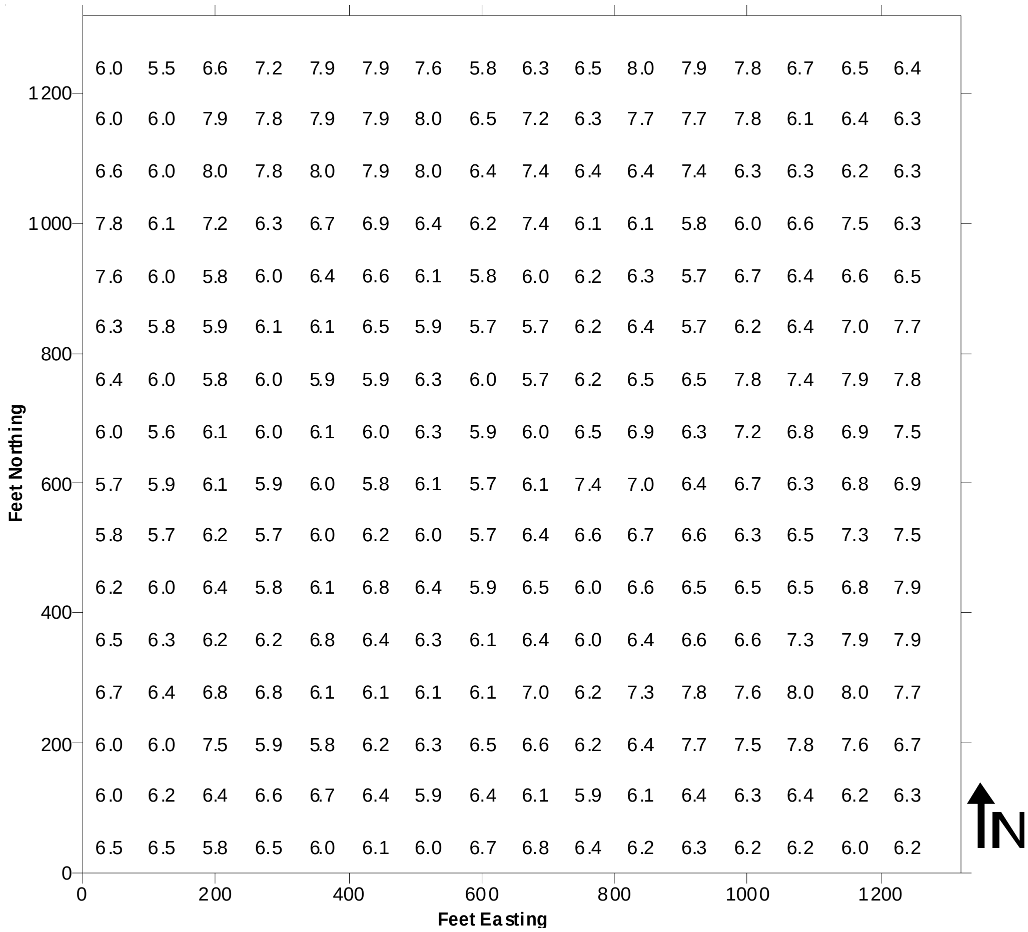


Figure 1-1.
Mansfield soil pH,
1961.

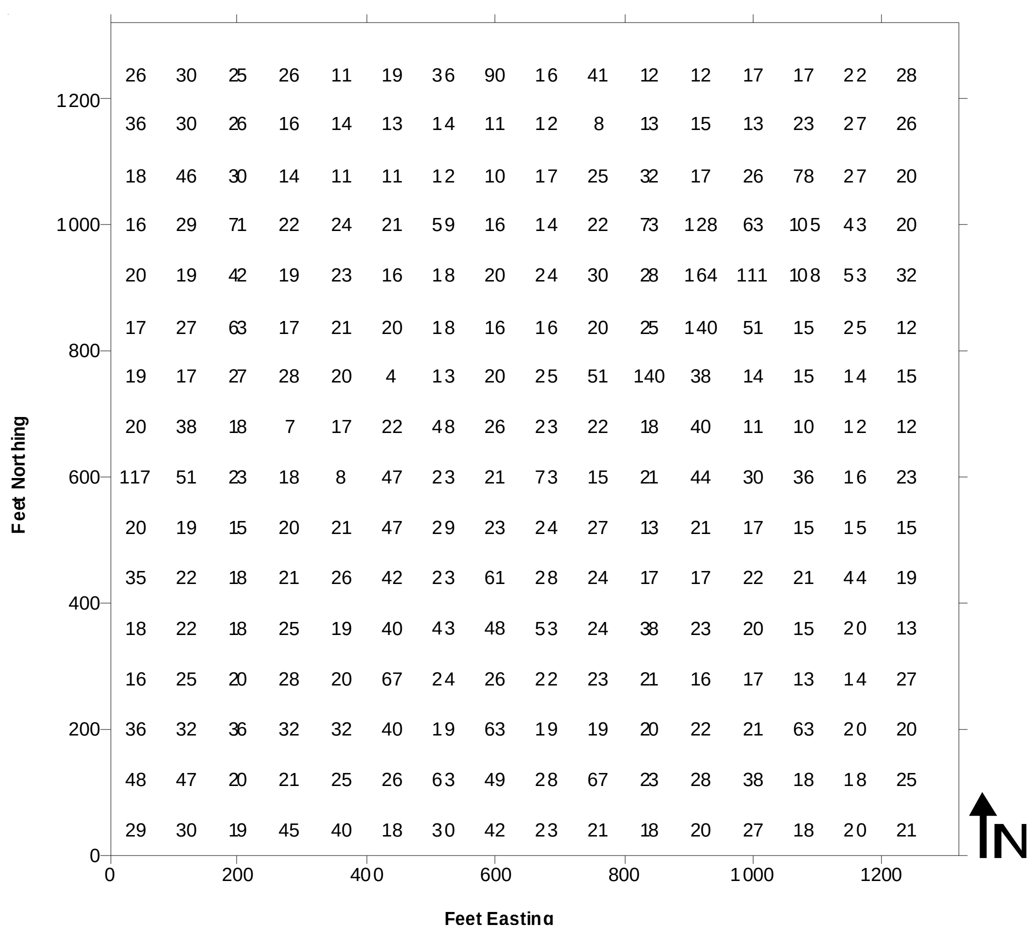


Figure 1-2.
Mansfield P,
1961.

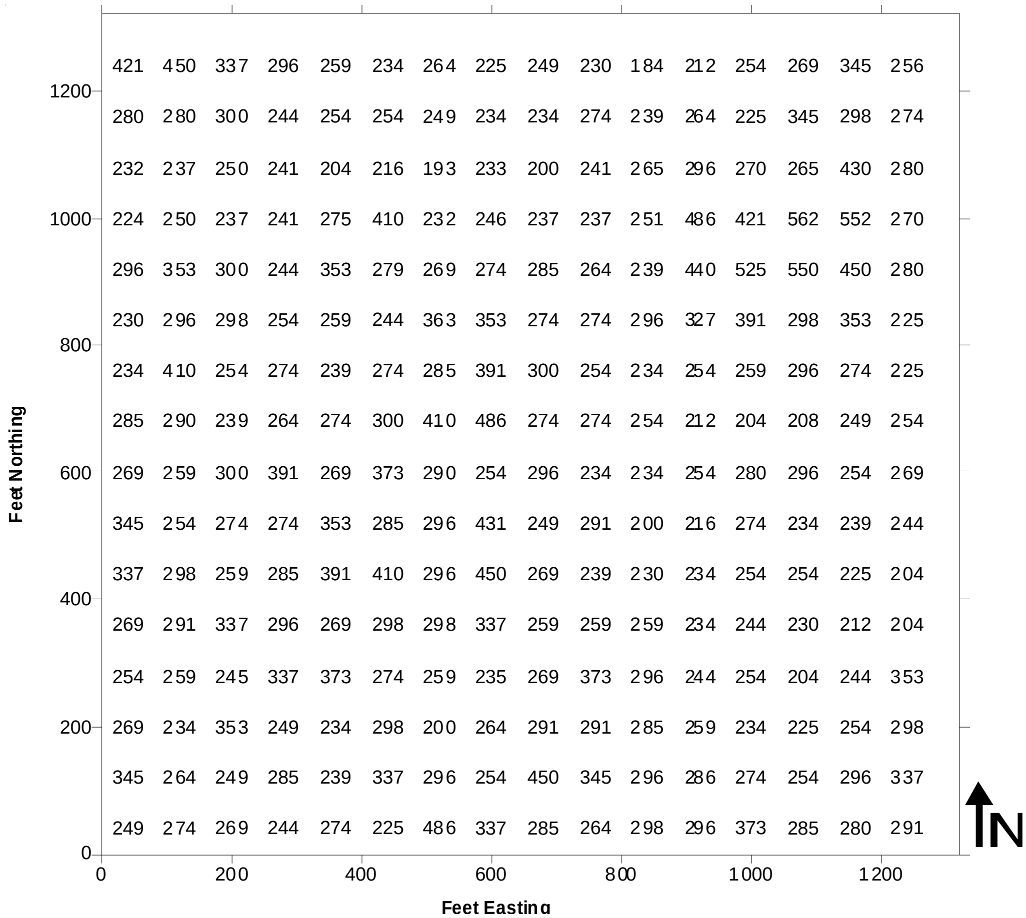


Figure 1-3. Mansfield K, 1961.

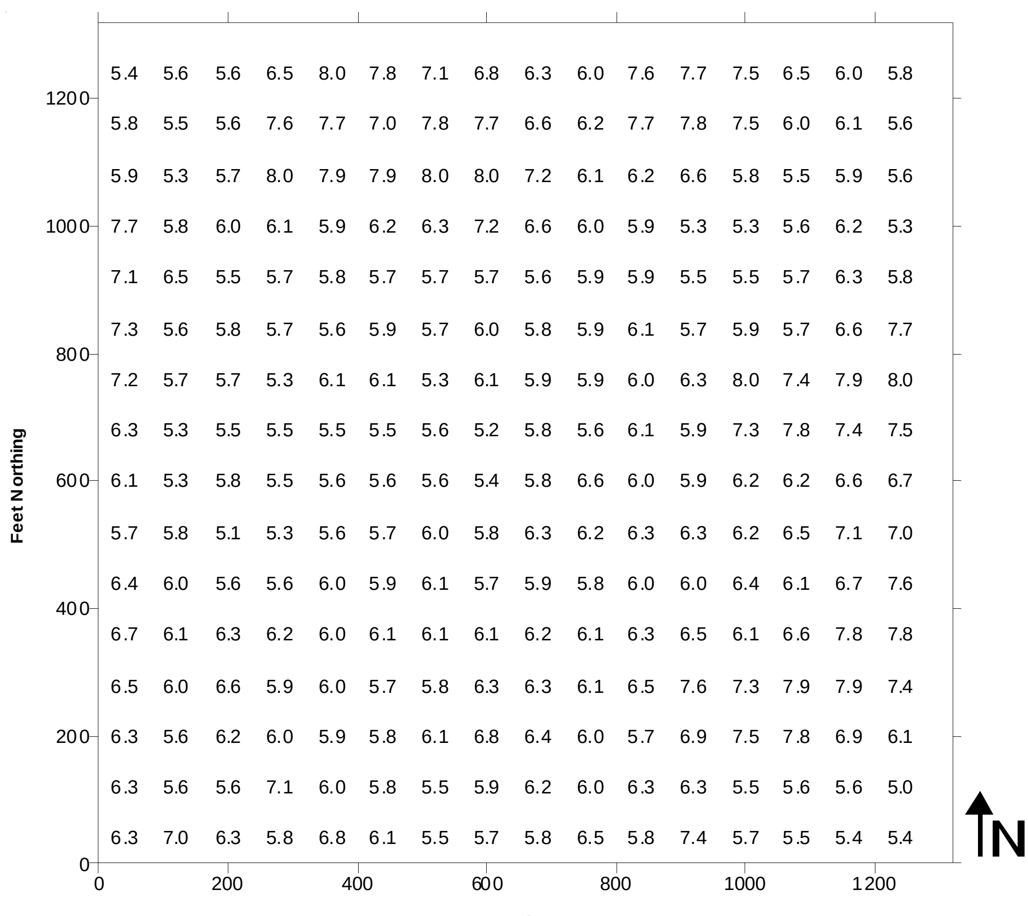


Figure 1-4. Mansfield pH, 1976.

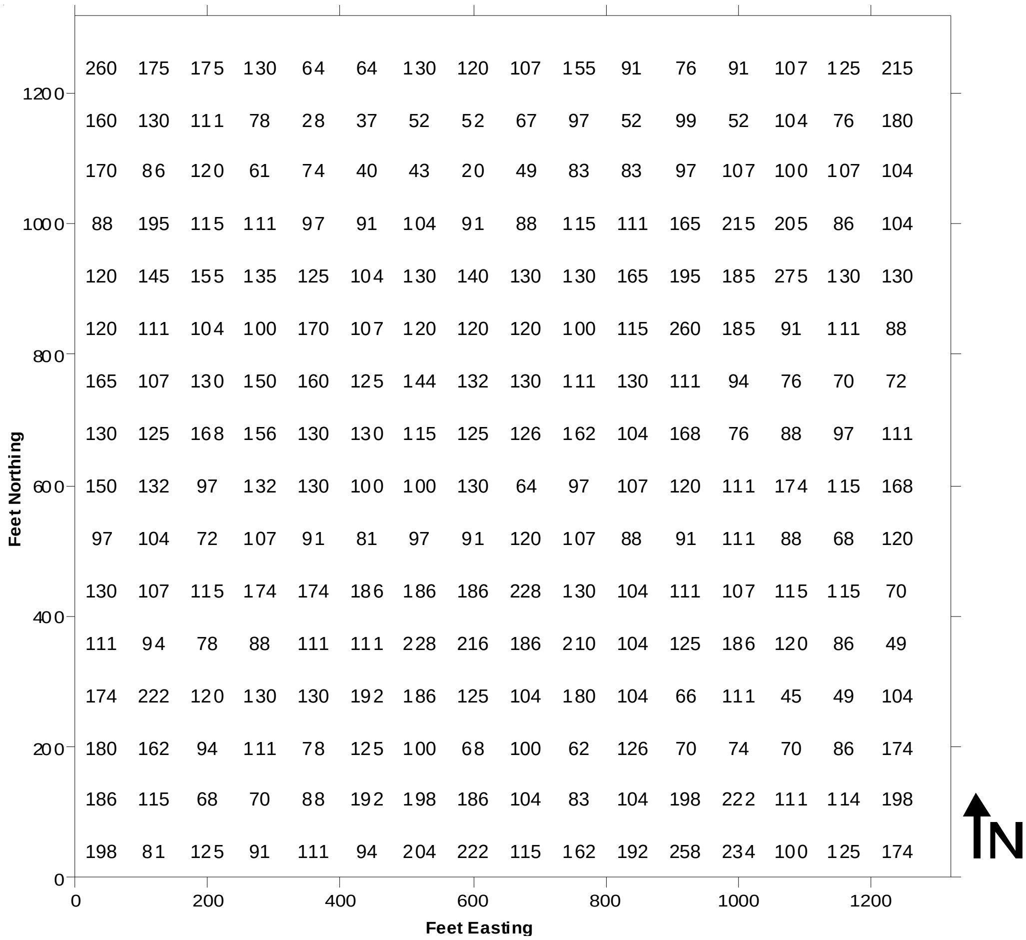


Figure 1-5. Mansfield P, 1976.

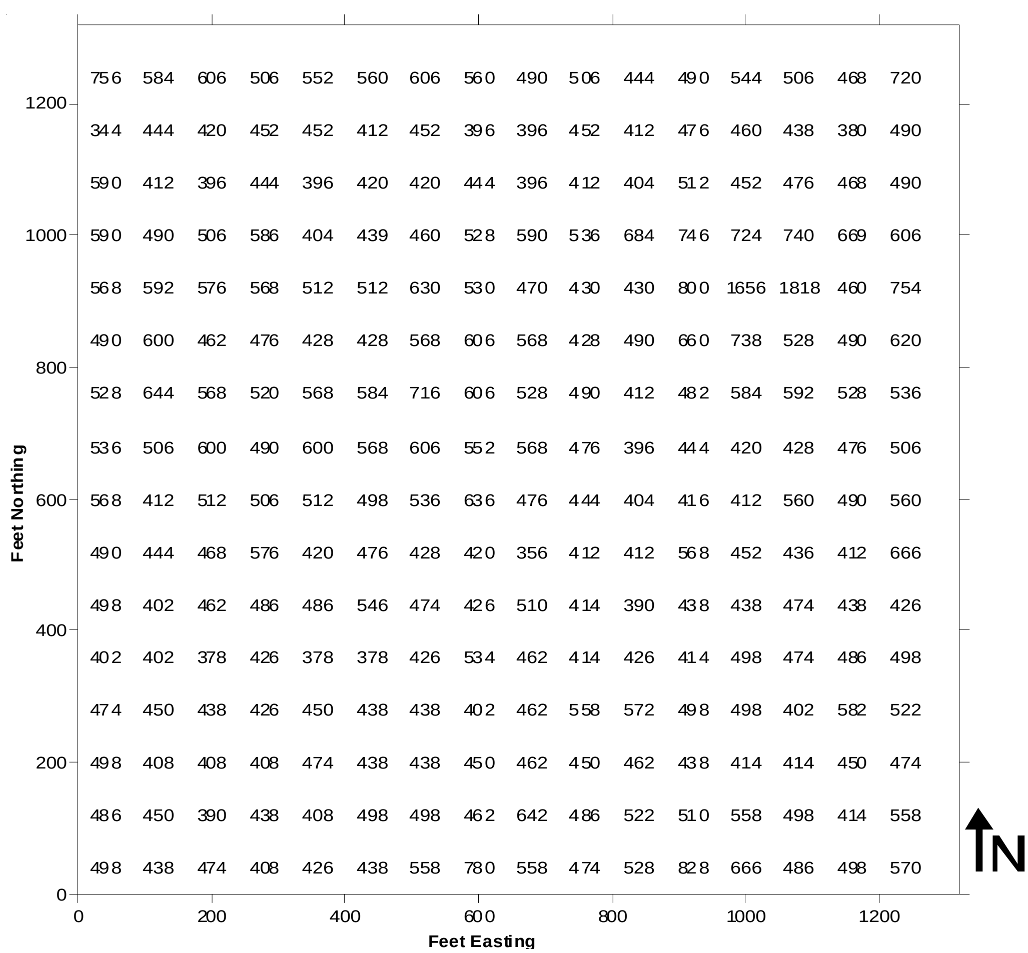


Figure 1-6. Mansfield K, 1976.

6.0	6.3	6.2	7.4	7.6	7.6	6.5	7.6	7.5	7.6	7.6	6.6	7.6	6.0	5.7	6.2
6.4	6.6	6.8	7.5	7.7	7.5	6.5	7.1	7.3	7.3	7.7	7.7	7.1	5.9	5.7	5.8
6.3	6.1	7.3	7.6	7.7	7.6	7.8	7.7	7.3	6.1	6.3	6.7	6.0	6.0	6.0	6.1
7.4	5.8	6.4	6.0	6.1	6.3	6.1	6.7	6.2	5.8	5.8	5.8	5.7	5.9	7.2	6.1
7.2	5.5	5.8	5.6	5.7	5.6	5.6	5.4	5.5	5.8	5.8	5.7	5.7	6.2	6.3	6.6
7.4	6.1	6.1	6.2	6.1	6.4	6.3	6.1	6.2	6.5	6.5	6.6	6.7	6.9	7.3	7.6
6.1	5.8	6.2	5.7	5.7	5.9	5.8	5.9	5.9	6.1	6.3	6.9	7.8	7.7	7.7	7.6
6.5	6.2	5.9	6.0	5.9	6.1	6.0	5.7	6.0	6.7	6.4	6.0	6.9	7.0	7.2	7.1
6.2	5.9	6.0	5.7	5.9	6.1	6.0	6.0	6.3	6.5	6.7	6.8	7.0	7.3	7.4	7.3
5.7	5.9	5.8	5.7	5.9	6.2	6.3	6.4	6.3	6.7	6.8	6.8	7.0	7.2	7.3	7.7
6.5	6.1	6.1	6.0	6.2	6.5	6.2	6.1	6.4	6.4	6.8	6.7	6.9	7.0	7.2	7.7
6.6	6.3	6.3	6.4	6.2	6.0	6.0	6.2	6.2	6.9	7.0	6.8	7.0	7.3	7.7	7.7
6.9	6.5	6.8	6.4	6.4	6.2	6.3	6.5	7.2	6.4	7.0	7.5	7.6	7.8	7.8	7.2
6.7	6.3	6.4	6.3	6.5	6.4	6.4	6.8	6.6	6.5	6.8	7.6	7.6	7.6	7.0	7.0
6.3	6.3	6.5	7.0	6.4	6.4	6.3	6.5	6.5	6.2	6.4	6.5	6.4	6.5	6.2	6.3
6.9	6.8	6.5	6.3	6.3	6.2	6.2	6.2	6.5	6.7	6.5	6.3	6.0	6.2	6.1	6.2

Feet Northing (0–1200); Feet Easting (0–1200); N

Figure 1-7. Mansfield pH, 1982.

104	131	120	104	28	64	94	88	91	100	100	55	64	83	78	145
111	81	97	49	10	31	36	34	53	91	28	37	40	91	86	184
120	78	66	40	43	54	33	30	50	93	93	90	100	126	90	93
78	138	82	66	80	93	120	80	90	107	126	250	138	164	80	74
80	126	82	78	85	60	78	80	66	96	90	154	120	146	103	111
93	87	107	72	80	66	82	70	50	80	103	154	138	87	76	70
120	59	82	96	85	74	62	72	70	90	82	62	33	33	29	74
120	107	88	91	91	78	104	62	111	74	70	70	59	62	53	81
120	78	61	74	64	78	76	91	86	64	70	83	72	76	76	100
81	59	55	58	86	68	81	100	131	72	64	58	68	55	58	55
100	53	59	62	76	91	88	111	100	83	52	76	78	64	59	40
74	59	40	62	68	90	90	107	73	60	42	64	72	56	41	57
76	74	68	82	100	111	100	82	74	107	66	42	47	34	43	103
100	90	100	68	66	90	68	47	59	47	59	34	35	36	68	90
120	70	45	42	72	80	93	76	56	41	57	62	96	64	46	62
83	64	72	78	62	72	97	107	81	72	72	76	100	72	61	88

Feet Northing (0–1200); Feet Easting (0–1200); N

Figure 1-8. Mansfield P, 1982.

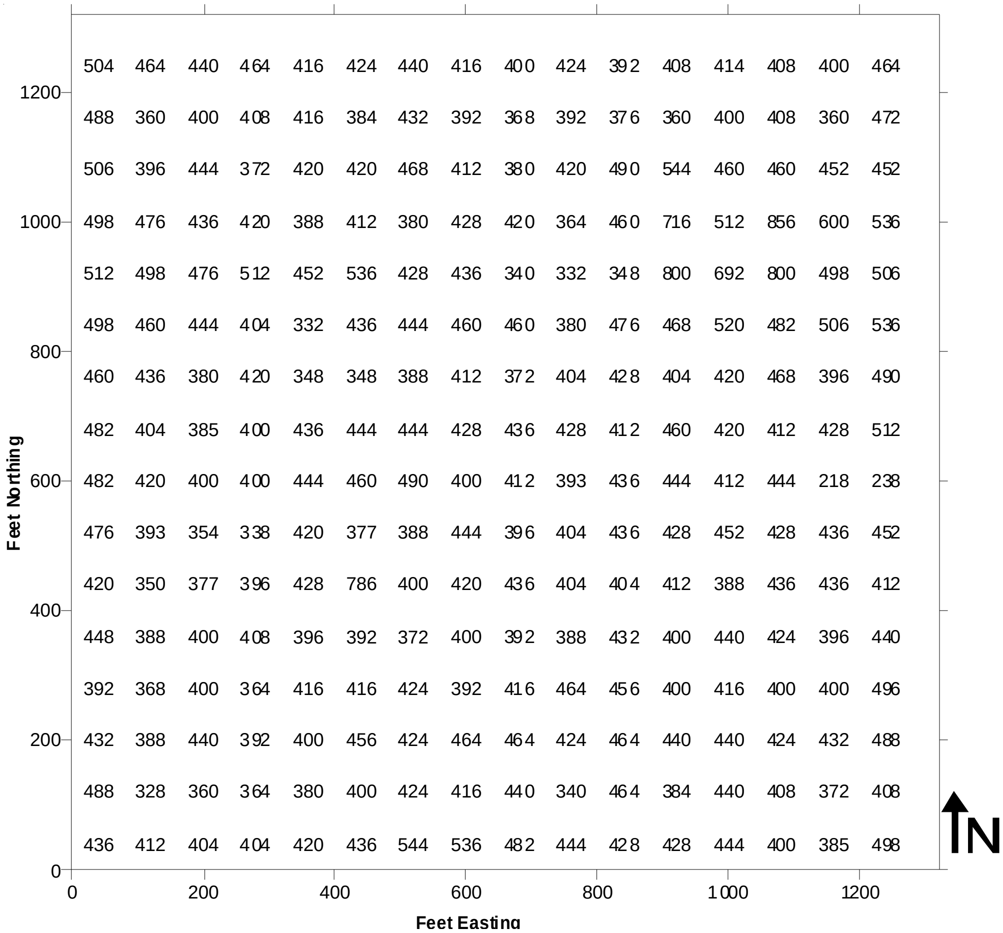


Figure 1-9. Mansfield K, 1982.

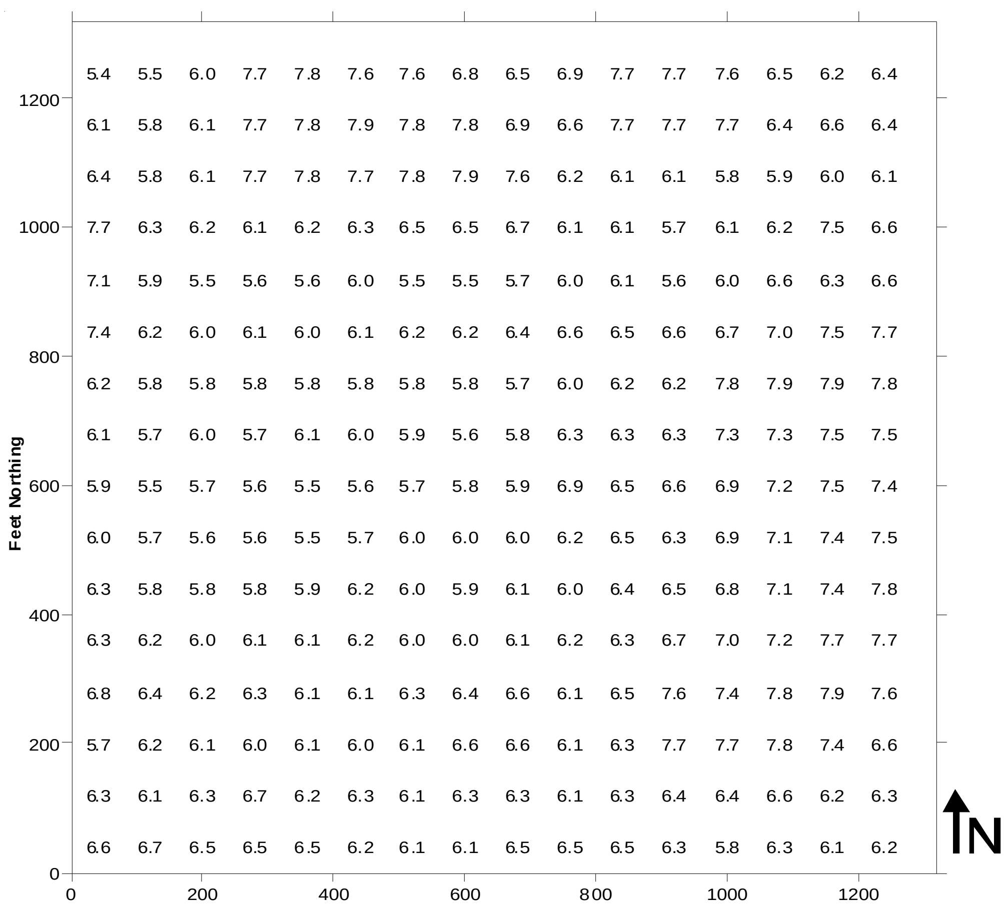


Figure 1-10. Mansfield pH, 1988.

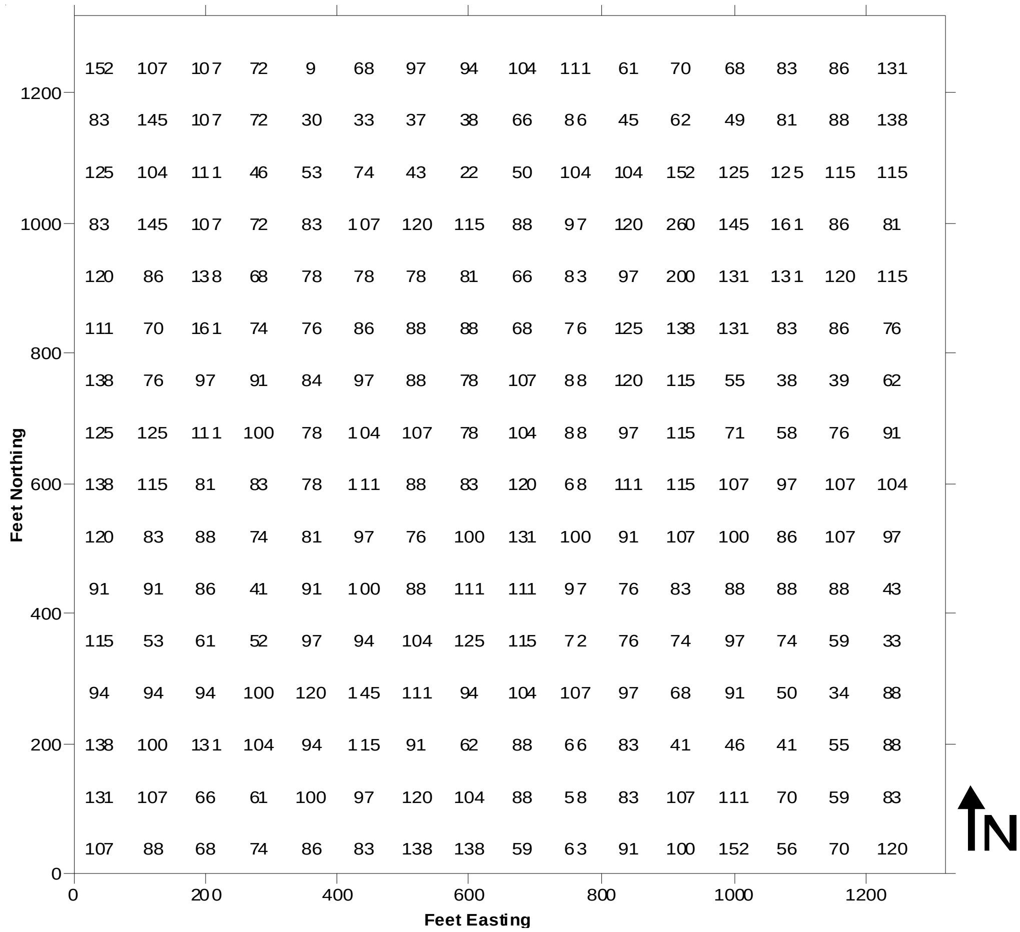


Figure 1-11. Mansfield P, 1988.

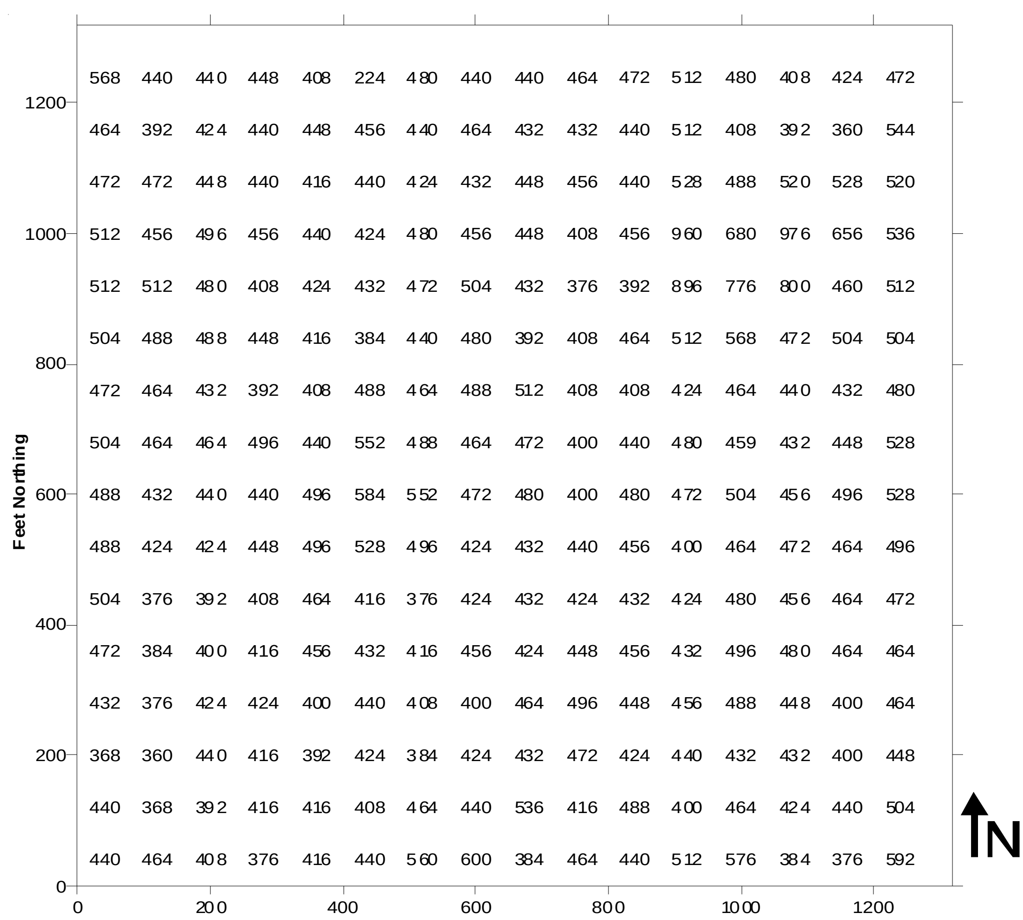


Figure 1-12. Mansfield K, 1988.

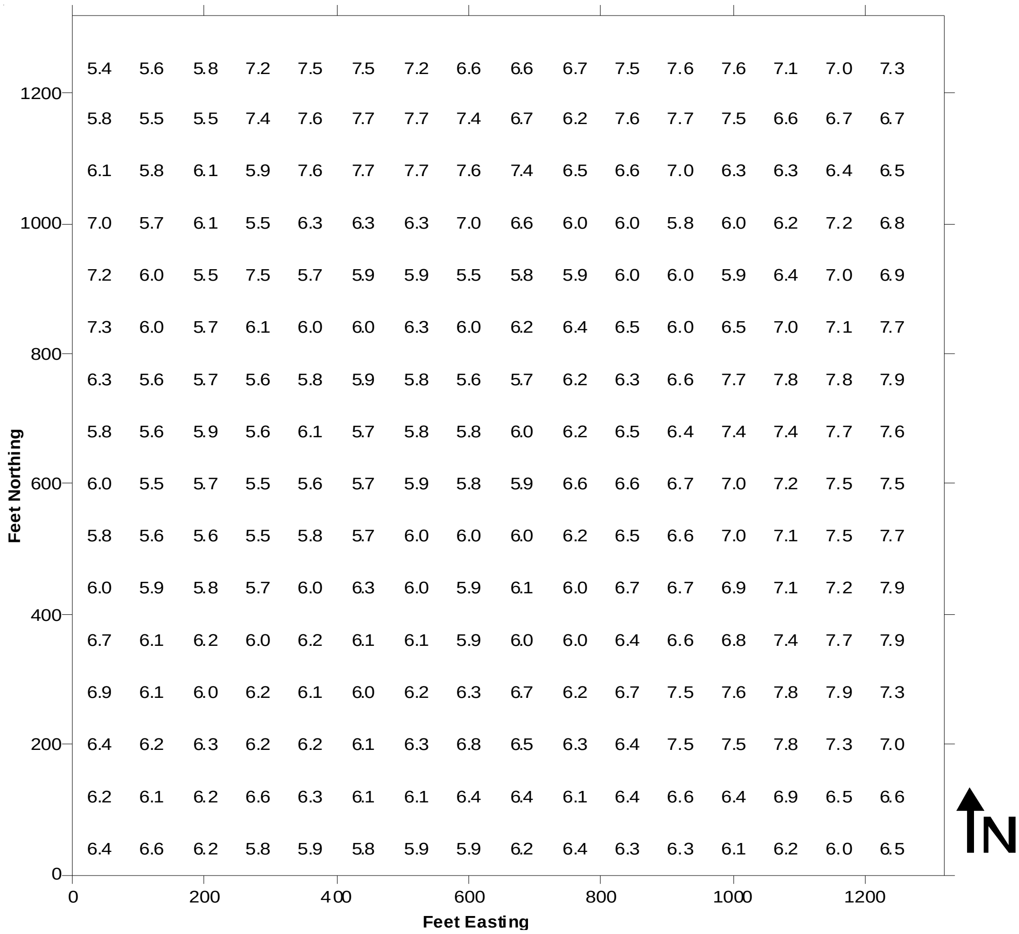


Figure 1-13. Mansfield pH, 1989.

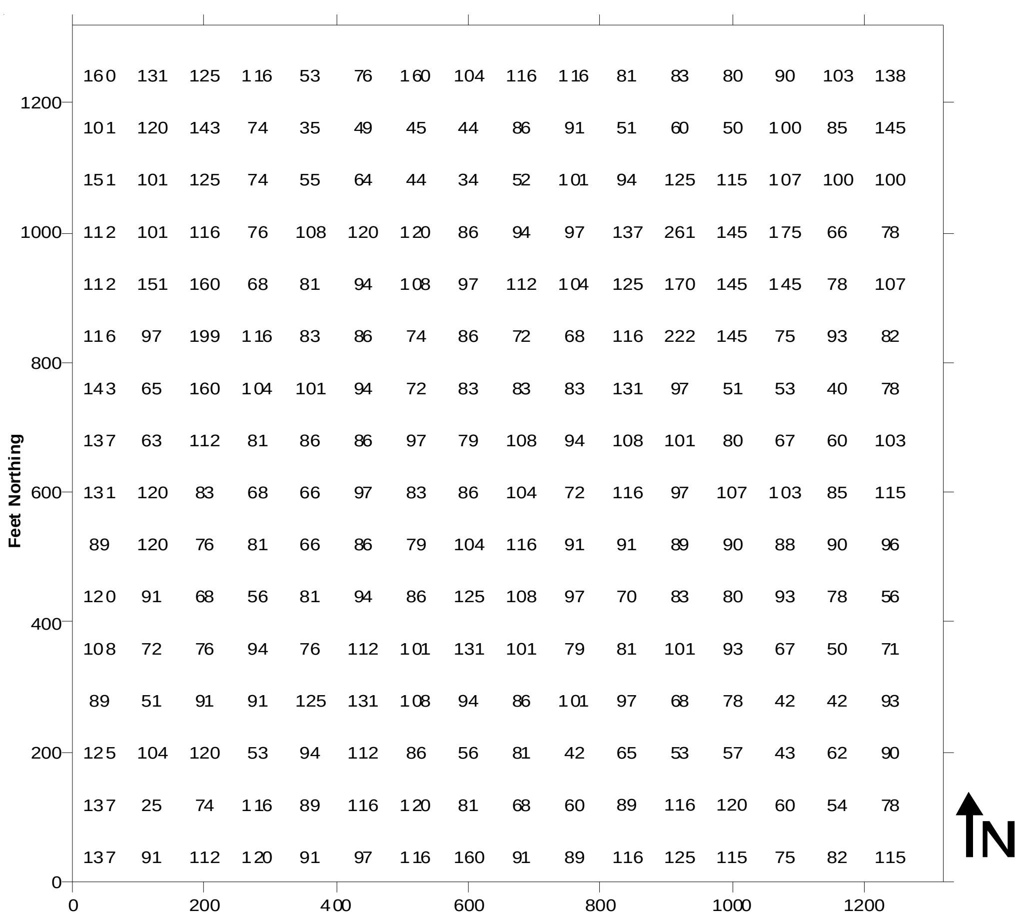


Figure 1-14. Mansfield P, 1989.

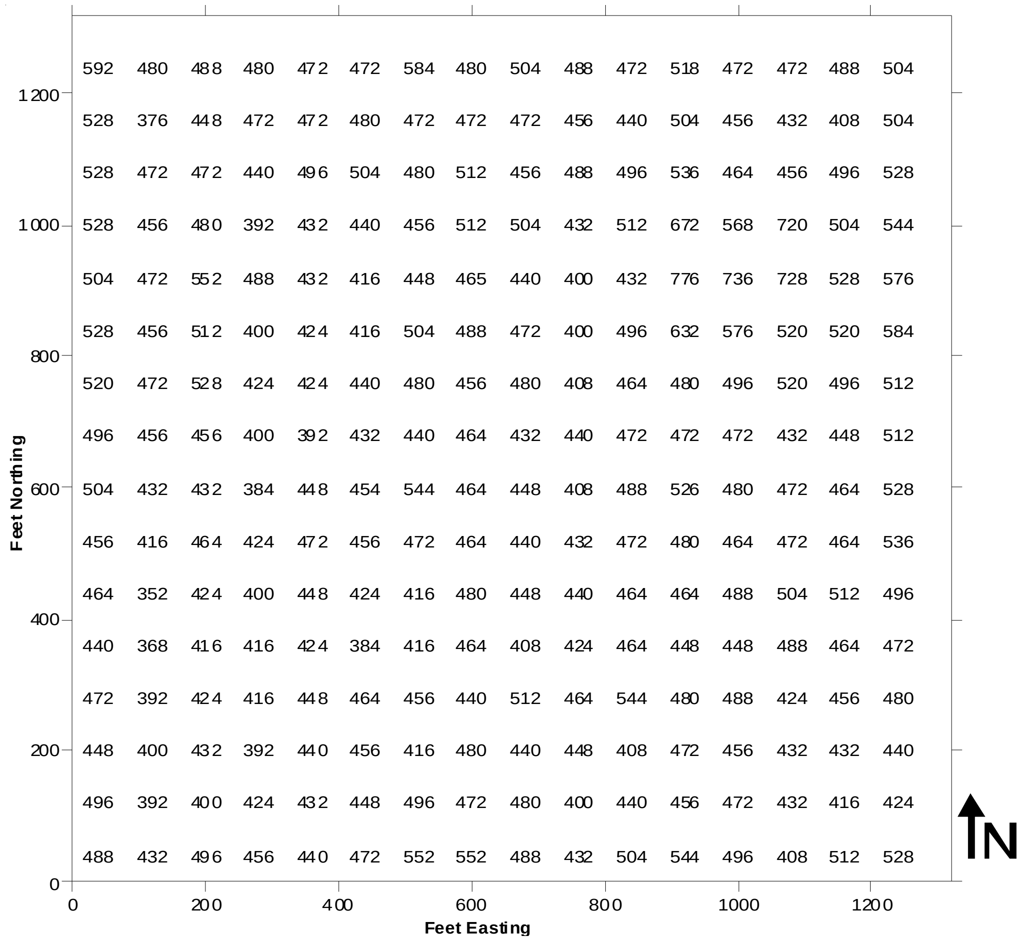


Figure 1-15. Mansfield K, 1989.

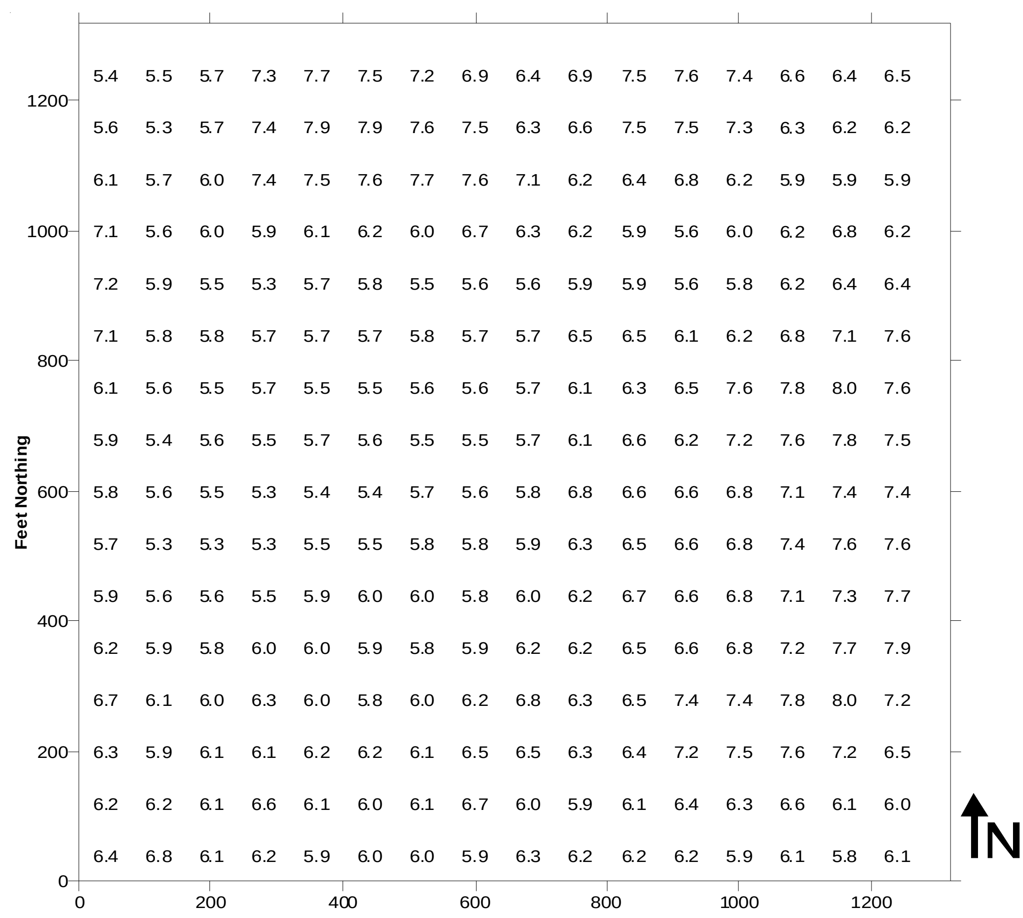


Figure 1-16. Mansfield pH, 1990.

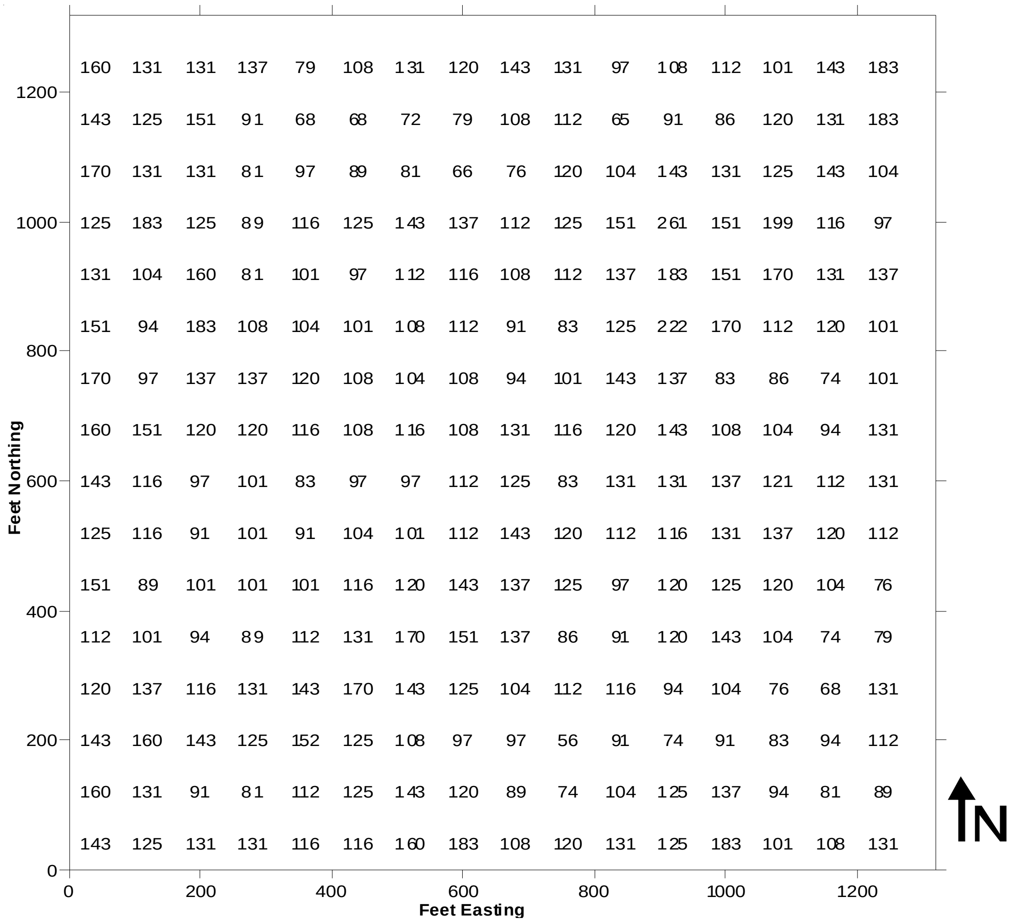


Figure 1-17. Mansfield P, 1990.

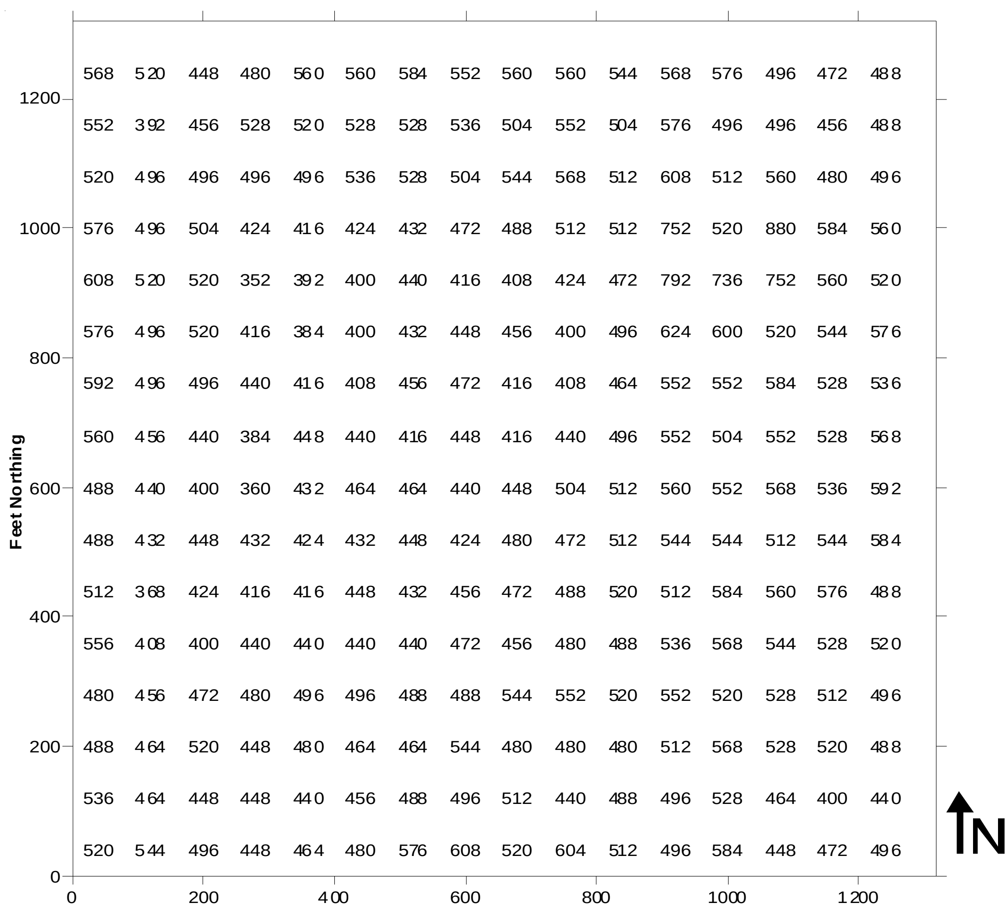


Figure 1-18. Mansfield K, 1990.

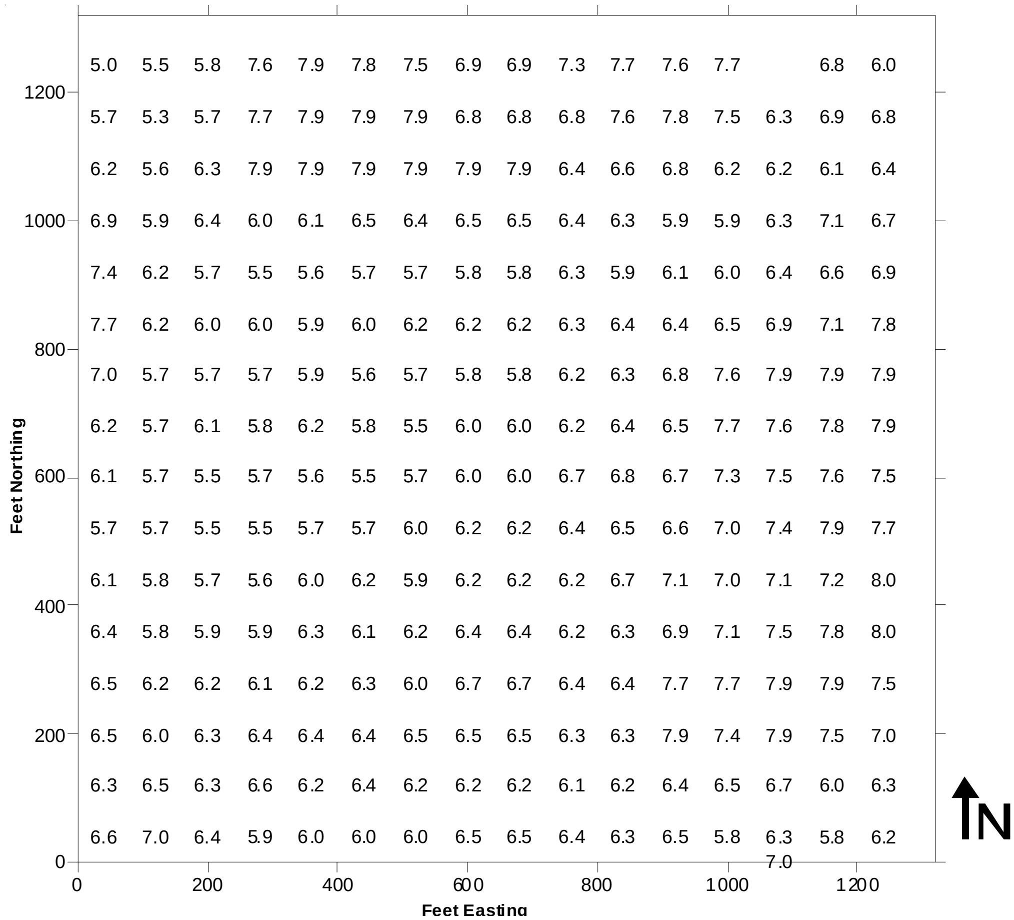


Figure 1-19. Mansfield pH, 1991.

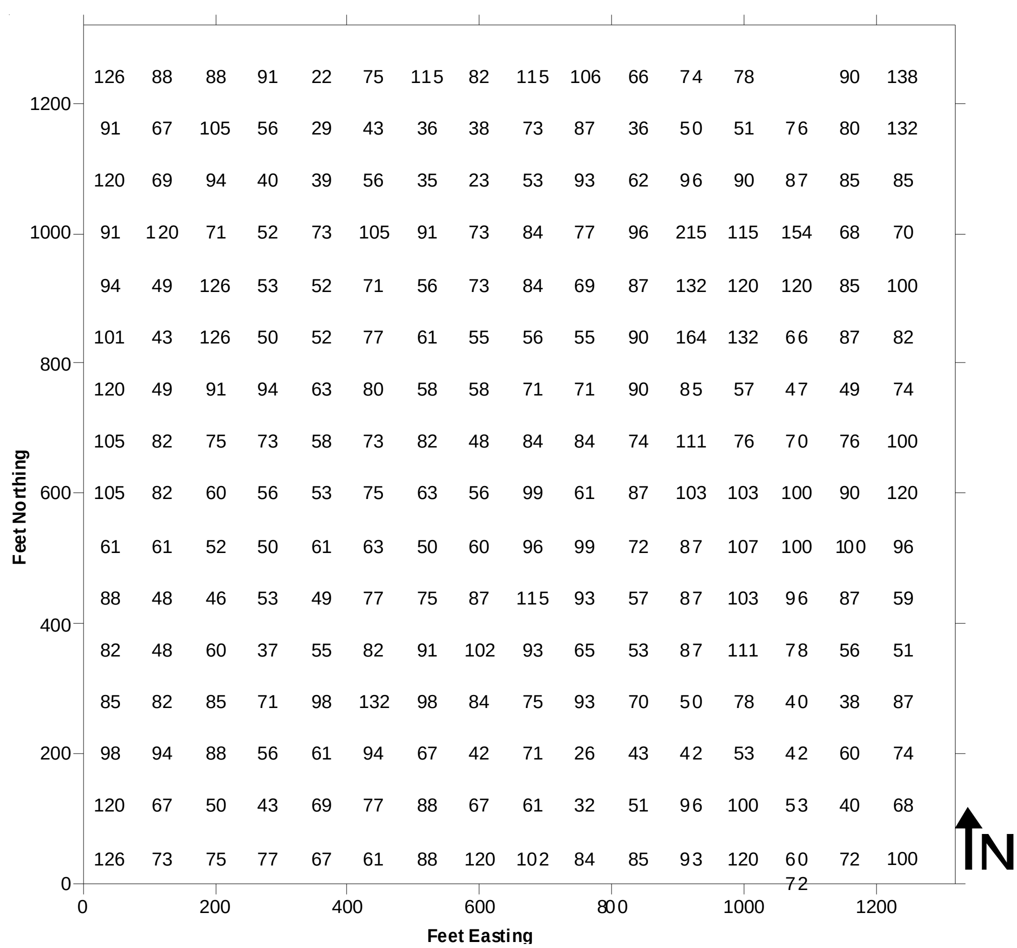


Figure 1-20. Mansfield P, 1991.

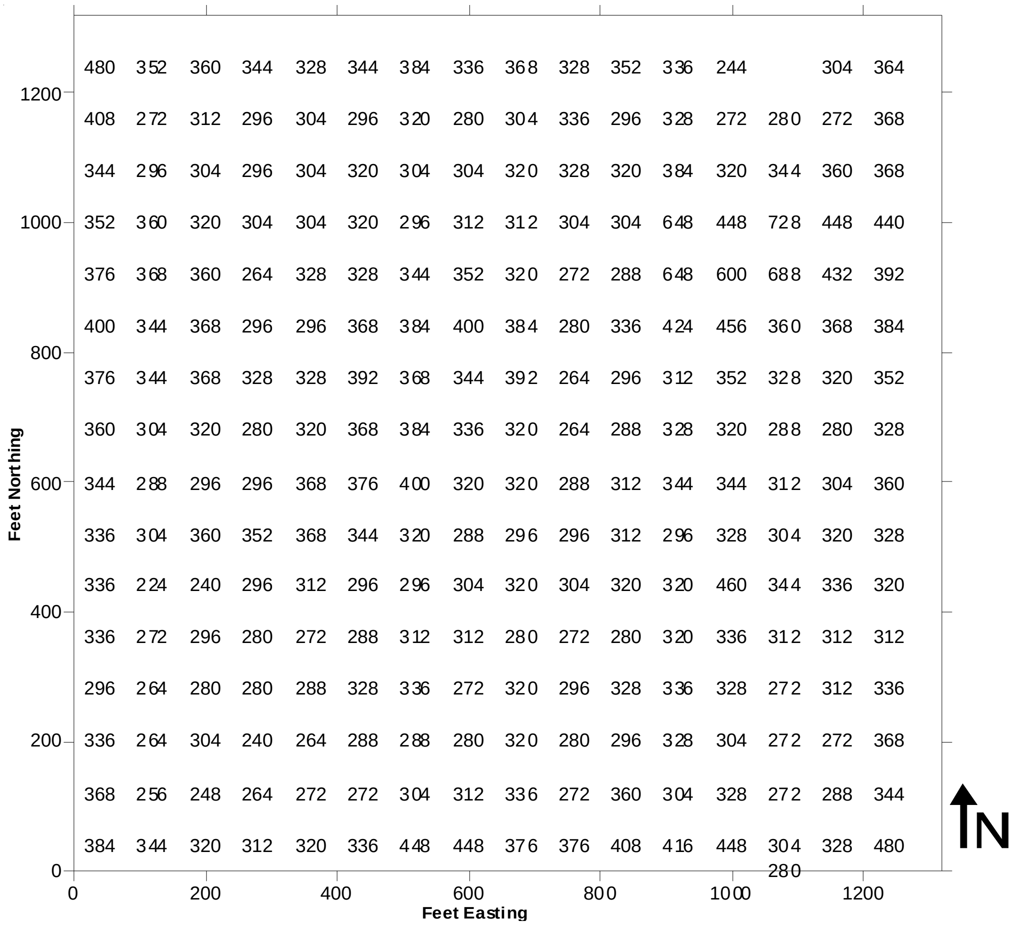


Figure 1-21. Mansfield K, 1991.

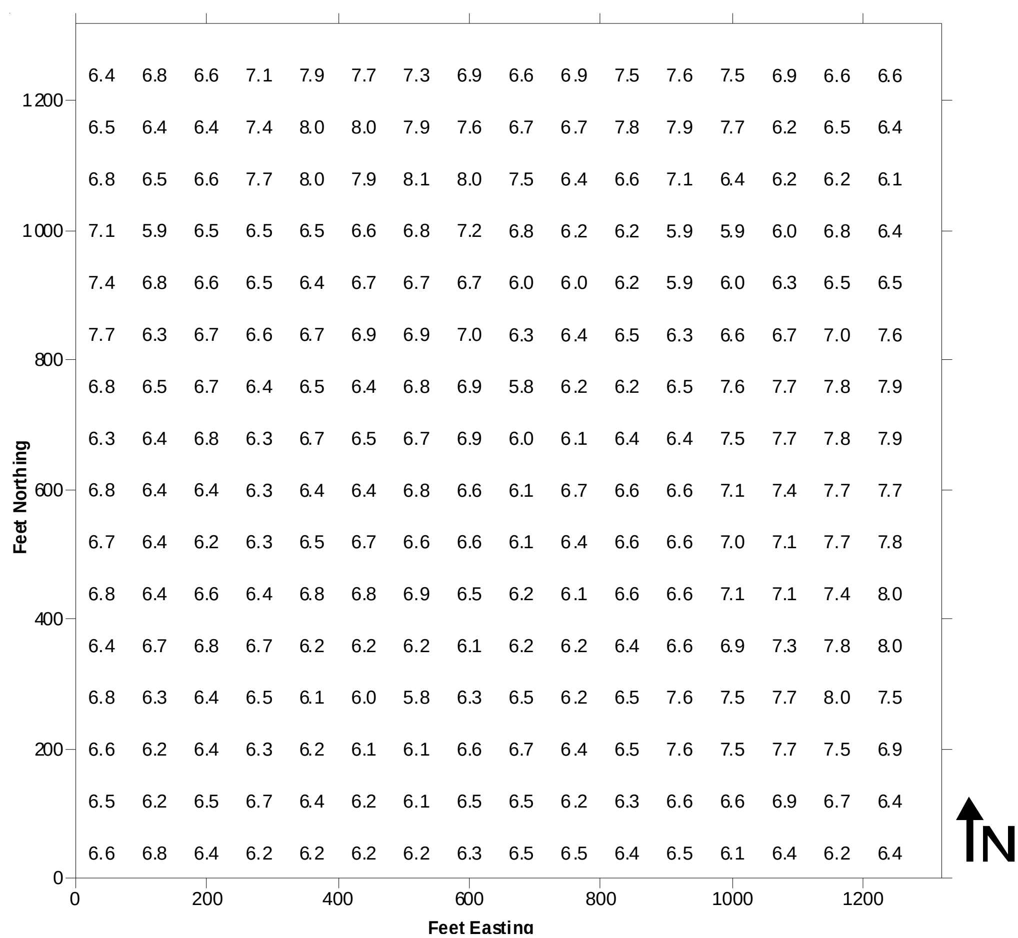


Figure 1-22. Mansfield pH, 1992.

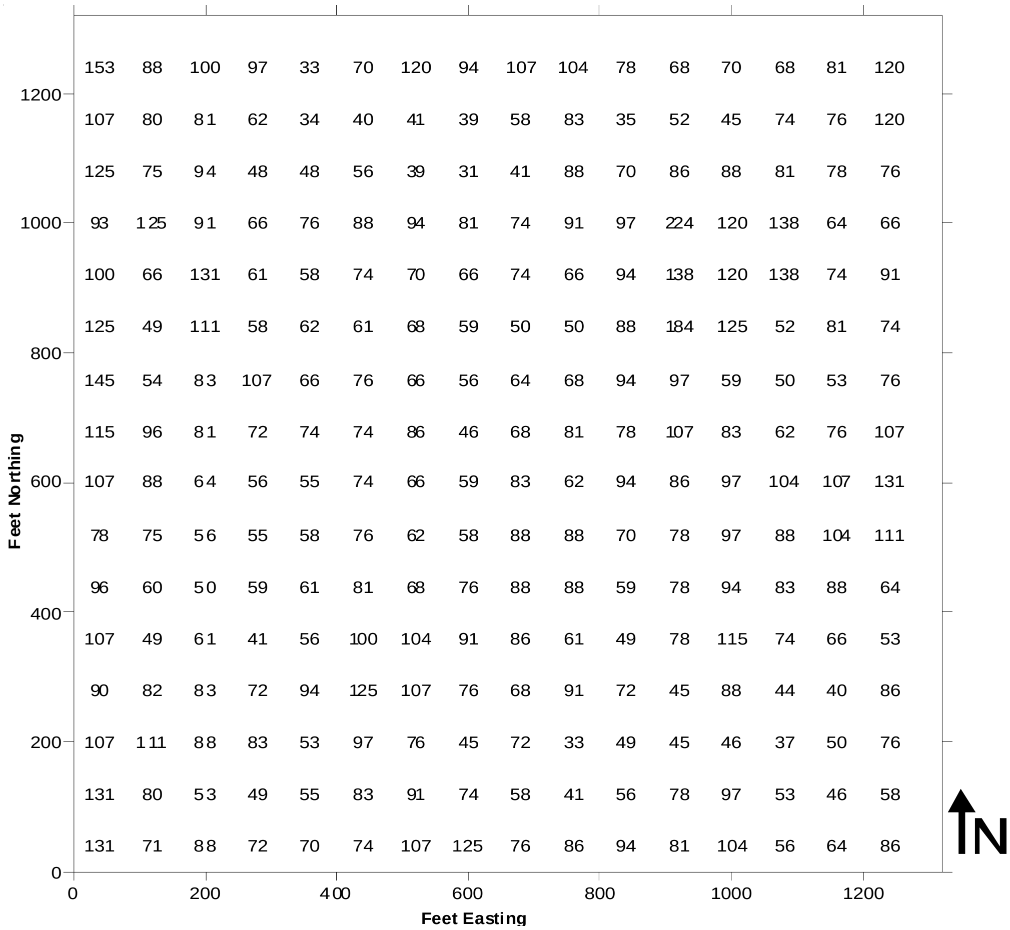


Figure 1-23. Mansfield P, 1992.

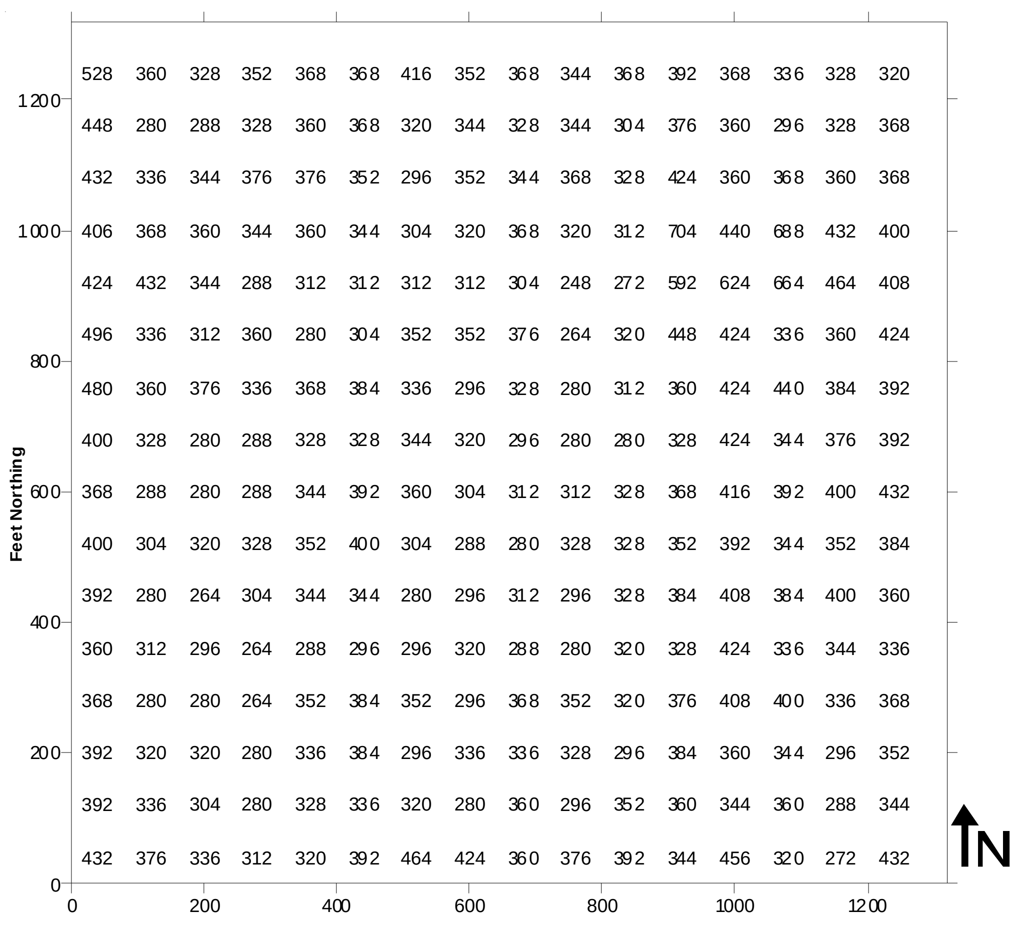


Figure 1-24. Mansfield K, 1992.

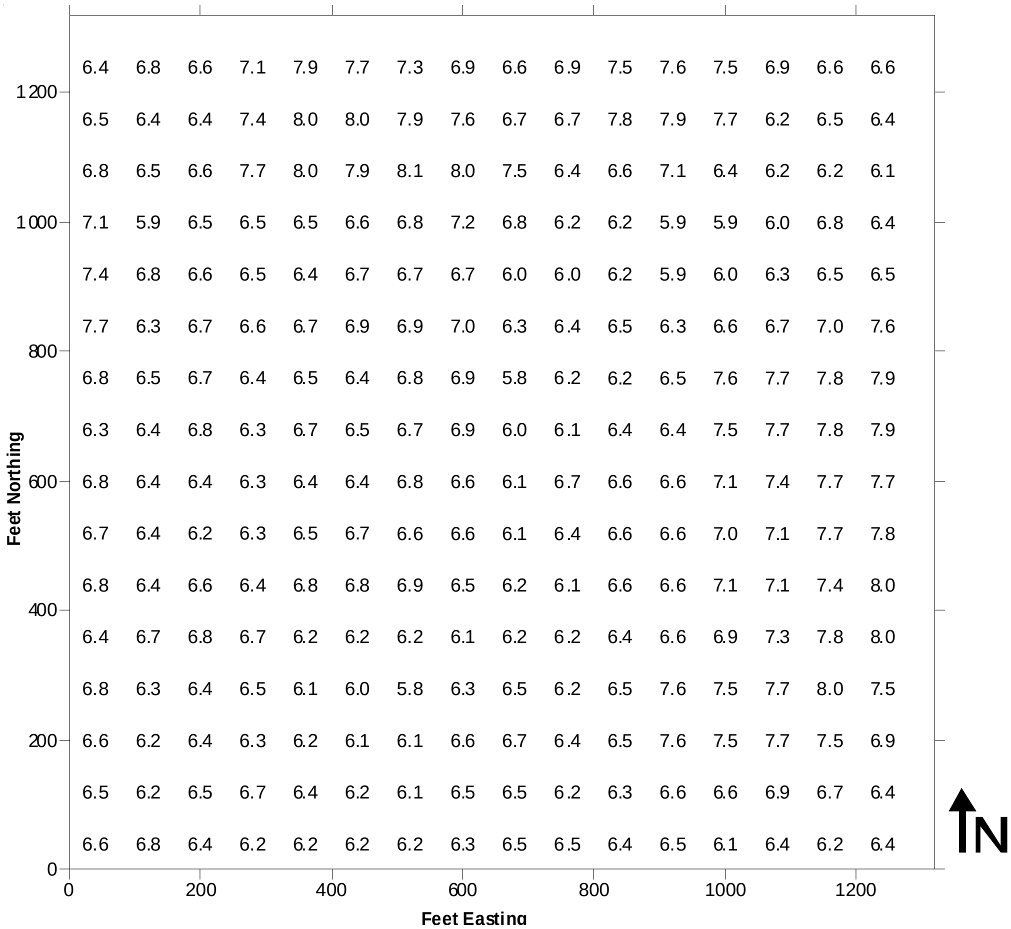


Figure 1-25. Mansfield pH, 1994.

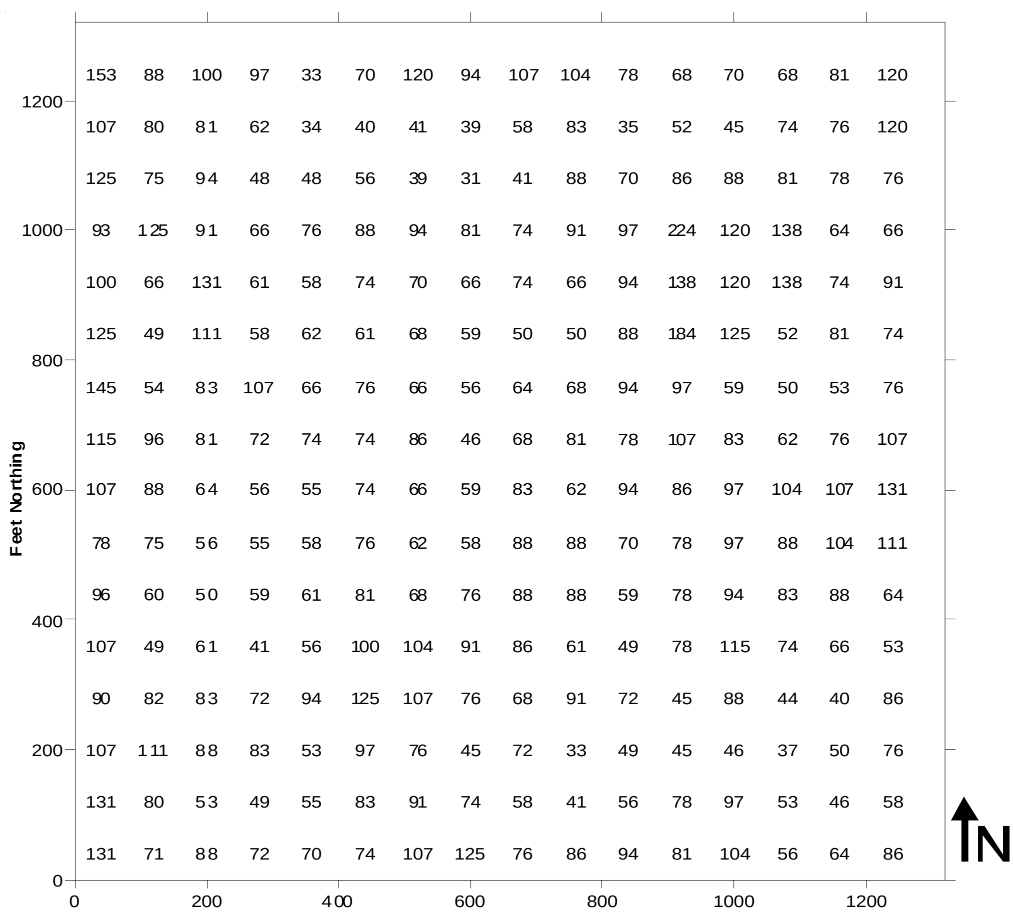


Figure 1-26. Mansfield P, 1994.

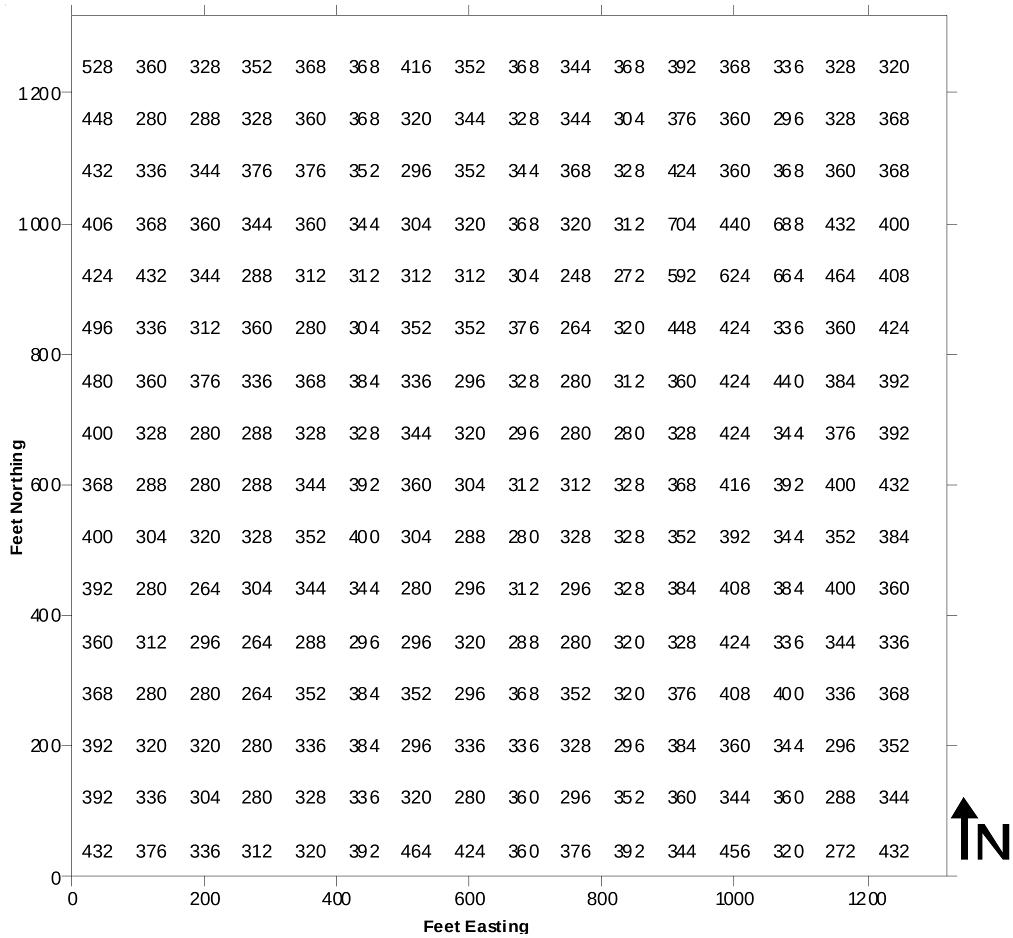


Figure 1-27. Mansfield K, 1994.

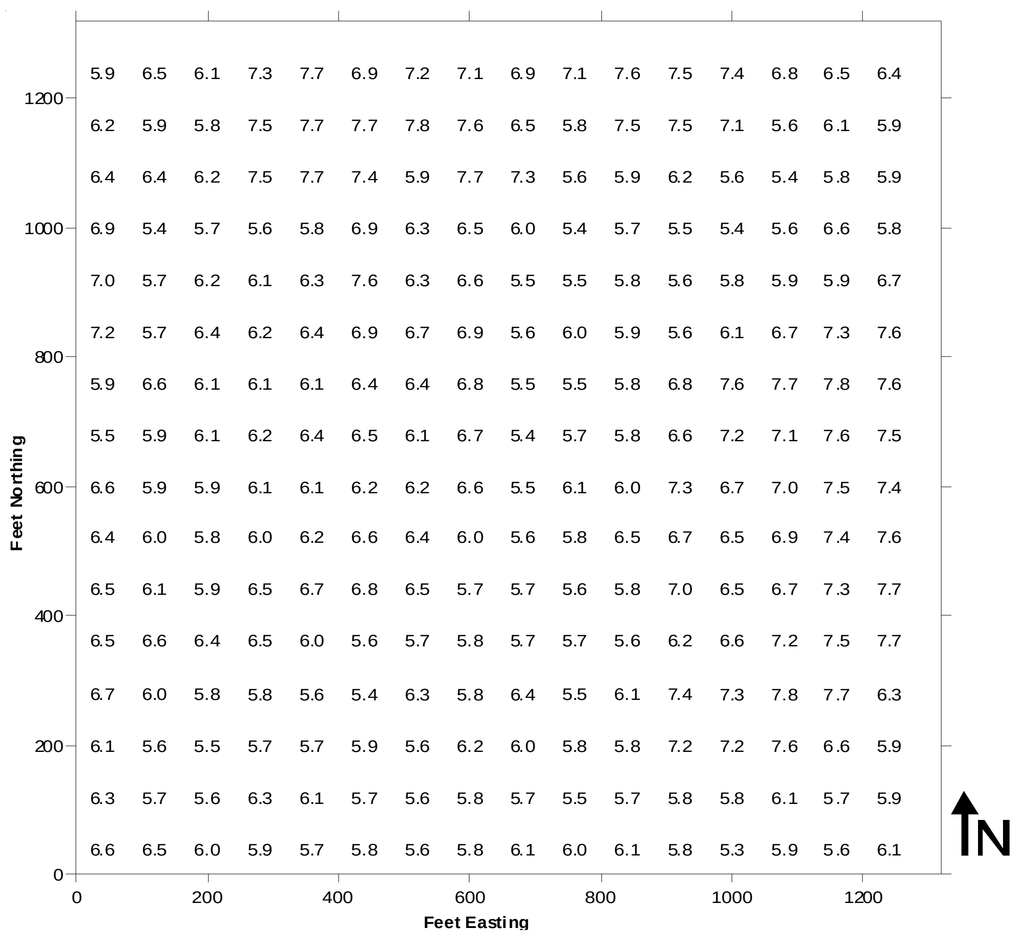


Figure 1-28. Mansfield pH, 1999.

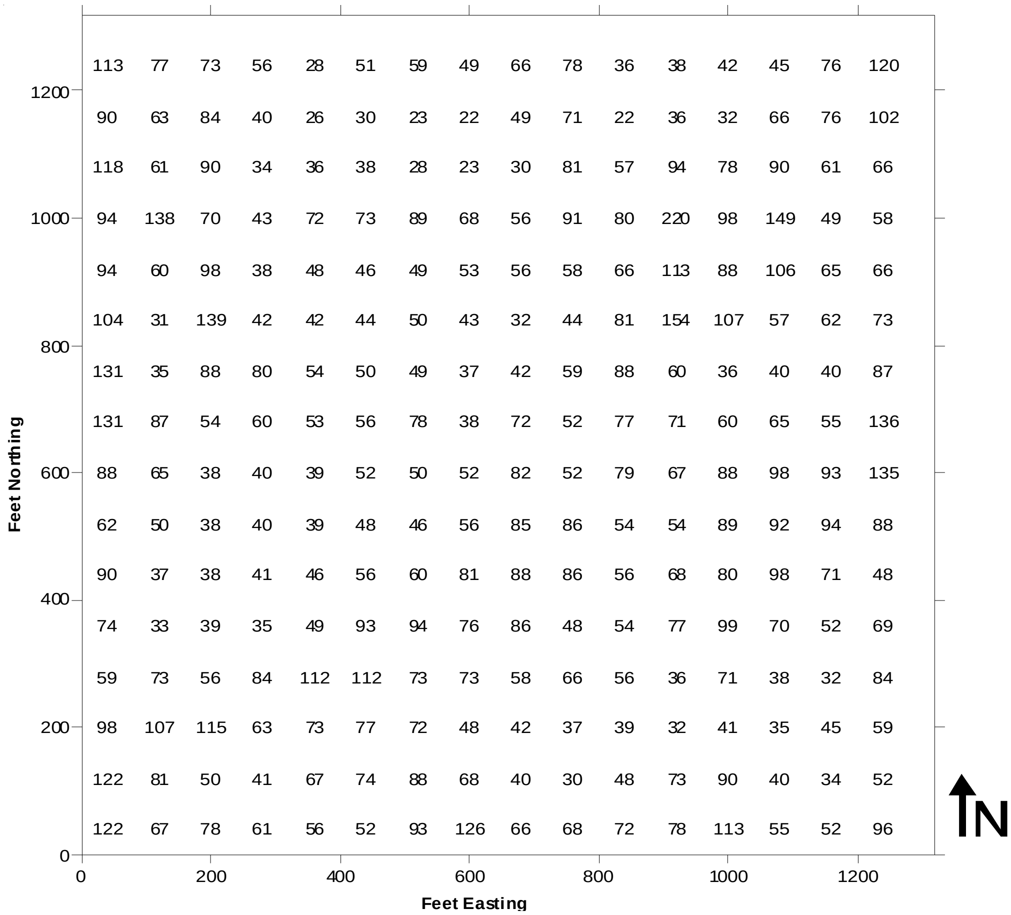


Figure 1-29. Mansfield P, 1999.

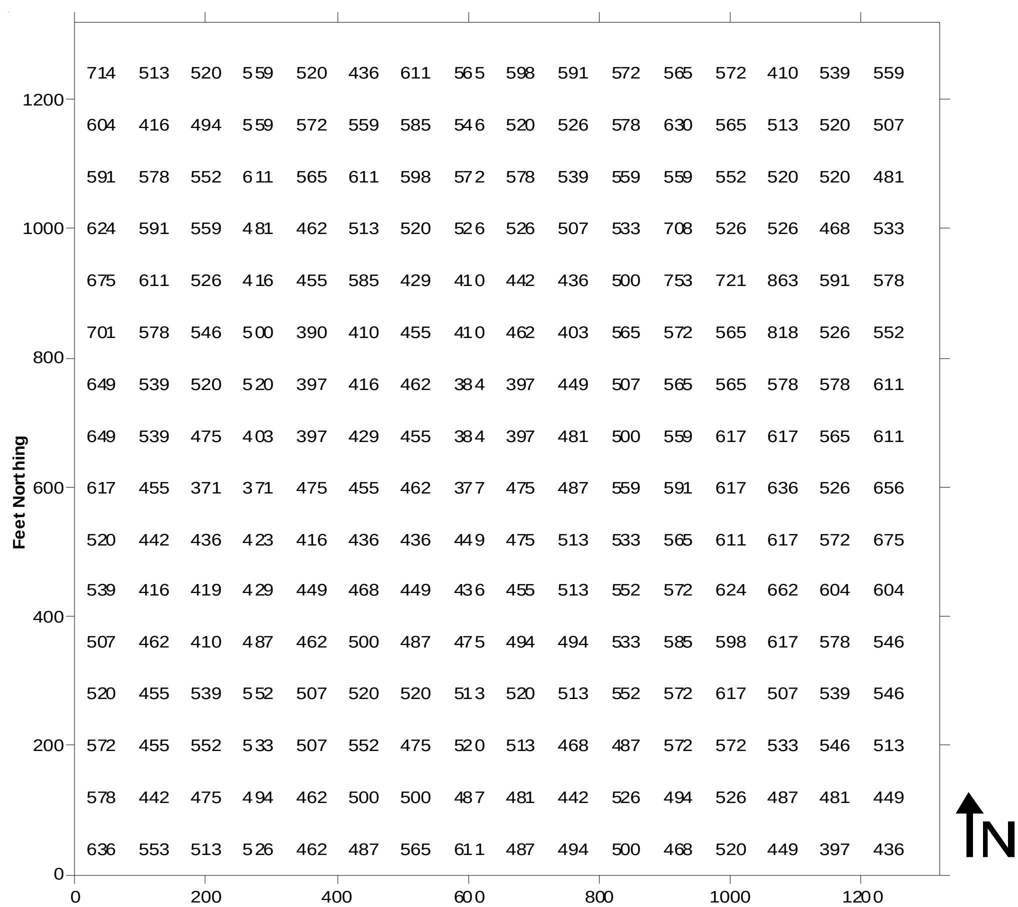


Figure 1-30. Mansfield K, 1999.

Figures 1-31 through 1-40 represent contour maps of the previous 30 plot maps of pH, P and K at Mansfield. These contour maps were constructed using kriging as described in the Methods discussion. The first contouring of these data was conducted in 1989 using inverse distance squared interpolation within Surfer. Subsequent geostatistical analysis showed strong spatial structure within the data; therefore, the following figures were developed taking advantage of that knowledge.

The contour mapping makes identifying soil fertility patterns within the field visually easier. At Mansfield, three areas of pH are higher than 7.0. Two are along the north border and the other is along the east side. The lowest pH area is in the center of the field, following a track from southwest to northeast. Liming in fall 1991 increased the pH of this area to almost 6.5 before it decreased again by the 1999 sampling. The pH of the higher pH areas was stable during the length of sampling, while the pH in the lower pH area tended to decrease rapidly between lime applications.

Soil P and K levels were relatively low throughout the field in 1961, except for an area in the northeast that was exceptionally high. We think that this area was near the site of an old farmstead, but we know of no other physical evidence supporting this theory. The evidence for the presence of a historic farmstead is based on proximity of high-fertility areas to known old farmsteads and suggests that this high-fertility area was the location of a livestock feeding enclosure far in the past. Soil P and K values rapidly increased until about 1988, when fertilizer P and K application was suspended. Values then rapidly decreased through the 1999 sampling date. The suspected old feedlot area continued to be easily identified by its unusually high P and K levels throughout the sampling study.

Comparing Figures 1-31 and 1-32, the P and K patterns are similar in the 1961 sampling; however, although P patterns in 1976 were similar to patterns in 1961, K patterns diverged, probably due to high K fertilization. By 1982, both P and K patterns were different than the 1961 sampling due to high P and K fertilization during that 20-year period. In ensuing years, due to P and K drawdown without P and K fertilization, the original P and K patterns began to be revealed again.

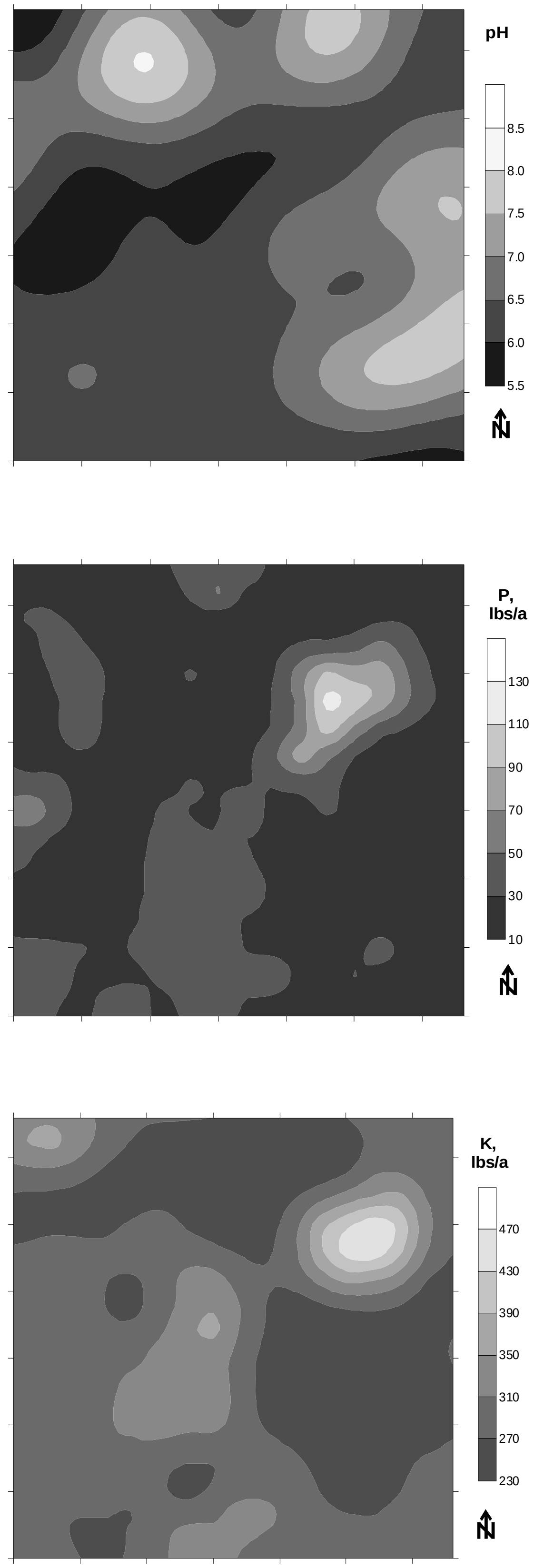


Figure 1-31.
Mansfield, kriged estimate contour maps, 1961.

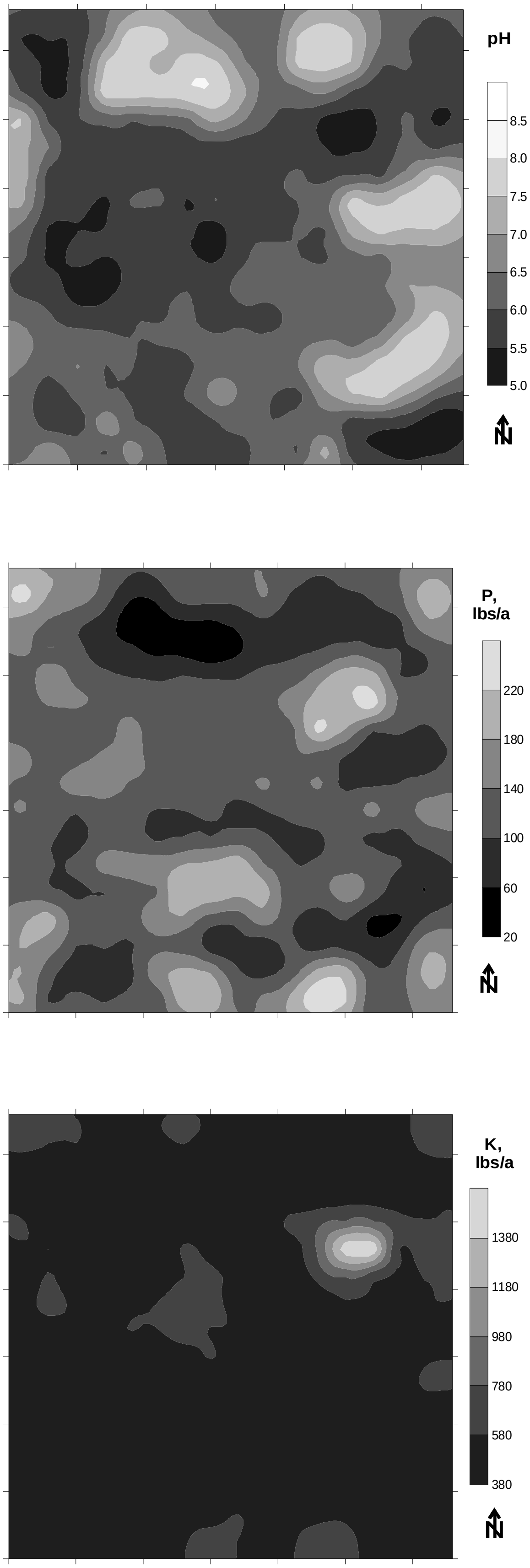


Figure 1-32.
Mansfield kriged estimate contour maps, 1976.

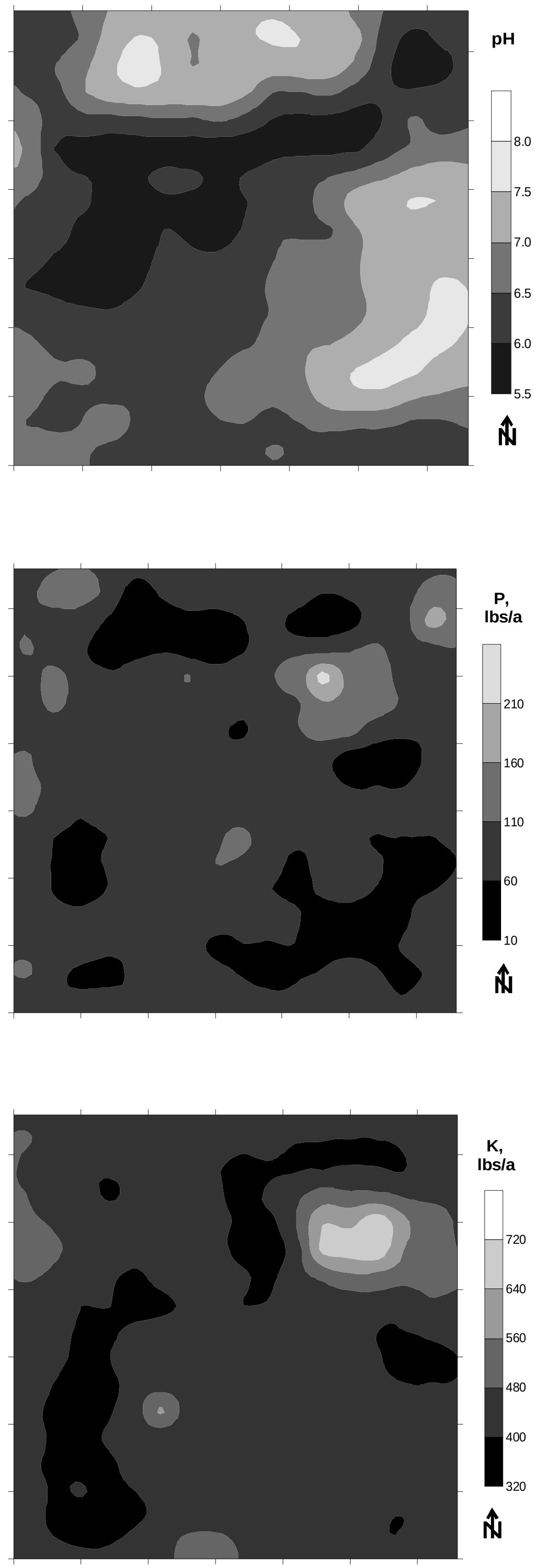


Figure 1-33.
Mansfield kriged estimate contour maps, 1982.

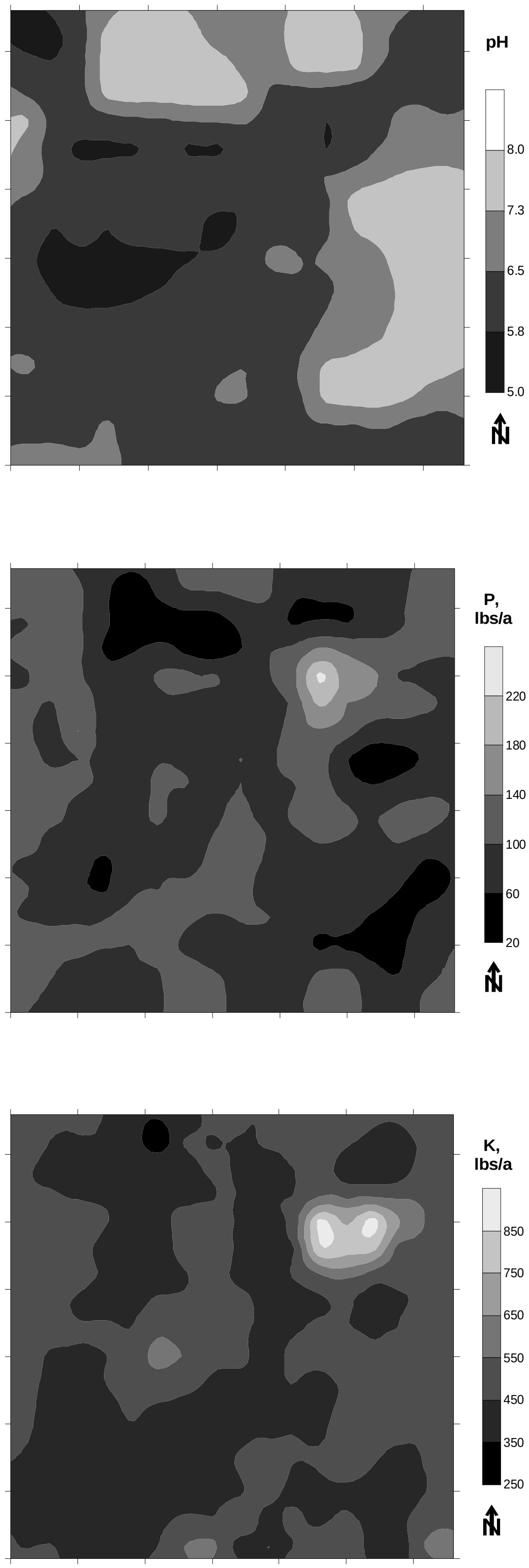


Figure 1-34.
Mansfield kriged contour maps, 1988.

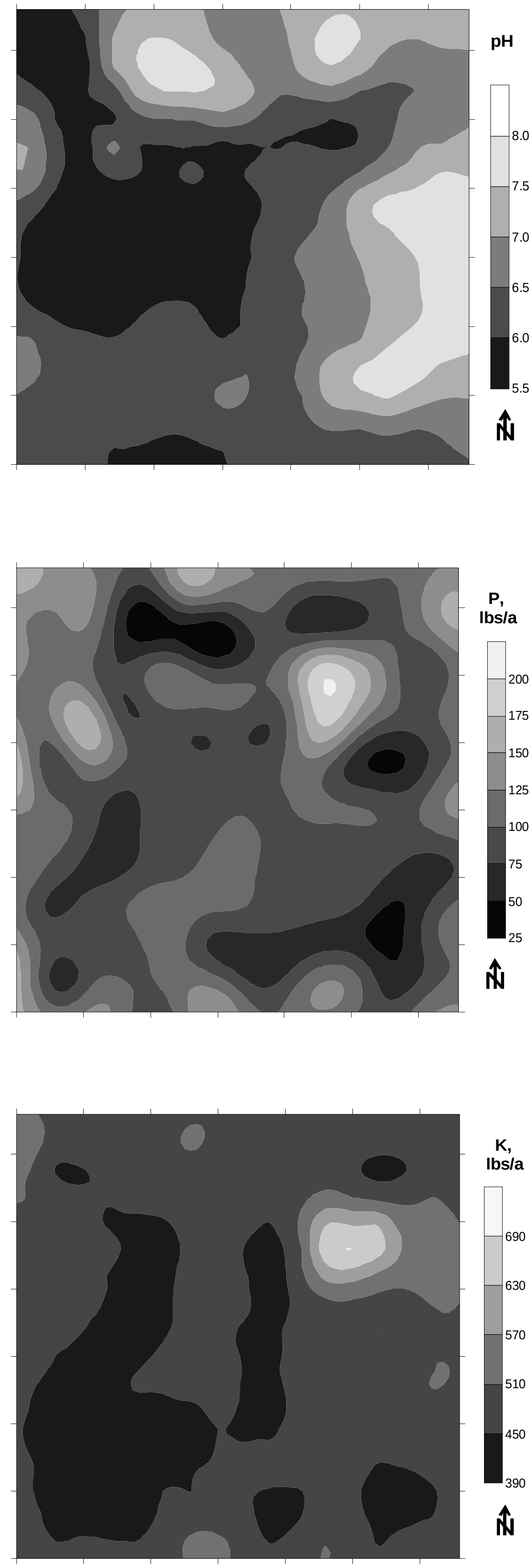


Figure 1-35.
Mansfield kriged contour maps, 1989.

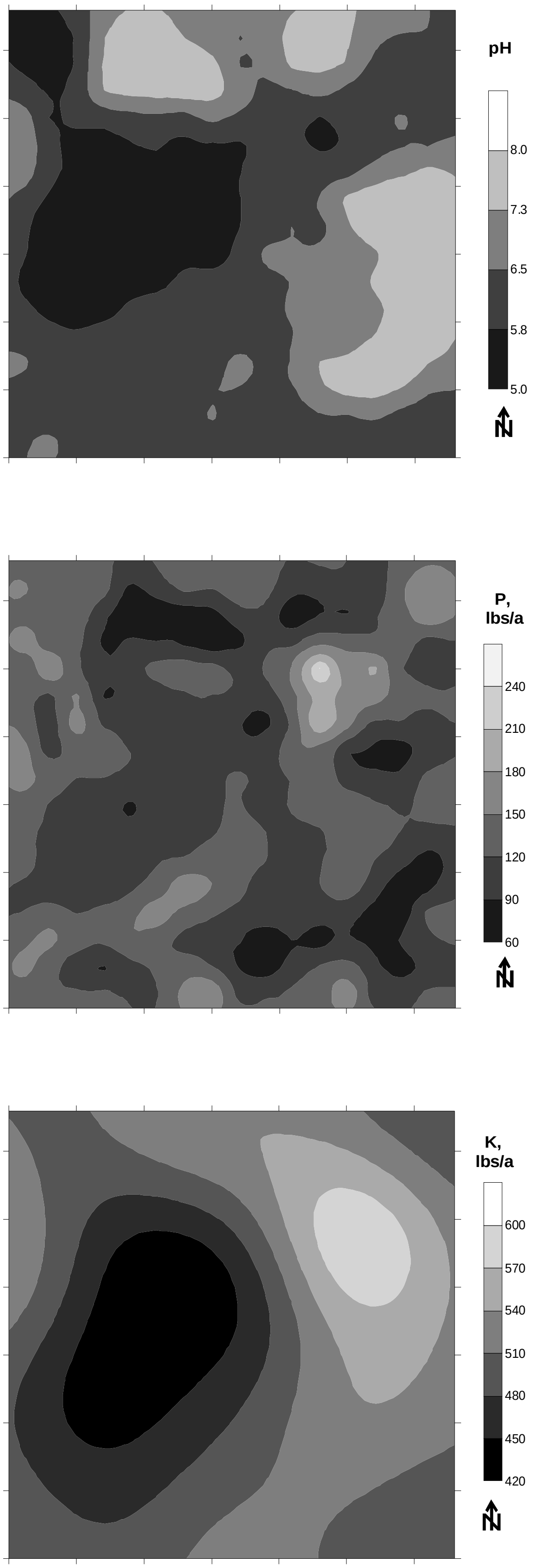


Figure 1-36.
Mansfield kriged contour maps, 1990.

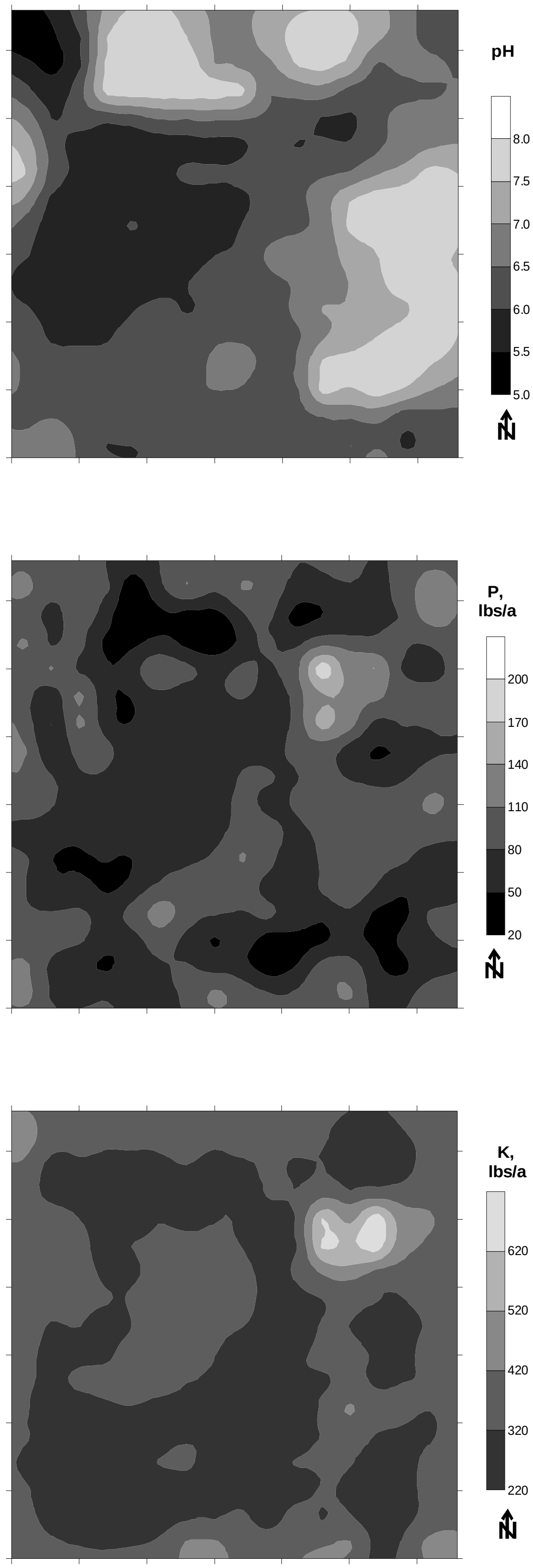


Figure 1-37.
Mansfield kriged contour maps, 1991.

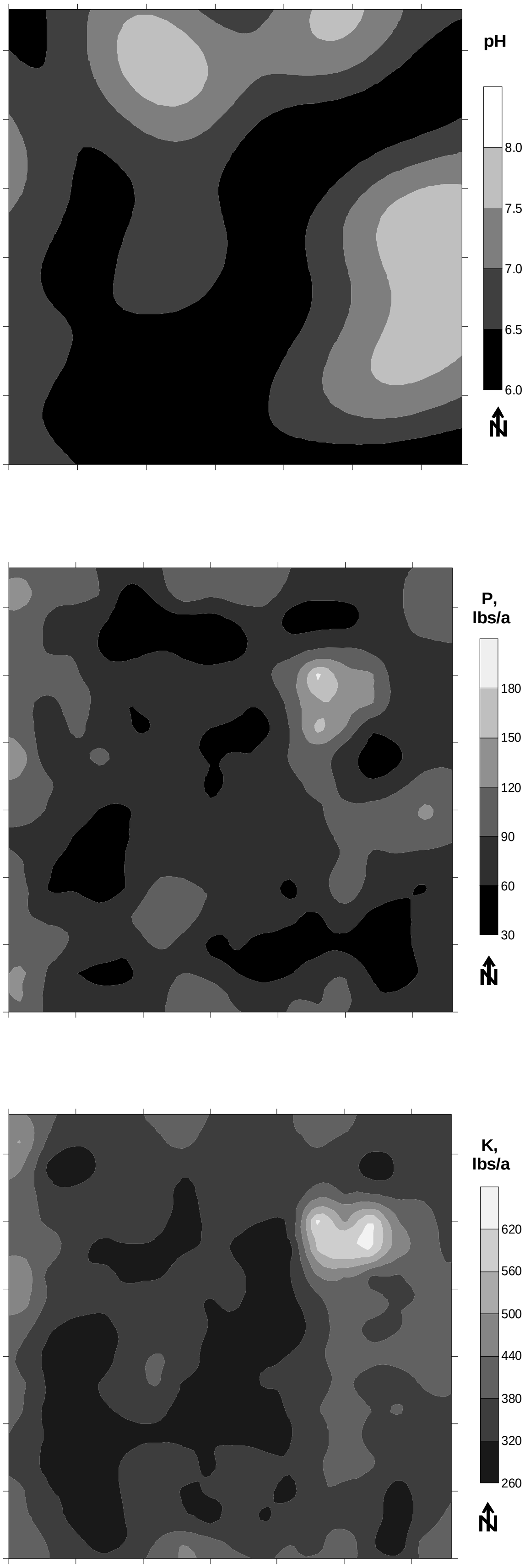


Figure 1-38.
Mansfield kriged contour maps, 1992.

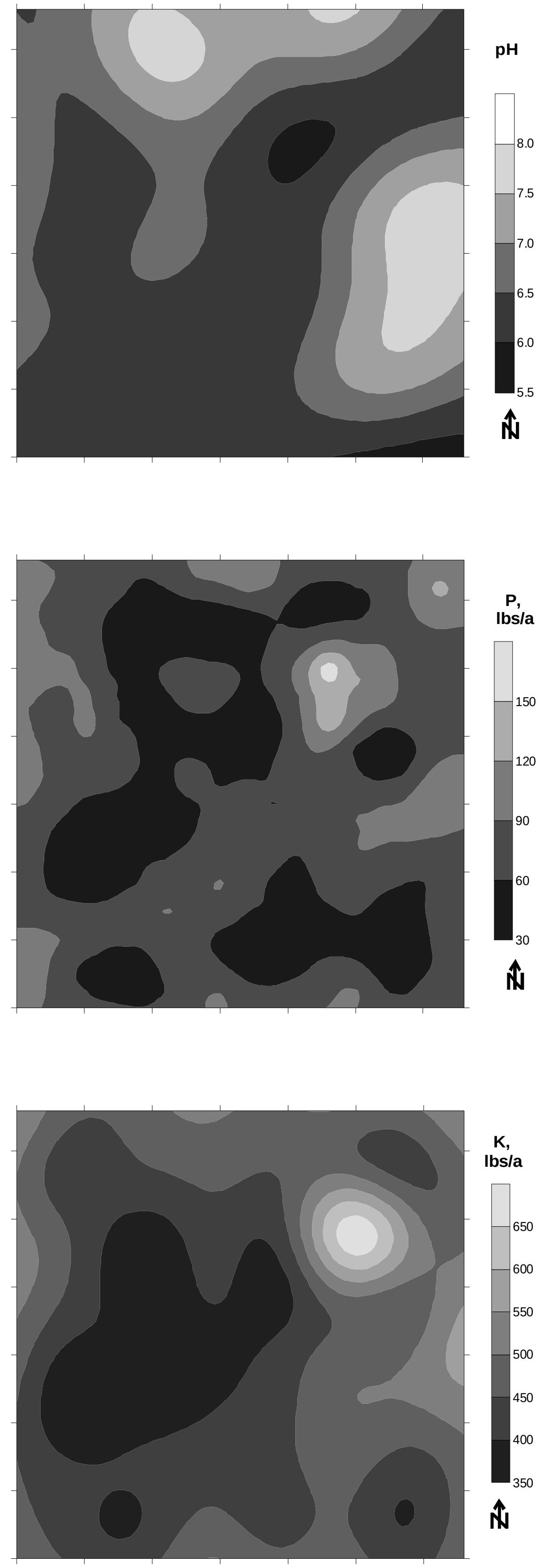


Figure 1-39.
Mansfield kriged contour maps, 1994.

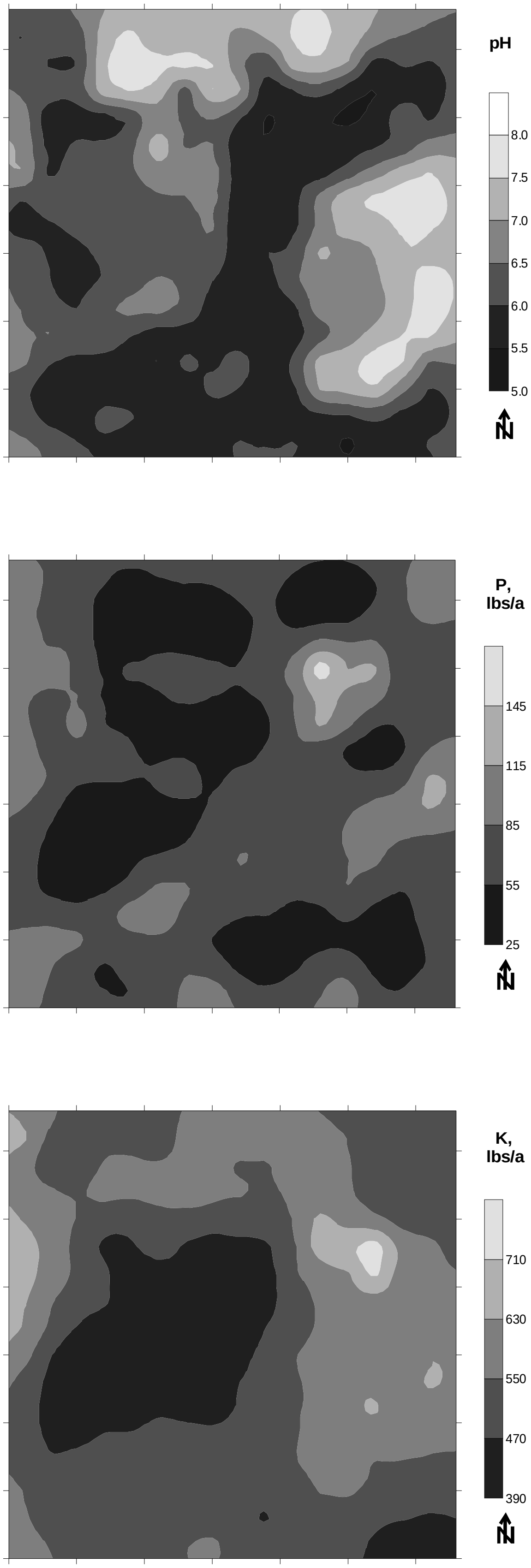


Figure 1-40.
Mansfield kriged contour maps, 1999.

Figures 1-41 through 1-51 show the combined effects of fertilizer application in excess of removal from 1961 through 1977, a maintenance approach to P and K application from 1978 through 1987 and drawdown of P and K levels from 1988. Although hundreds of combinations of possible differences are possible, only those differences between years that were most likely to be helpful in understanding spatial changes in soil pH, P and K levels were selected.

Changes in pH were directed by lime application to certain areas of the field and by the differential change in pH directed by soil type differences. The ridges in the field, likely naturally low in buffering carbonate minerals, decreased in pH through time, while other parts of the field were stable under the same environment and management practices.
Soil P and K levels also tended to be more volatile on the ridges than in the lower areas of the field.

Table 1. Differences between sampling years are shown in Figures 41 through 51. The contour maps again were developed in a similar manner to the methods described for contour maps 31 through 40. N rates for corn unavailable after 1993.

Year	Crop	Yield	N	P_2O_5	K_2O	Lime	P_2O_5 removed	K_2O removed	pH change	P1 change	K change
		bu/a	lb/a	lb/a	lb/a	T/a	lb/a	lb/a			
1961	Corn	123	120	40	90		53	34			
1962	Corn	126	120	110	80		54	35			
1963	Corn	154	130	42	70	2.0	66	44			
1964	Corn	134	130	49	84		57	37			
1965	Corn	143	175	49	105		62	40			
1966	Corn	111	170	56	149		47	31			
1967	Corn	137	162	56	150		59	39			
1968	Corn	108	170	101	150		46	31			
1969	Corn	137	209	101	150		59	38			
1970	Corn	122	198	114	150		53	34			
1971	Corn	154	192	121	154		67	43			
1972	Corn	156	182	147	156		67	44			
1973	Corn	121	164	134	156		53	34			
1974	Corn	78	219	134	140	2.0	34	20			
1975	Corn	136	169	125	137		58	38			
1976	Corn	168	168	94	123		72	47	-0.3	+104	+240
1977	Corn	112	200		120	2.0S	48	31			
1978	Bean	58					53	81			
1979	Corn	178	197				76	50			
1980	Bean	48					41	62			
1981	Corn	149	182	80	100		60	39			
1982	Bean	55				3.5N	47	72	+0.3	-49	-84
1983	Corn	110	184	99	99		47	31			
1984	Bean	43					37	56			
1985	Corn	199	184	92	90		86	56			
1986	Bean	56					48	73			
1987	Corn	183	188	76	98		79	51			
1988	Bean	45					38	58	+0.3	+15	+33
1989	Corn	160	180				69	45	0.0	+ 4	+10
1990	Bean	65					55	85	- 0.1	+25	+29
1991	Corn	165	180			4spot	71	46	+0.15	-45	-186
1992	Bean	42					36	56	+0.1	-19	-26
1993	Corn	160					69	45			
1994	Bean	61					52	81	+0.1	+6	+94
1995	Corn	132					57	37			
1996	Bean	49					42	64			
1997	Corn	160					69	45			
1998	Bean	49					42	65			
1999	Corn	201					86	56	-0.2	-3	+81
2000	Bean	56					48	74			
2001	Corn	182					78	51			
2002	Bean	42					36	56			
2003	Corn	196					84	55			
2004	Bean	55					47	73			
2005	Corn	177					76	50			
2006	Bean	62					53	82			
SUM				1,820	2,551		2,637	2,315			

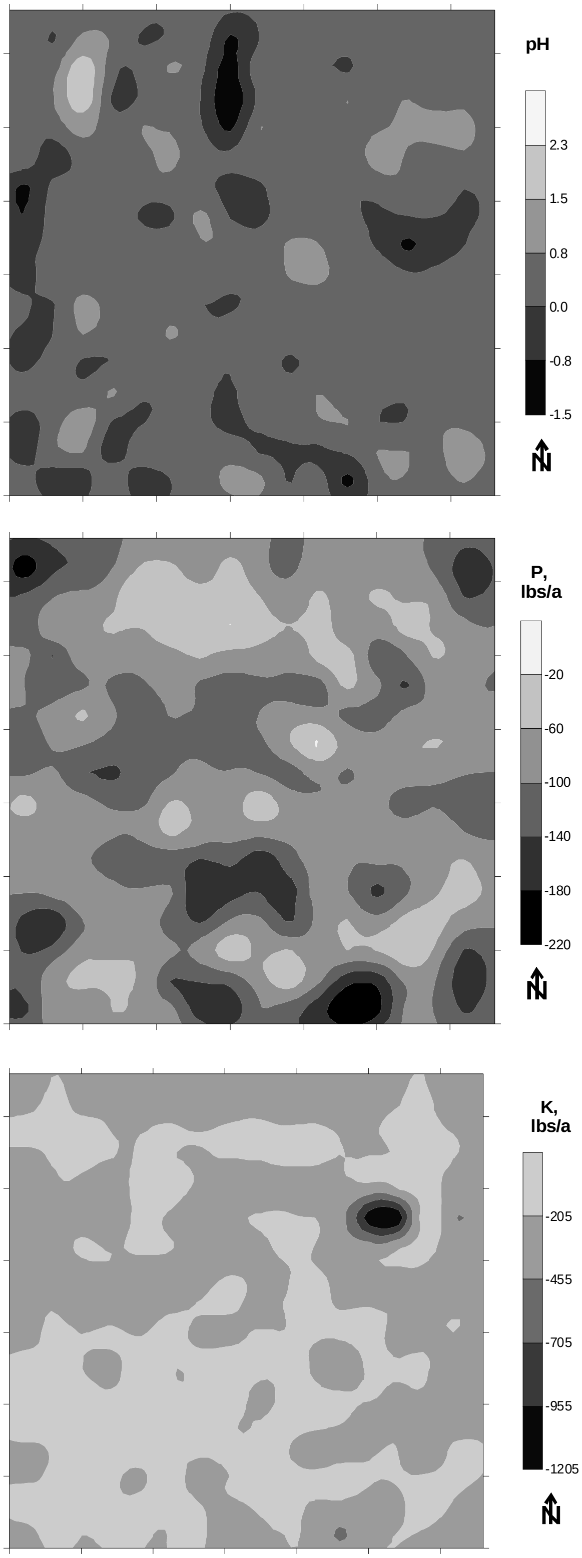


Figure 1-41.
Mansfield differences in soil test levels, 1961 through 1976. These data were calculated by subtracting 1976 values from those of 1961. A negative change indicates an increase in value; a positive change indicates a decrease. An increase in P and K was observed in all areas due to heavy fertilization of crops.

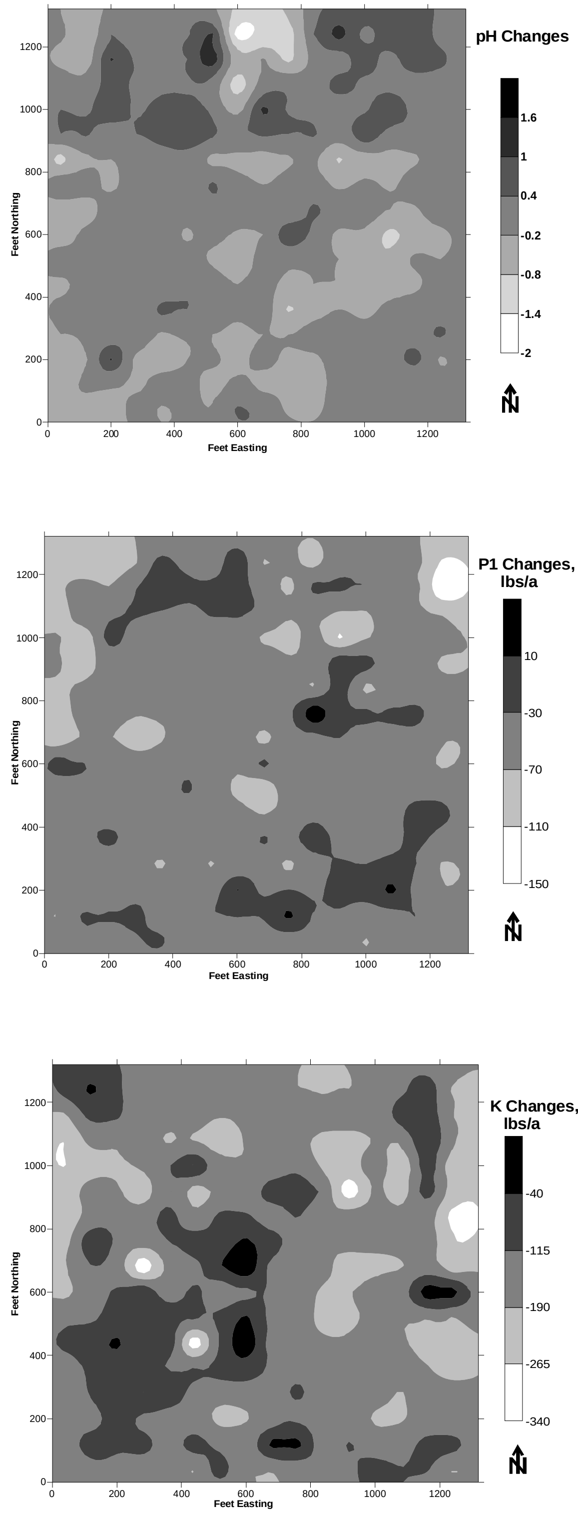


Figure 1-42.
Mansfield pH, P and K changes, 1976-1982. These data were calculated using the 1961 values minus the 1976 values. Negative numbers indicate an increase in value. Positive numbers indicate a decrease.
An increase in pH was observed in the north half of the field due to liming. Increases in P and K levels were seen as a continued result of P and K fertilization.

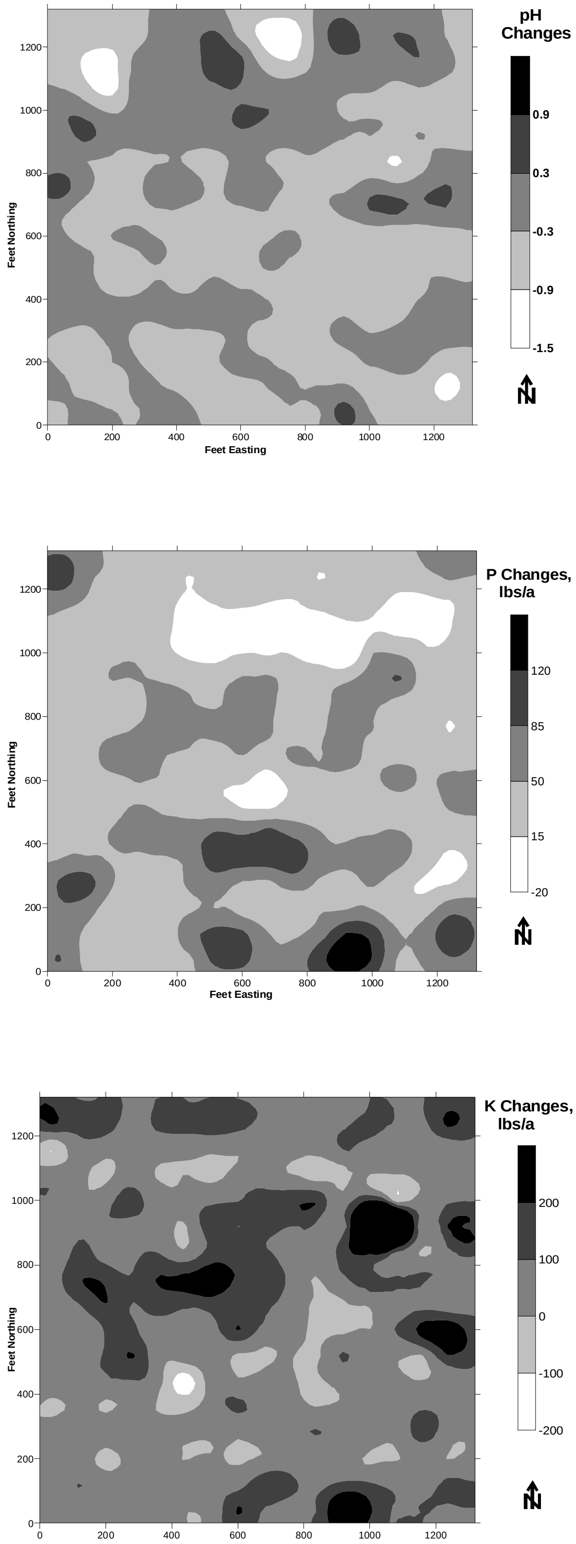


Figure 1-43.
Mansfield changes in soil pH, P and K, 1976-1982. The north half of the field increased in pH due to liming. The P and K values in some parts of the field decreased due to lower P and K rates applied and higher crop yield.

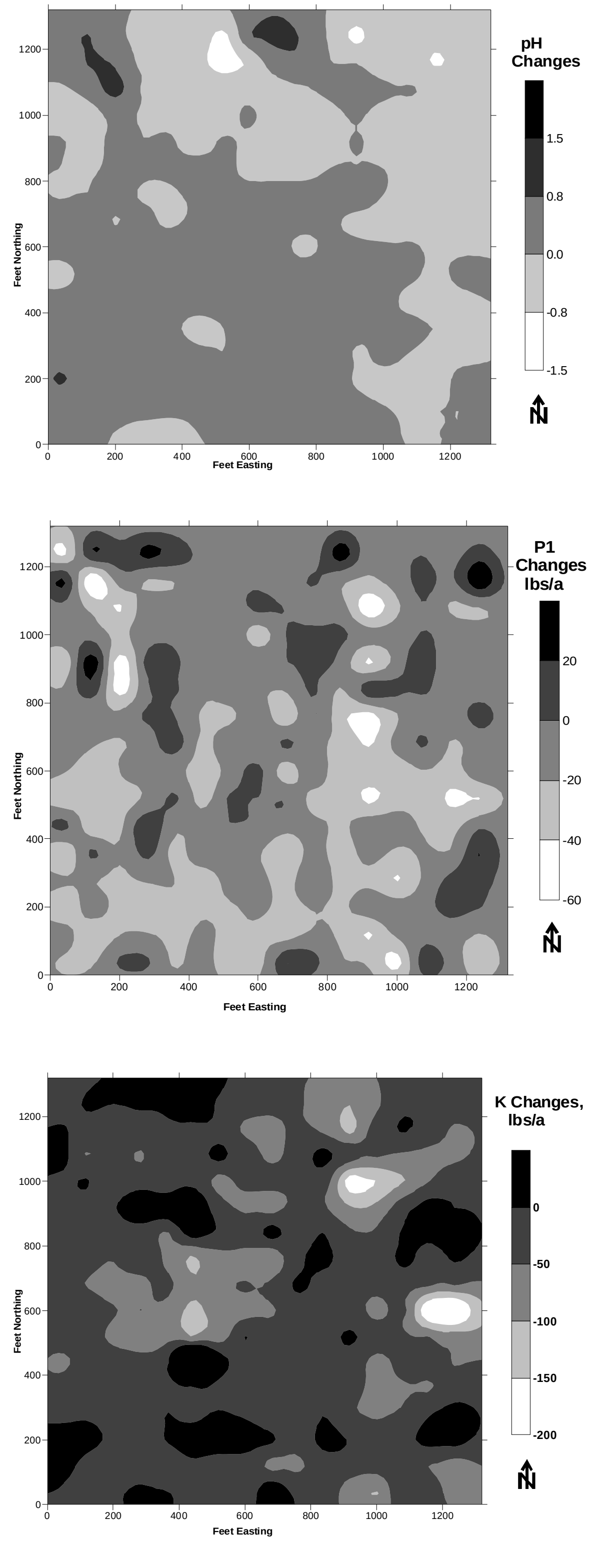


Figure 1-44.
Mansfield pH, P and K changes, 1982-1988. Soil pH decreased in the southwestern part of the field. Soil P tended to increase in the southern half of the field, while the northern half tended to remain constant. Soil K tended to increase except in a small area of the east and the old feedlot area.

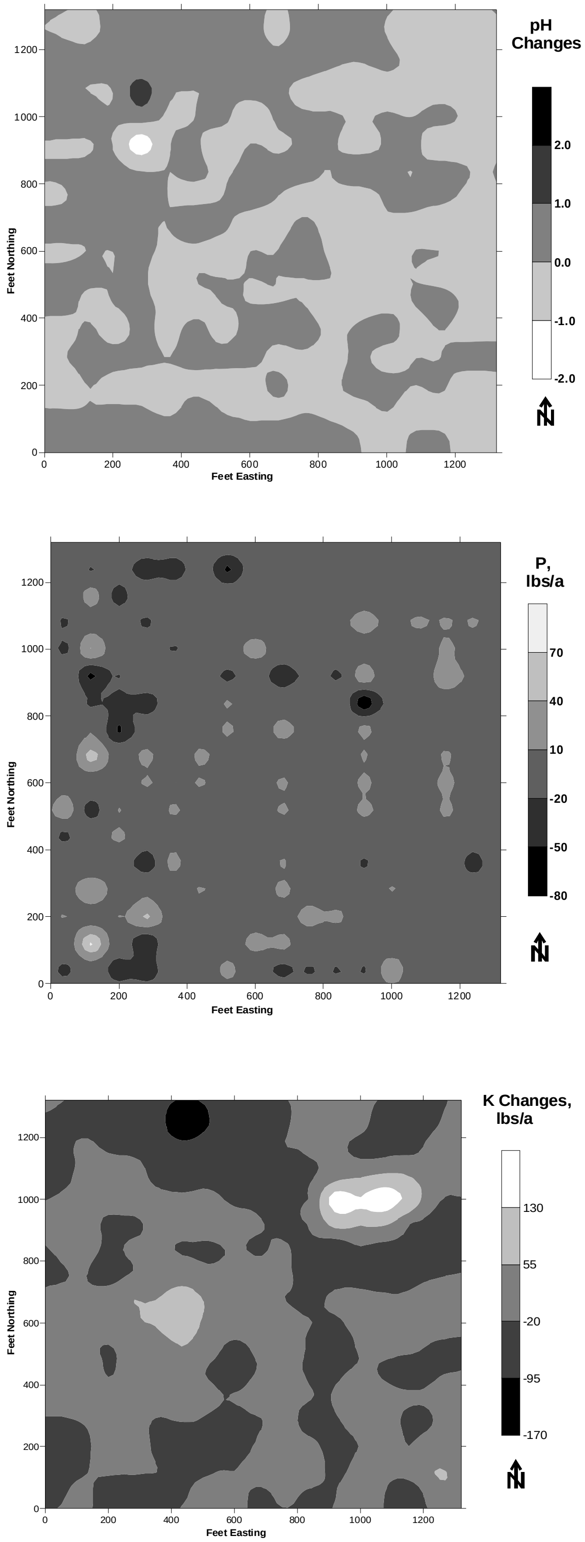


Figure 1-45.
Mansfield pH, P and K changes, 1988-1989.
Soil pH and P changes were relatively small. Soil K increased, except for a decrease in the old feedlot area.

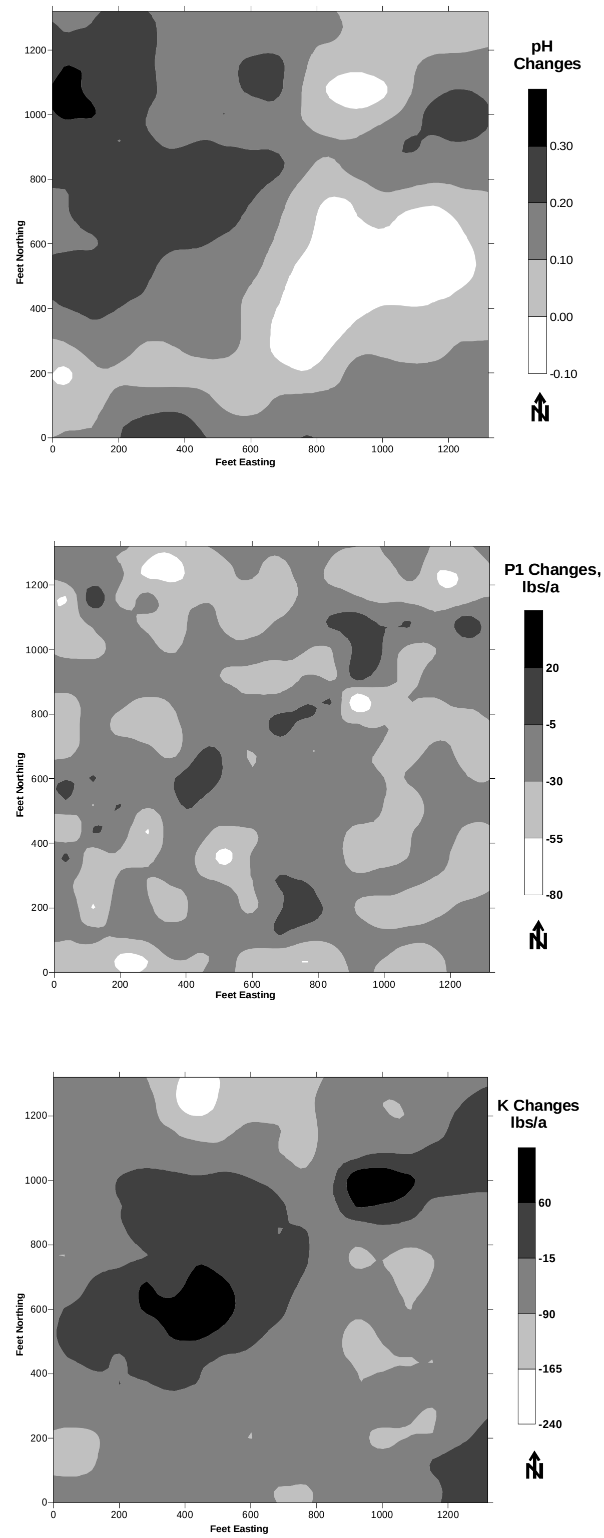


Figure 1-46.
Mansfield pH, P and K changes, 1988-1990.
Soil pH increased in the northwestern part of the field. Soil P levels were relatively constant, while K levels decreased in the southwest to northeast.

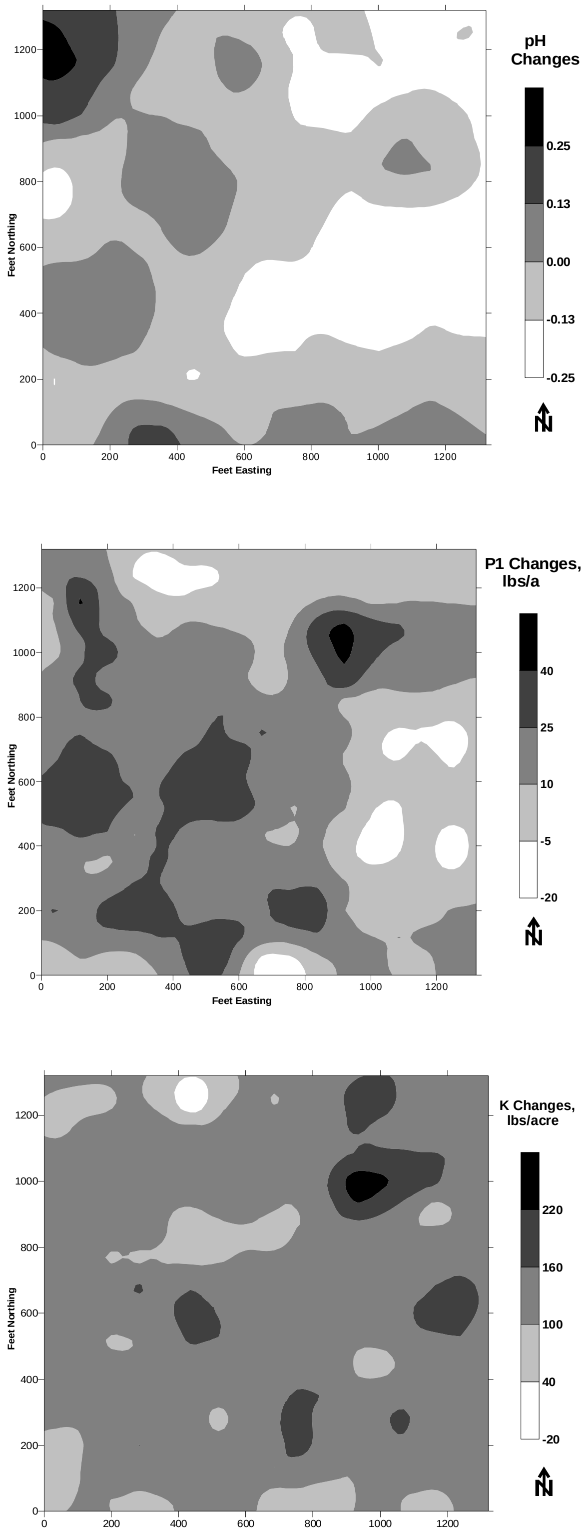


Figure 1-47.
Mansfield pH, P and K changes, 1988-1991.
Soil pH decreased in all but the northeastern part of the field. Soil P levels decreased in all but the eastern part of the field. K levels tended to decrease, especially in the old feedlot area.

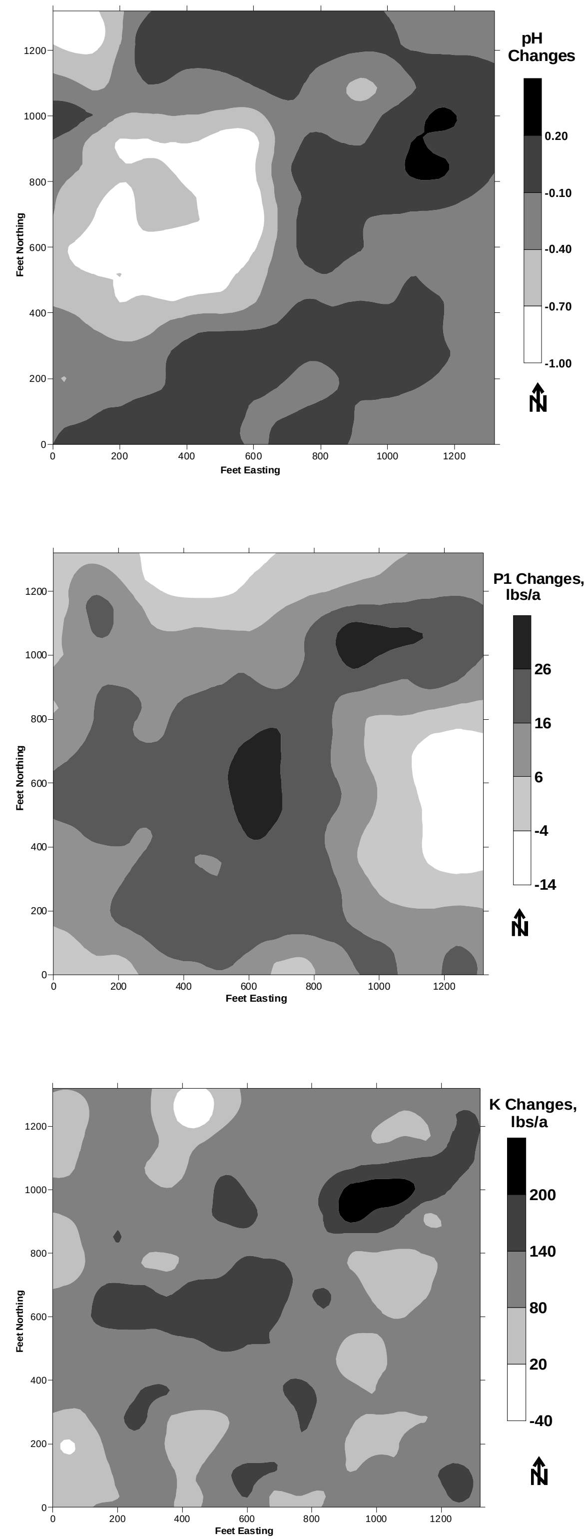


Figure 1-48.
Mansfield pH, P and K changes, 1988-1992. Soil pH increased in the southwestern to northeastern part of the field in response to liming in fall 1991. Soil P decreased in the southwestern to northeastern part of the field, but was relatively constant in the north and east. Soil K levels decreased in most of the field.

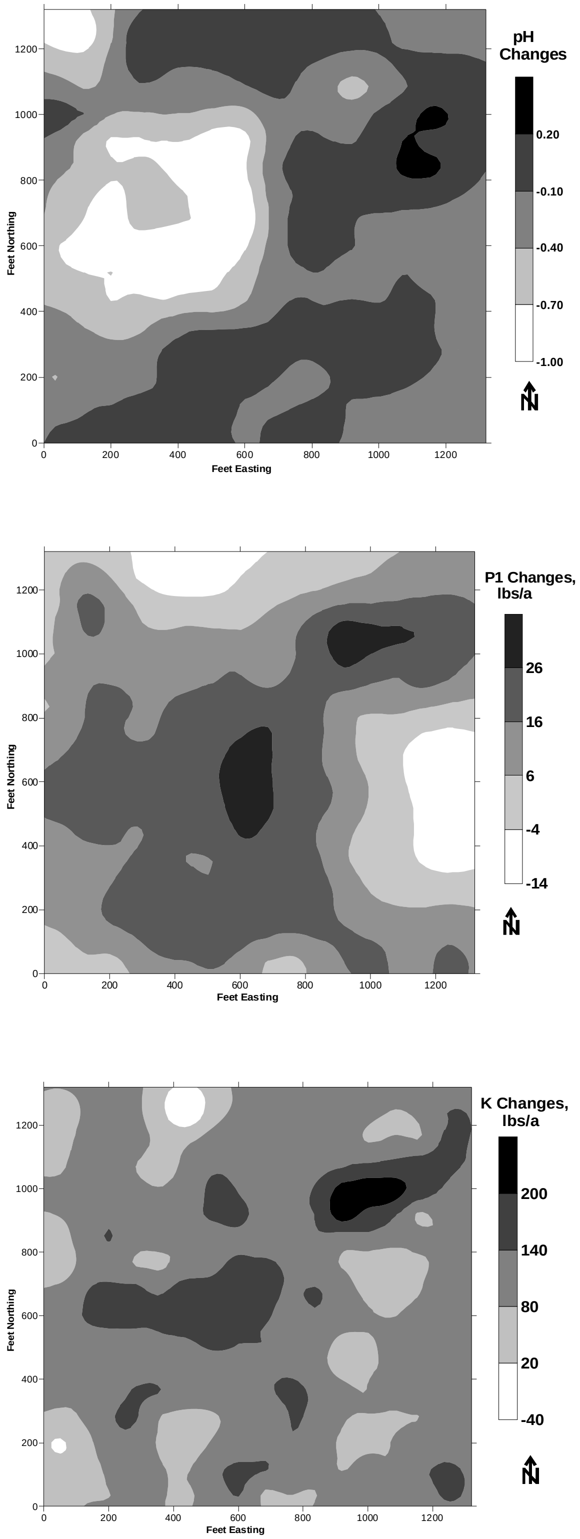


Figure 1-49.
Mansfield pH, P and K changes, 1988-1994.
Soil pH increased in the southwestern to northeastern part of the field in response to fall 1991 liming. Soil P decreased in the southwestern to northeastern part of the field. Soil K levels decreased in most of the field.

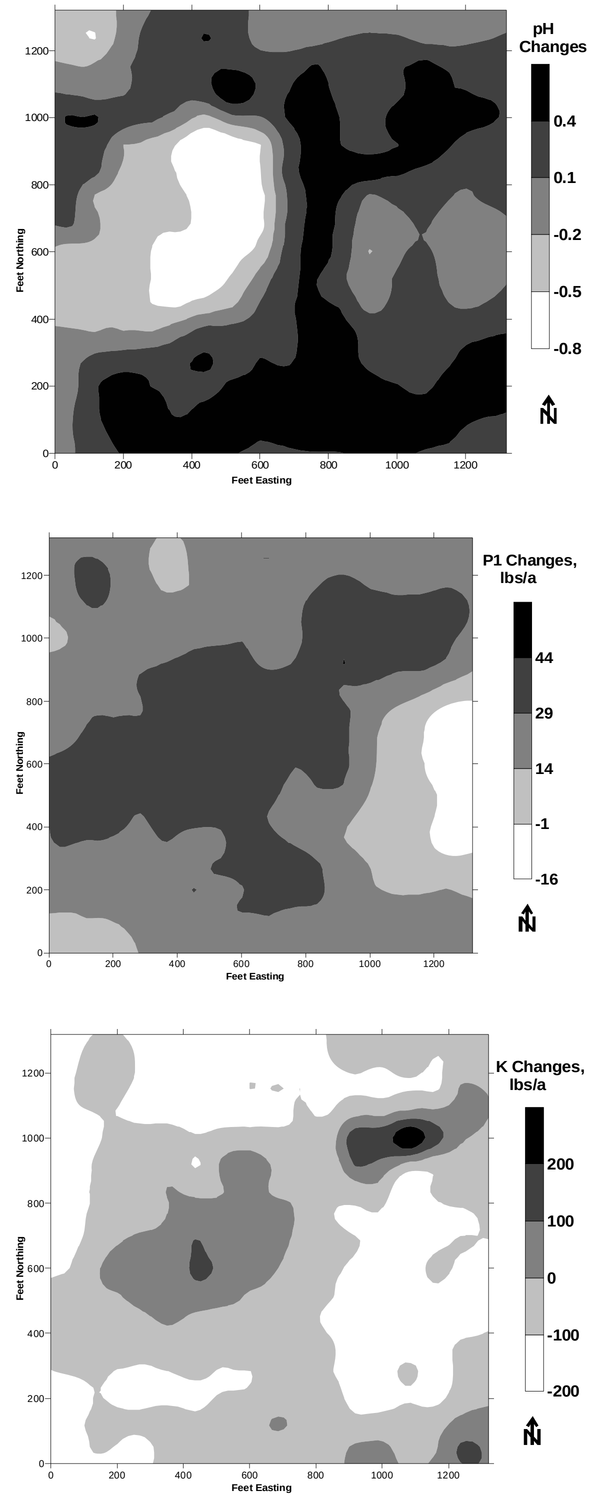


Figure 1-50.
Mansfield pH, P and K changes, 1988-1999.
Soil pH increased in the southwestern part of the field.
Soil pH decreased in most of the rest of the field.
Soil P decreased in the southwestern to northeastern part of the field. Soil P increased in the southeast.
Soil K decreased in the southwestern to northeastern part of the field. Soil K increased in the east and north.

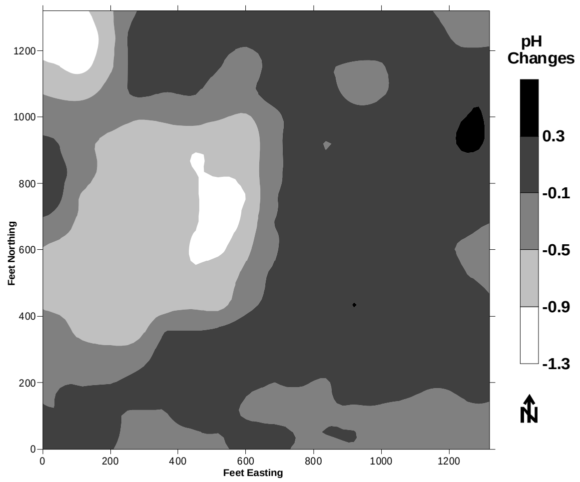


Figure 1-51.
Mansfield pH changes in response to site-specific liming, 1991-1992.

Buildup application of P fertilizer increased the P1 test by 1 pound (lb) for each 5.4 lb phosphorous pentoxide (P_2O_5) applied.

Once P applications ceased, the P1 test decreased 69 pounds per acre (lb/a) when 543 lb P_2O_5 were removed, or an average of 1 lb P1 test for each 7.9 lb P_2O_5 removed. In this soil, P was less easily depleted than the buildup rate would suggest.

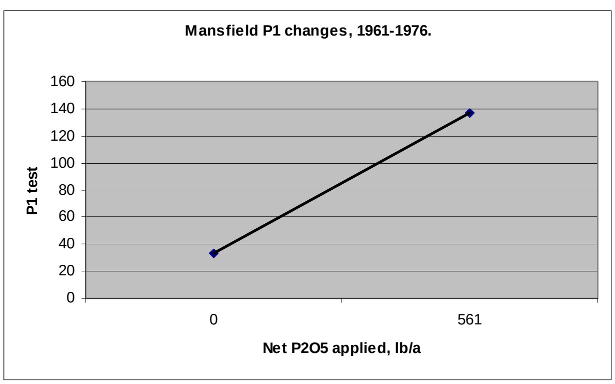


Figure 1-52.
Changes in Mansfield P1 test with net additions of P fertilizer.

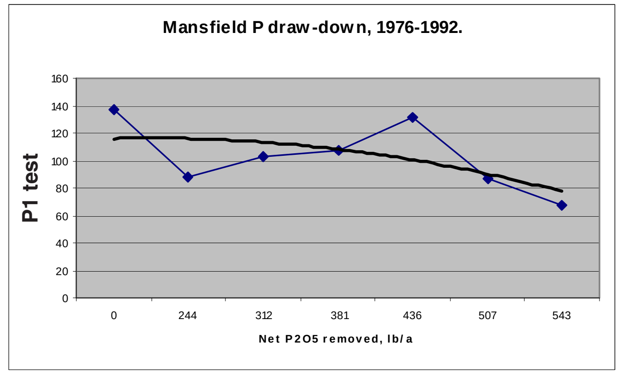


Figure 1-53. Changes in P1 soil test with net removal of P through crop removal.

At Mansfield, 1,448 lb/a potassium oxide (K_2O) resulted in a K soil test increase of 240 lb/a, for an average of 1 lb K soil test increase for each 6 lb K_2O added. However, removal of 387 lb/a K_2O resulted in a decrease of 222 lb/a in the K soil test, for an average rate of 1 lb K soil test decrease with every 1.7 lb/a K_2O. This disparity also could be the result of years with no K additions and the movement of K to more unavailable forms during this period of no fertilizer K additions.

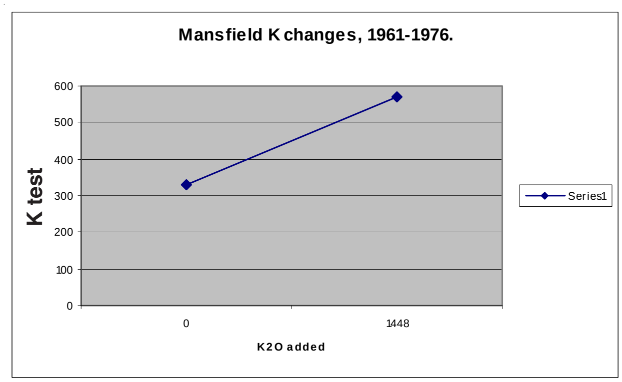


Figure 1-54. Changes in K soil test with net addition of K fertilizer.

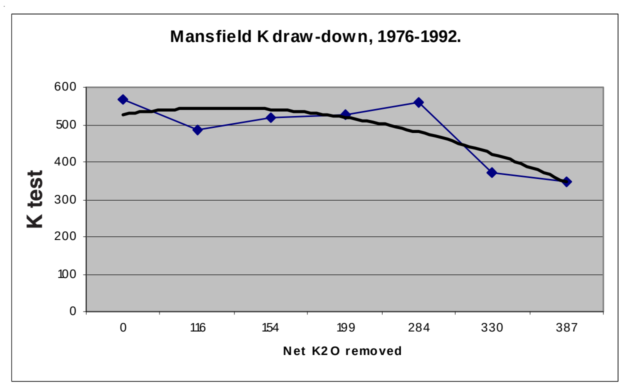


Figure 1-55. Changes in K soil test with net removal of K through crop removal.

Figures 2-1 through 2-39 show soil pH, P and K levels at Thomasboro from 1982 through 2001.
Blank areas in the southeast are due to the presence of an abandoned U.S. Air Force radar building in this area. The researchers did not know why the blank areas are different between 1982 and the next sampling year. Other differences in blank areas reflect larger farm equipment used in later years that could not negotiate the small areas between the large independently located radar antenna and the building area.

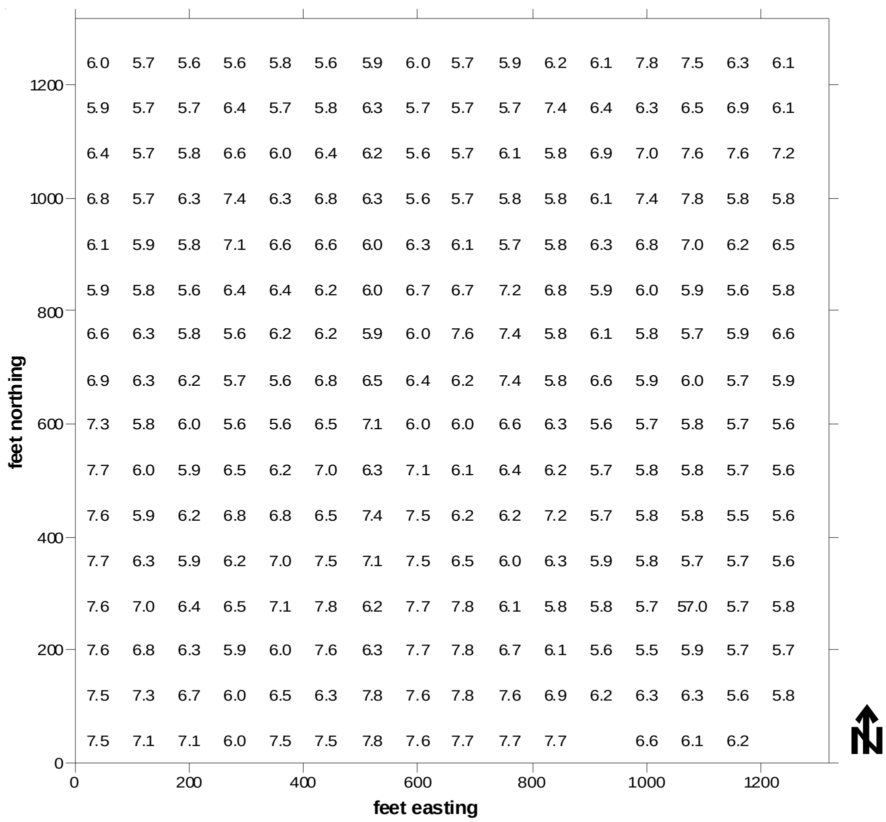


Figure 2-1.
Thomasboro soil pH,
1982.

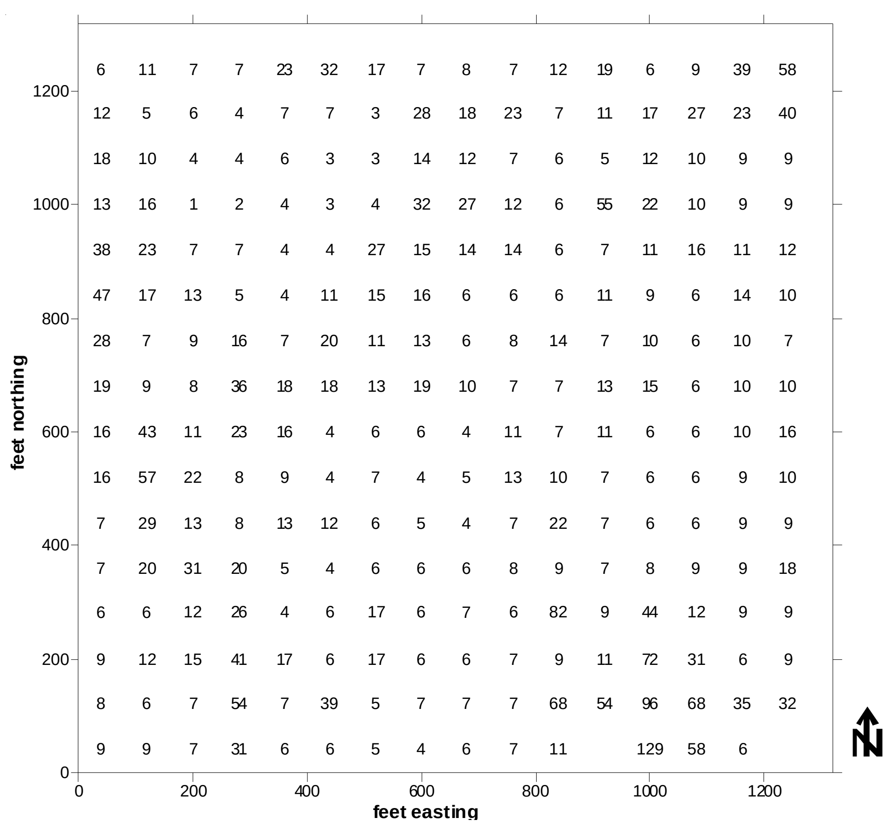


Figure 2-2.
Thomasboro P,
1982.

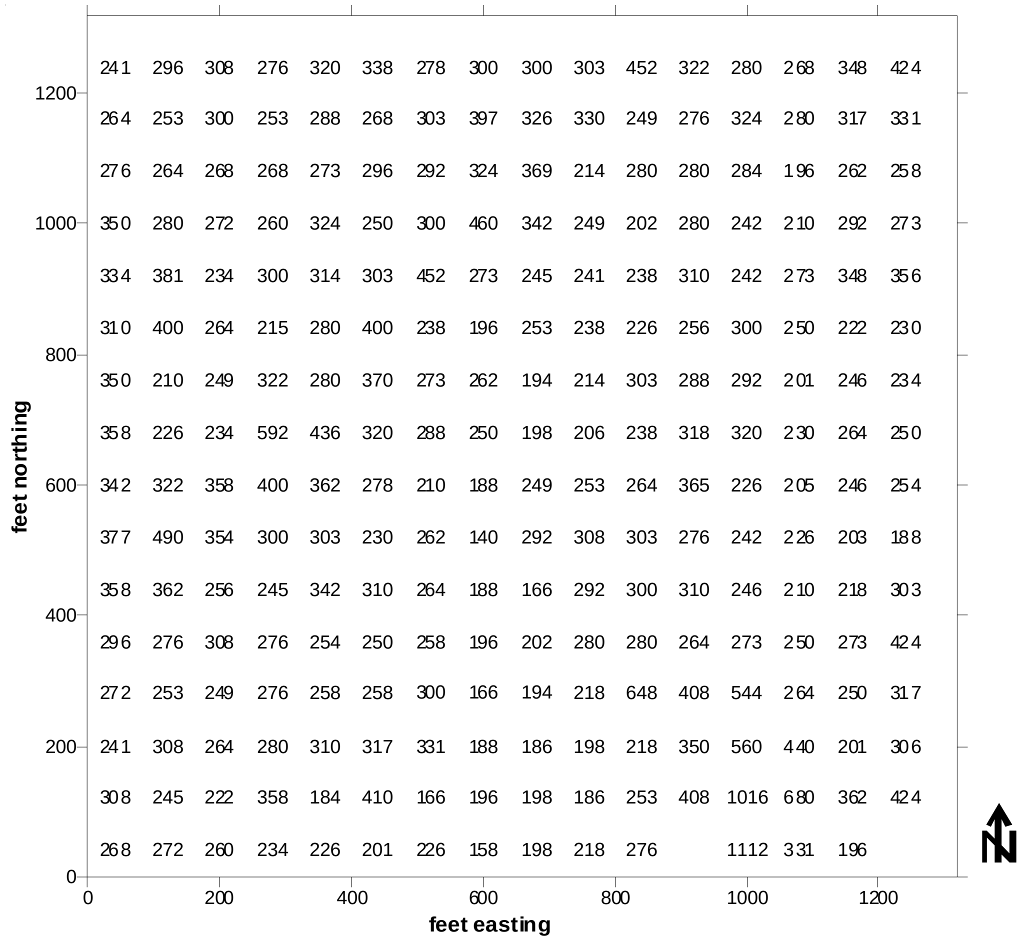


Figure 2-3.
Thomasboro K, 1982.

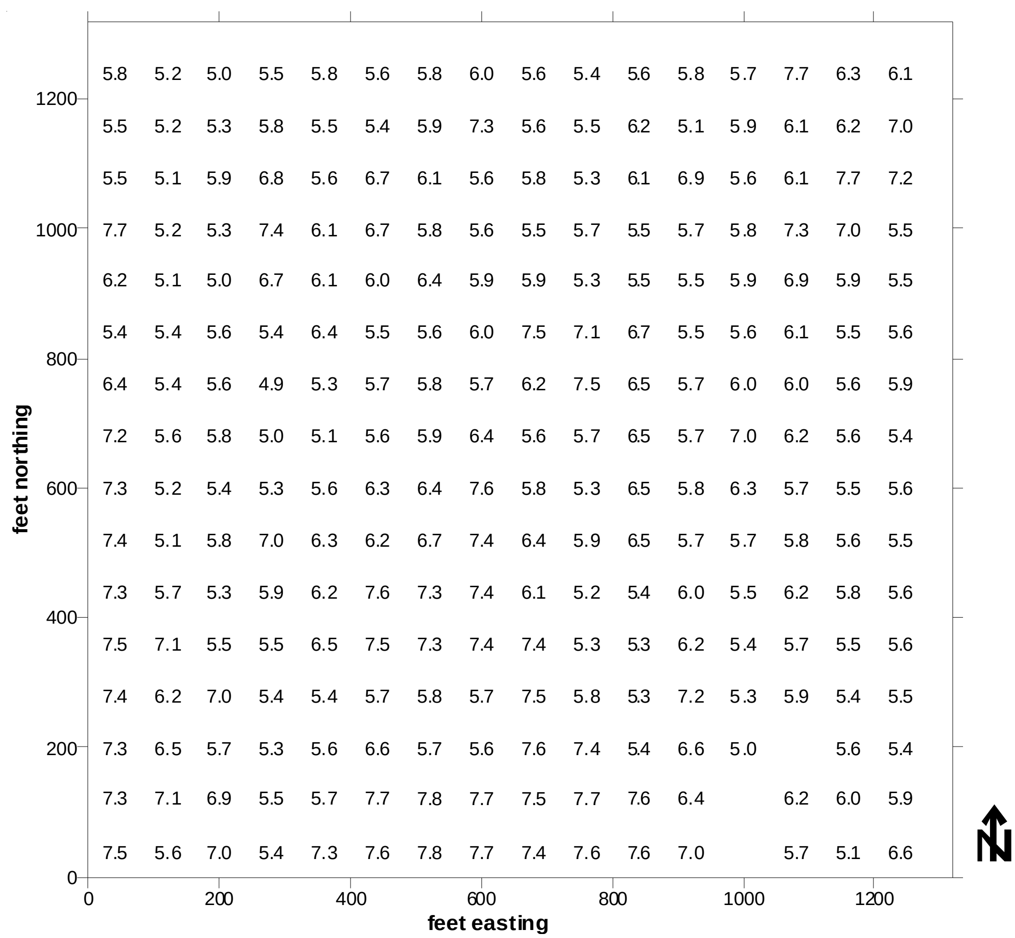


Figure 2-4.
Thomasboro soil pH,
1986.

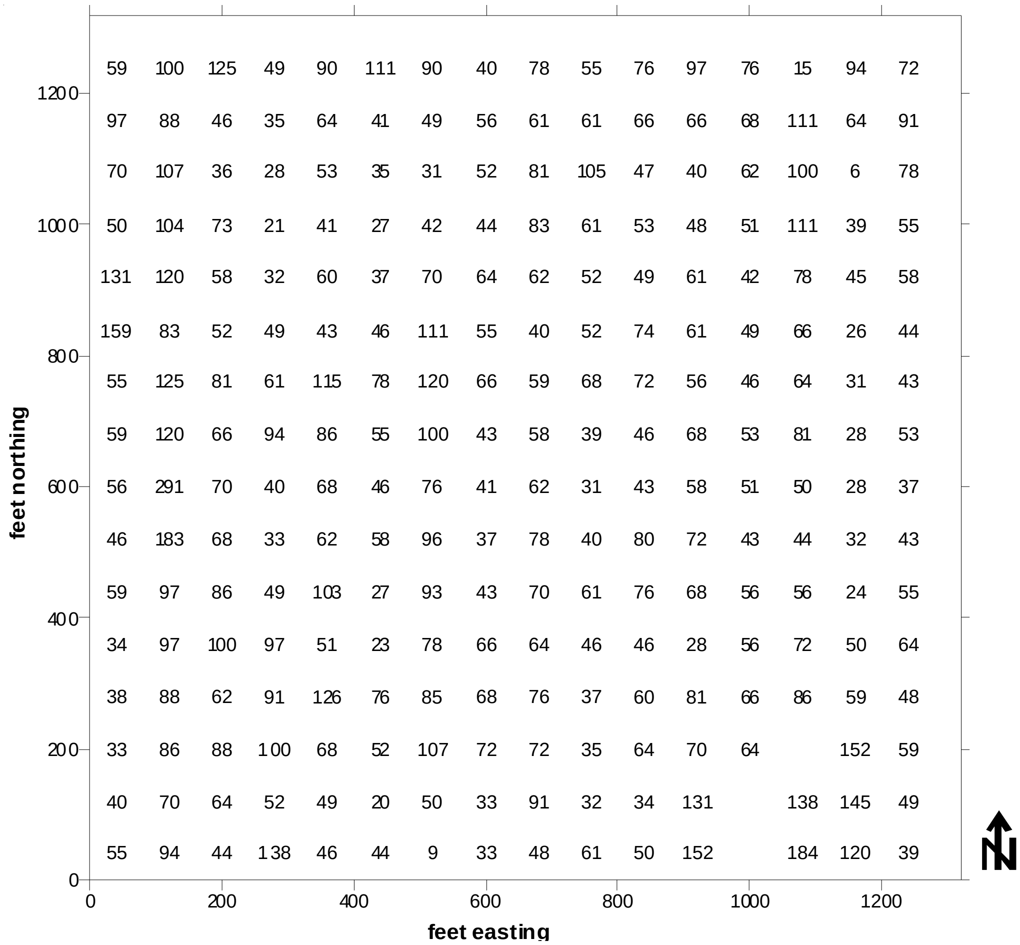


Figure 2-5. Thomasboro P, 1986.

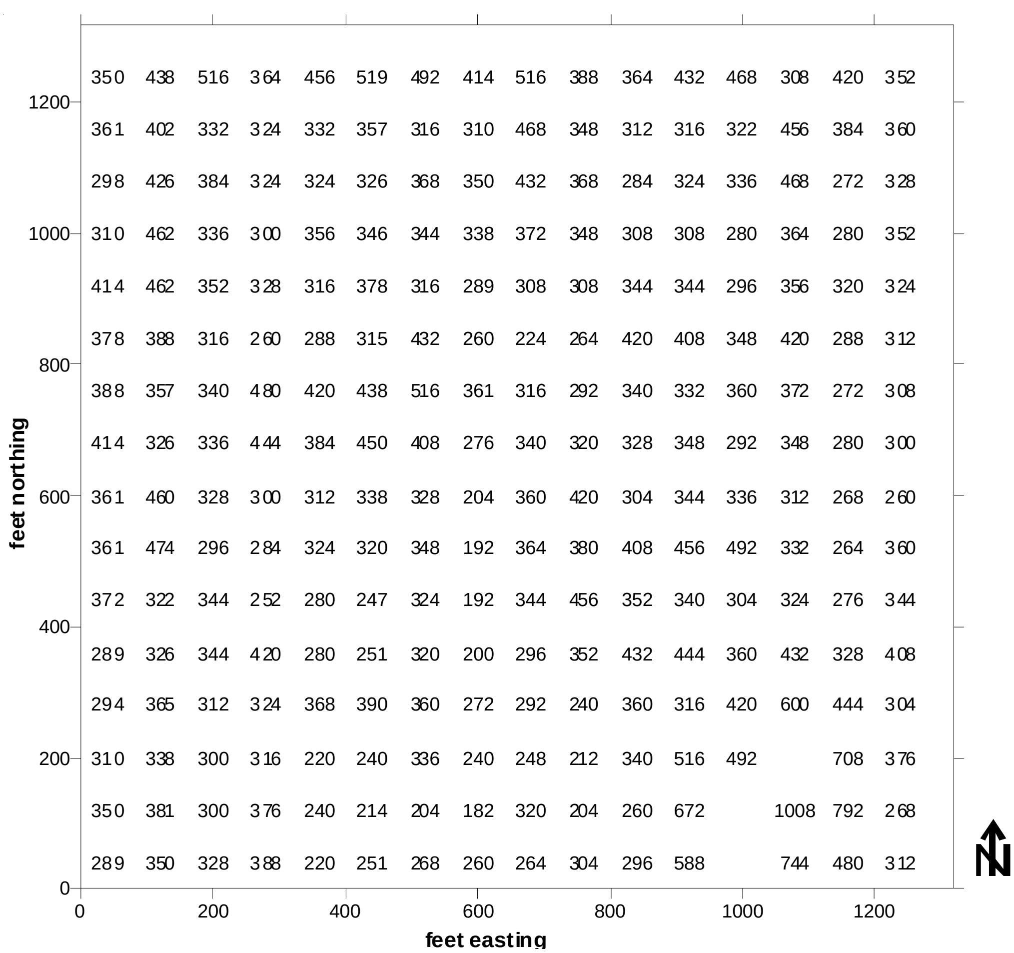


Figure 2-6. Thomasboro K, 1986.

feet northing (0–1200) vs. feet easting (0–1200)

6.0	5.5	5.2	5.1	5.6	5.6	5.4	6.0	5.8	5.5	5.6	5.7	6.2	7.8	6.9	5.8
5.8	5.2	5.4	6.2	5.5	5.8	5.3	7.1	5.5	5.9	5.4	5.8	6.1	6.2	6.3	6.5
7.2	5.1	5.5	6.3	6.2	6.3	6.8	5.9	5.6	6.8	5.7	6.6	5.9	6.7	7.7	7.6
6.8	5.7	5.1	6.2	5.8	7.0	6.7	5.9	5.9	5.7	5.4	5.3	6.3	7.5	6.9	5.6
5.7	5.0	5.6	5.9	5.9	5.7	5.8	5.7	6.0	5.4	5.6	5.1	6.0	7.0	6.0	6.6
5.6	5.7	5.5	5.8	5.8	5.4	5.5	7.0	6.8	6.0		7.4	6.0	6.2	5.9	5.7
6.9	5.6	5.6	5.0	6.1	5.6	5.8	6.9	5.7	6.1	6.6	5.8	6.8	6.0	5.8	5.9
7.1	6.1	5.7	4.9	5.3	5.5	6.0	6.8	5.7	6.0	5.5	5.6	6.2	6.3	5.7	5.7
7.3	5.4	5.5	5.3	5.2	5.9	6.2	7.7	6.3	5.7	5.5	6.5	6.1	6.1	5.7	5.4
7.3	5.8	5.9	7.0	5.6	6.4	6.8	7.4	6.5	6.1	5.7	6.3	5.8	6.0	5.8	5.6
7.2	6.1	6.0	5.7	6.6	7.4	7.0	7.1	6.7	5.9	5.6	5.4	5.7	6.5	5.9	5.3
7.5	7.5	5.6	5.7	6.7	7.5	7.2	7.2	7.6	6.0	5.4	5.3	5.8	5.8	5.8	6.1
7.3	6.2	6.9	5.5	5.4	6.8	5.8	5.9	7.5	7.1	6.2	5.2	5.6	5.8	5.4	5.6
7.3	6.4	5.5	5.2	5.6	6.2	5.6	5.6	7.6	7.4	7.7	5.5	5.0	6.0	5.9	5.5
7.4	7.1	6.9	5.3	5.8	7.4	7.5	7.4	7.6	7.1	7.6	7.6		6.3	6.2	6.0
7.2	6.9	6.8	5.1	6.9	7.5	7.6	7.2	7.5	7.3	7.8	7.7		6.0	5.8	6.2

N

Figure 2-7. Thomasboro soil pH, 1987.

feet northing (0–1200) vs. feet easting (0–1200)

30	59	79	56	89	22	103	53	84	84	84	99	84	28	132	99
53	115	63	33	68	65	74	77	72	66	87	53	63	120	103	111
38	129	65	19	50	42	36	32	99	99	55	48	46	96	22	45
52	87	111	39	58	69	55	43	132	53	77	44	50	132	96	58
87	120	87	24	89	56	99	70	81	68	87	81	23	99	89	36
132	61	74	31	59	35	132	74	103		53	63	28	87	27	42
58	81	89	77	99	26	99	72	77	66	111	92	53	126	43	36
53	106	120	72	106	39	89	74	50	48	68	49	40	77	81	33
62	204	53	66	99	35	87	46	59	28	79	52	28	50	45	34
32	126	87	24	66	46	79	43	40	44	74	72	31	68	26	25
24	111	99	132	55	55	50	72	58	56	72	106	42	52	36	55
32	55	156	156	46	73	70	56	63	33	39	44	31	139	70	42
34	139	126	120	132	75	96	72	99	53	53	72	45	49	72	36
28	74	139	99	59	29	79	96	72	46	63	74	56	99	183	53
28	56	61	103	40	70	30	43	43	31	50	139		168	168	33
29	126	74	74	84	48	25	35	81	89	72	156		156	132	50

N

Figure 2-8. Thomasboro P, 1987.

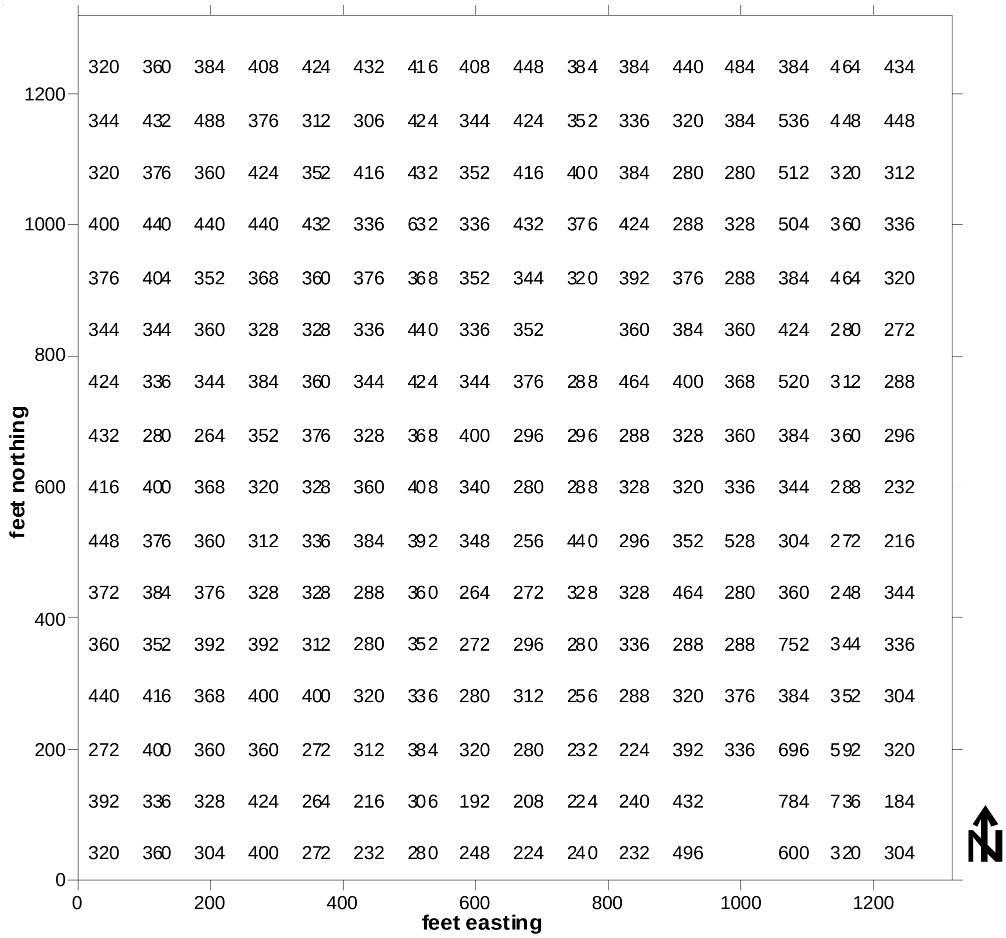


Figure 2-9.
Thomasboro K,
1987.

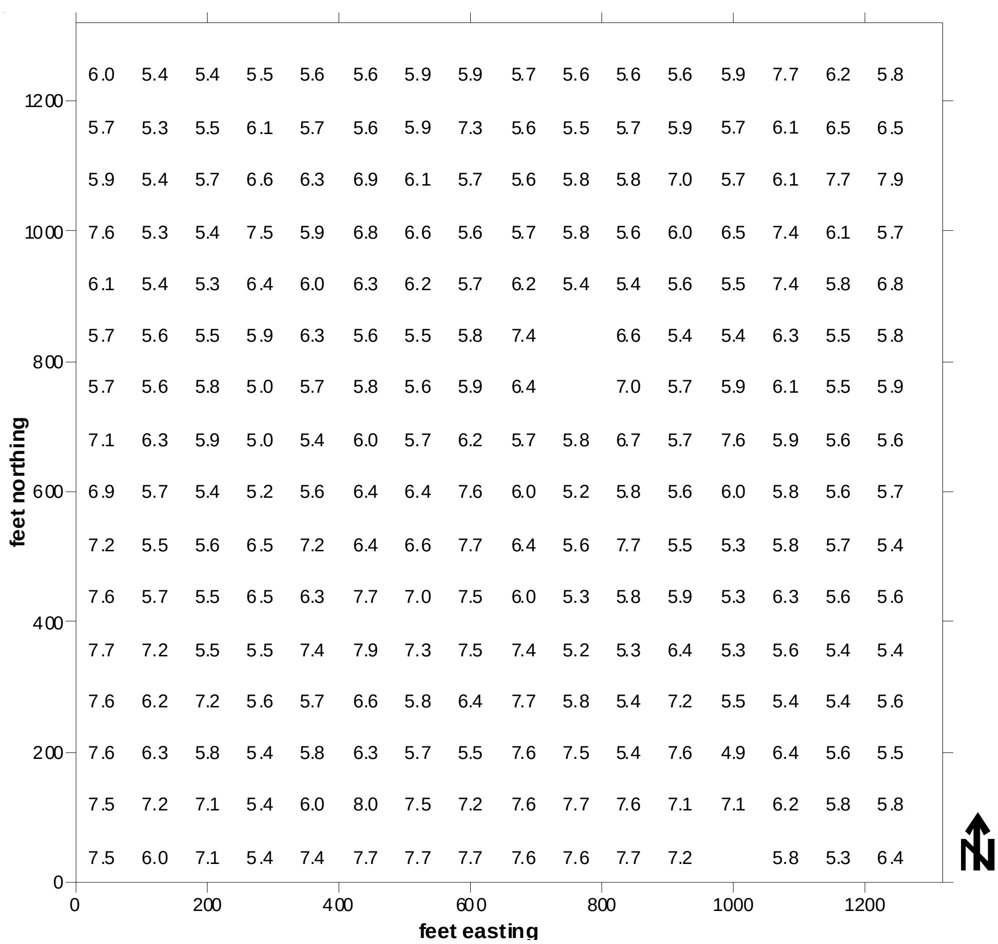


Figure 2-10.
Thomasboro soil pH,
1988.

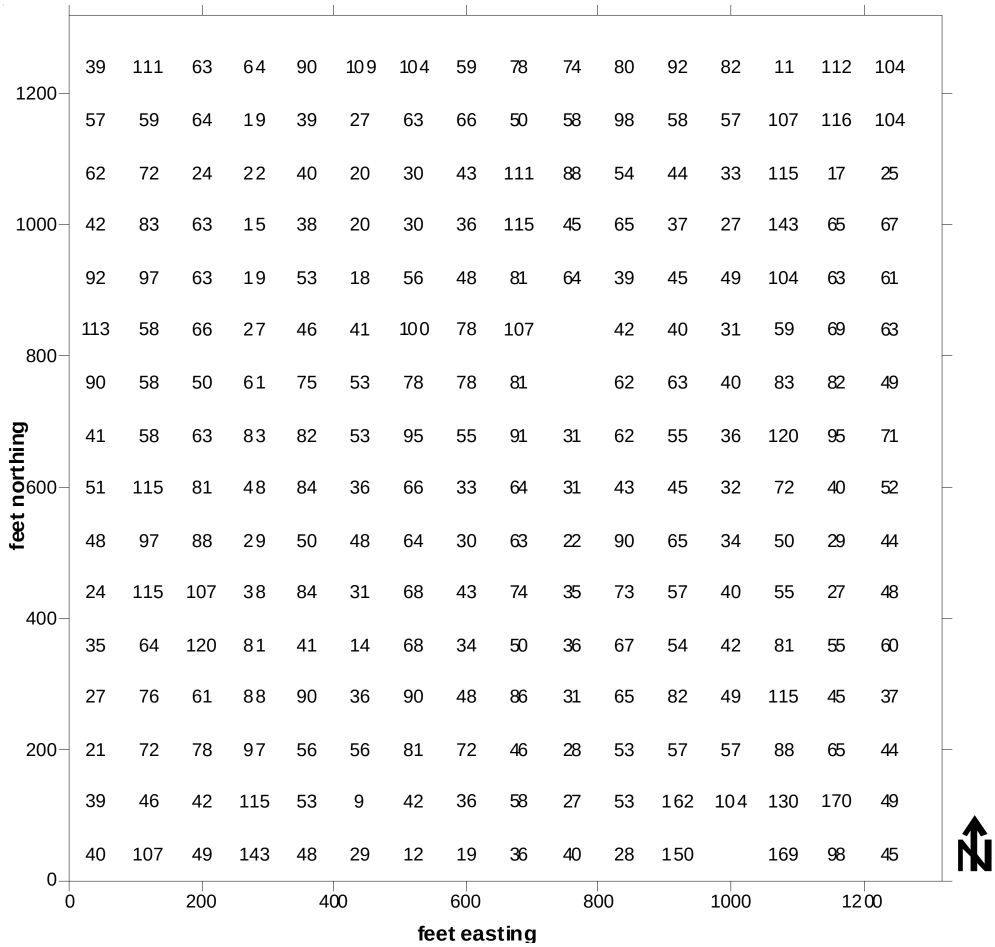


Figure 2-11.
Thomasboro P,
1988.

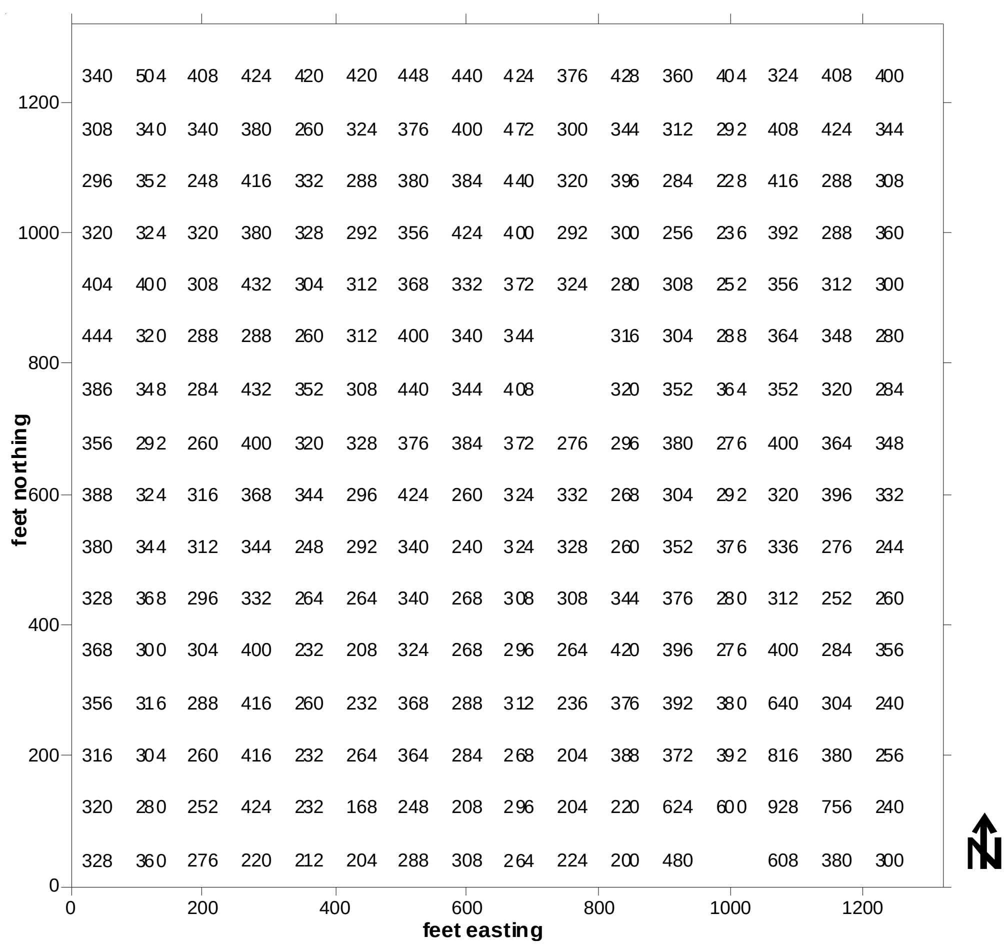


Figure 2-12.
Thomasboro K,
1988.

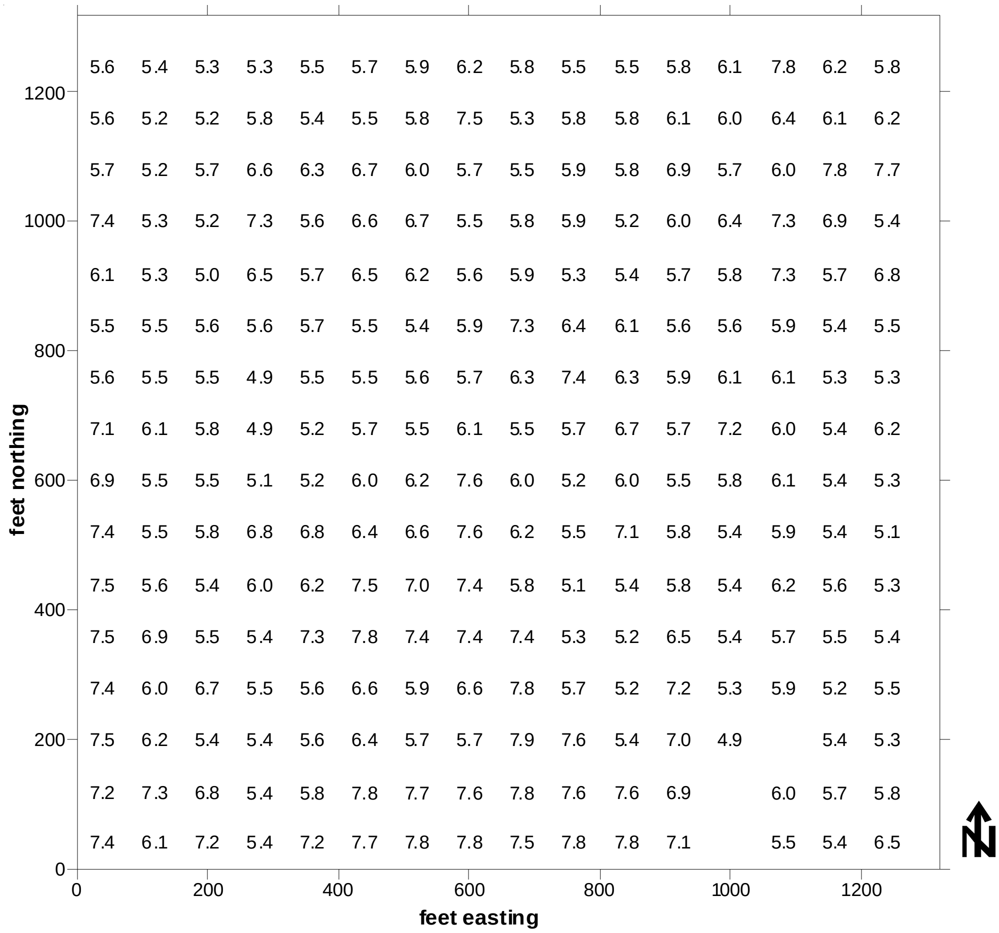


Figure 2-13. Thomasboro soil pH, June 1989.

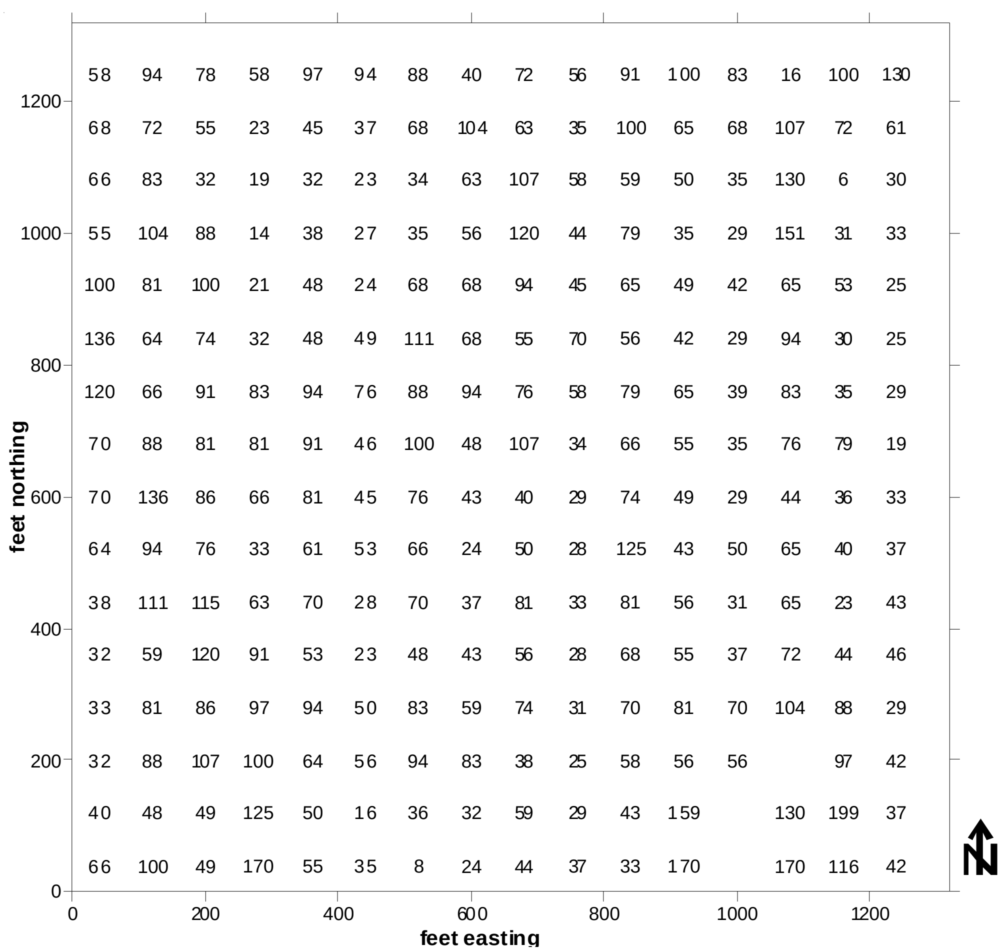


Figure 2-14. Thomasboro P, June 1989.

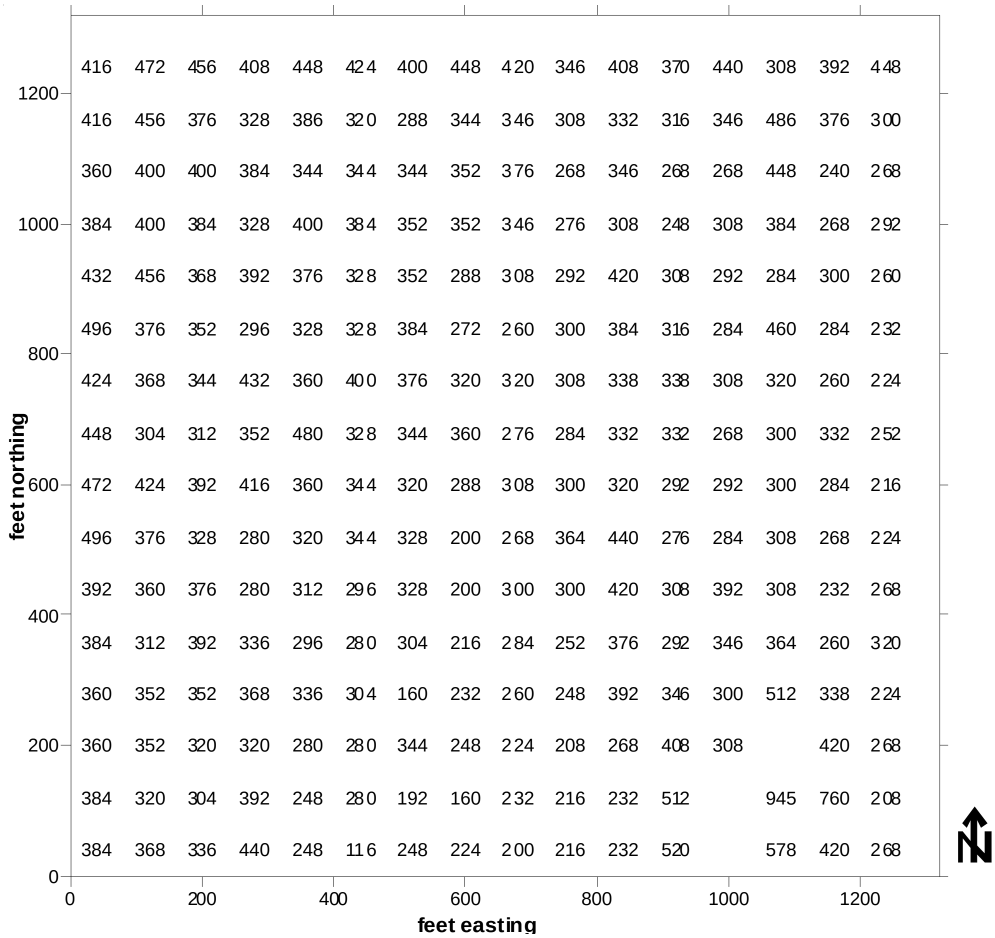


Figure 2-15. Thomasboro K, June 1989.

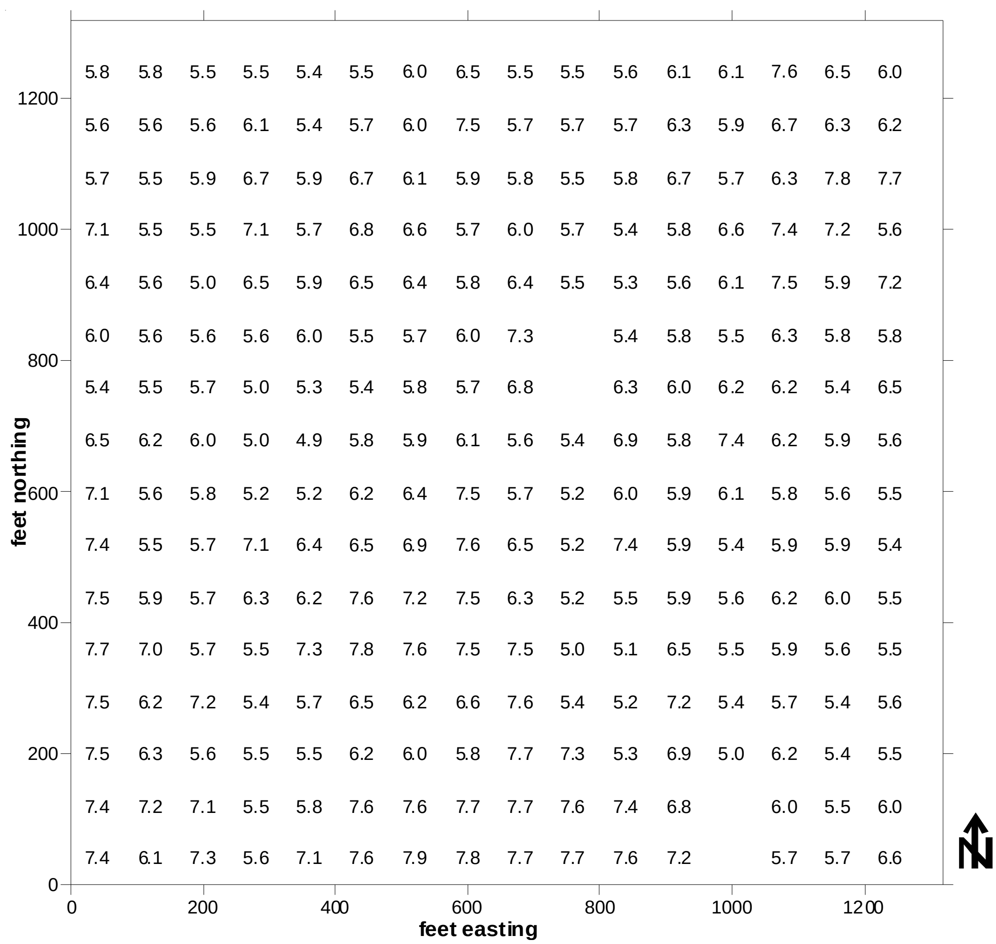


Figure 2-16. Thomasboro soil pH, October 1989.

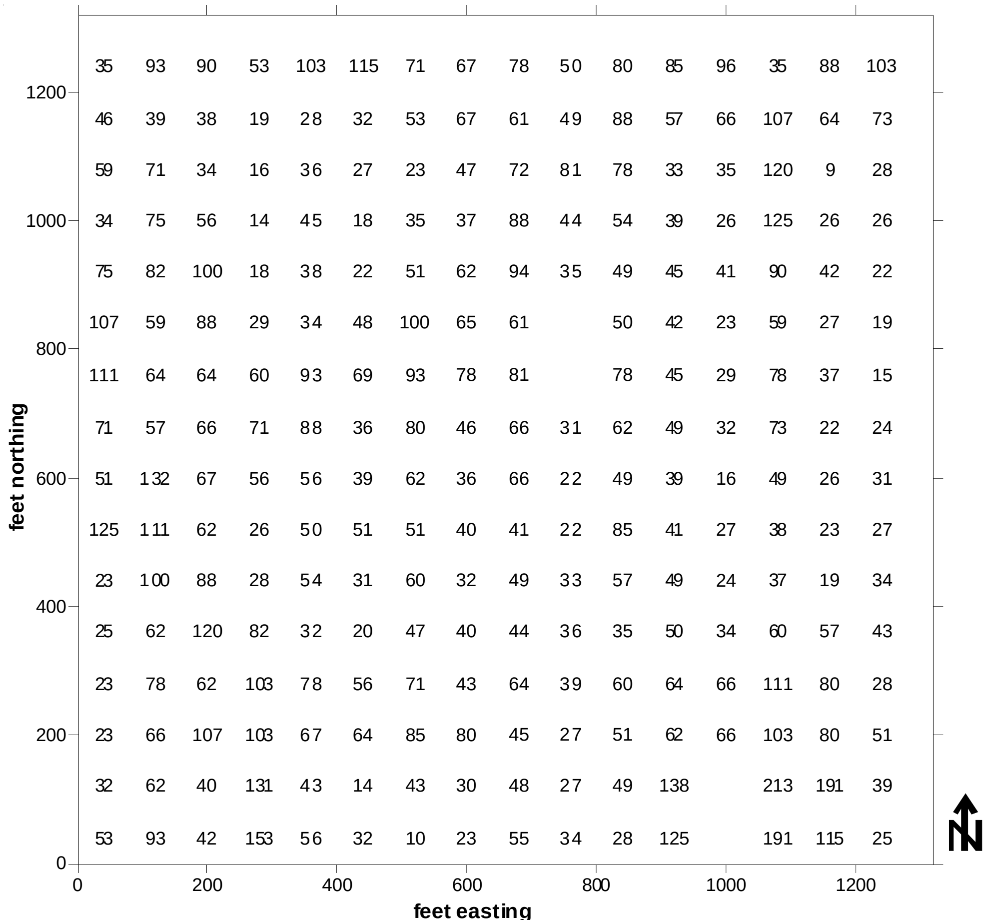


Figure 2-17.
Thomasboro P,
October 1989.

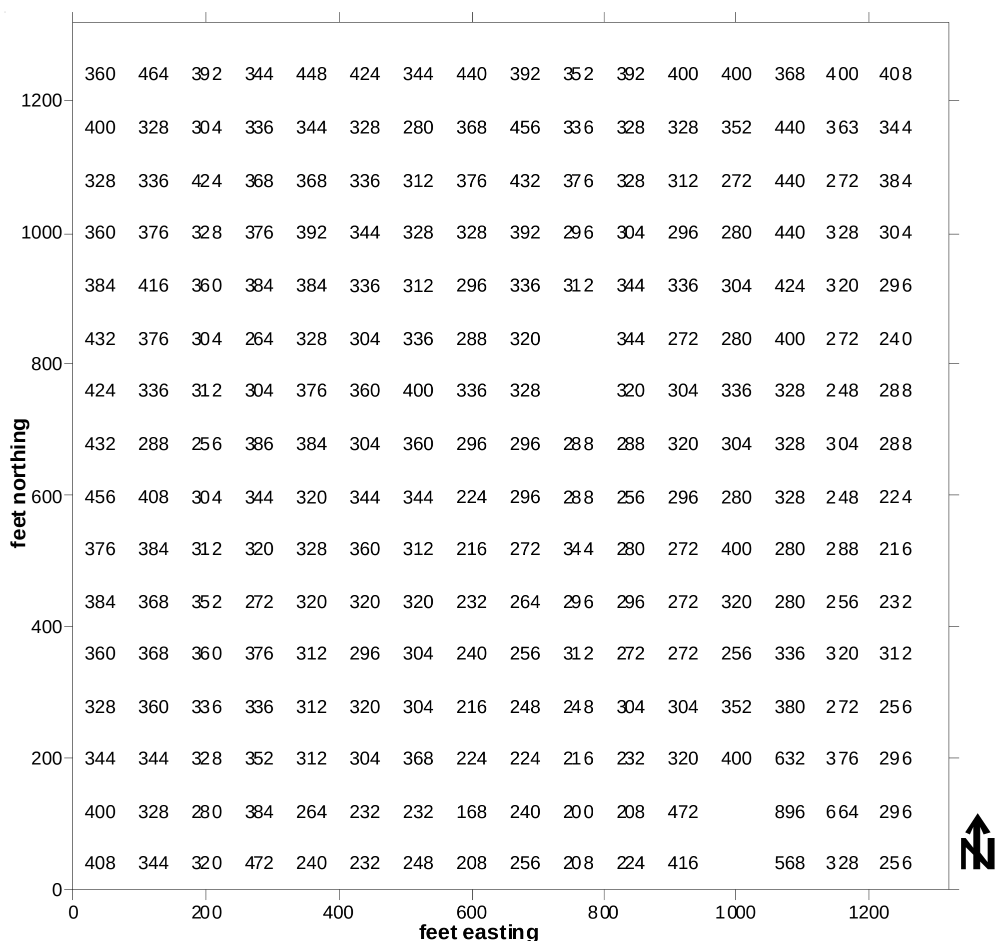


Figure 2-18.
Thomasboro K,
October 1989.

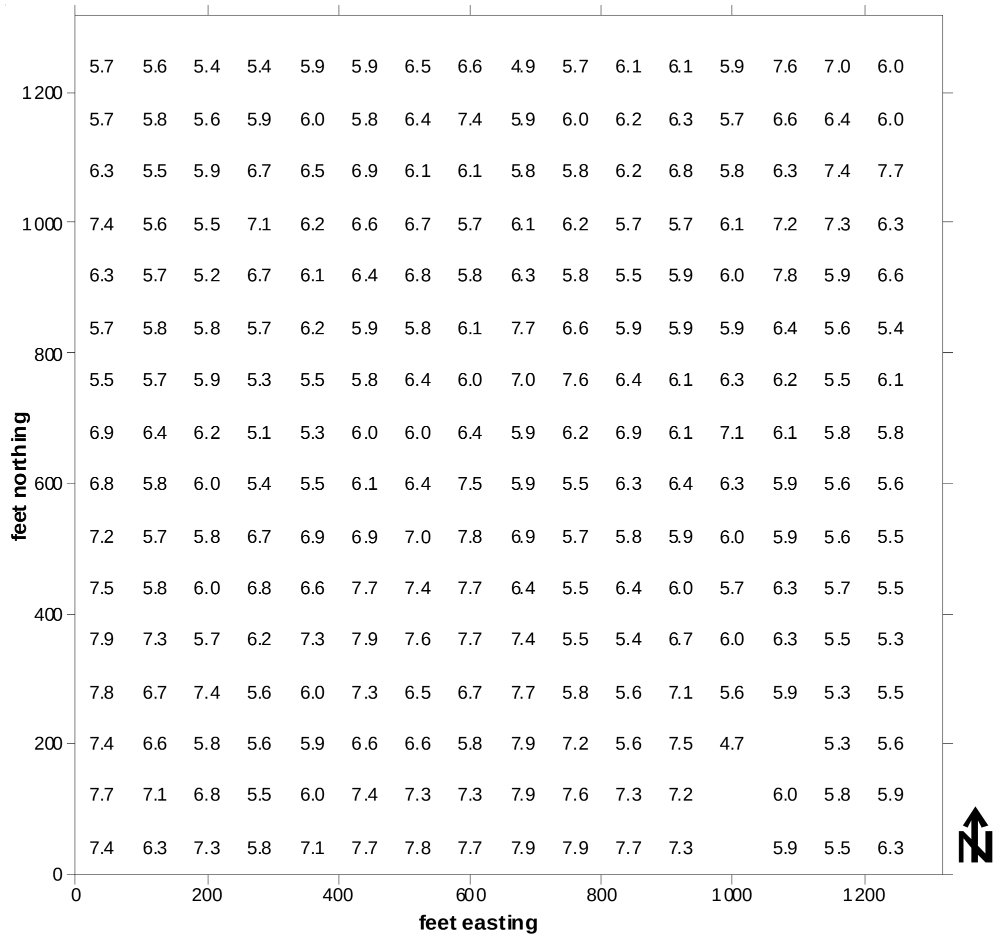


Figure 2-19. Thomasboro soil pH, 1990.

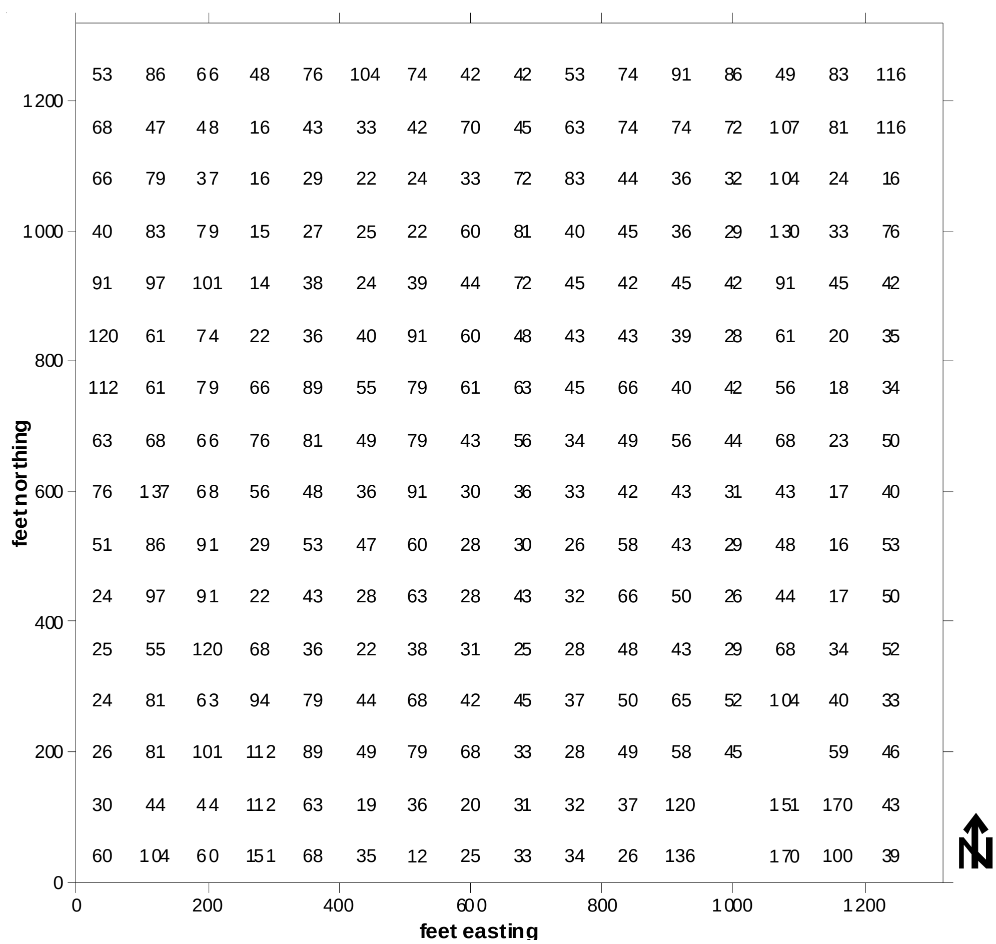


Figure 2-20. Thomasboro P, 1990.

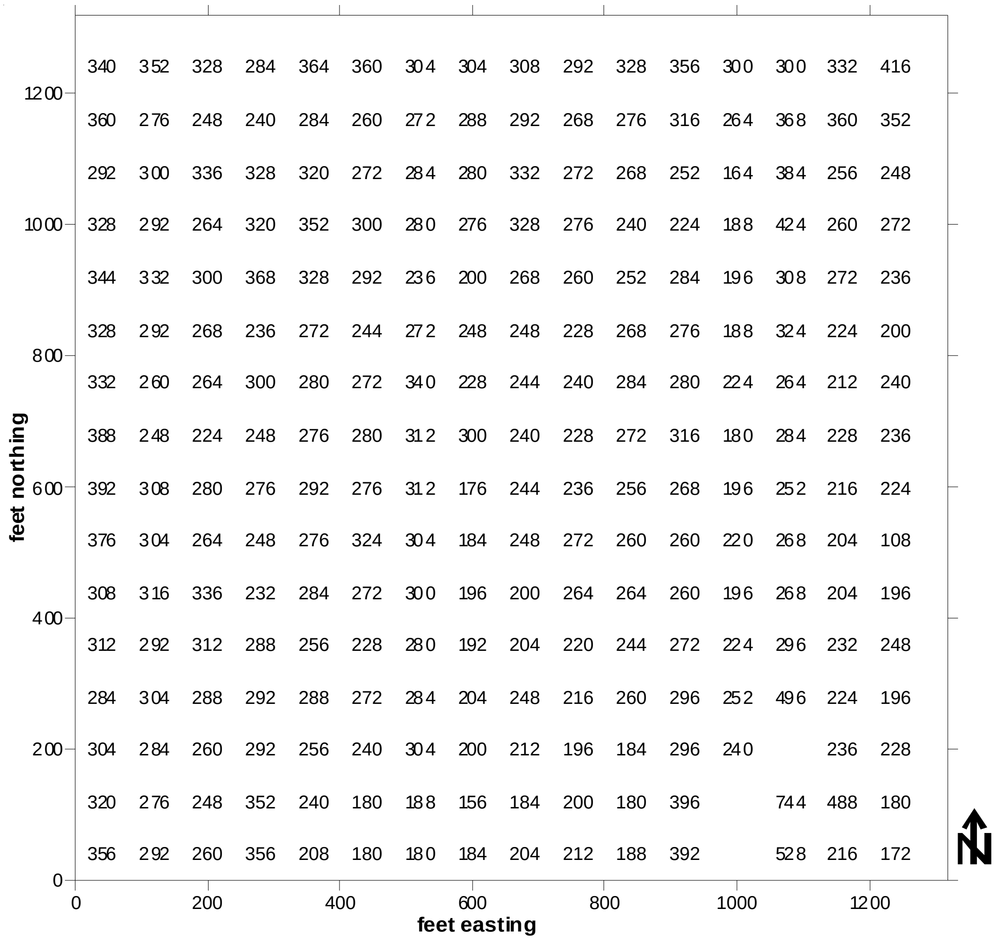


Figure 2-21. Thomasboro K, 1990.

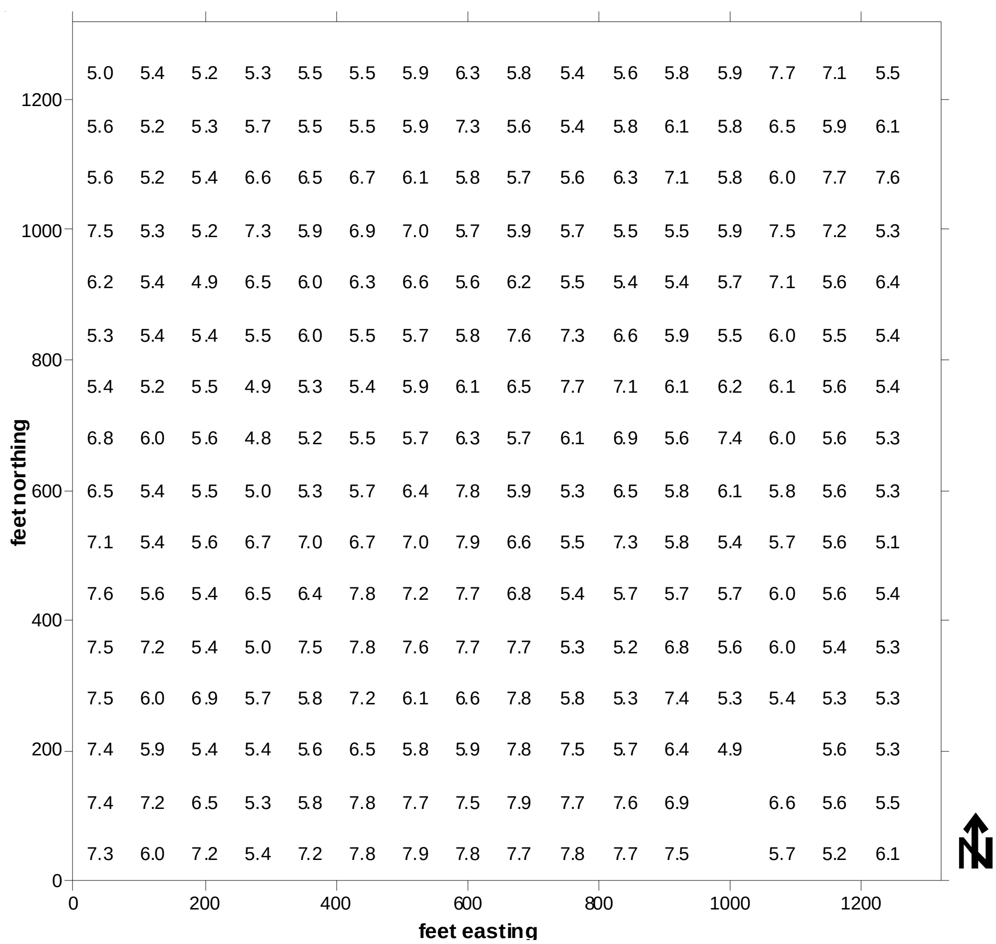


Figure 2-22. Thomasboro soil pH, 1991.

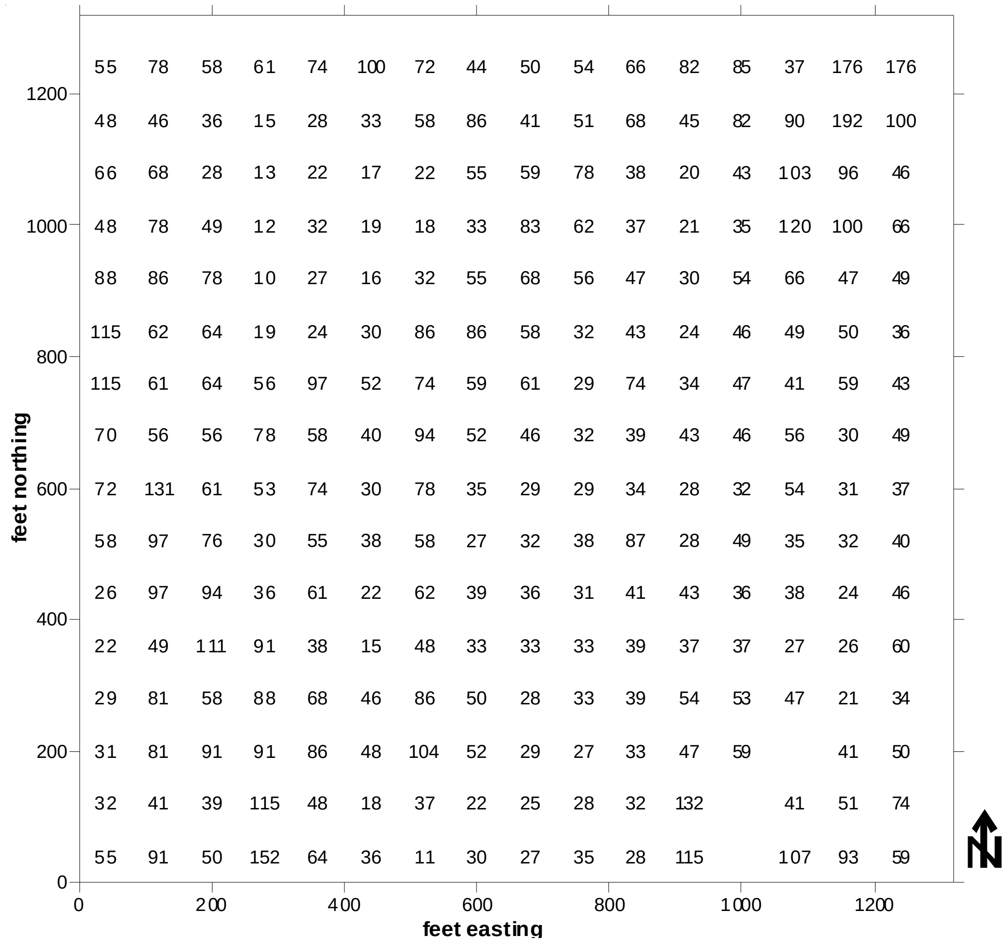


Figure 2-23. Thomasboro soil P, 1991.

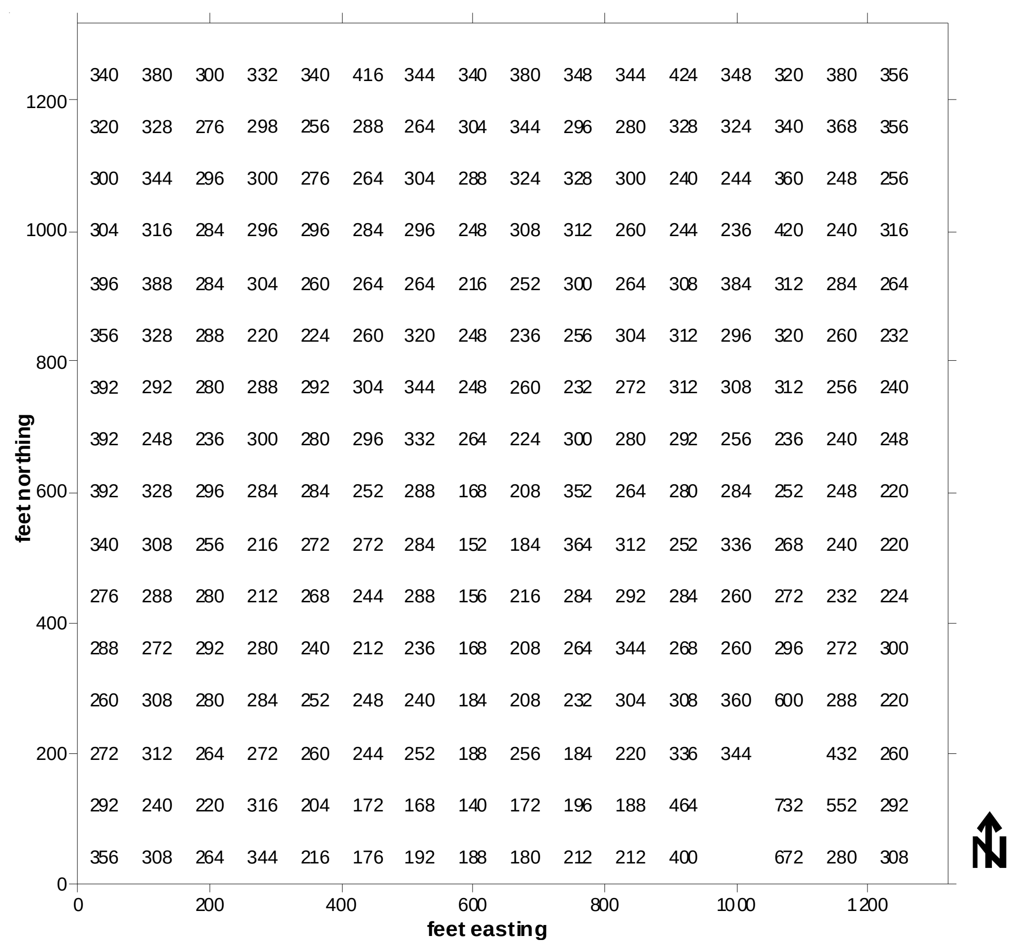


Figure 2-24. Thomasboro K, 1991.

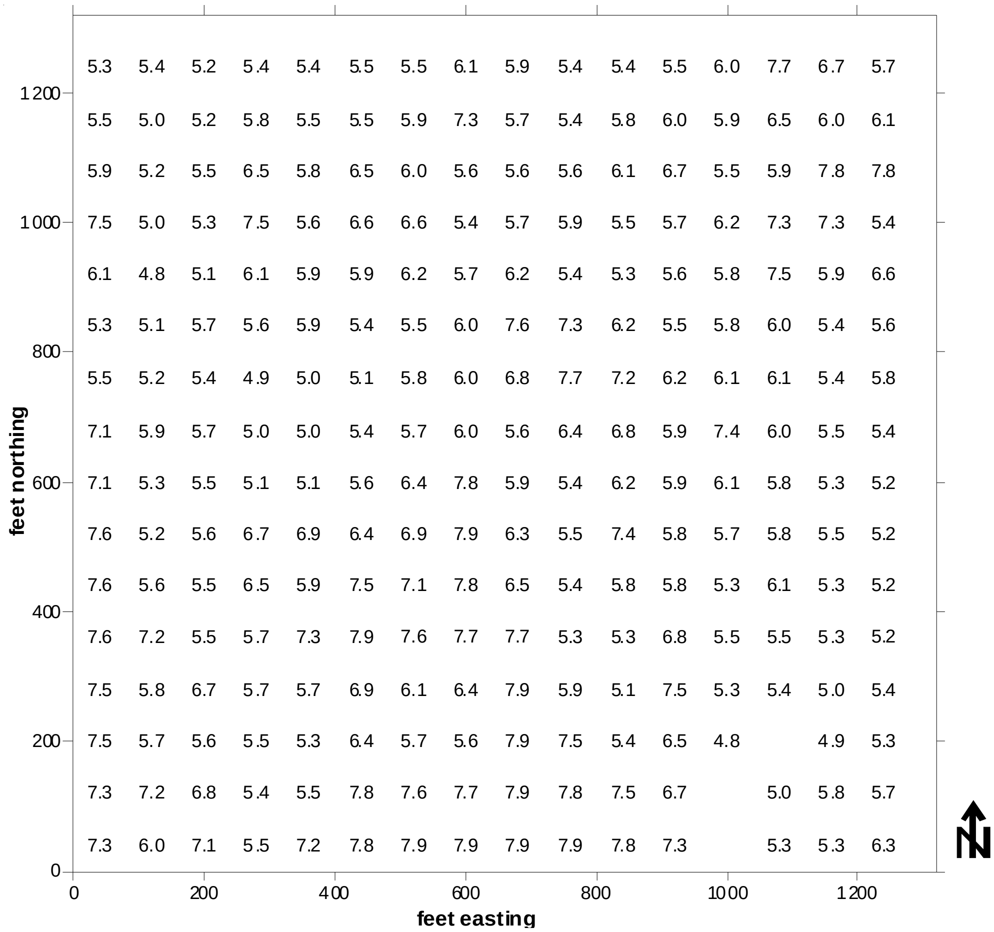


Figure 2-25. Thomasboro soil pH, 1992.

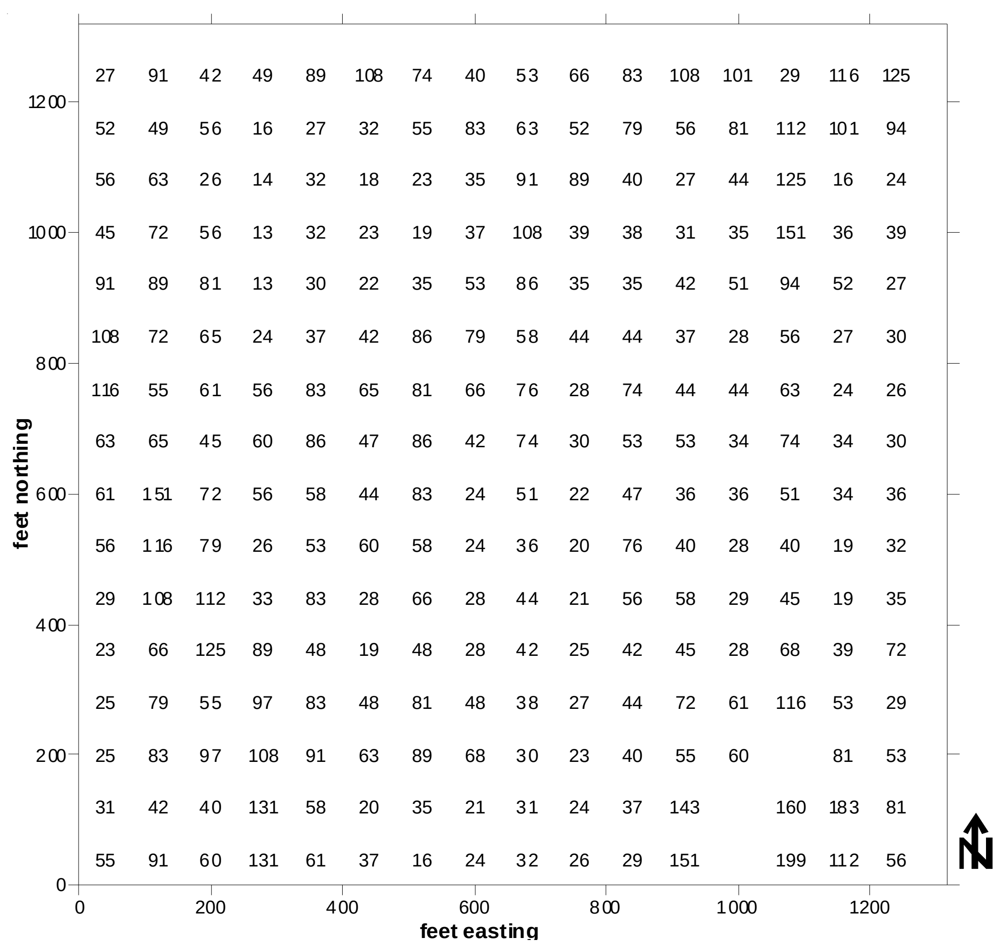


Figure 2-26. Thomasboro P, 1992.

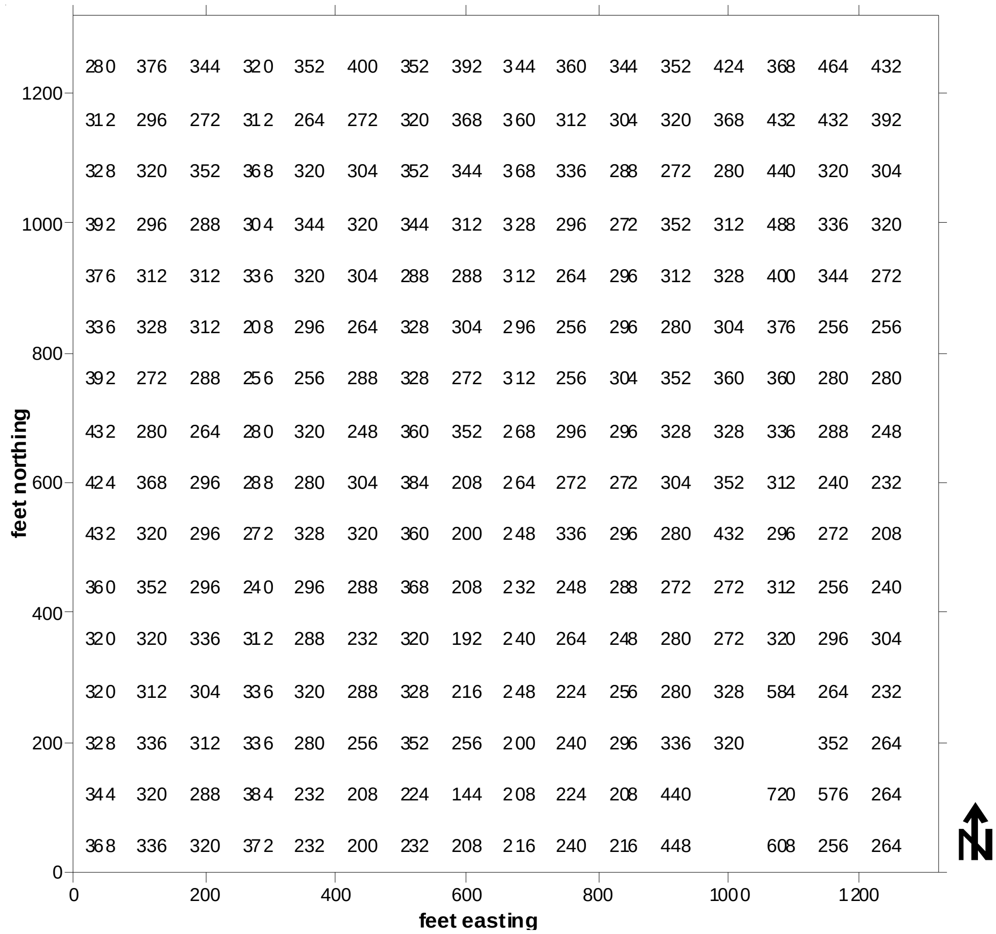


Figure 2-27. Thomasboro K, 1992.

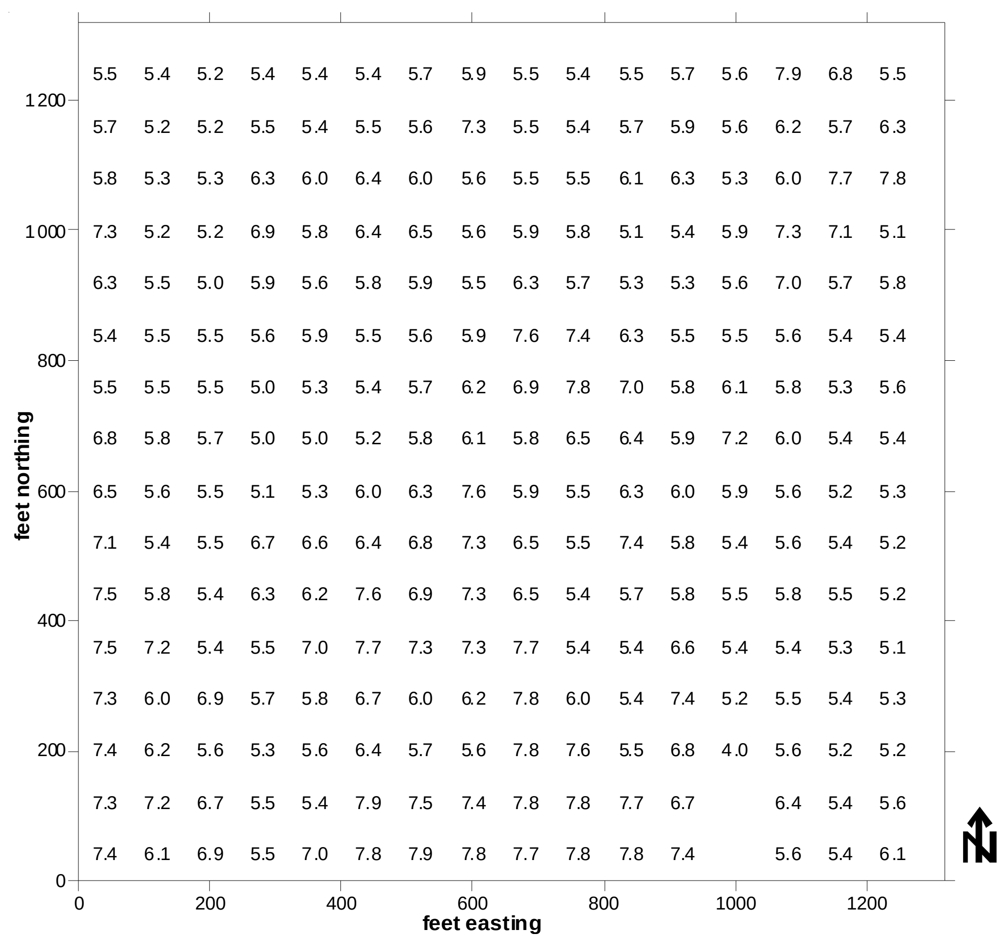


Figure 2-28. Thomasboro soil pH, 1994.

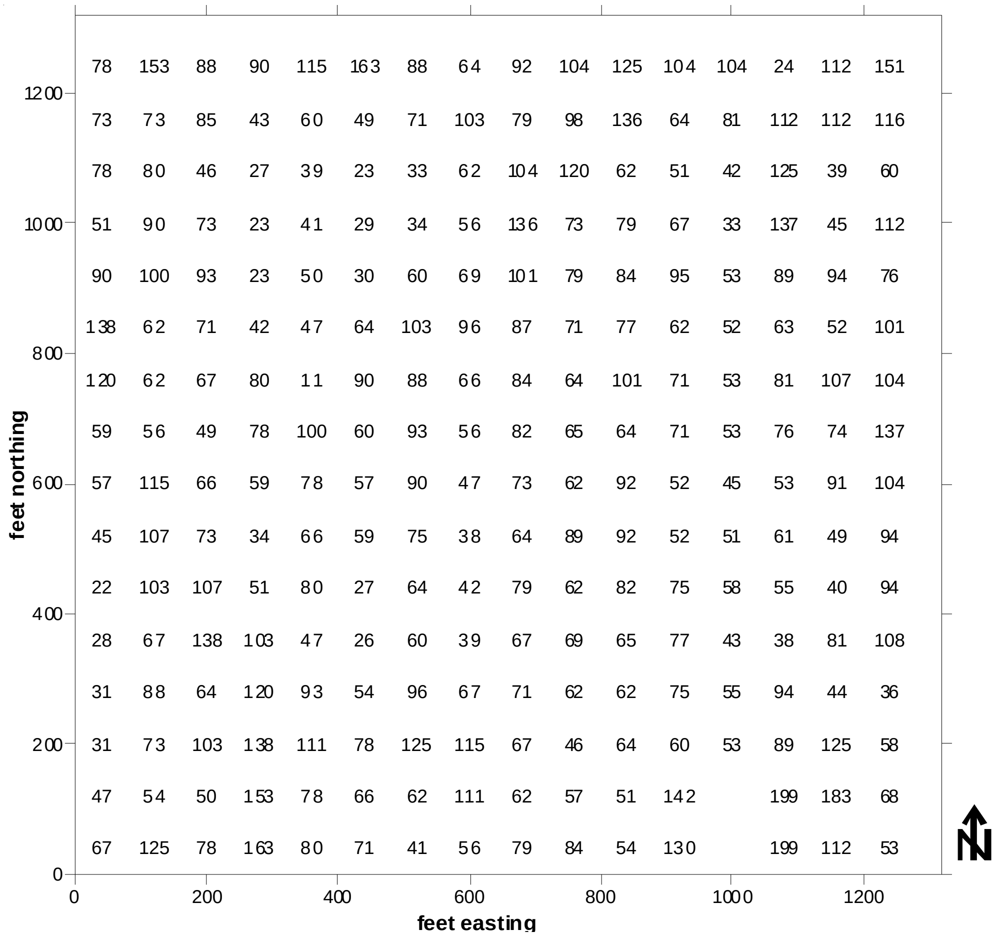


Figure 2-29. Thomasboro P, 1994.

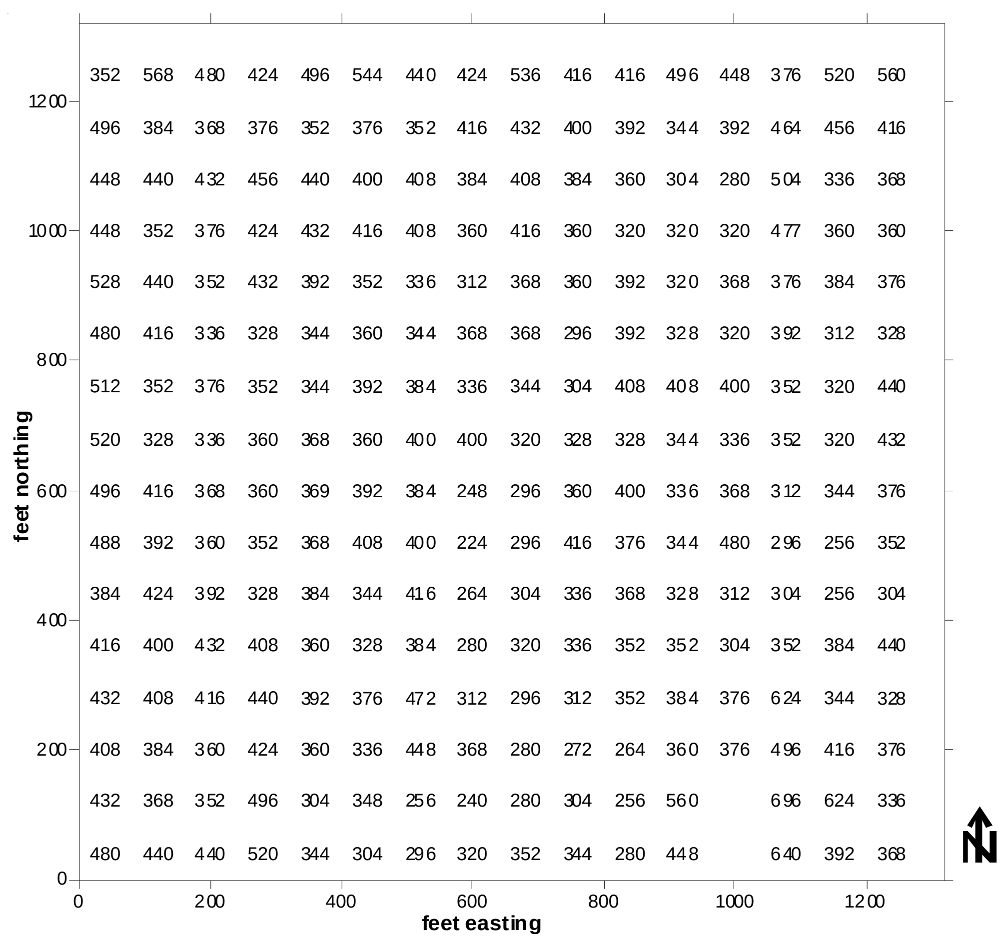


Figure 2-30. Thomasboro K, 1994.

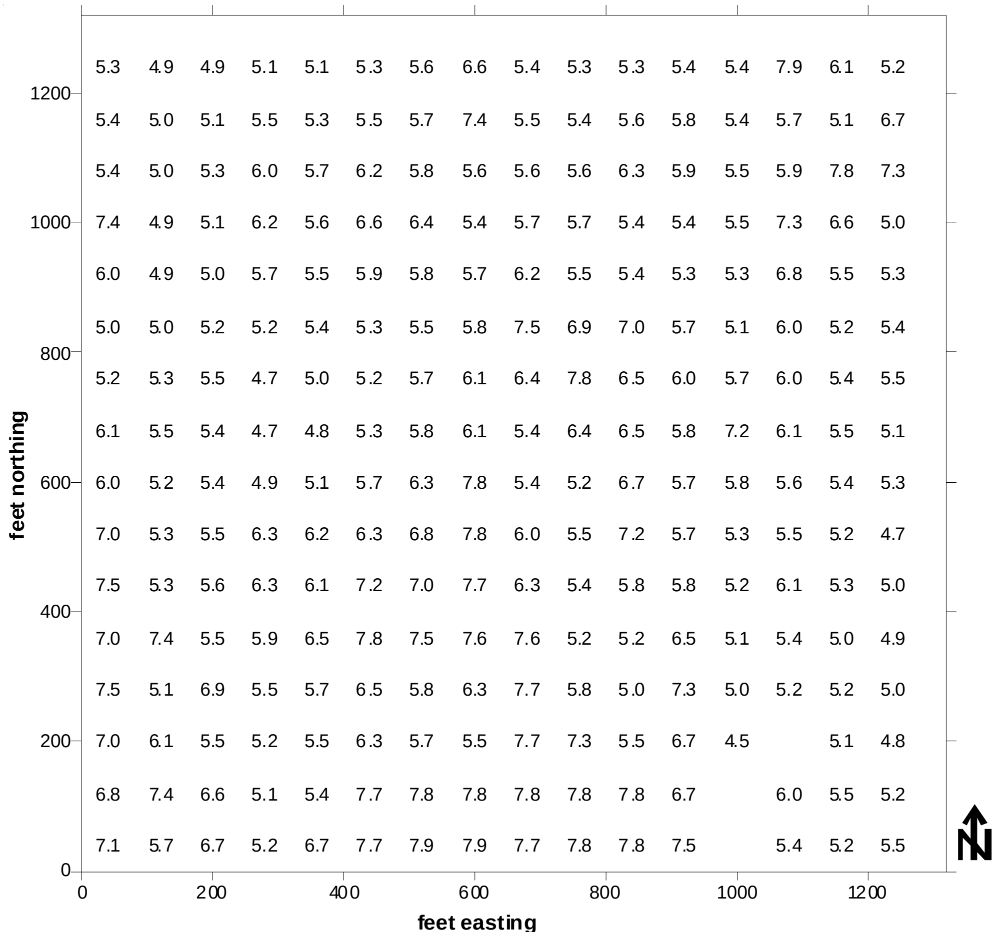


Figure 2-31.
Thomasboro soil pH,
1995.

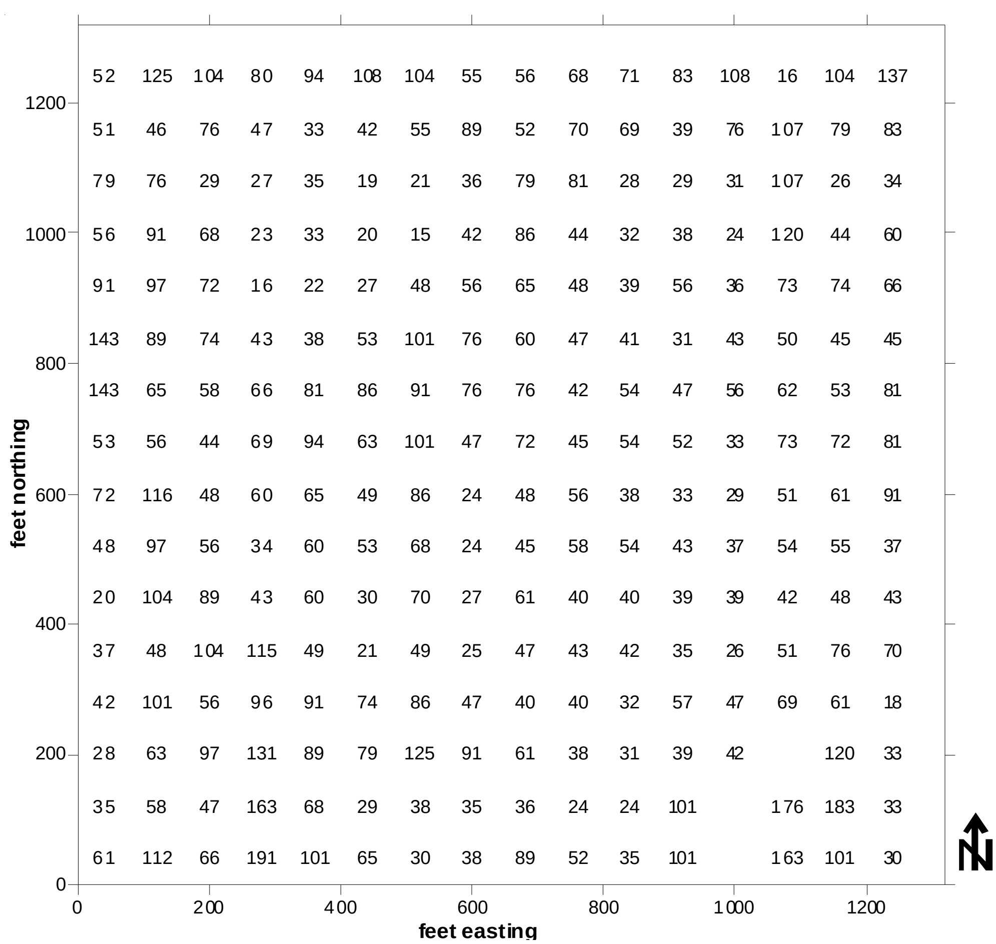


Figure 2-32.
Thomasboro P,
1995.

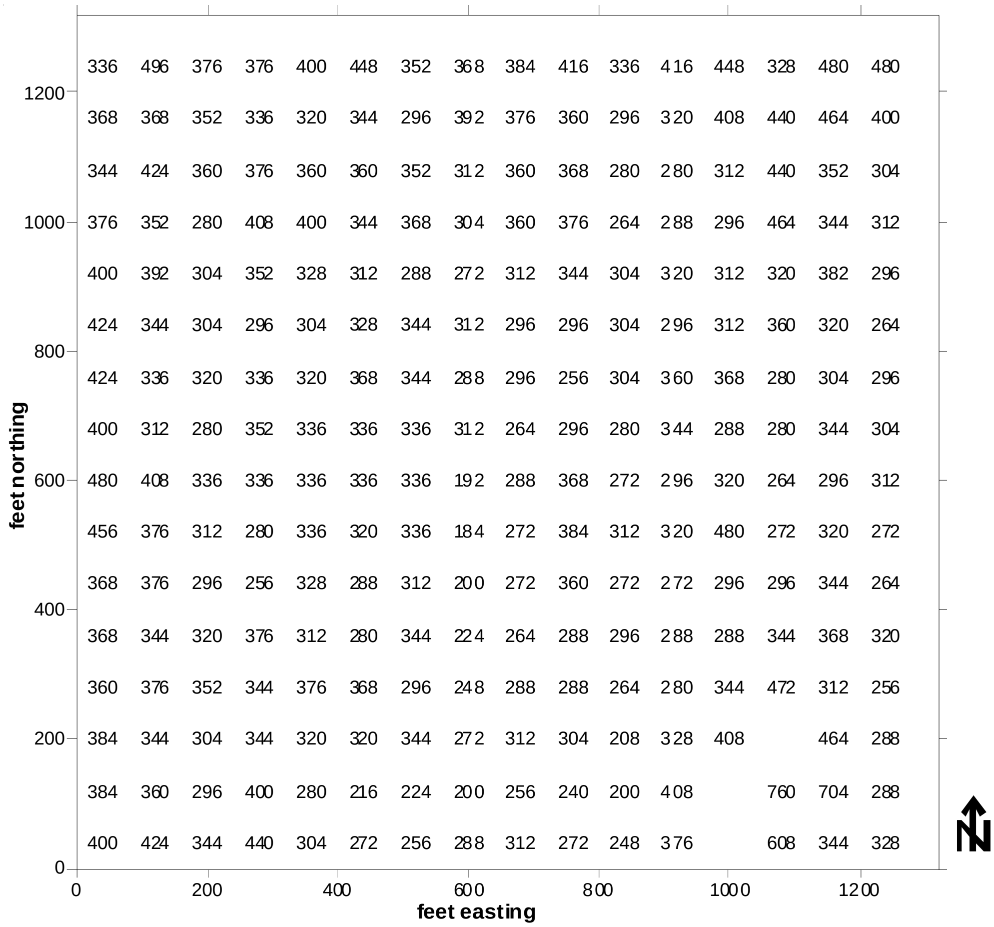


Figure 2-33. Thomasboro K, 1995.

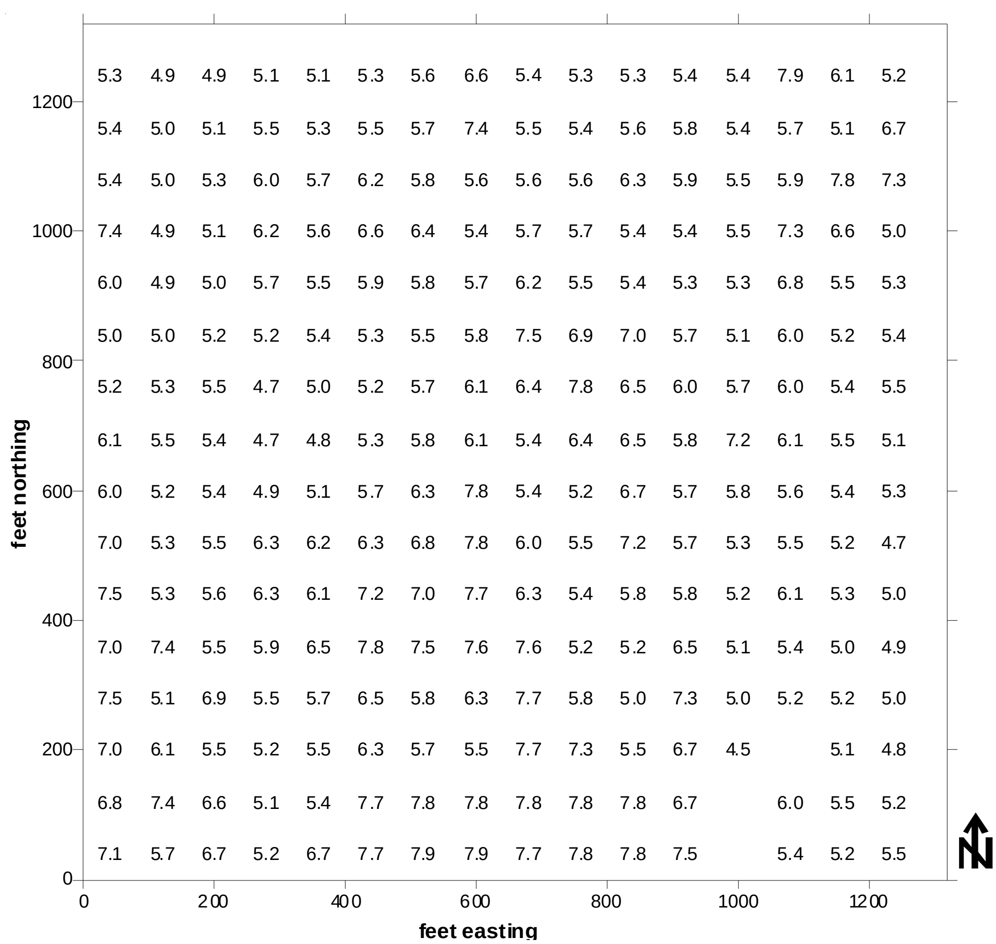


Figure 2-34. Thomasboro soil pH, 1999.

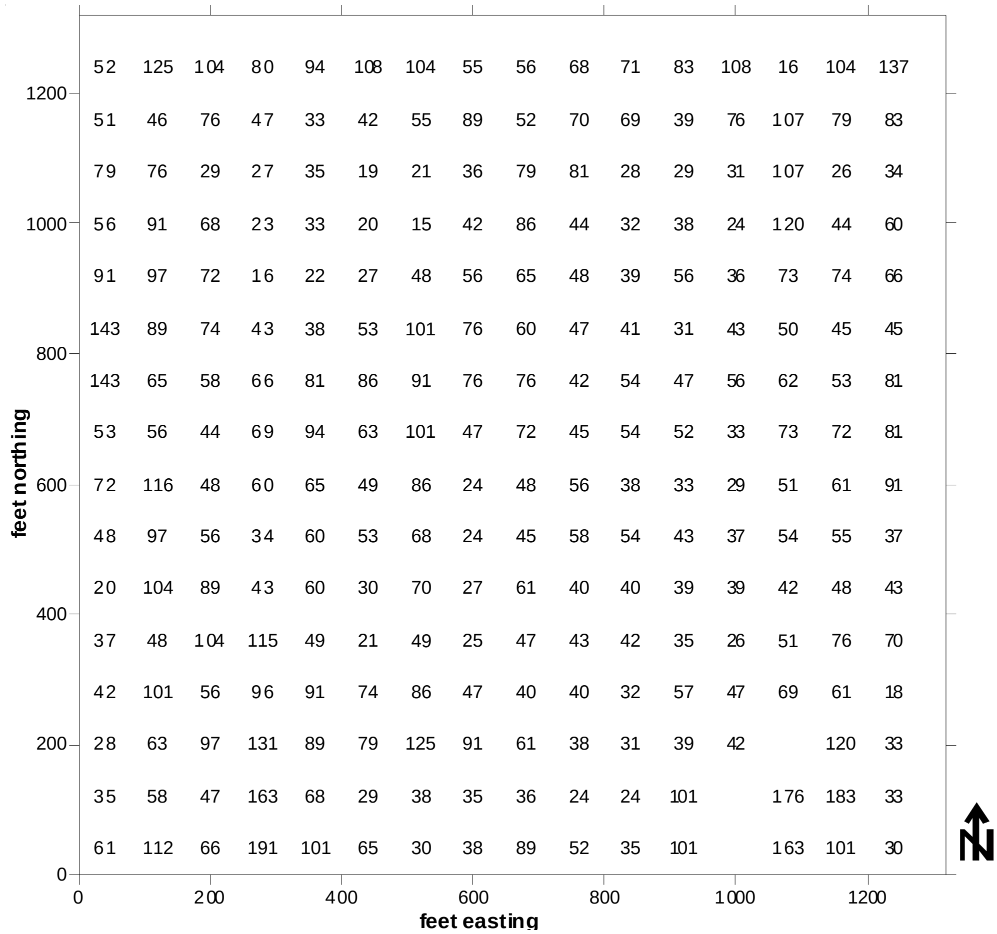


Figure 2-35. Thomasboro P, 1999.

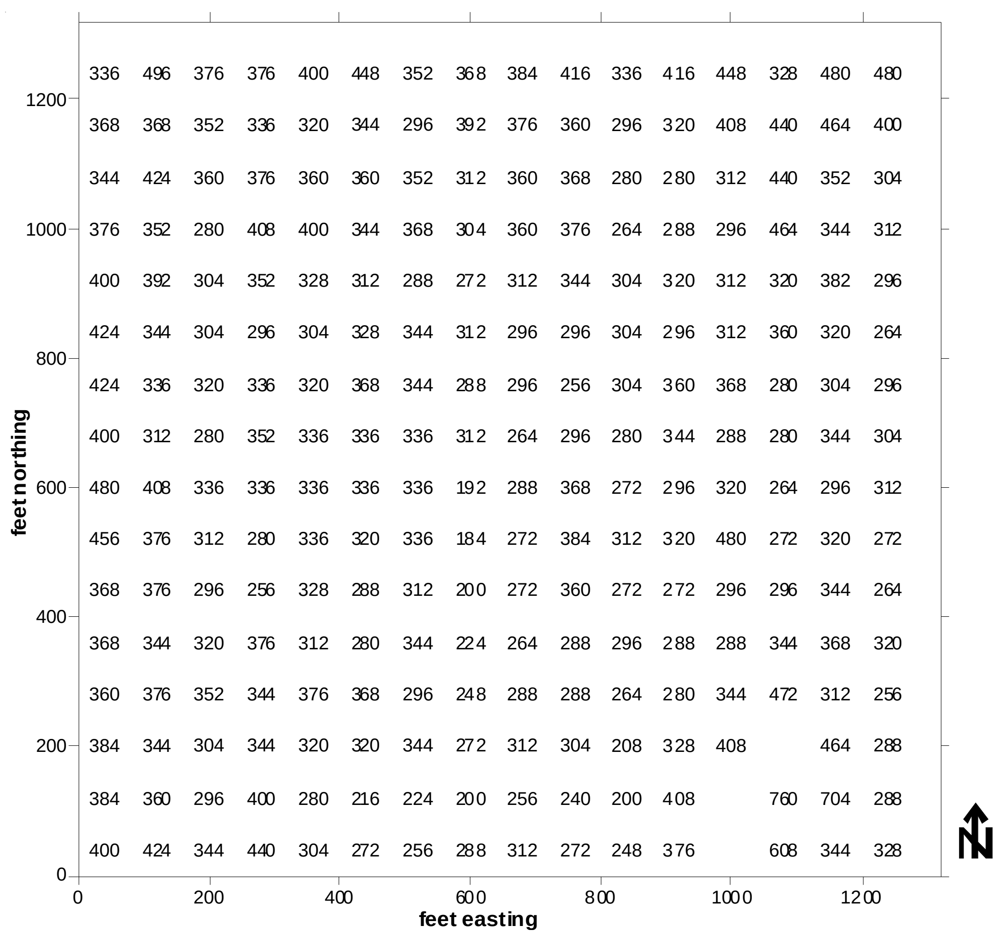


Figure 2-36. Thomasboro K, 1999.

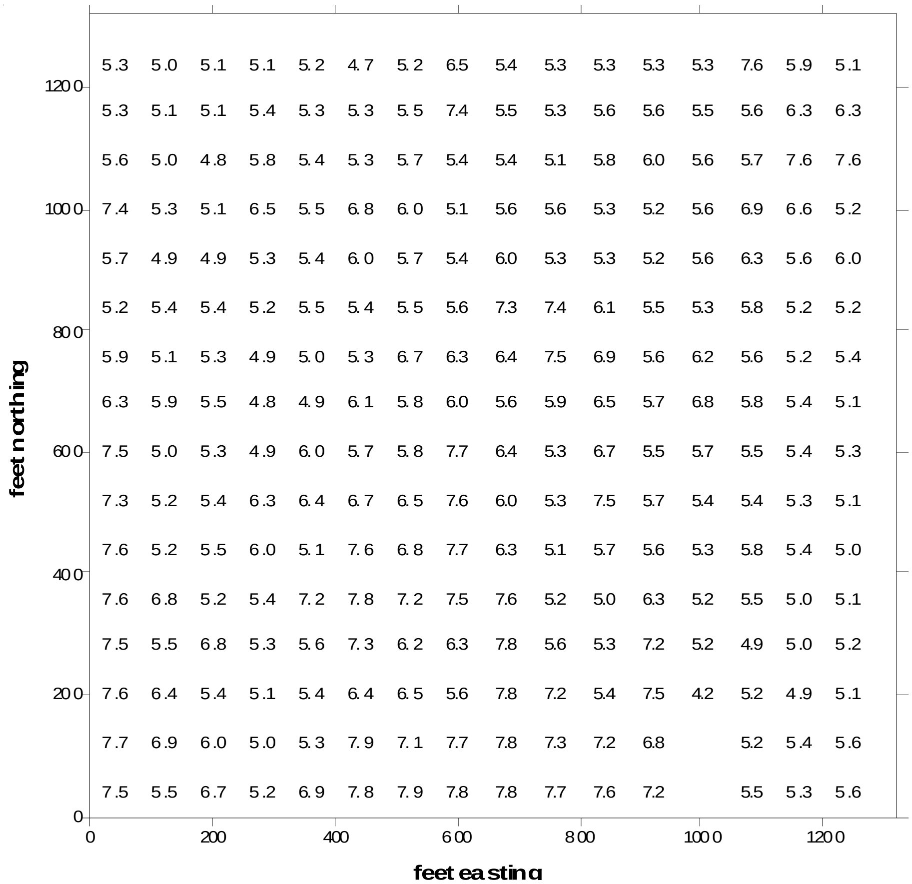


Figure 2-37. Thomasboro pH, 2001.

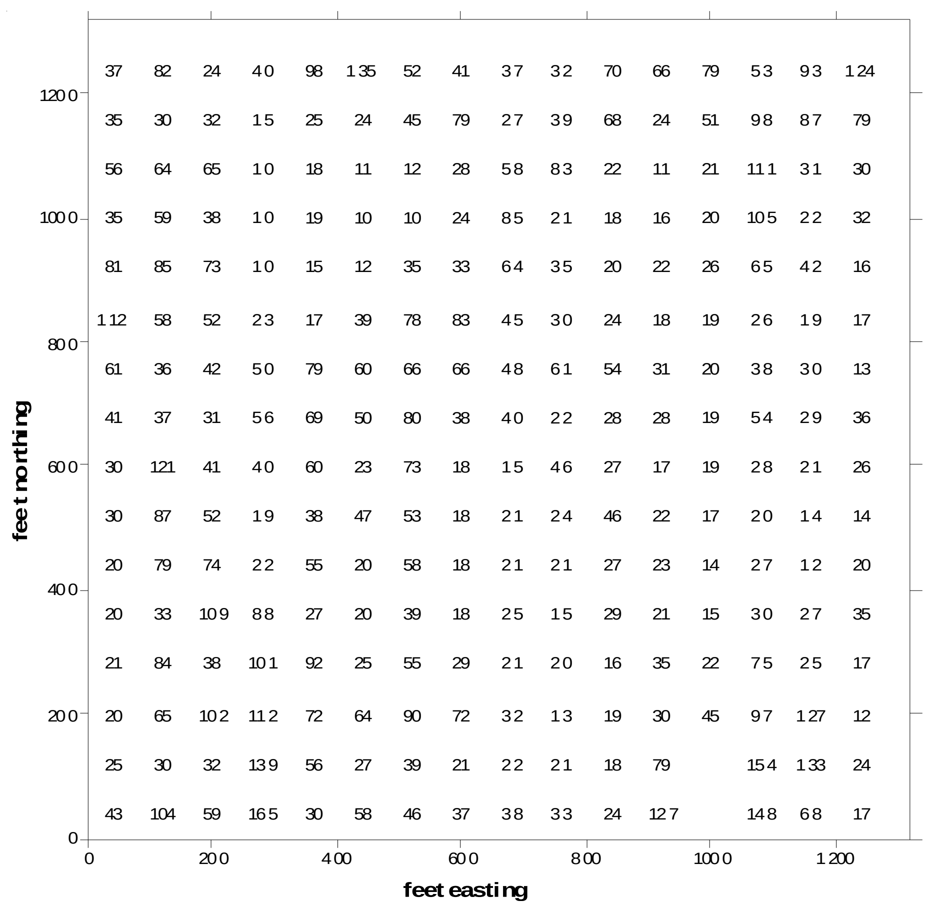


Figure 2-38. Thomasboro P, 2001.

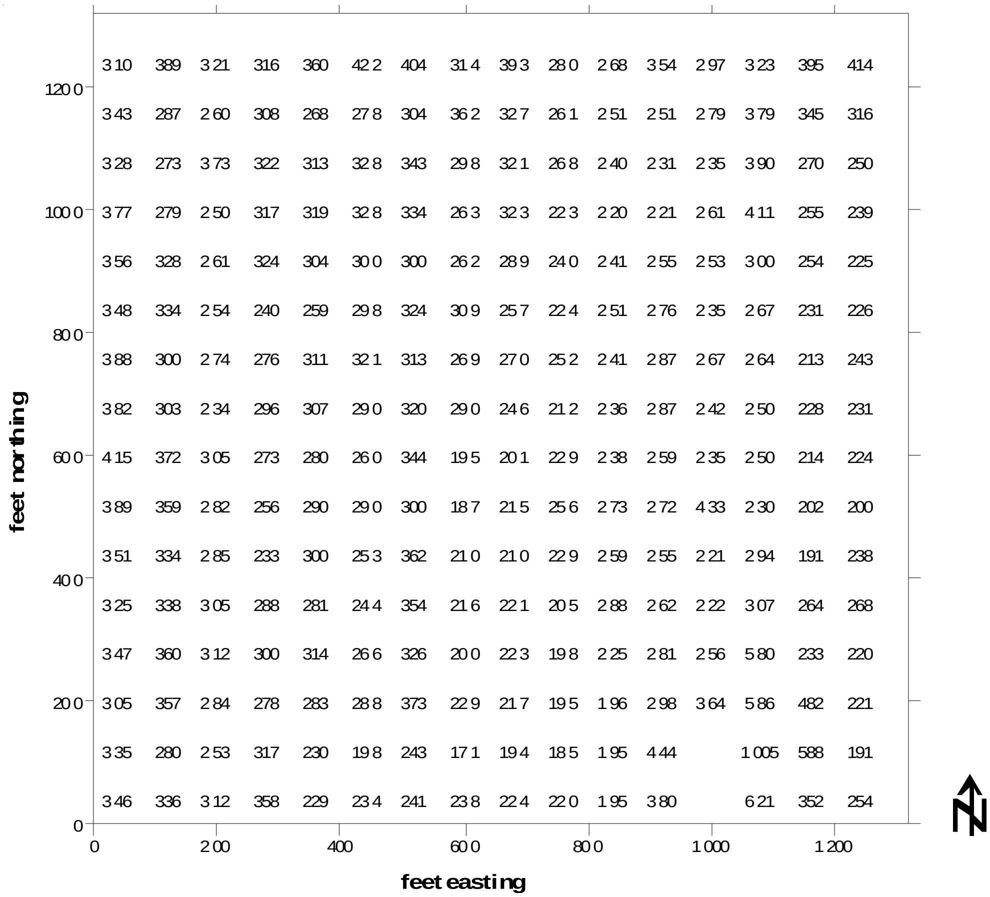


Figure 2-39. Thomasboro K, 2001.

The contour maps in Figures 2-40 through 2-52 depict the kriged estimates from the plot maps previously shown. The patterns in the field almost always show distinct areas in the northeastern, northwestern and south-central part of the field in soil pH, P and K. These areas are less clear following large applications of buildup P and K, but are more easily detected following periods of nutrient drawdown in later years. The south-central pattern forms an area similar to a “rabbit’s head.” The area surrounding the building site always is associated with high soil P and K levels. As Peck once proclaimed at a national meeting, “It seems wherever there were people, there is always a lot of P.”

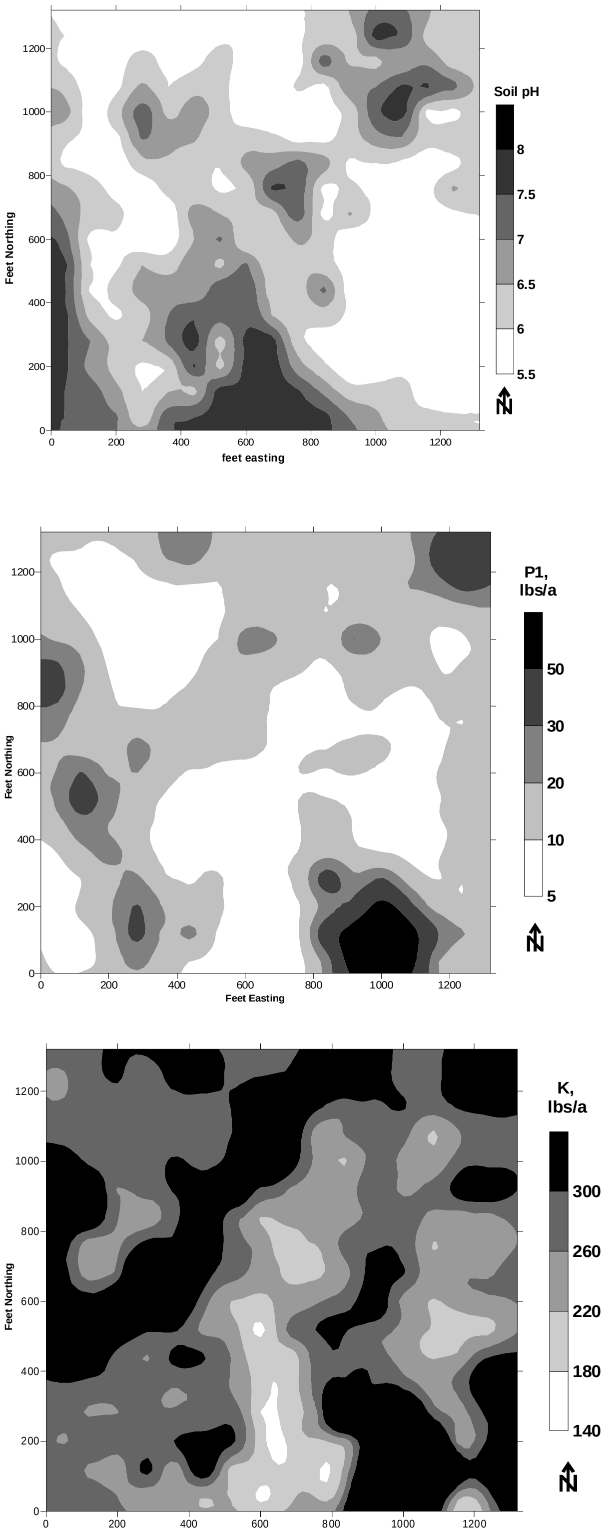


Figure 2-40.
Thomasboro, pH, P and K, 1982. This was the first year of grid soil sampling for this site. Note the distinct pattern in the south-central area resembling a rabbit's head in the P map.

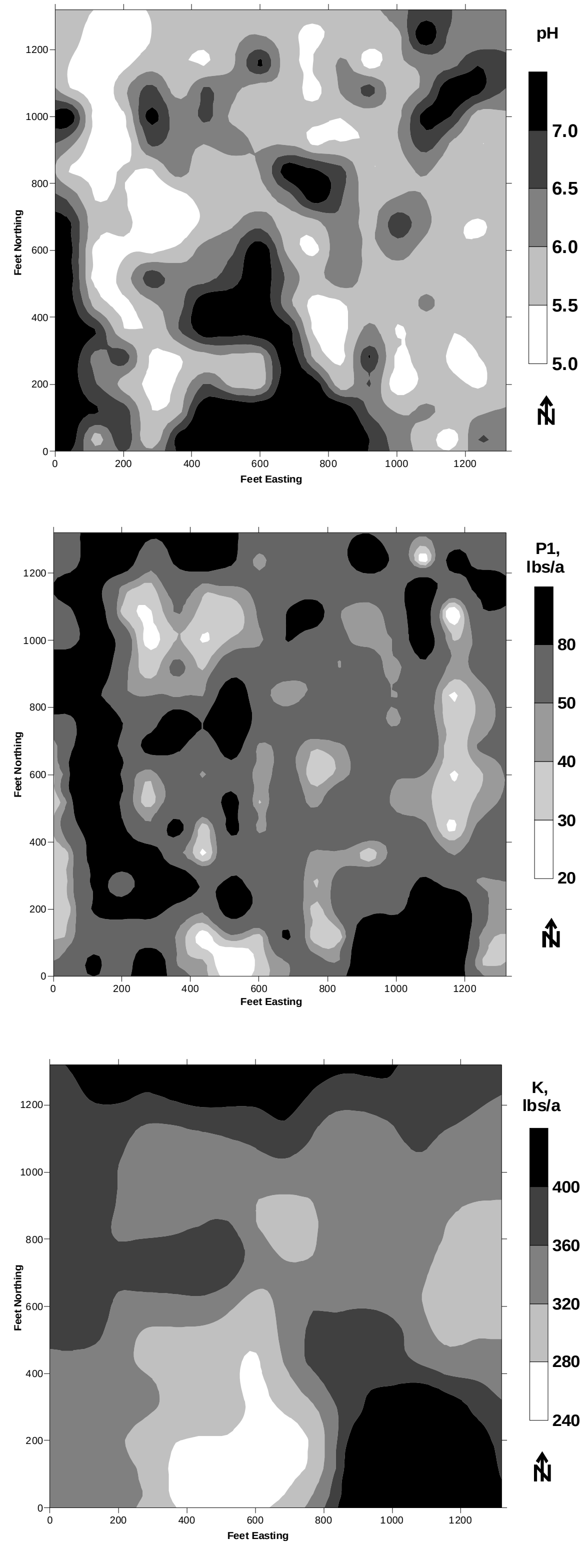


Figure 2-41.
Thomasboro, soil pH, P and K, 1986.

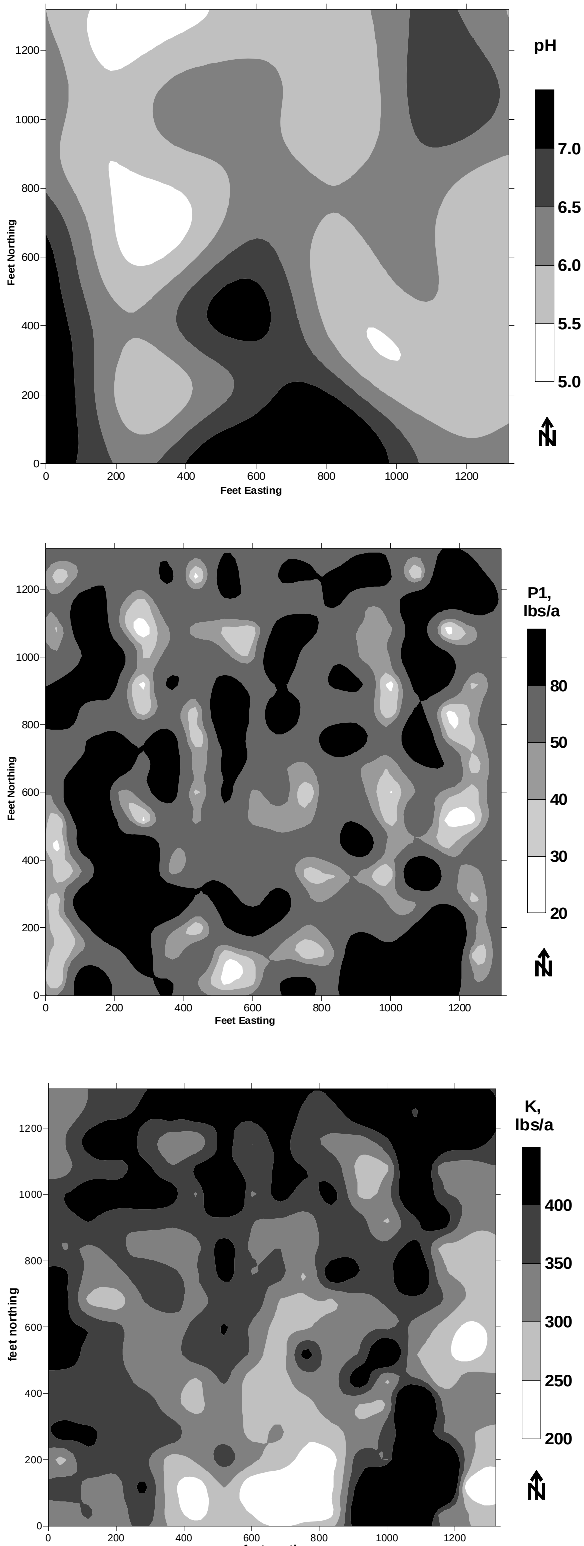


Figure 2-42.
Thomasboro soil pH, P and K, 1987. High P and K fertilization has obliterated the original P pattern and made the pattern in the K map harder to see.

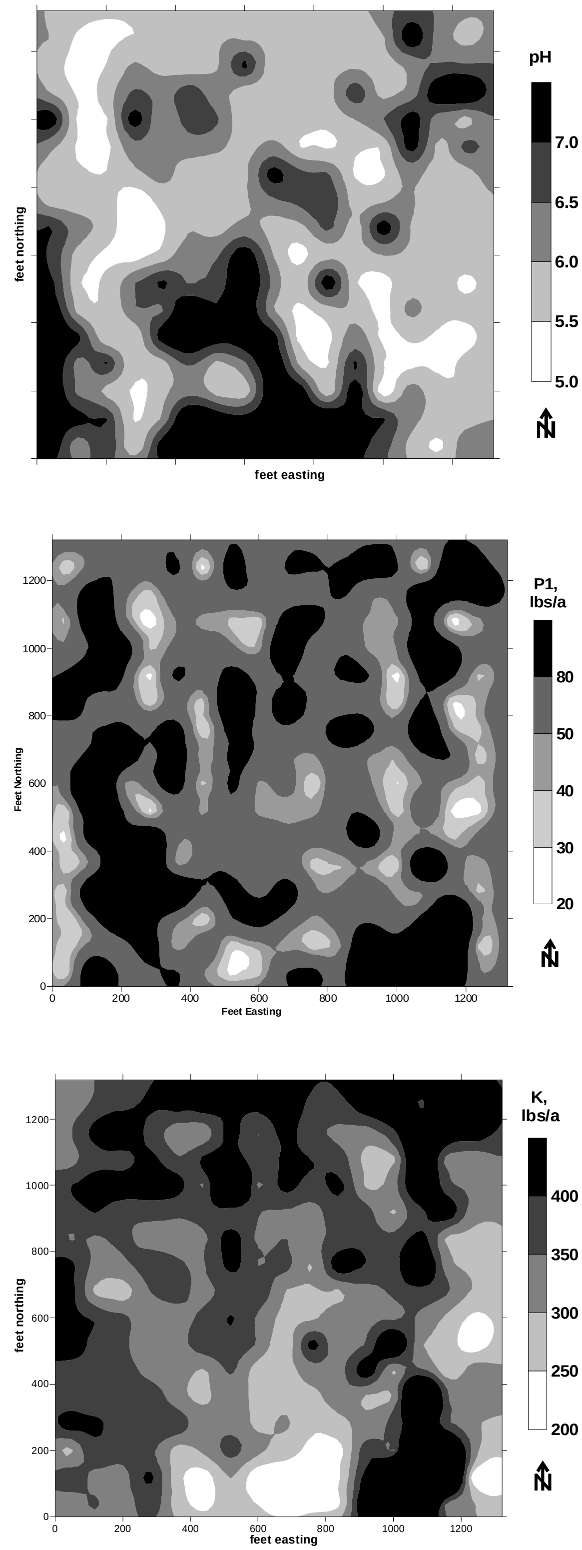


Figure 2-43.
Thomasboro soil pH, P and K, 1988.

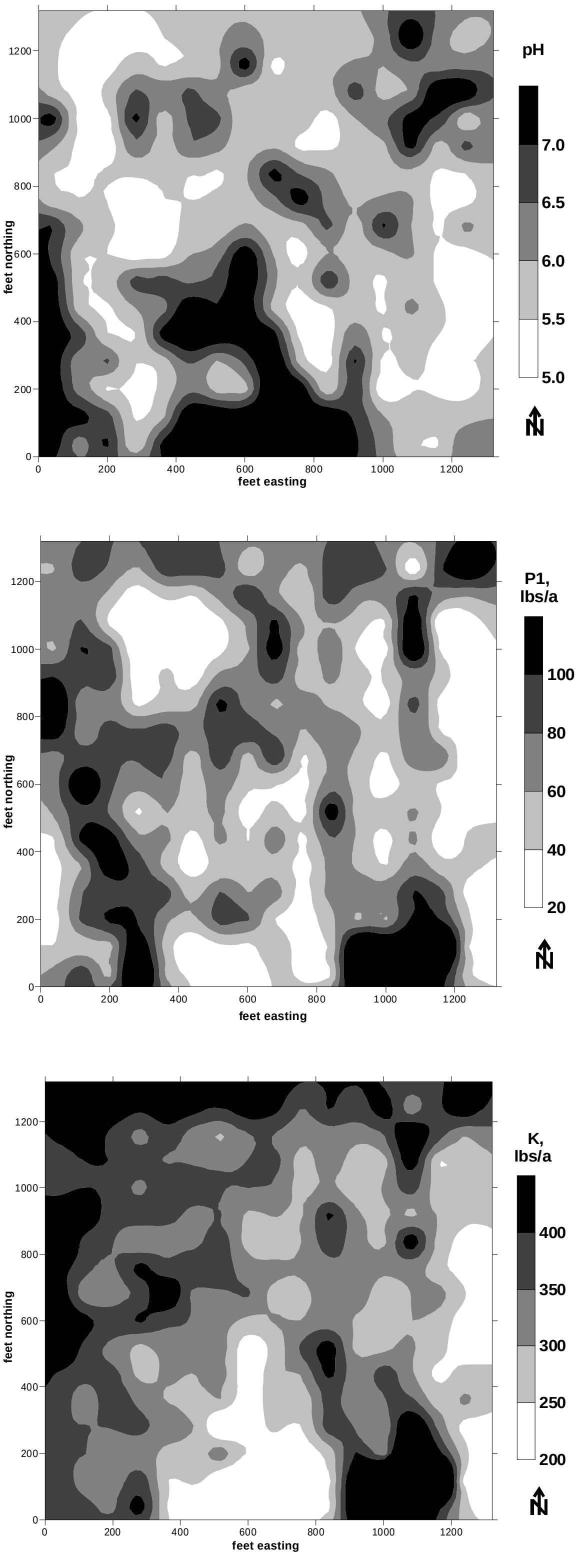


Figure 2-44.
Thomasboro soil pH, P and K, June 1989.

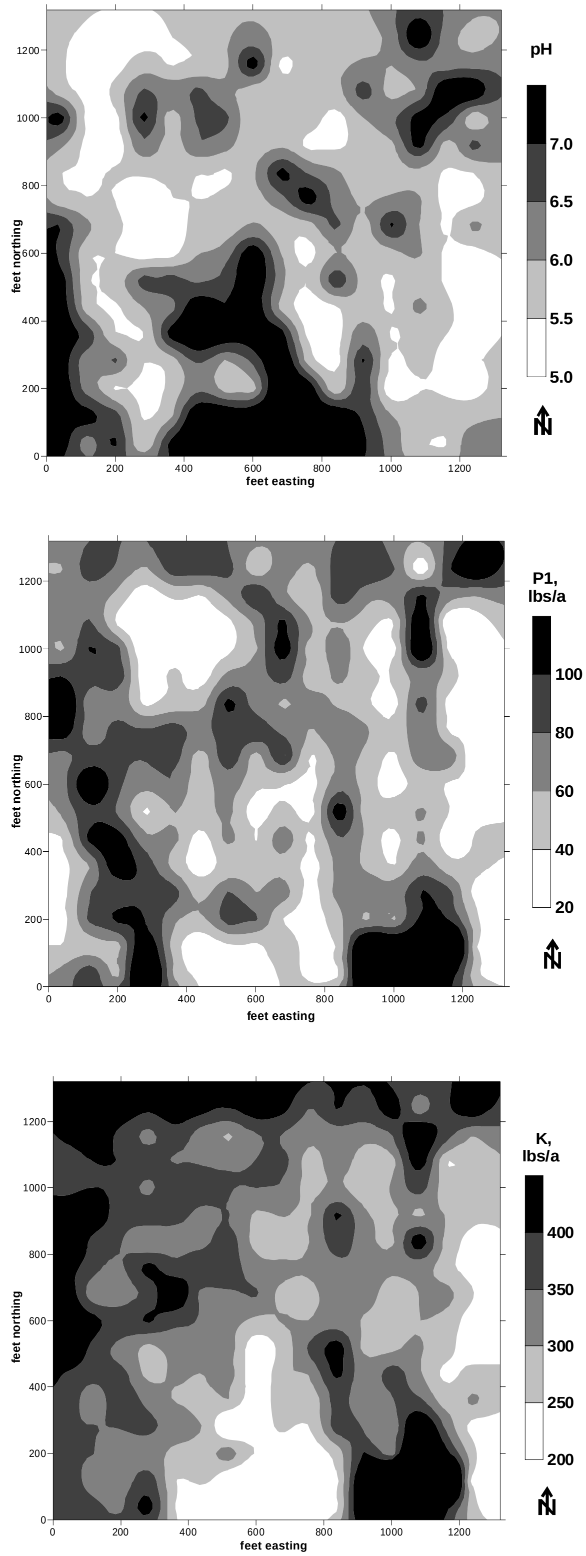


Figure 2-45.
Thomasboro soil pH, P and K, October 1989.

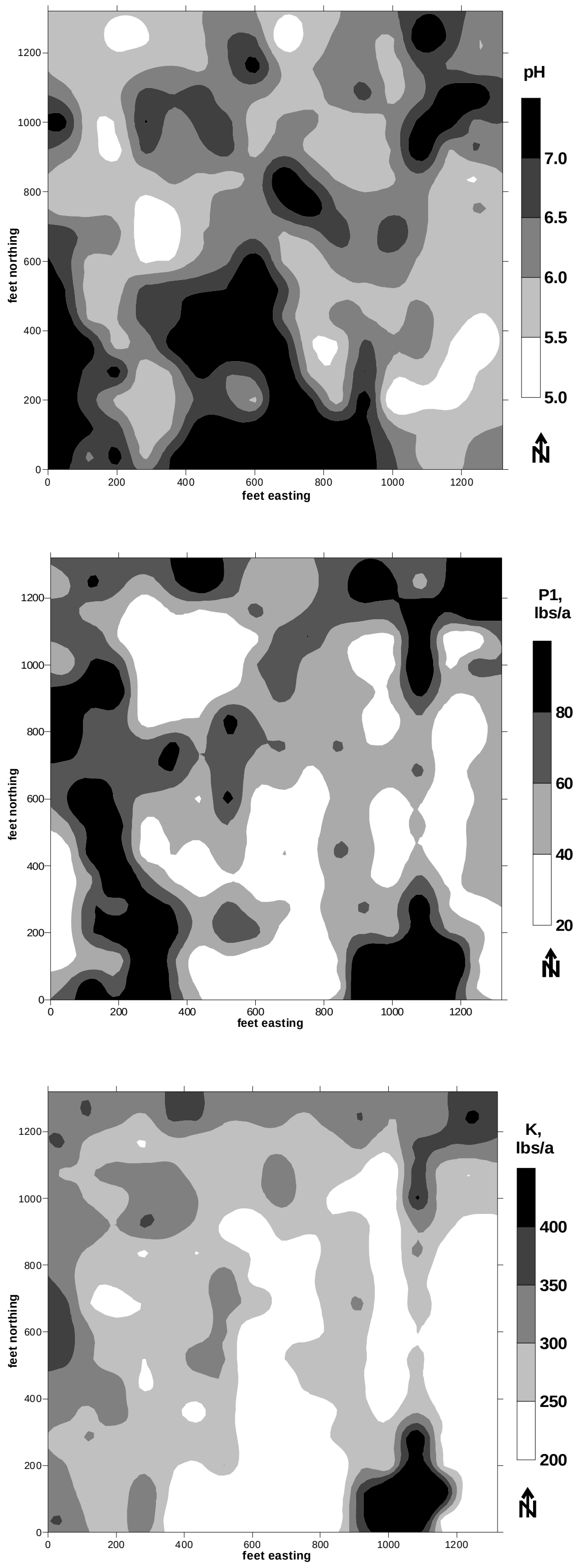


Figure 2-46.
Thomasboro soil pH, P and K, 1990. By this sampling date, drawdown of P and K begin to reveal original P and K patterns.

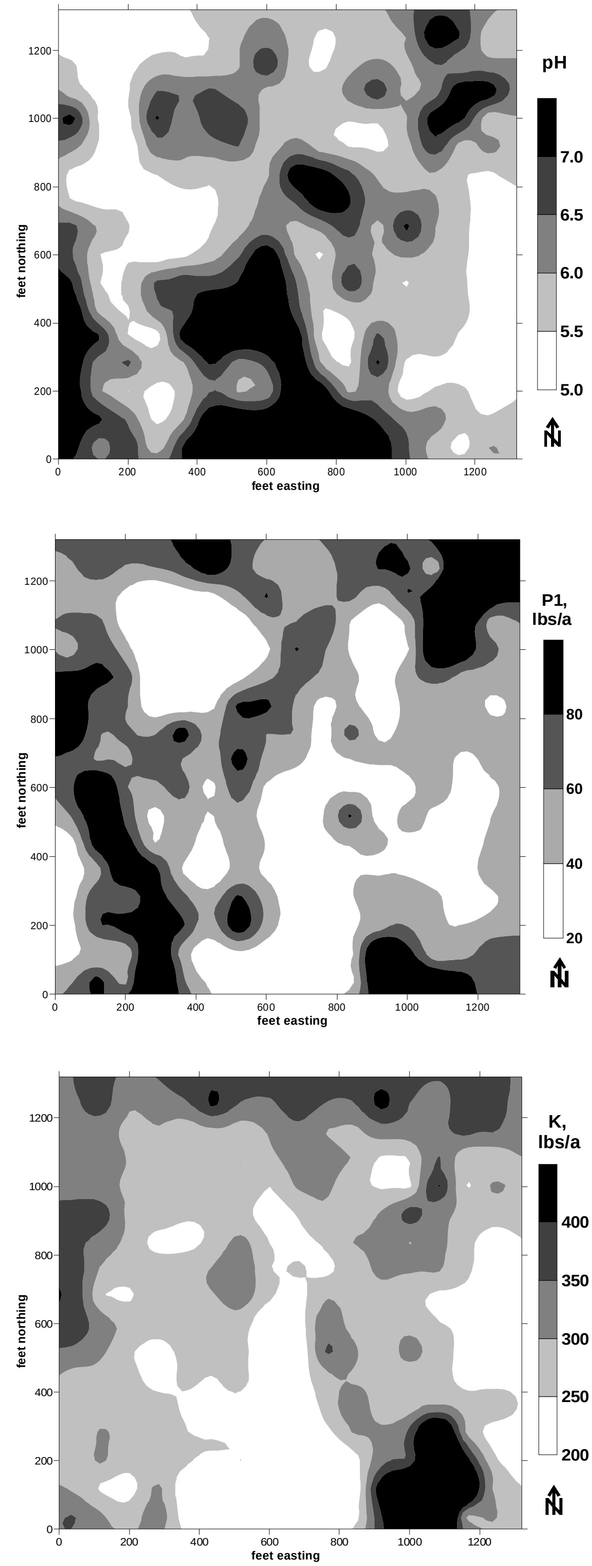


Figure 2-47.
Thomasboro soil pH, P and K, 1991.

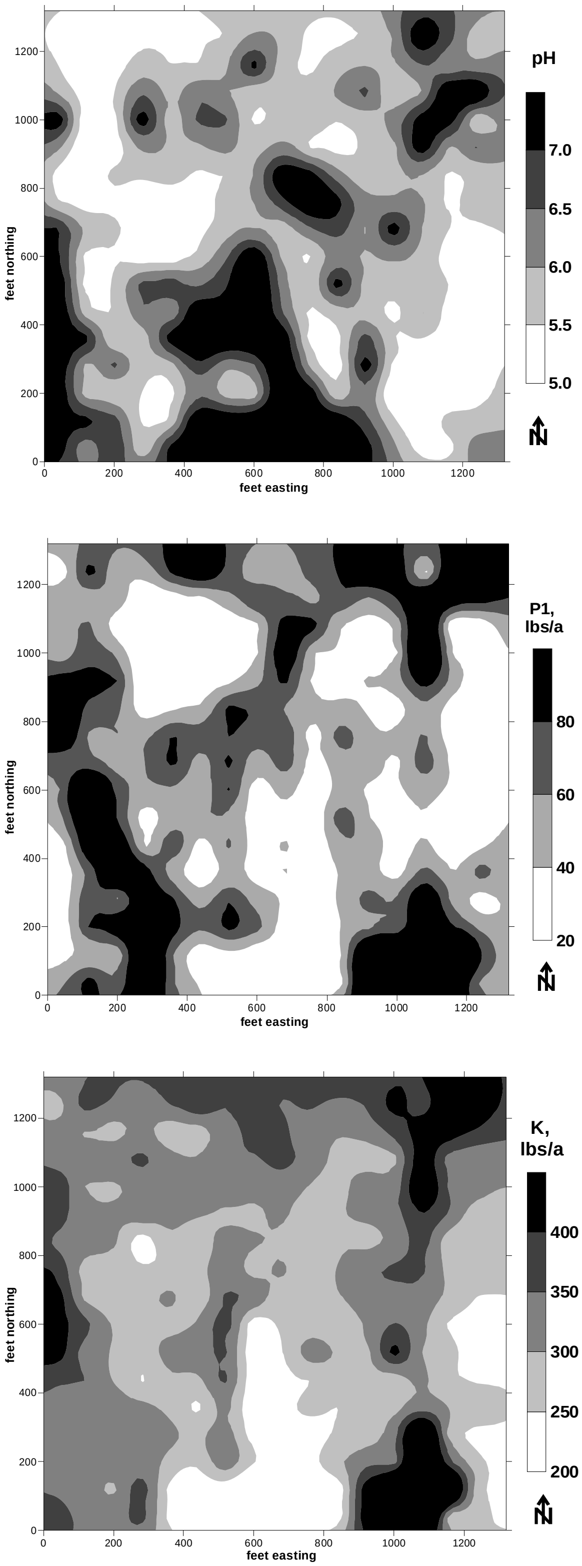


Figure 2-48.
Thomasboro soil pH, P and K, 1992.

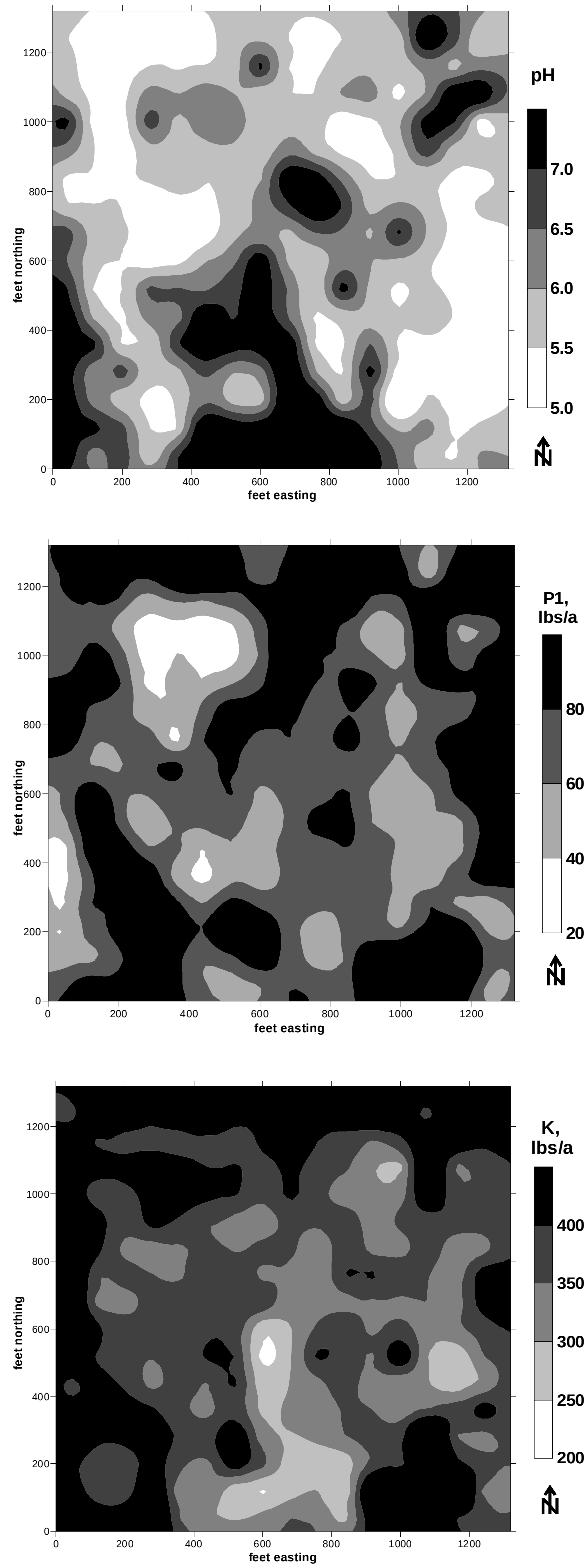


Figure 2-49.
Thomasboro soil pH, P and K, 1994.

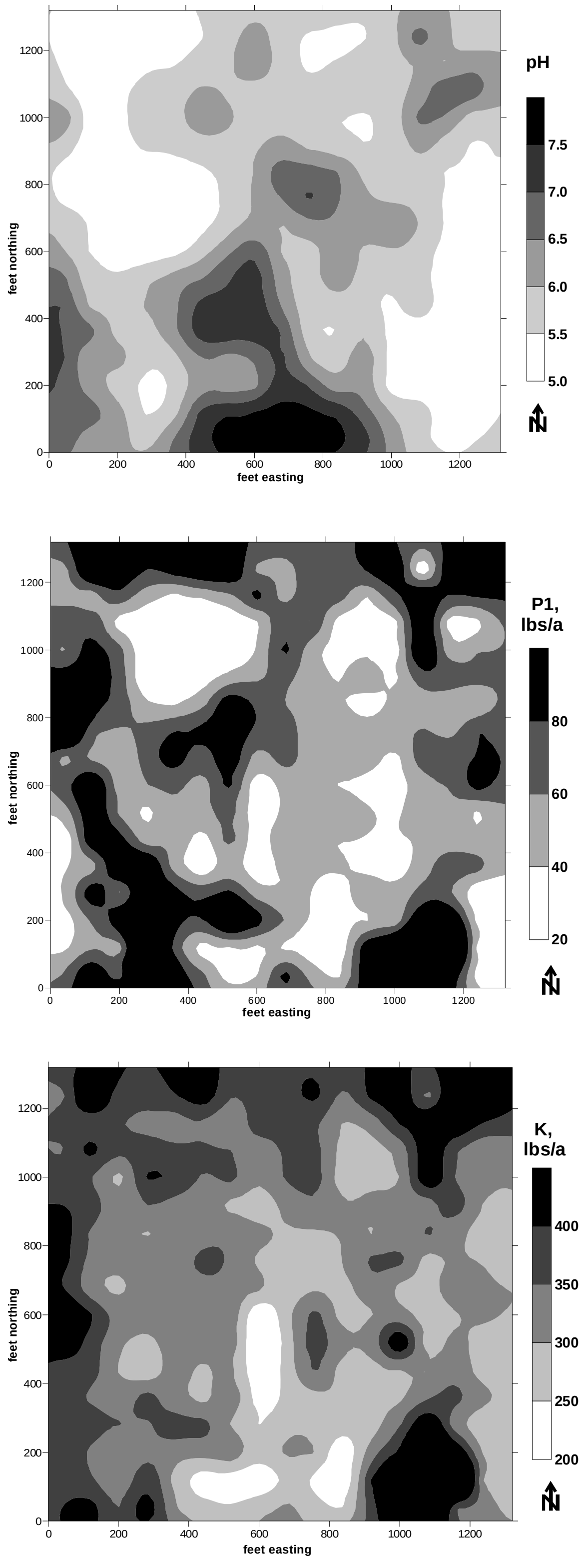


Figure 2-50.
Thomasboro soil pH, P and K, 1995.

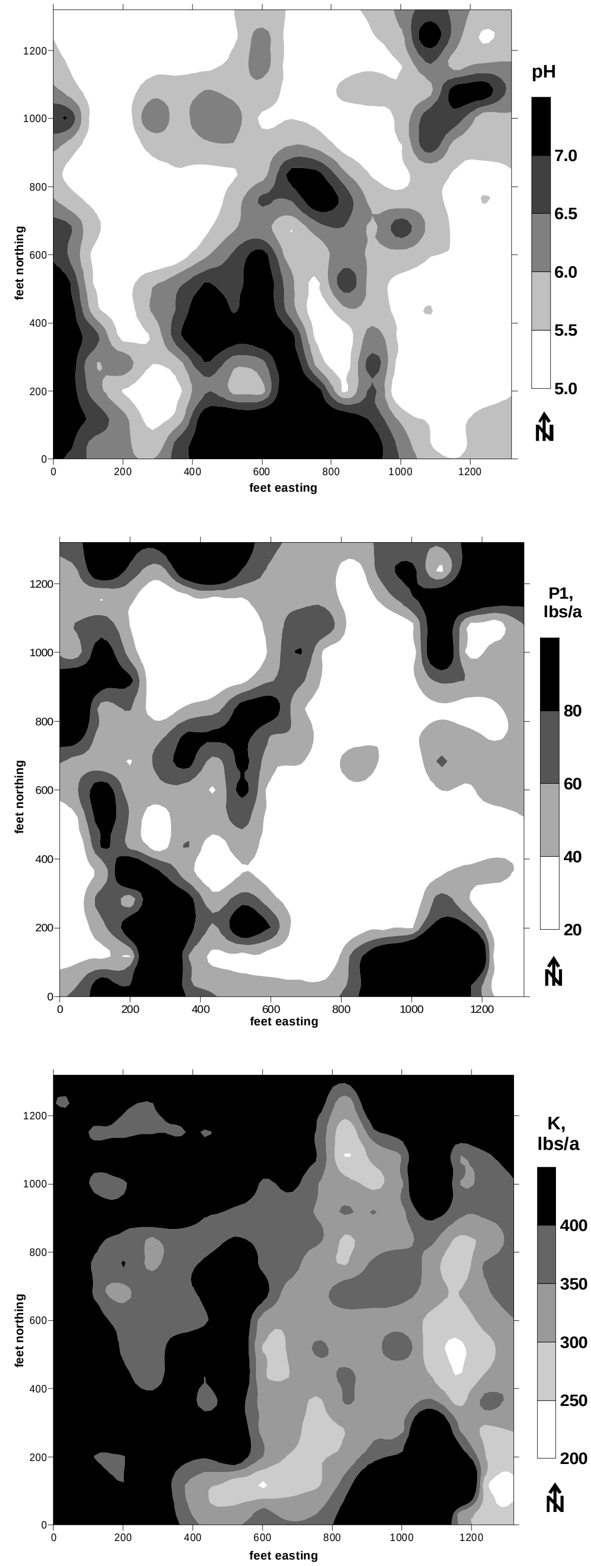


Figure 2-51.
Thomasboro soil pH, P and K, 1999.

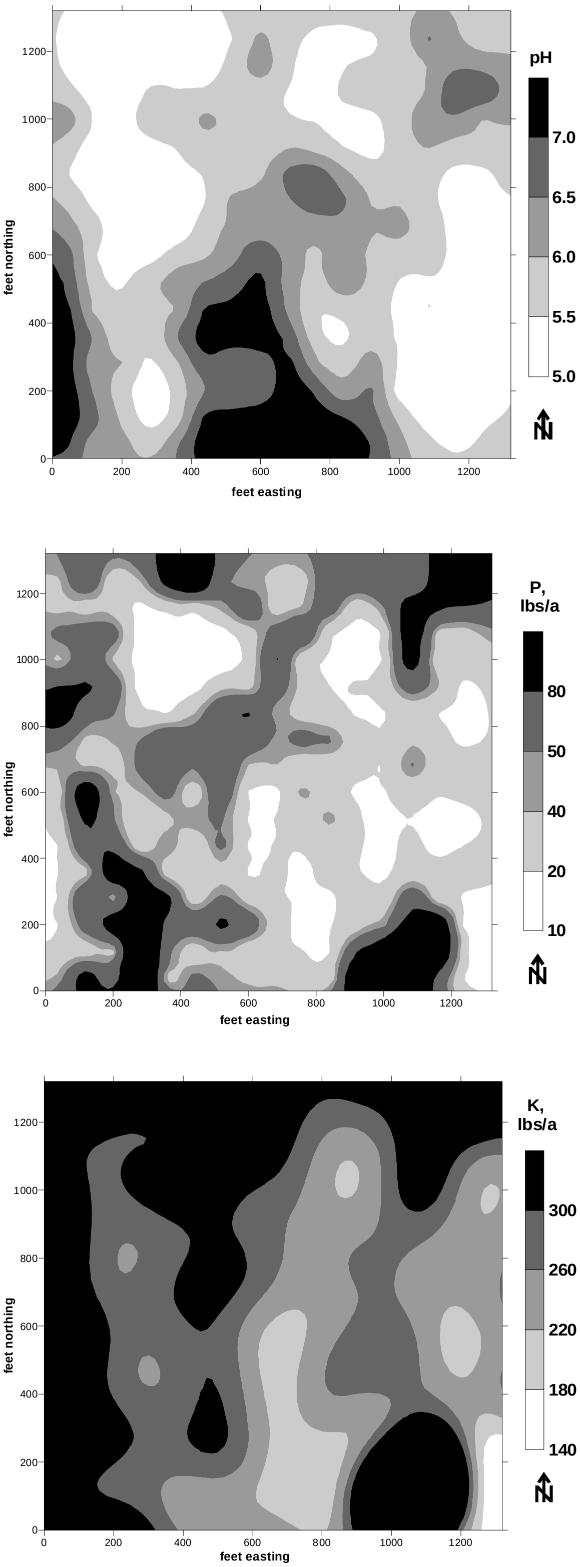


Figure 2-52.
Thomasboro soil pH, P, and K, 2001.

Nutrient changes through time

The following maps depict changes in soil pH, P and K levels through time for selected intervals. The data were generated by taking the values of the first date and subtracting the data from the ending date. For example, if the K level in 1986 was 400 and the K level in 1987 for the same point was 450, the difference would be minus 50, or an increase in 50 lb K/acre. Negative numbers therefore indicate an increase in value through time, while positive numbers show a decrease through time.

The maps are most meaningful at wider time spacing.

Table 2. Cropping and fertilization history at Thomasboro. In this chart, a positive change means an increase in value from initial sampling to the date of change.

Year	Crop	Yield	N	P_2O_5	K_2O	P_2O_5 removed	K_2O removed	PH change	P1 change	K change
		bu/a	lb/a	lb/a	lb/a	lb/a	lb/a			
1983	Corn	131	165	160	180	51	33			
1984	Corn	150	179	141	185	58	38			
1985	Corn	171	183	138	180	66	43			
1986	Corn	164	192	92	120	63	41	-0.3	+59	+75
1987	Corn	162	201	141	122	62	40		+ 5	+ 8
1988	Corn	83	185			36	18		-10	-26
1989	Corn	175	179			68	44		-4	- 4
1990	Corn	173	161			67	44		-3	-63
1991	Corn	37	130			14	9		-8	+12
1992	Corn	188	180	*	*	47	47		+10	+28
1993	Corn	113				49	32			
1994	Corn	142				61	40	0	+12	+33
1995	Corn	105				45	29	-0.2	-14	-47
1996	Bean	51				44	68			
1997	Corn	136				58	38			
1998	Bean	52				45	69			
1999	Corn	156				67	59	0	-9	+65
2000	Bean	53				46	70			
2001	Corn	138				59	39	0	-8	-110
2002	Bean	55				47	73			
2003	Corn	155				67	43			
2004	Bean	48				41	64			
2005	Corn	178				77	50			
2006	Bean	51				44	68			
SUM				672	787	1282	1099			

* Variable rate application P and K conducted.

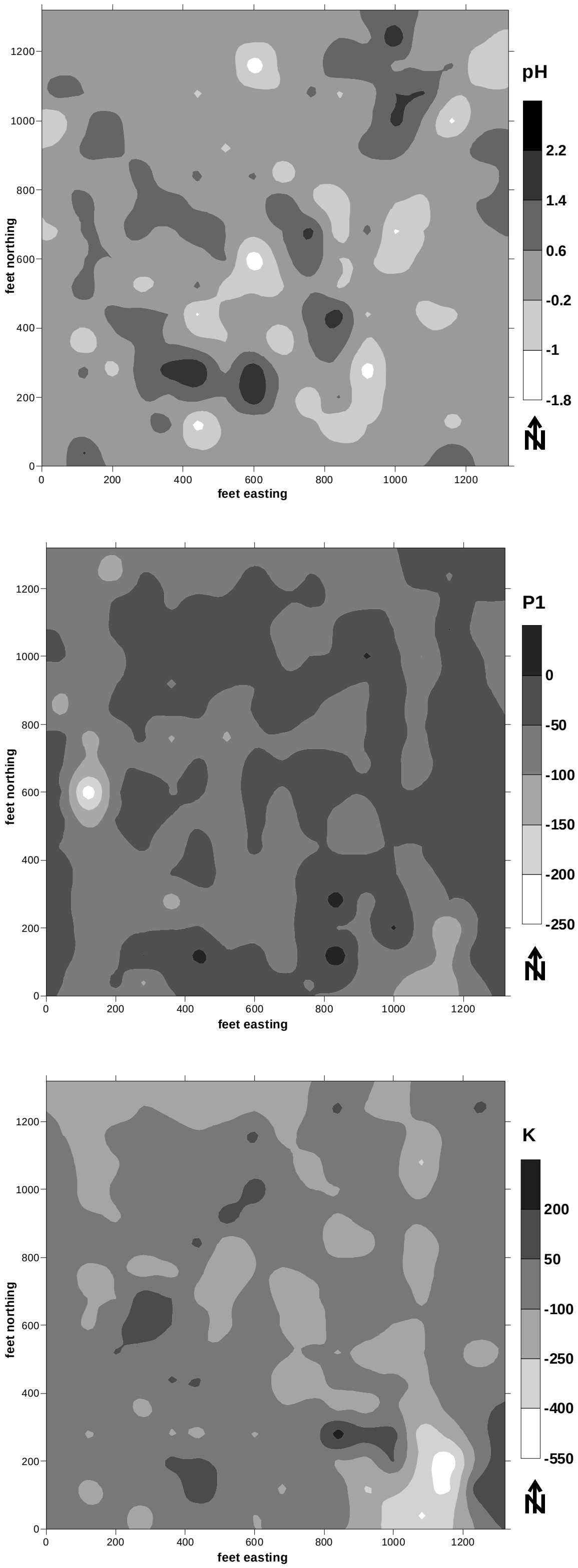


Figure 2-53.
Thomasboro soil pH, P and K differences, 1982-1987. This represents the period of large fertilizer P and K applications. All other difference maps represent crop removal, with no addition P or K added until 1991.

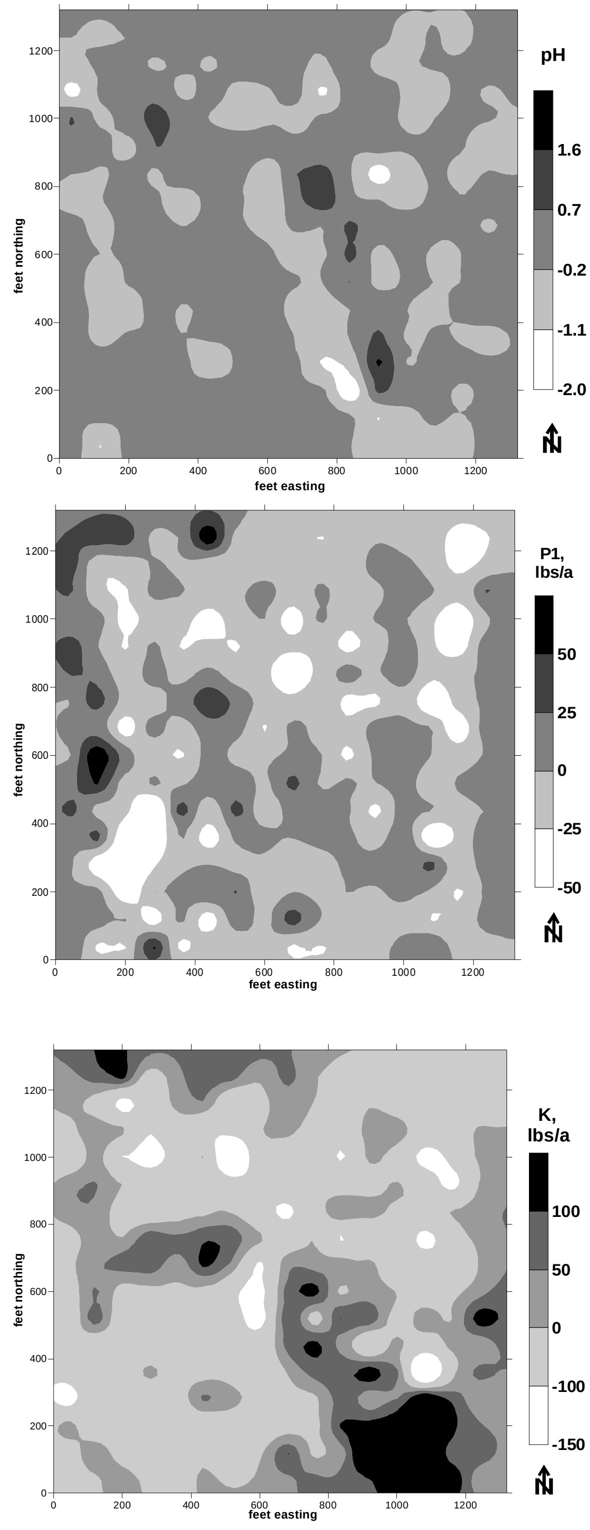


Figure 2-54.
Thomasboro pH, P and K changes, 1986-87. Virtually no changes in pH were observed. Some wide swings in P and K were observed, but this could be due to slight position differences between sampling point years in areas of small-scale variability.

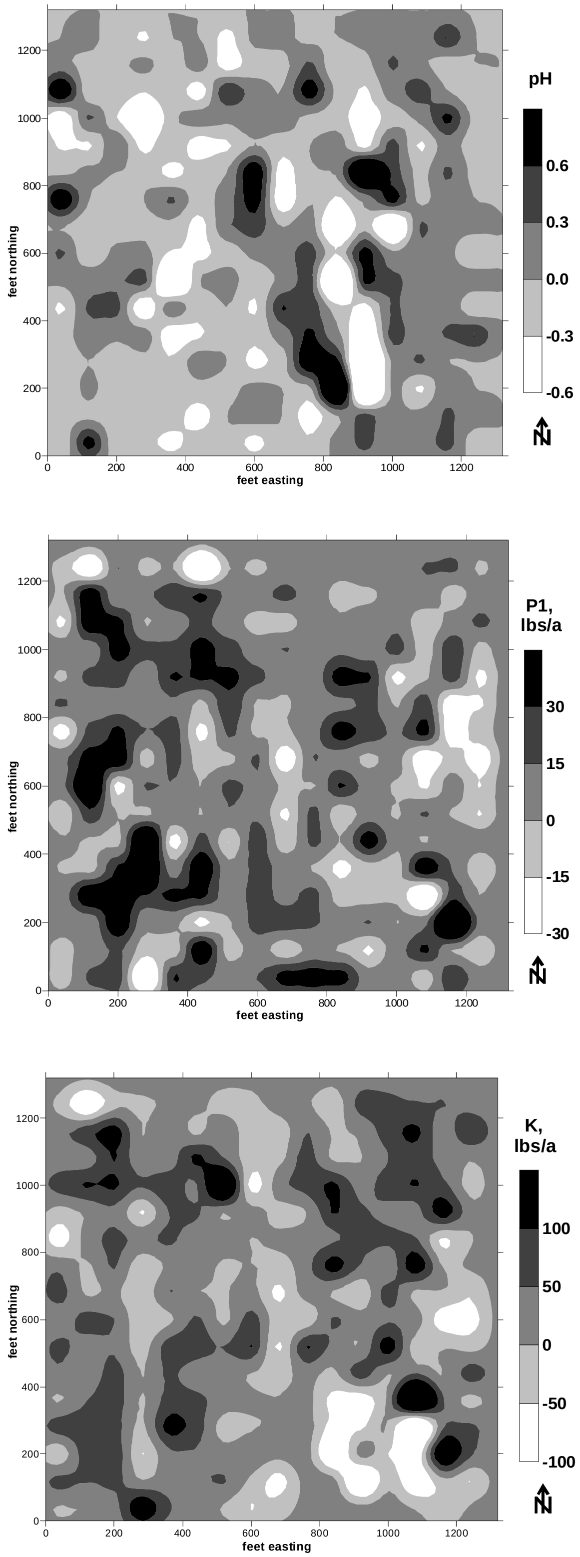


Figure 2-55.
Thomasboro pH, P and K changes, 1987-1988.
This is the year where no fertilizer application began. Soil pH tended to decrease in the east and increase in the west. Soil P levels tended to remain constant. Soil K tended to decrease.

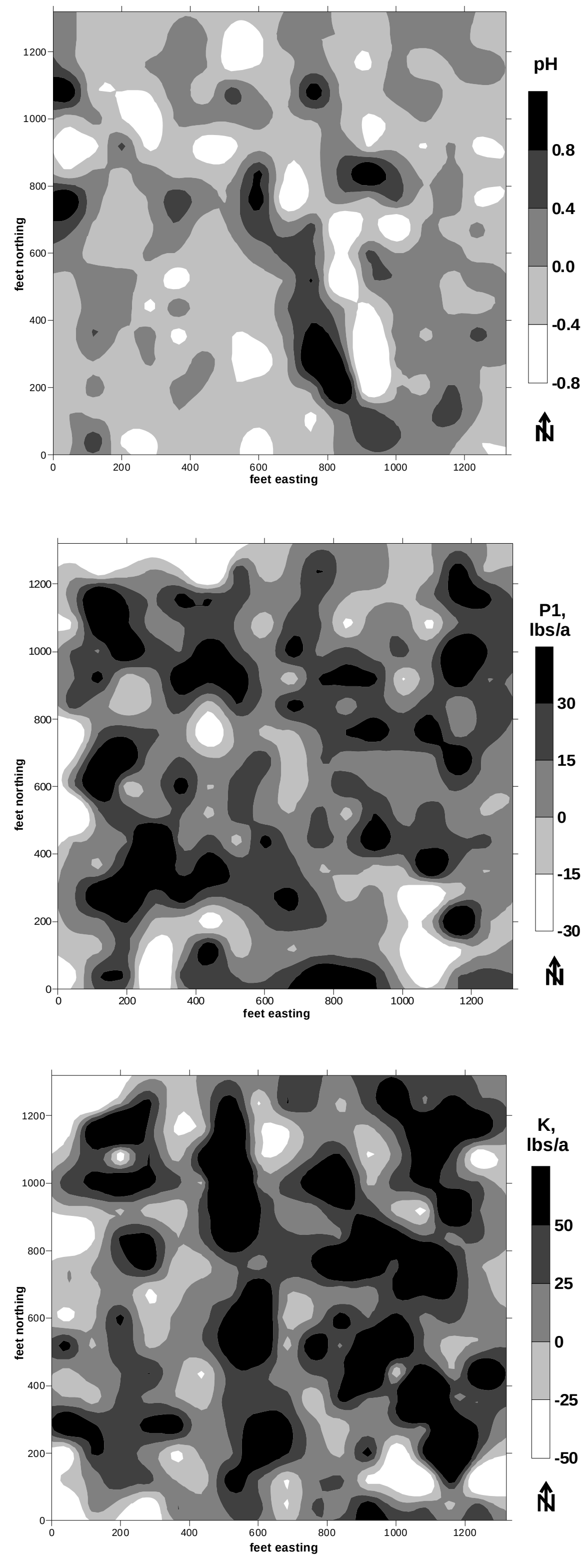


Figure 2-56.
Thomasboro pH, P and K changes, 1987-1989 (October only). Soil pH tended to increase slightly. Soil P and K levels were relatively constant on average.

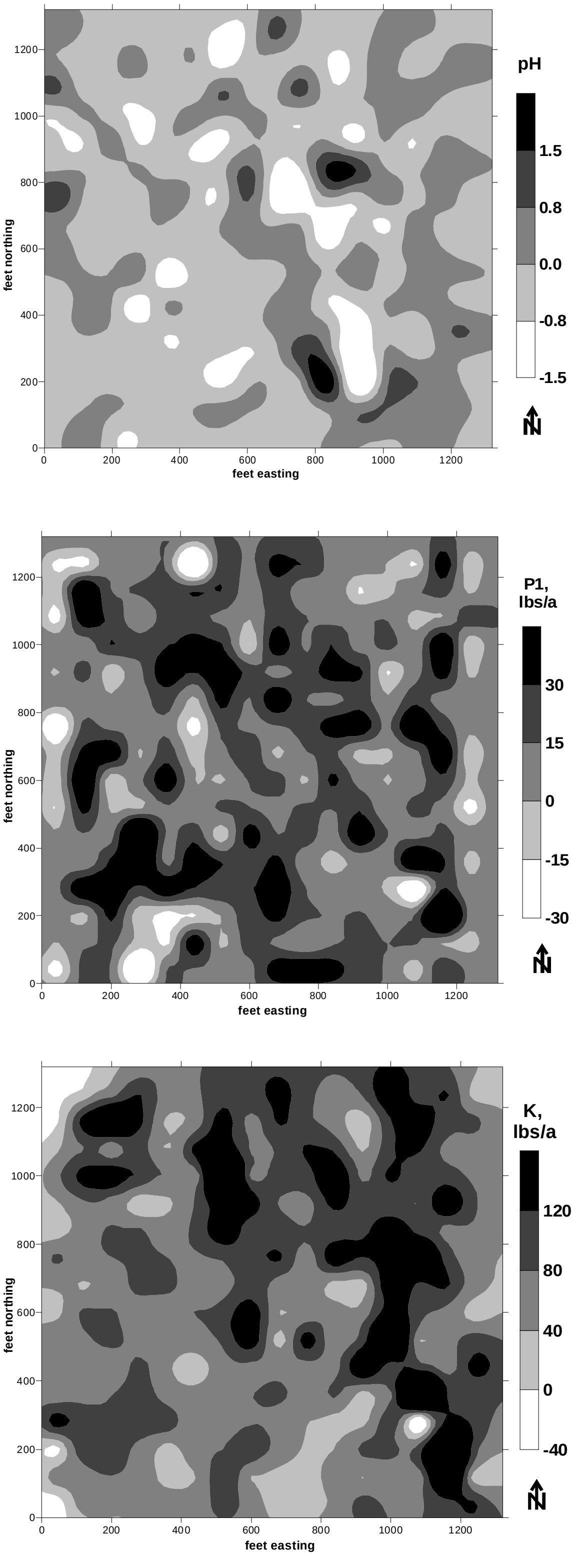


Figure 2-57.
Thomasboro pH, P and K changes, 1987-1990.
Soil pH tended to increase, soil P tended to decrease slightly and K levels decreased overall.

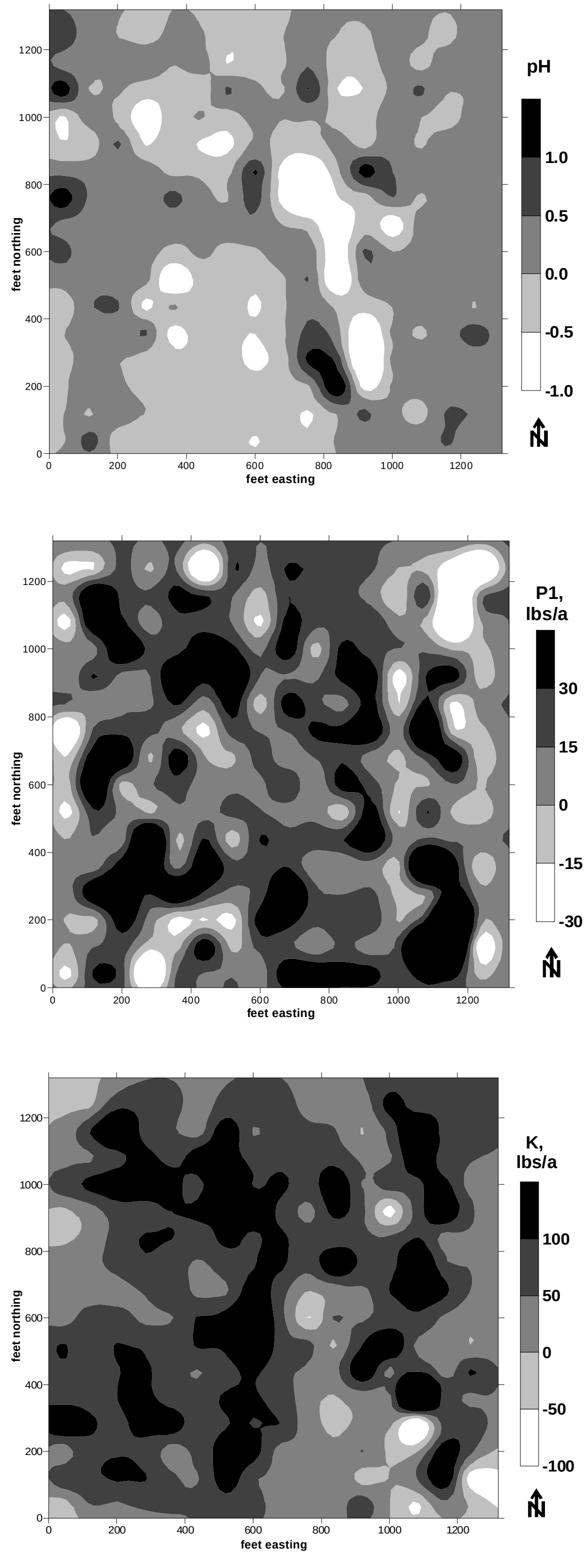


Figure 2-58.
Thomasboro pH, P and K changes, 1987-1991.
Soil pH tended to remain constant. Soil P and K tended to increase in some areas and decrease in others.

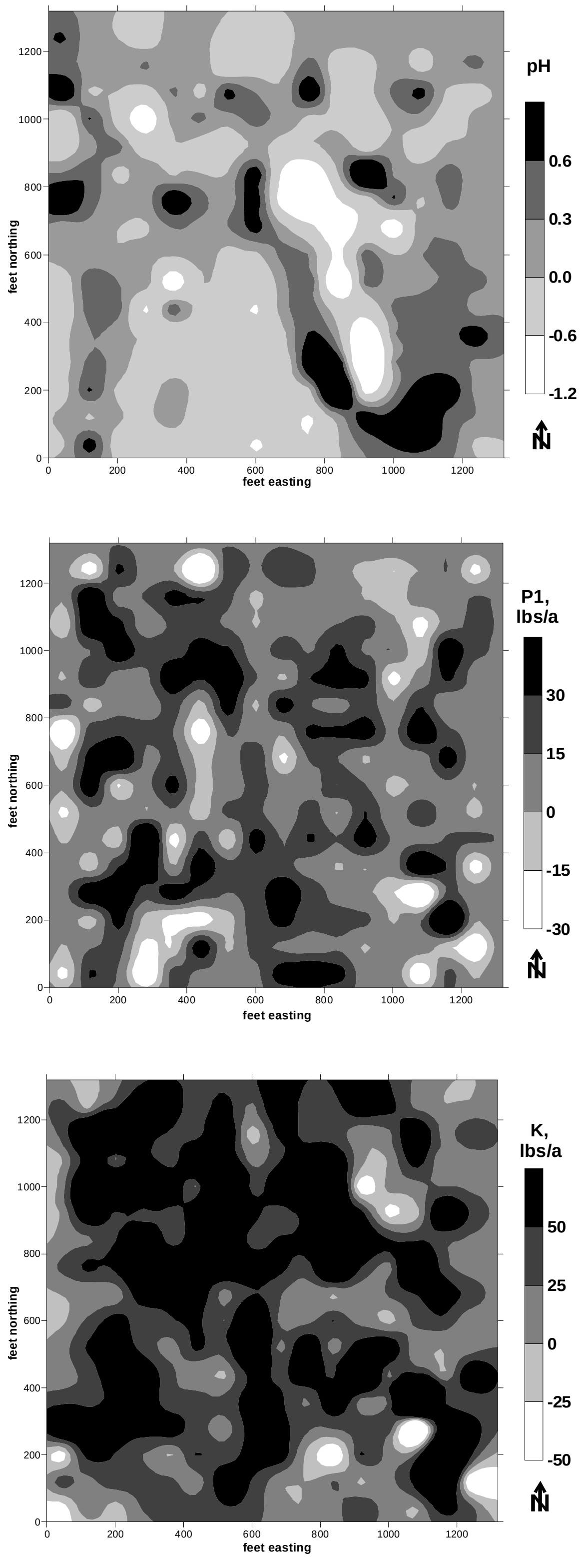


Figure 2-59.
Thomasboro pH, P and K changes, 1987-1992. Soil pH tended to increase. Changes in soil P and K were variable, with a trend toward decreasing.

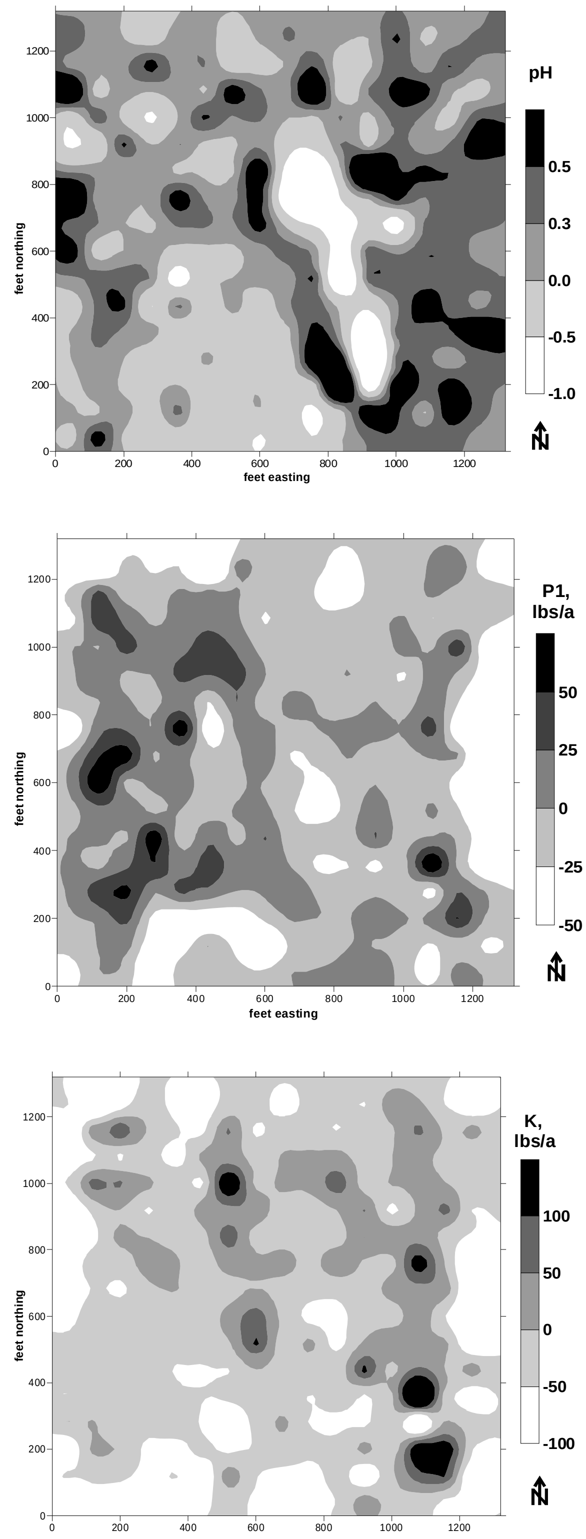


Figure 2-60.
Thomasboro pH, P and K changes, 1987-1994. Soil pH tended to decrease in the east and remain constant or increase in the center and west. Soil P levels tended to increase in the east and remain constant or decrease in the west. Soil K levels increased in most areas.

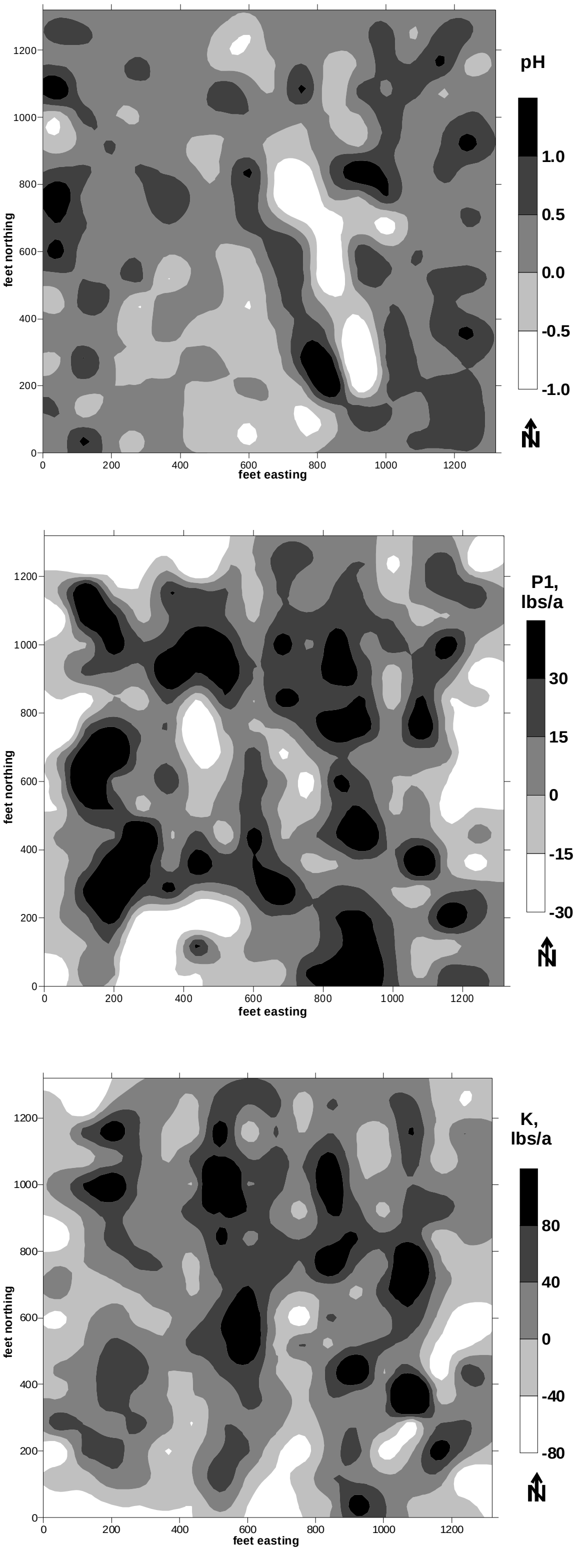


Figure 2-61.
Thomasboro pH, P and K changes, 1987-1995.
Soil pH remained mostly constant, with some smaller areas of higher or lower pH. Soil P and K changes were variable, with a trend toward decreasing levels.

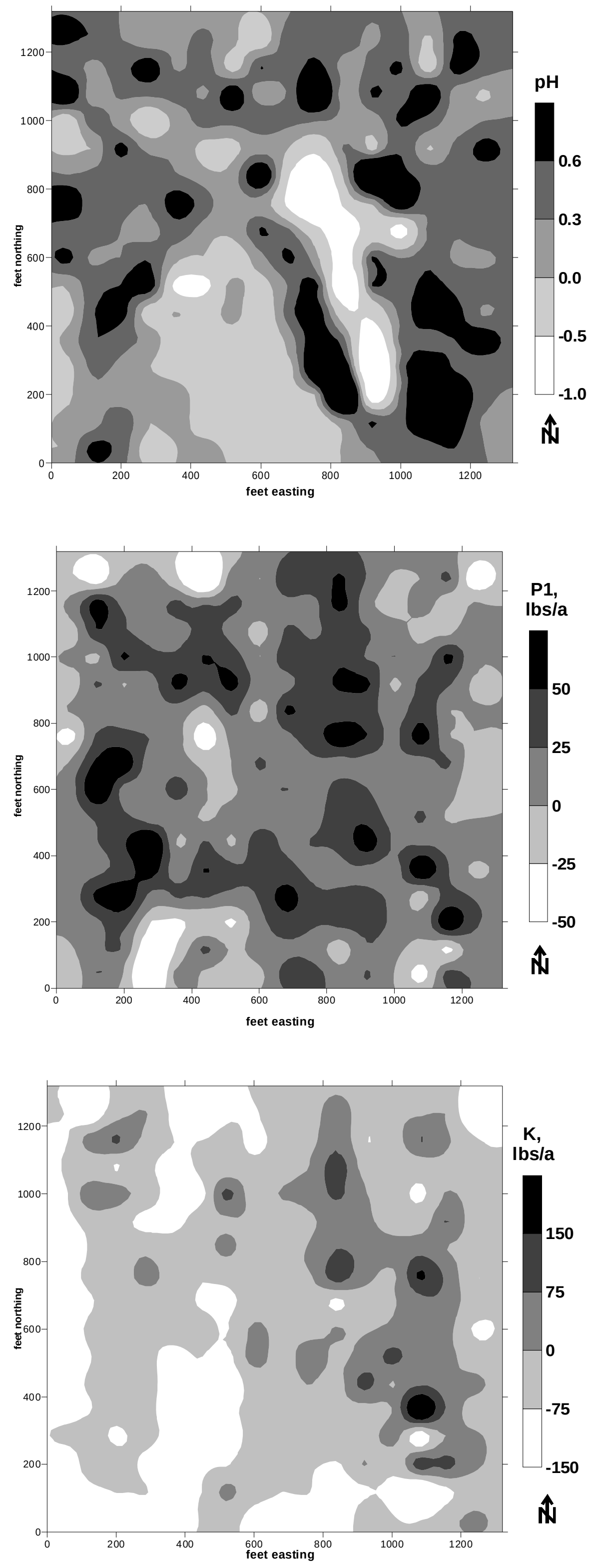


Figure 2-62.
Thomasboro pH, P and K changes, 1987-1999.
Soil pH changes tended to be variable, with a trend toward decreasing levels. Soil P changes also were variable, but tended to decrease. Soil K tended to increase except for an area in the east.

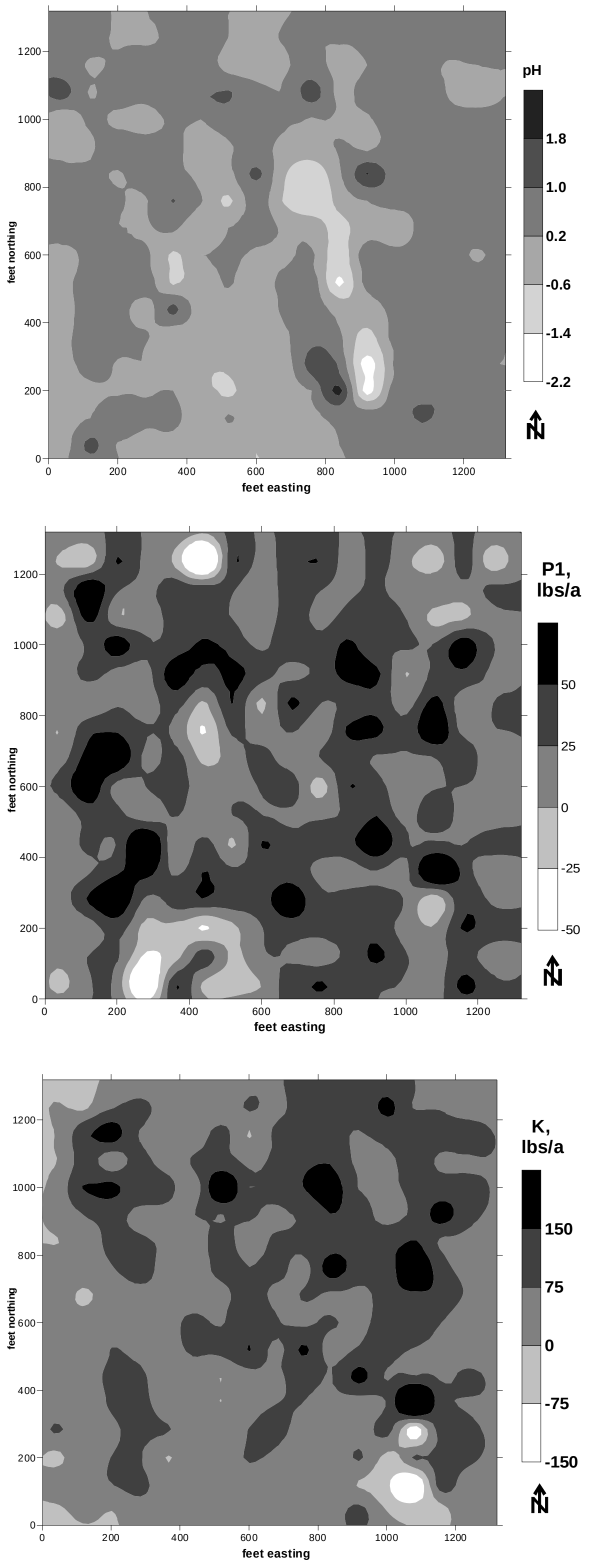


Figure 2-63.
Thomasboro pH, P and K changes, 1987-2001.
Soil pH decreased except in a few small areas.
Soil P changes were highly variable, but tended to decrease. Soil K decreased in all but a few small areas.

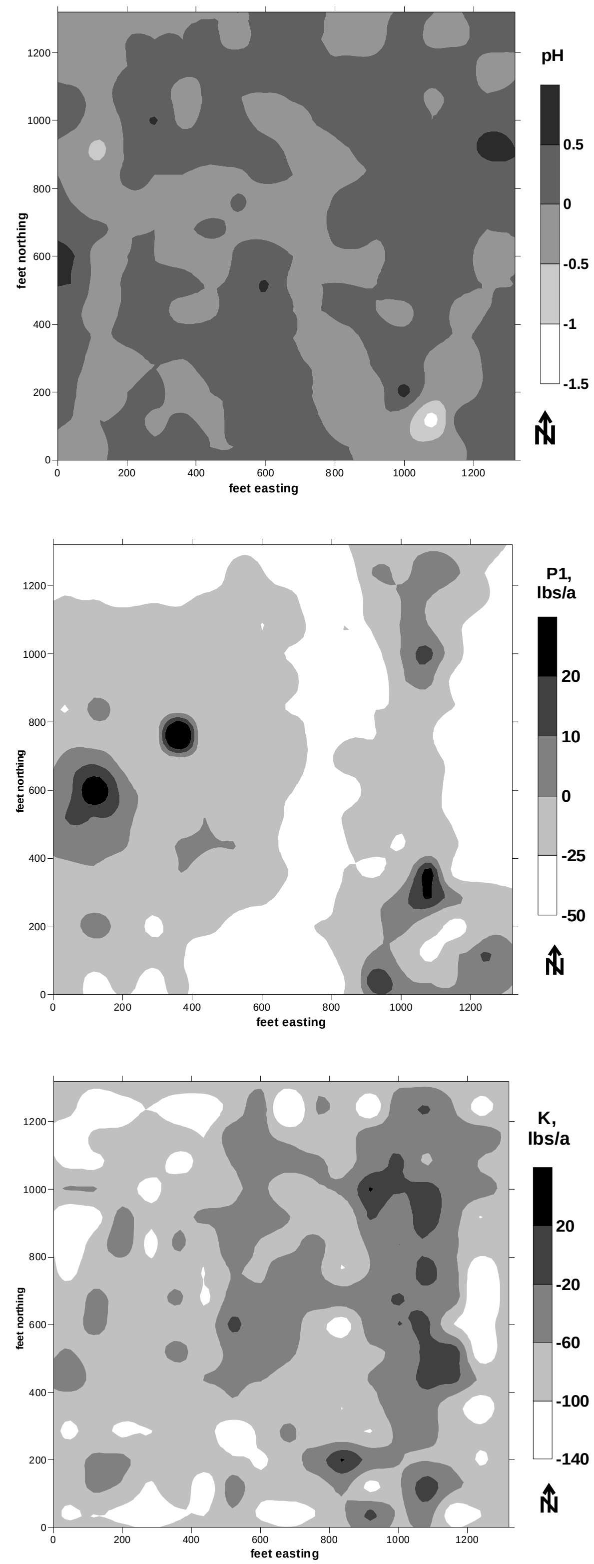
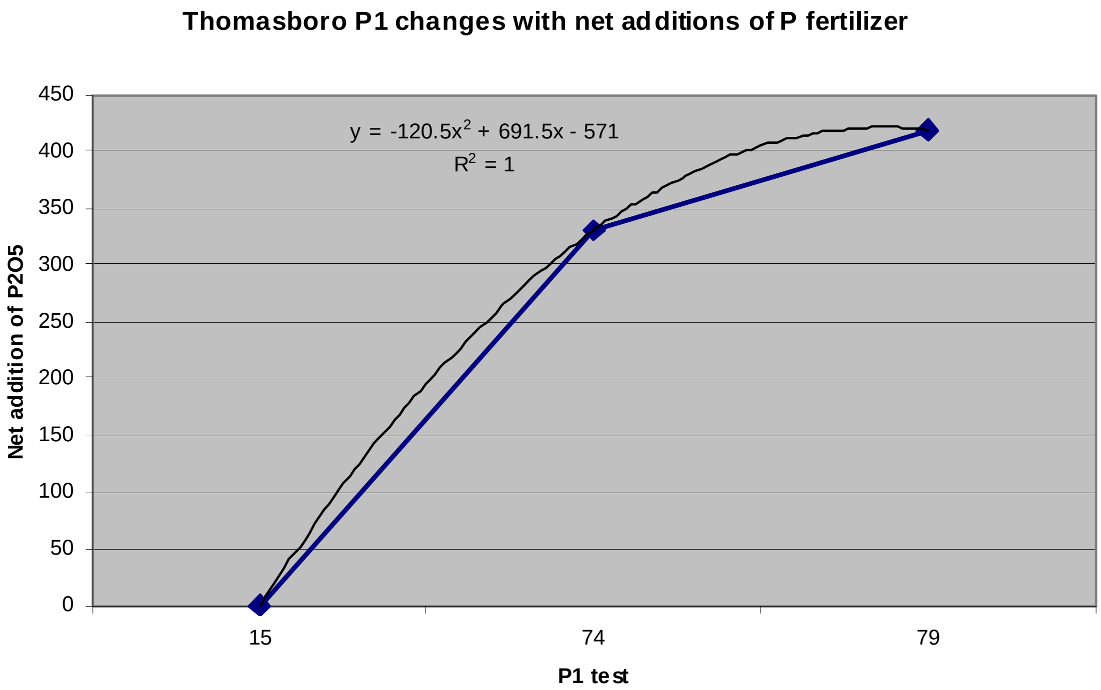


Figure 2-64.
Thomasboro pH, P and K changes, 1992-1994.
Soil pH tended to decrease. Soil P levels increased.
Soil K decreased in the east and decreased in the west.



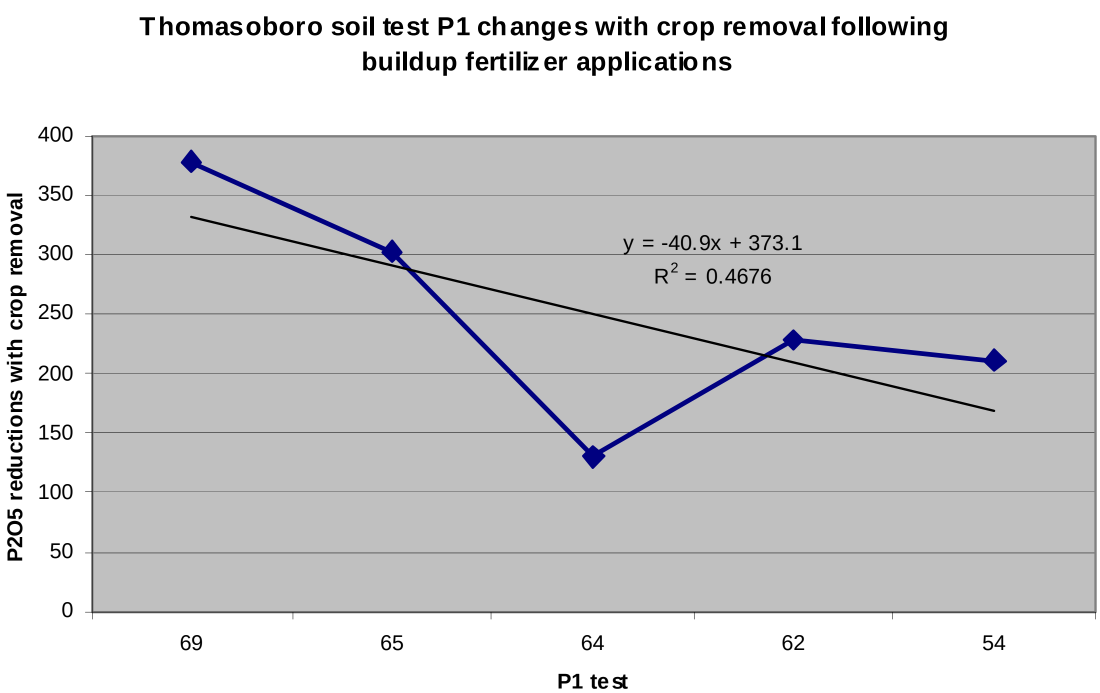
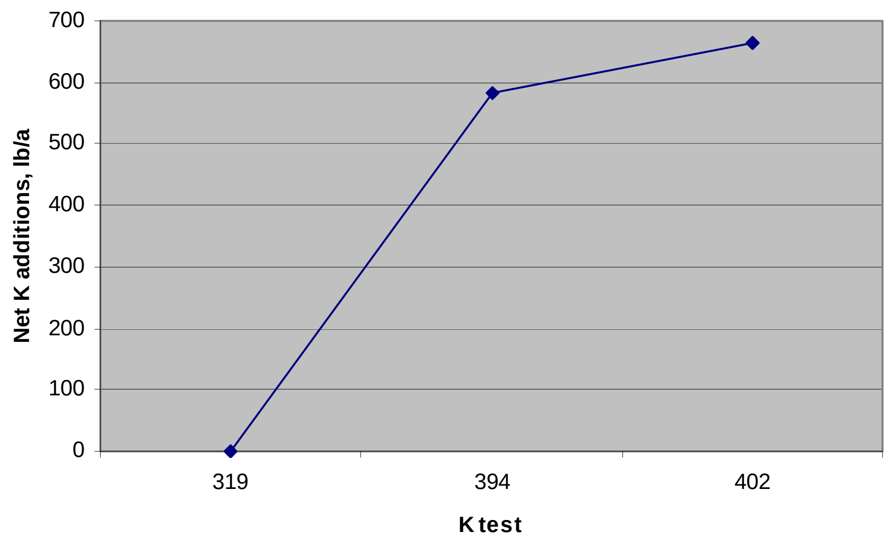


Figure 2-65.
Changes in Thomasboro P with fertilizer buildup and crop removal drawdown without fertilizer additions.

The P1 increase as a result of adding 364 lb/a P_2O_5 was 64 lb/a P1 test, or 5.8 lb P_2O_5/unit P1 test. Following buildup, the rate of change was a decrease of 15 P1 test with the removal of 232 lb/a P_2O_5, or 15 lb P_2O_5 removed for every 1 lb/a change in P1 test.

Thomasboro K changes with net additions of K fertilizer, 1982-1987



K test reduction with K removal, 1988-1992

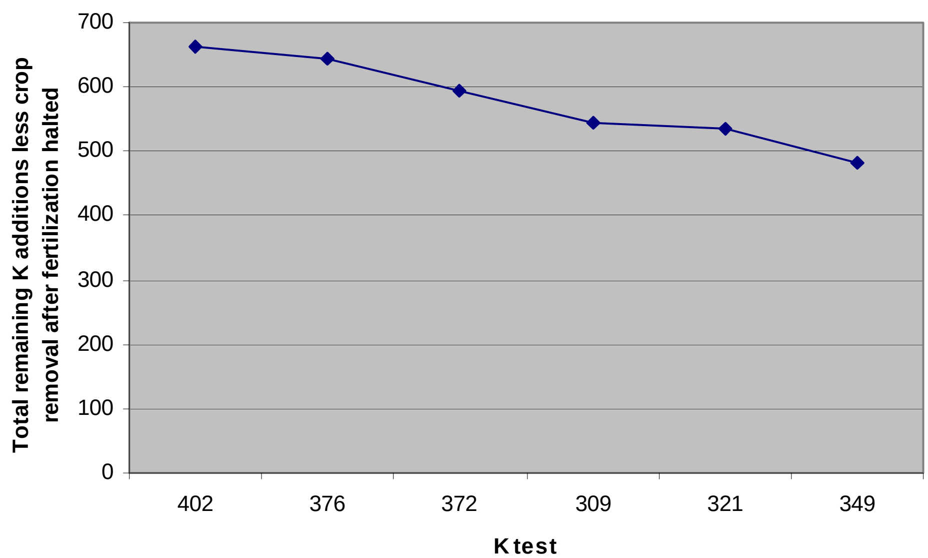


Figure 2-66.
Changes in Thomasboro soil test K during buildup fertilizer application and drawdown due to crop removal without fertilizer application.

Net K added was 592 lb/a K_2O, which increased the K test by 83 lb/a, for a rate of 1 lb K test increase for each 7.1 lb/a K_2O. Subsequent removal of 162 lb/a K_2O through crop removal resulted in a decrease of 53 lb soil test K, or a rate of 1 lb K test change for each 3 lb/a K_2O removed.

Crop Yields – Mansfield

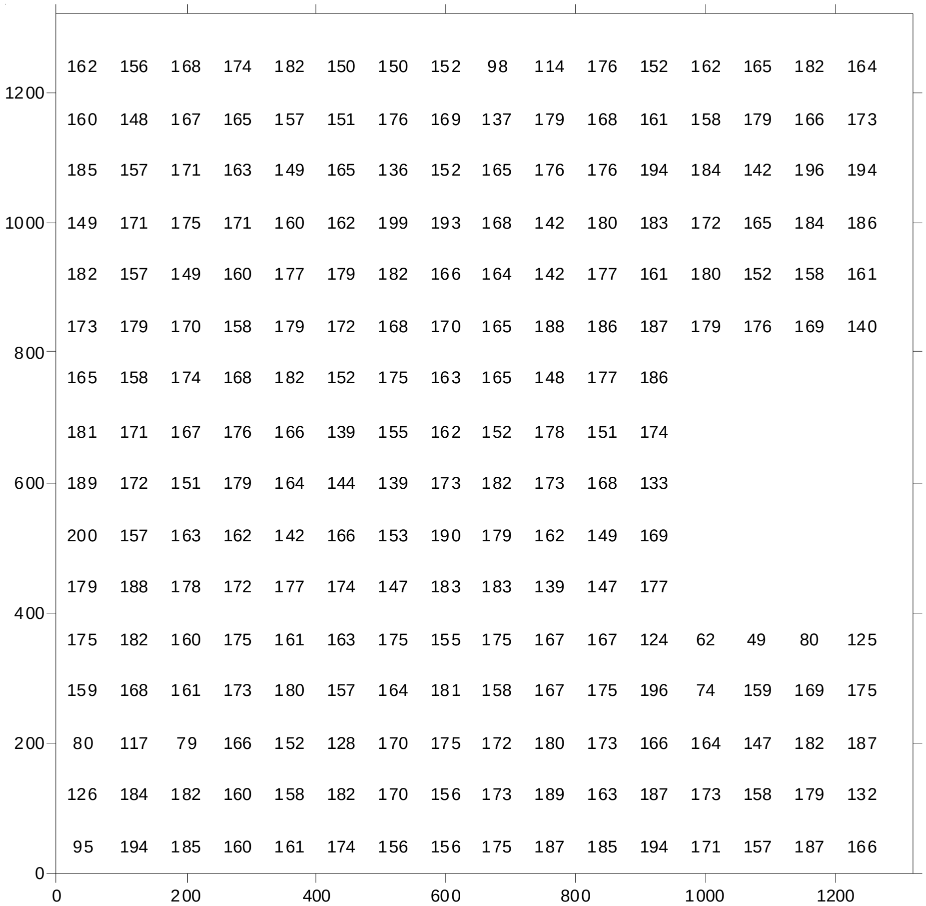


Figure 3-1.
Mansfield, corn yield, bu/a, 1991. Blank area in the east was an area enrolled in the USDA set-aside program chosen because of its soil wetness characteristics.

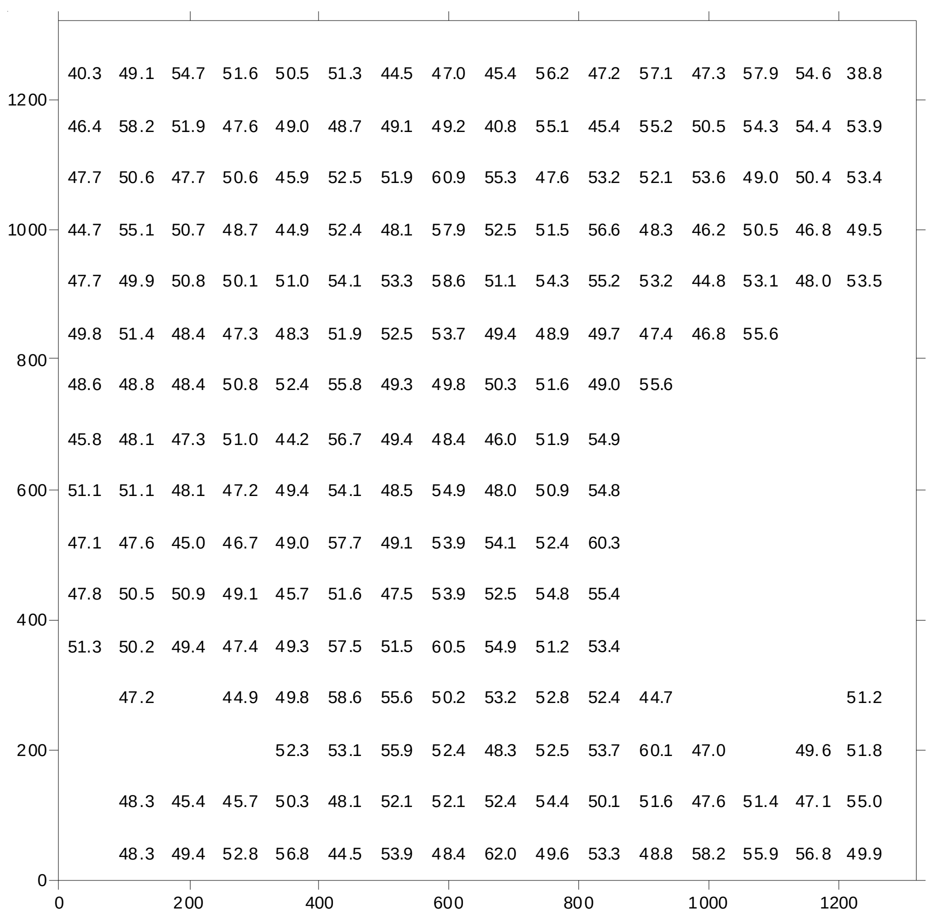


Figure 3-2.
Mansfield soybean yield, 1992. Blank areas contained no crop due to excessive water early in the season.

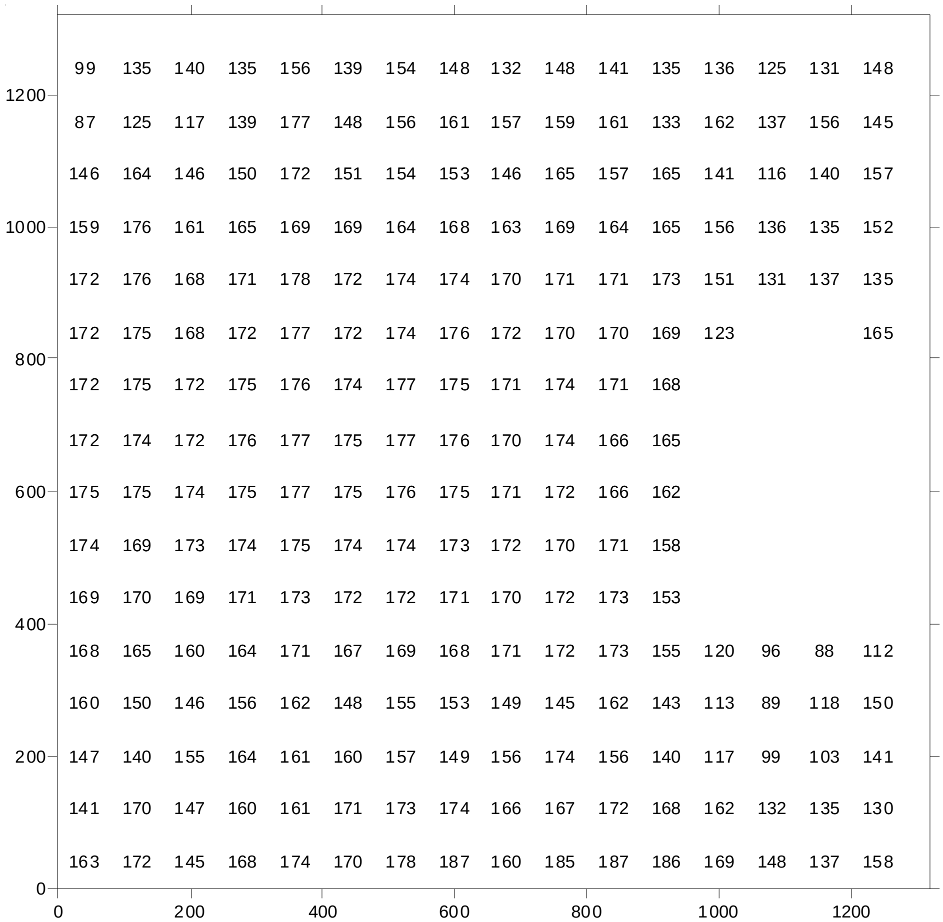


Figure 3-3.
Mansfield, corn yield, bu/a, 1993. As in 1991, the area in the east was enrolled in the USDA corn set-aside program. Its wetness is shown by relatively low yields surrounding the area and two grids directly to the north that yielded 0 bushels due to excessive wetness.

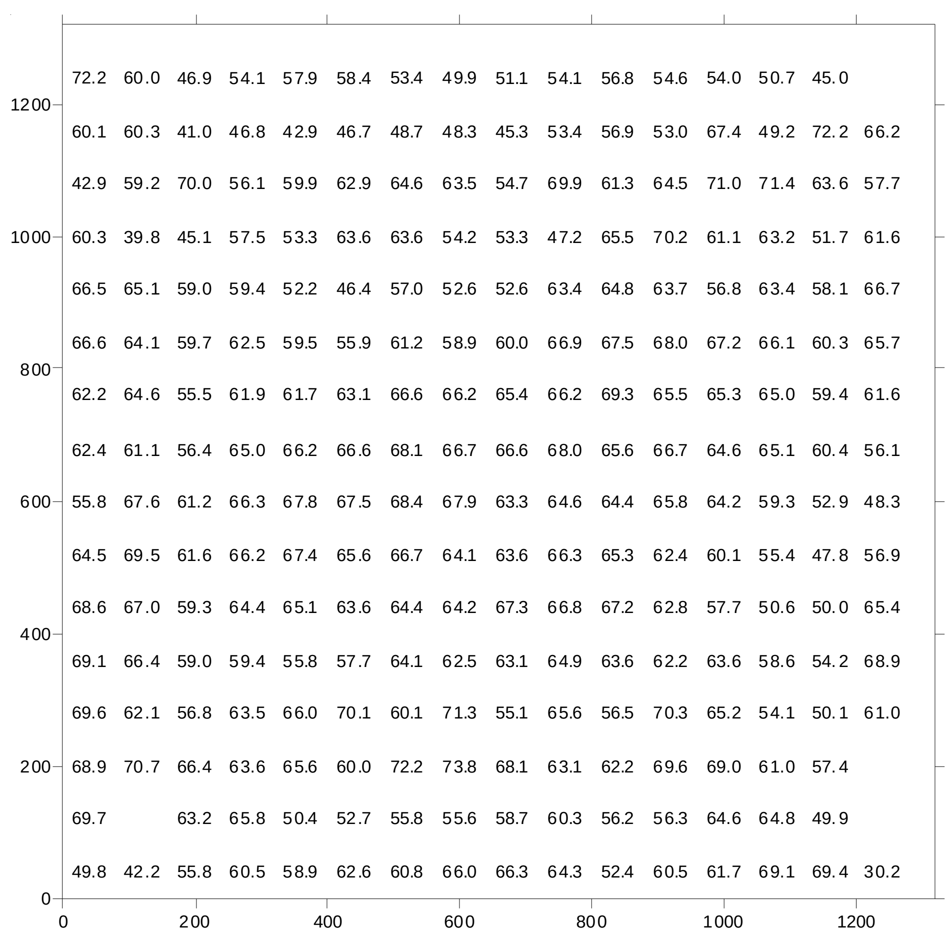


Figure 3-4.
Mansfield, soybean yield, bu/a, 1994.
Blank areas were due to wetness.

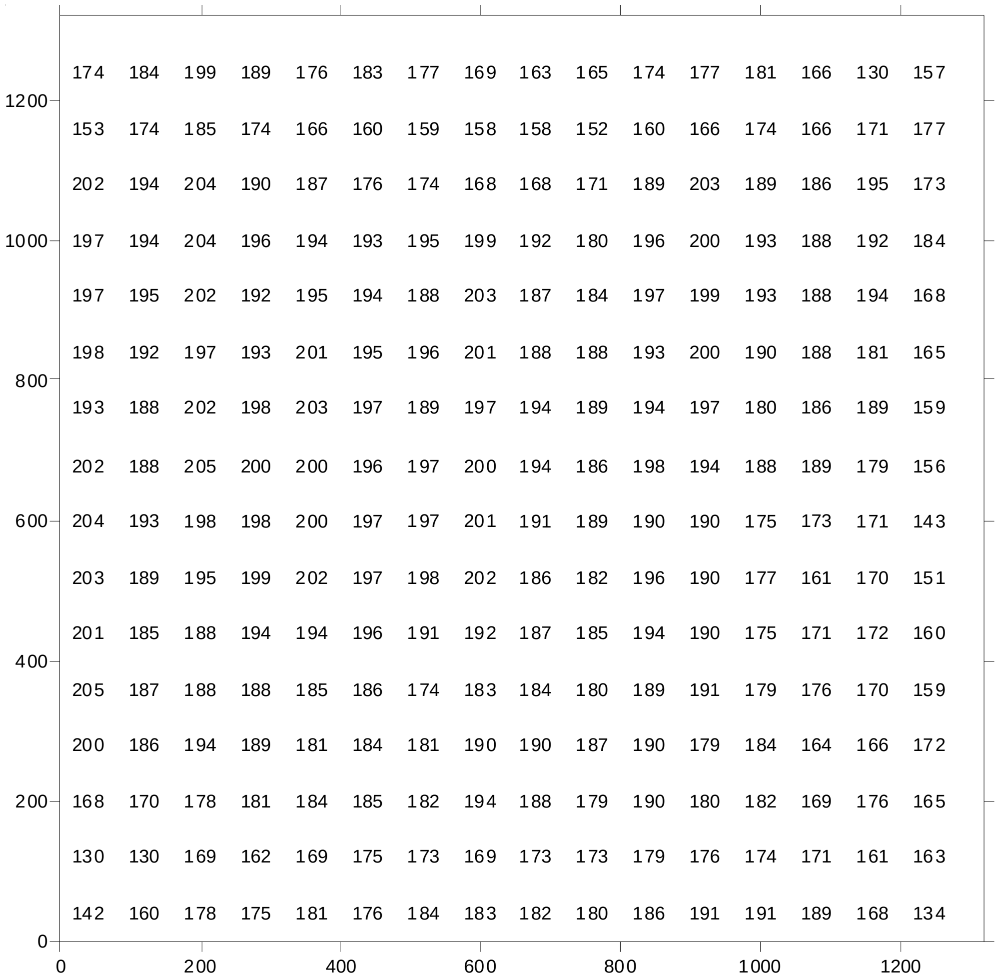


Figure 3-5.
Mansfield corn yield,
bu/a, 1999.

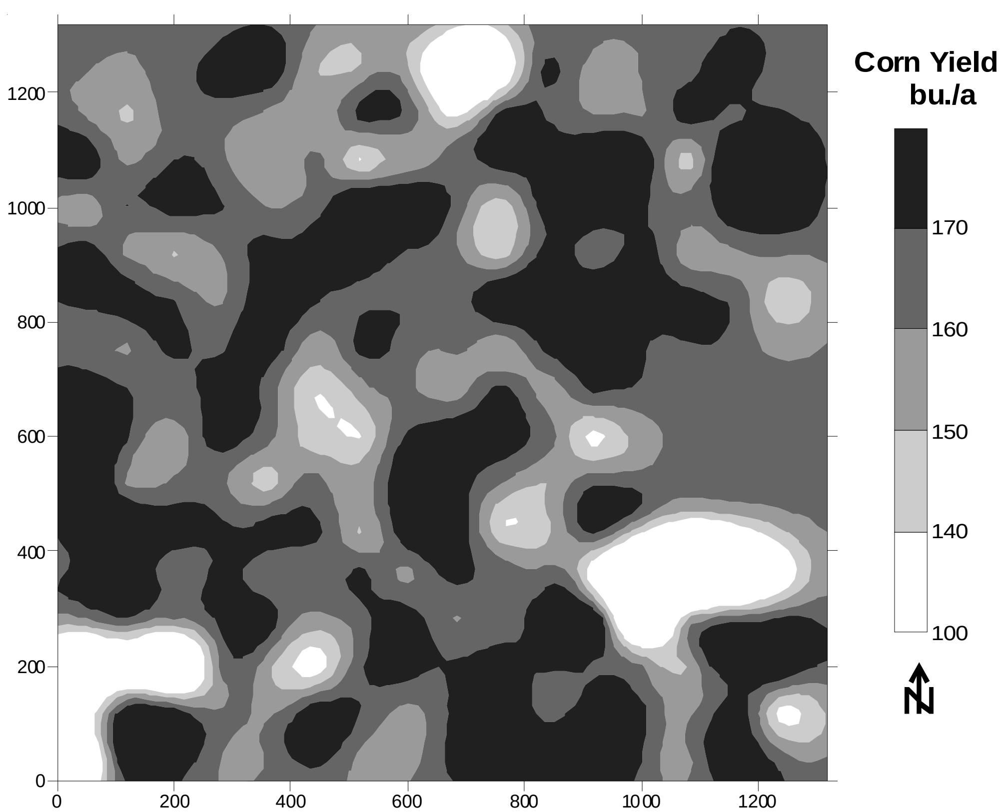


Figure 3-6.
Mansfield corn yield,
bu/a, 1991.

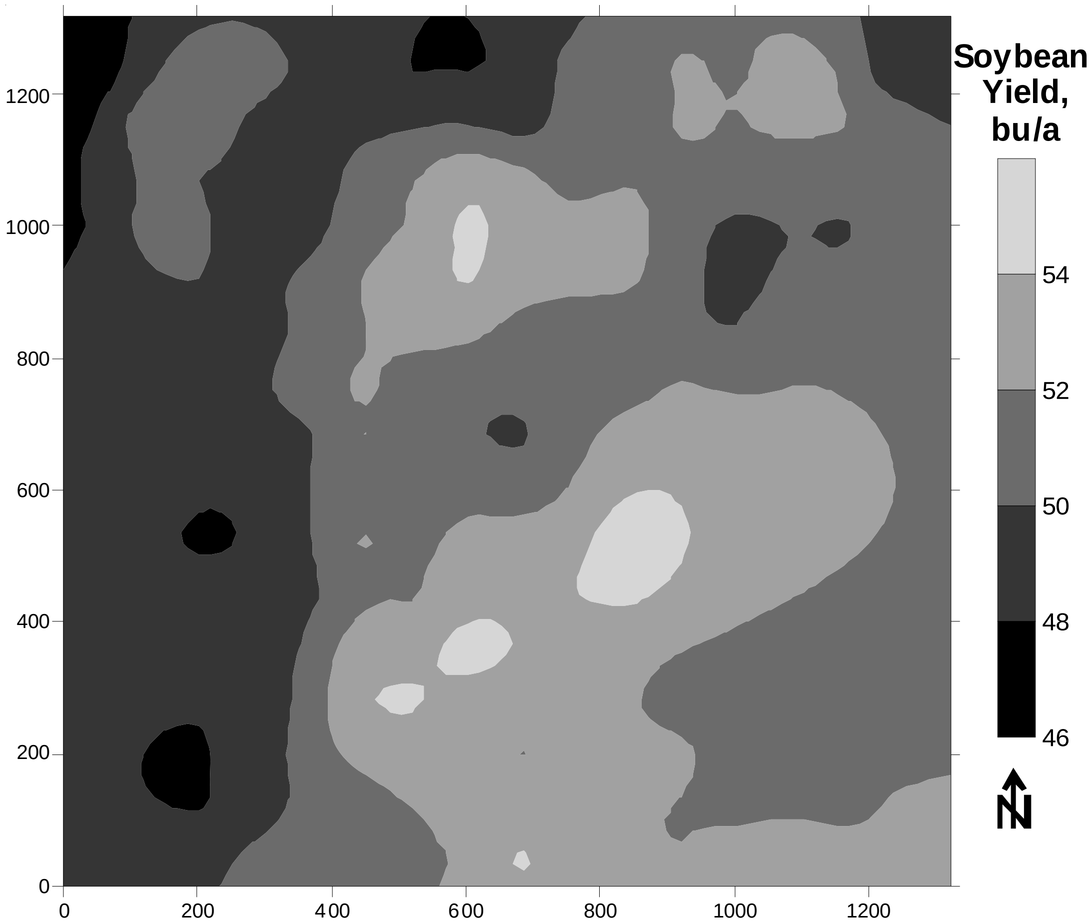


Figure 3-7. Mansfield soybean yield, bu/a, 1992.

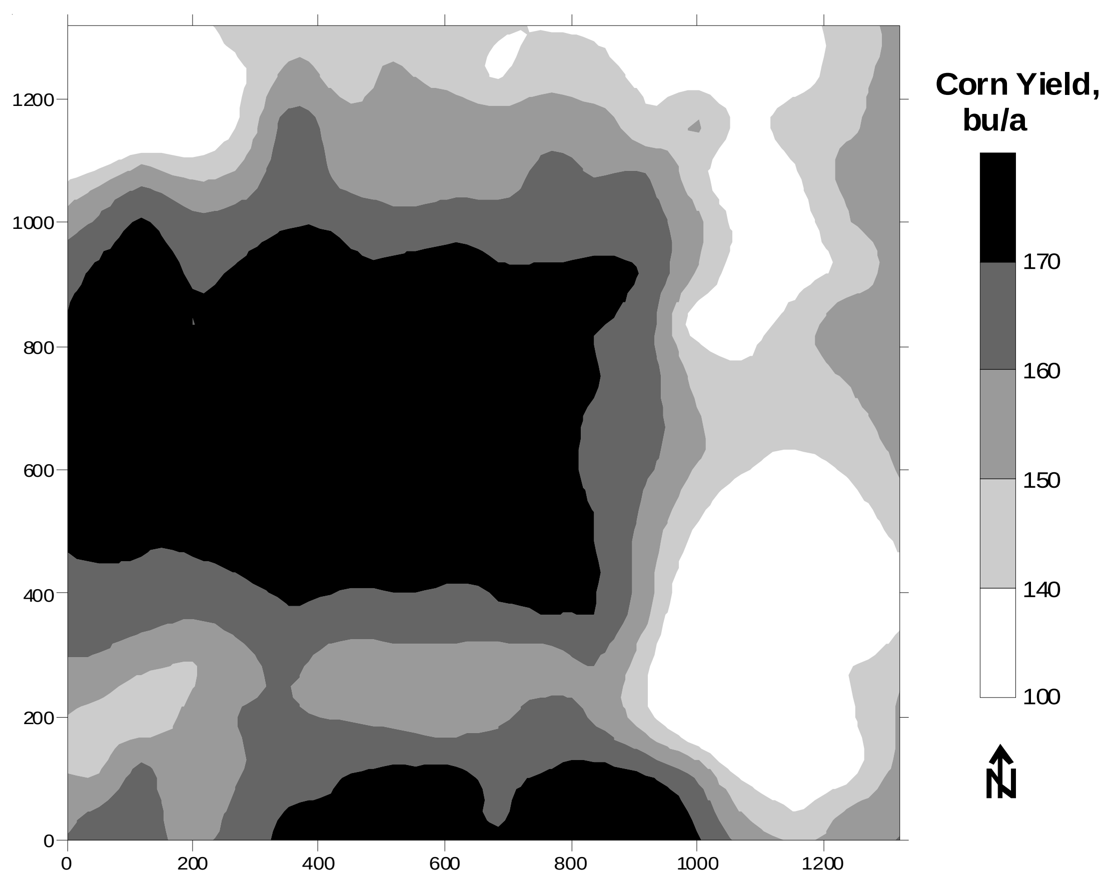


Figure 3-8. Mansfield corn yield, bu/a, 1993.

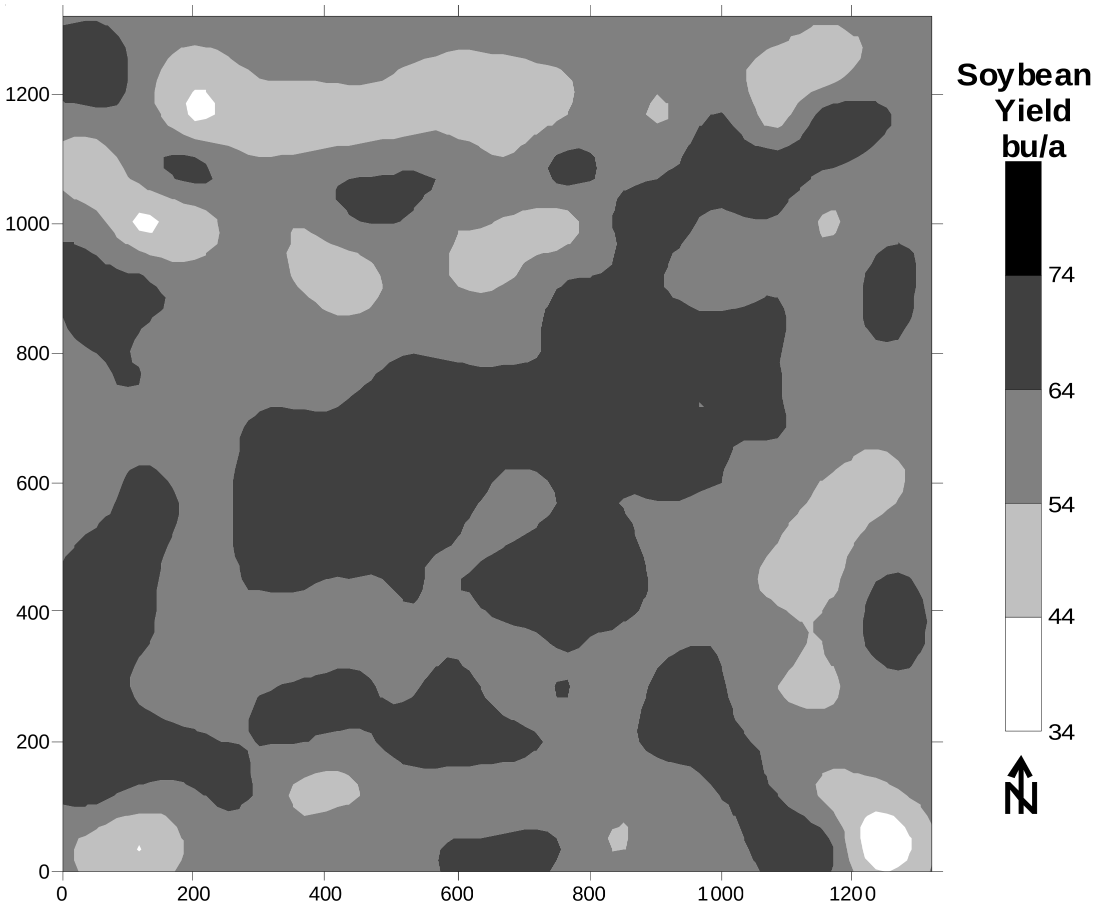


Figure 3-9. Mansfield soybean yield, bu/a, 1994.

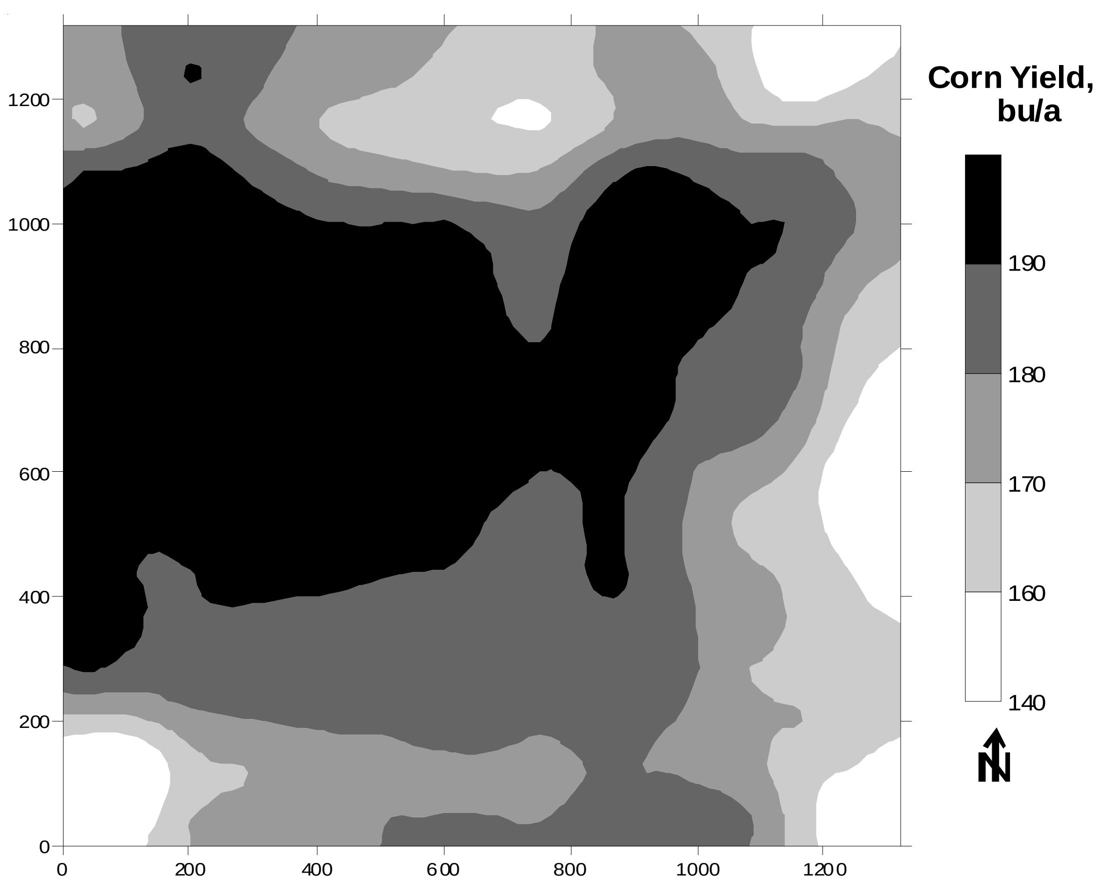


Figure 3-10. Mansfield corn yield, bu/a, 1999.

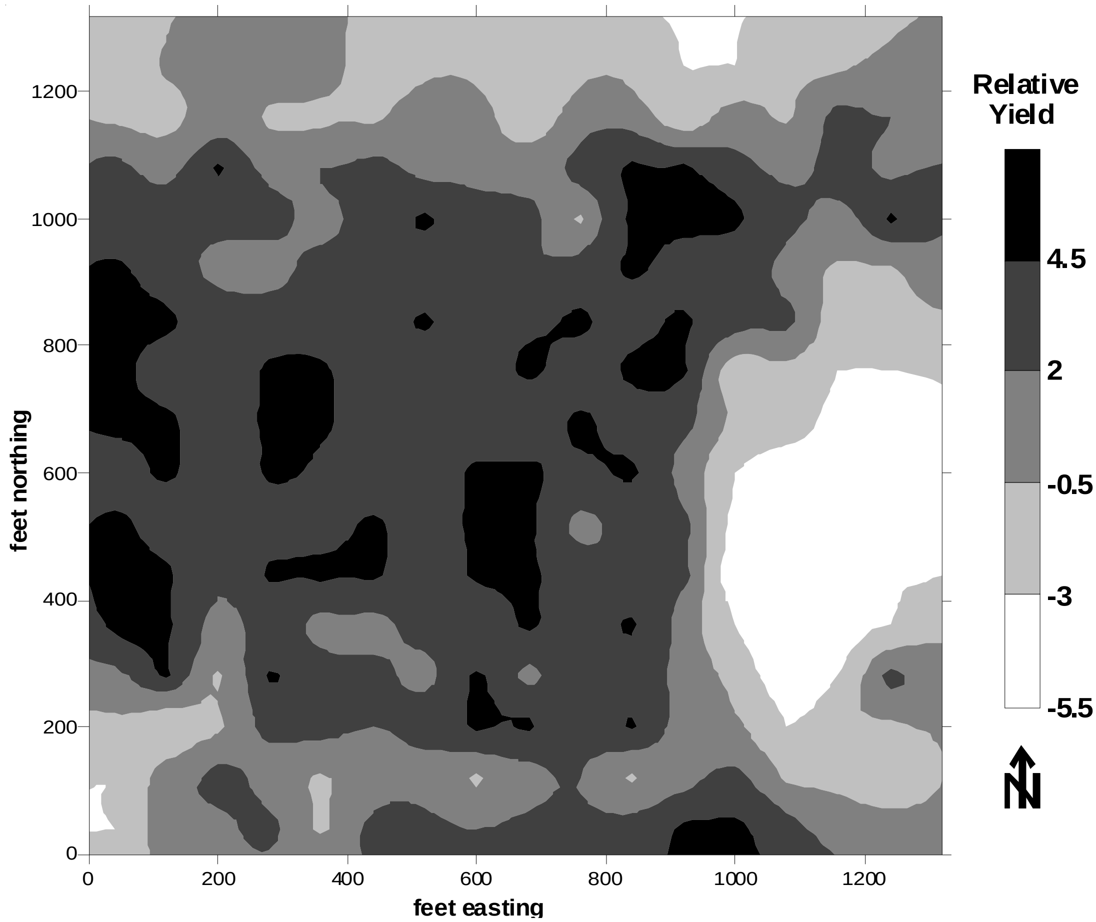


Figure 3-11.
Mansfield yield frequency, 1991, 1992, 1993, 1994 and 1999. Each grid in the previous five yield plot maps was given a value of 0 if average, -1 if below average and +1 if above average. Each grid then was added to the subsequent years. The sum is mapped in this figure. Negative numbers indicate a tendency to be lower than average; numbers near 0 show a tendency to be average in yield. Positive numbers show a tendency to be higher in productivity.

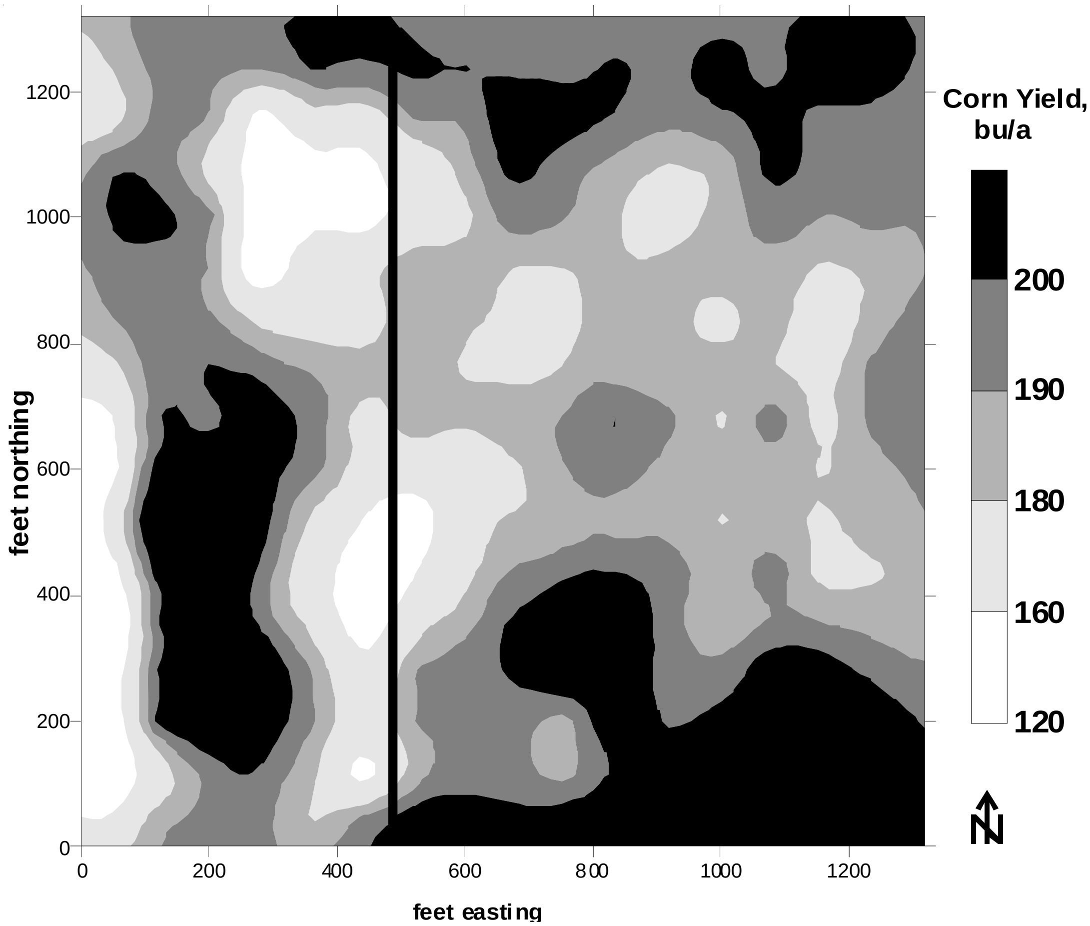


Figure 4-1. Thomasboro corn yield, 1992. The vertical line shows the location of the tree line within the field.

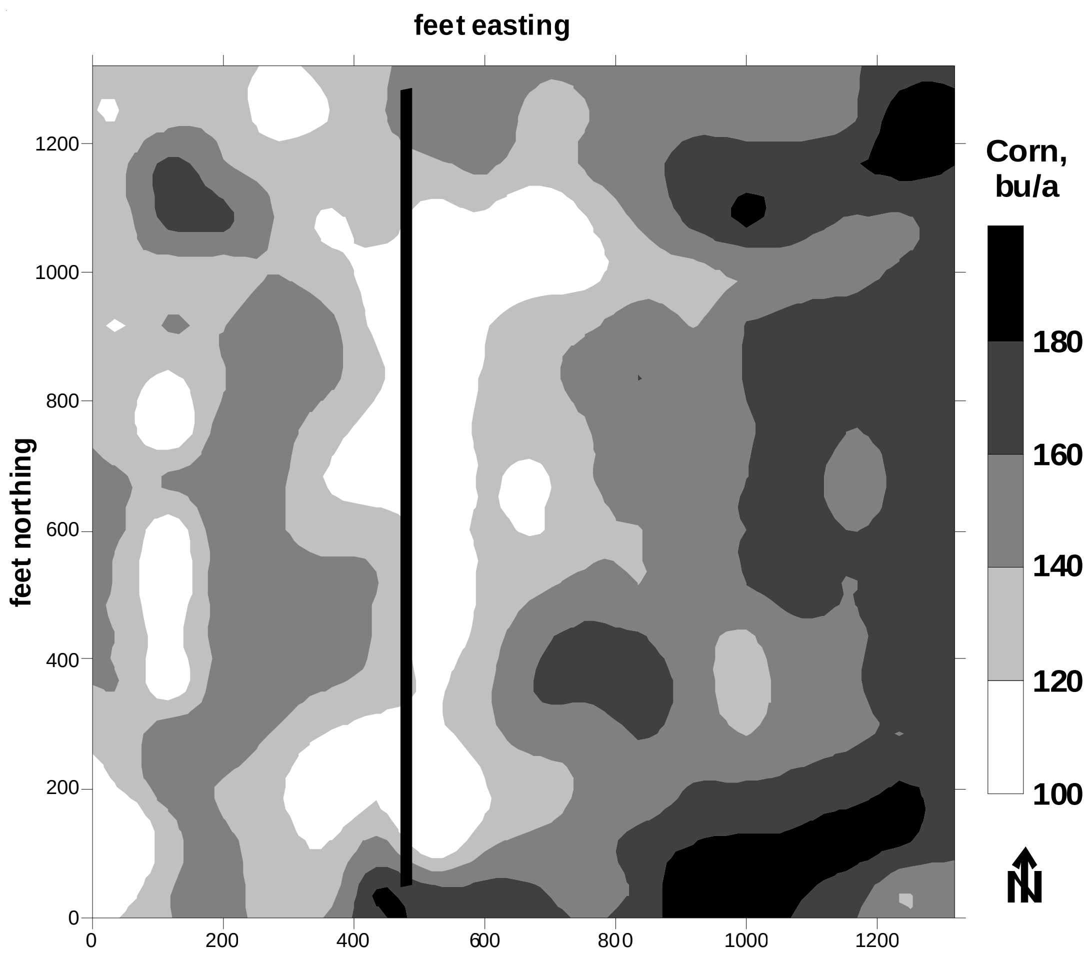


Figure 4-2. Thomasboro corn yield, 1994. Lower corn yield near the tree line probably is due to the direct effect of tree root competition for water and the poorer drainage on both sides of the tree line.

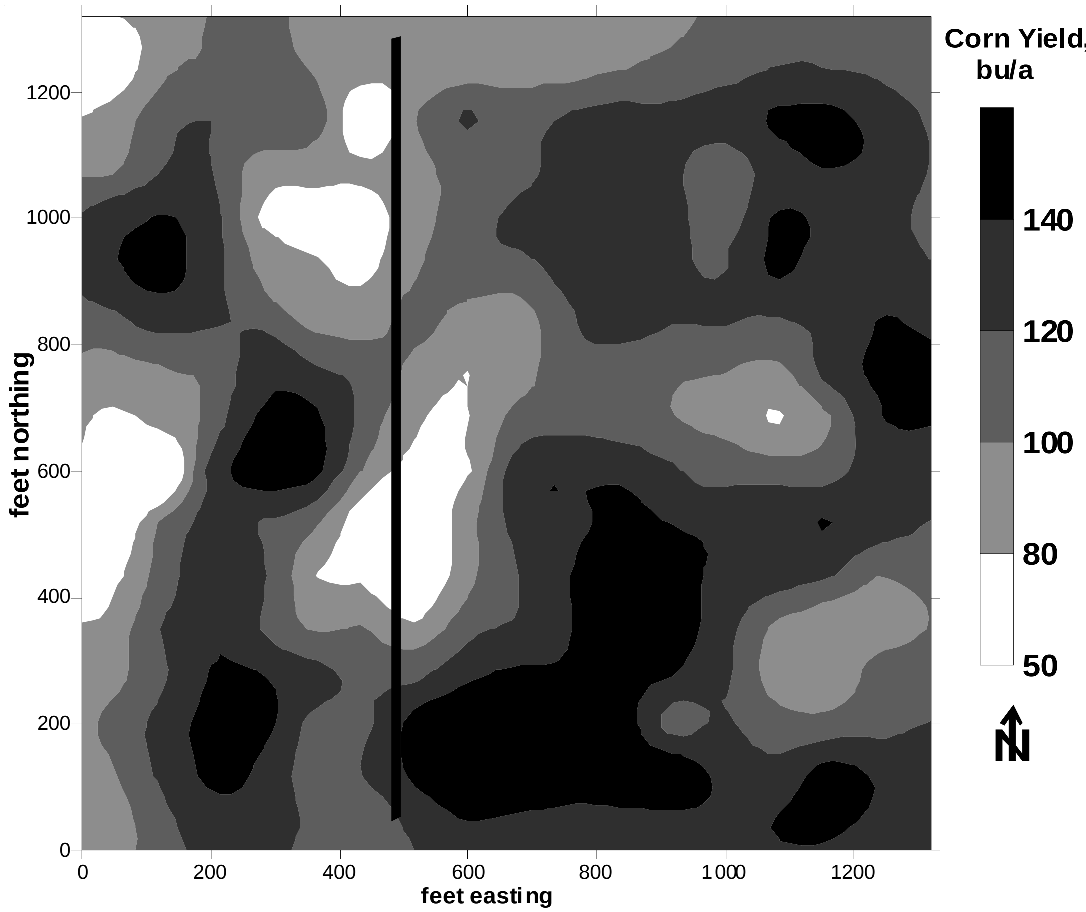


Figure 4-3. Thomasboro corn yield, 1995.

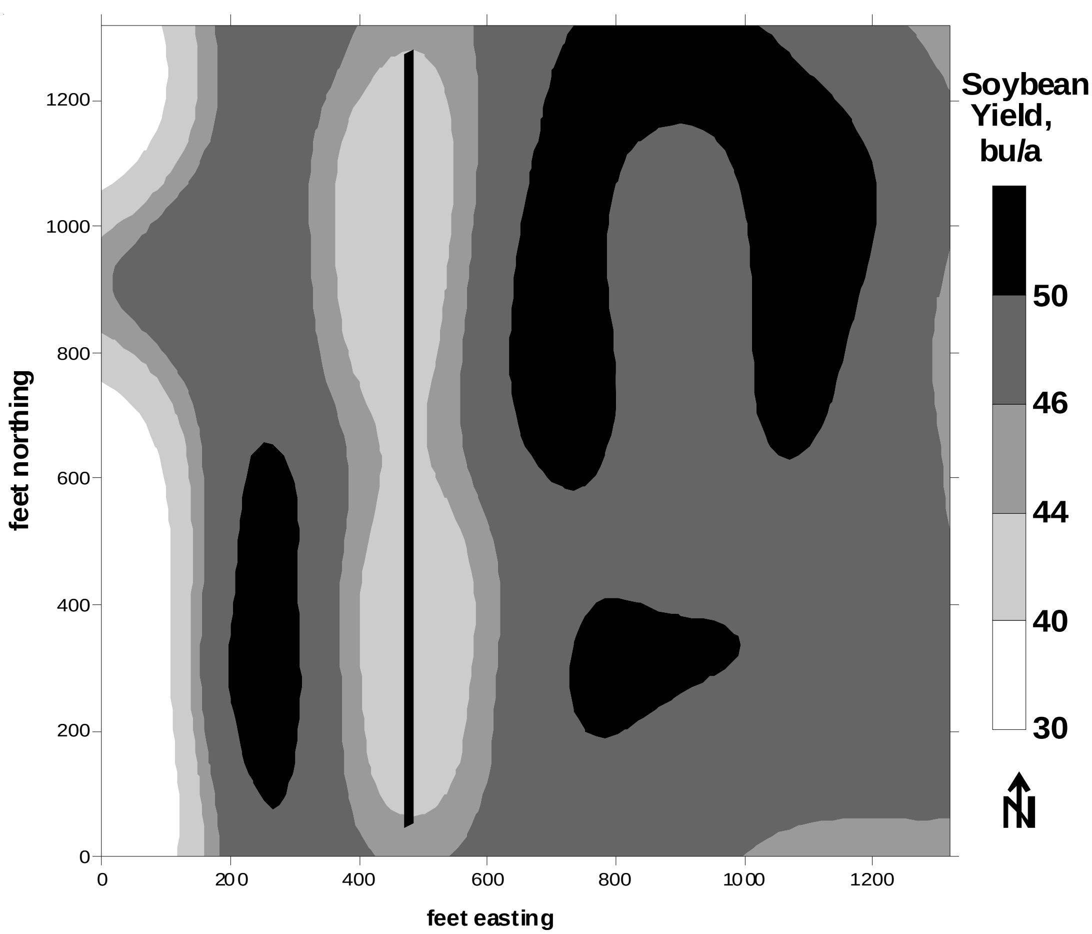


Figure 4-4. Thomasboro soybean yield, 1996.

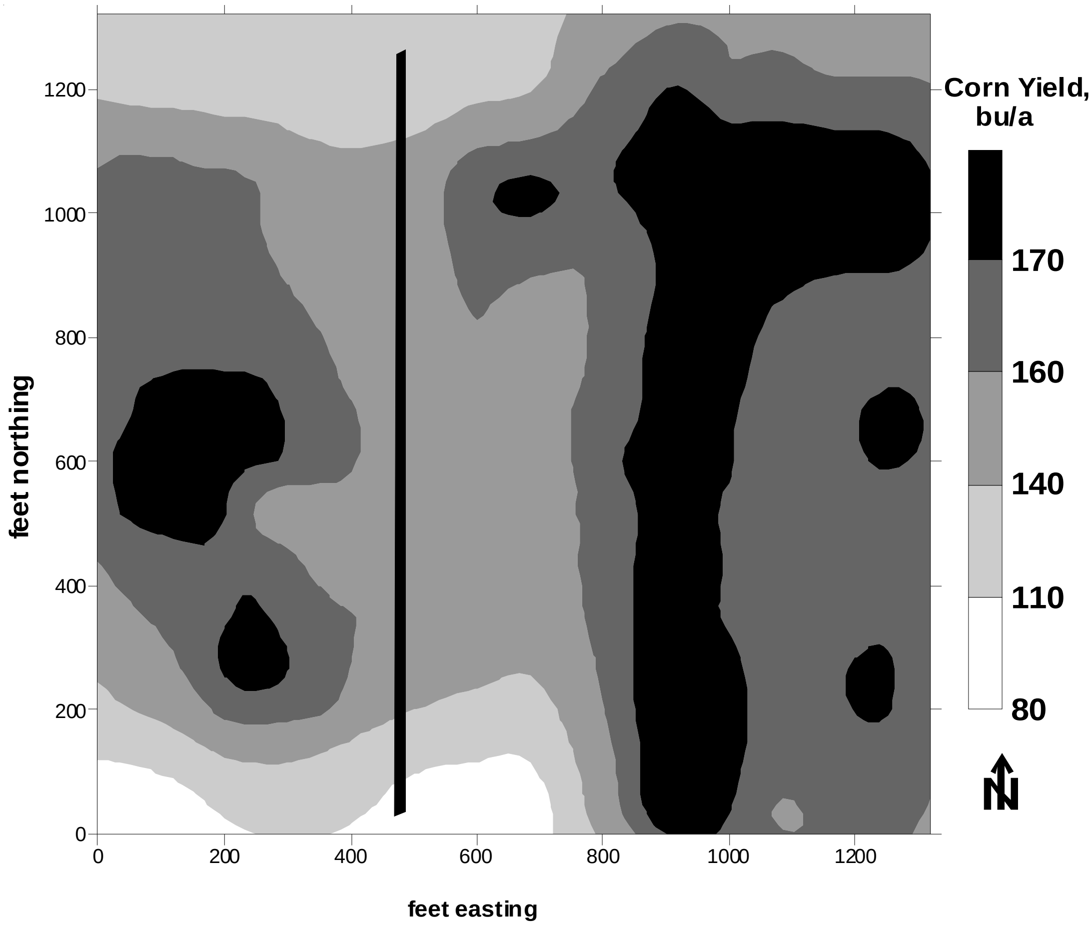


Figure 4-5. Thomasboro corn yield, 1999.

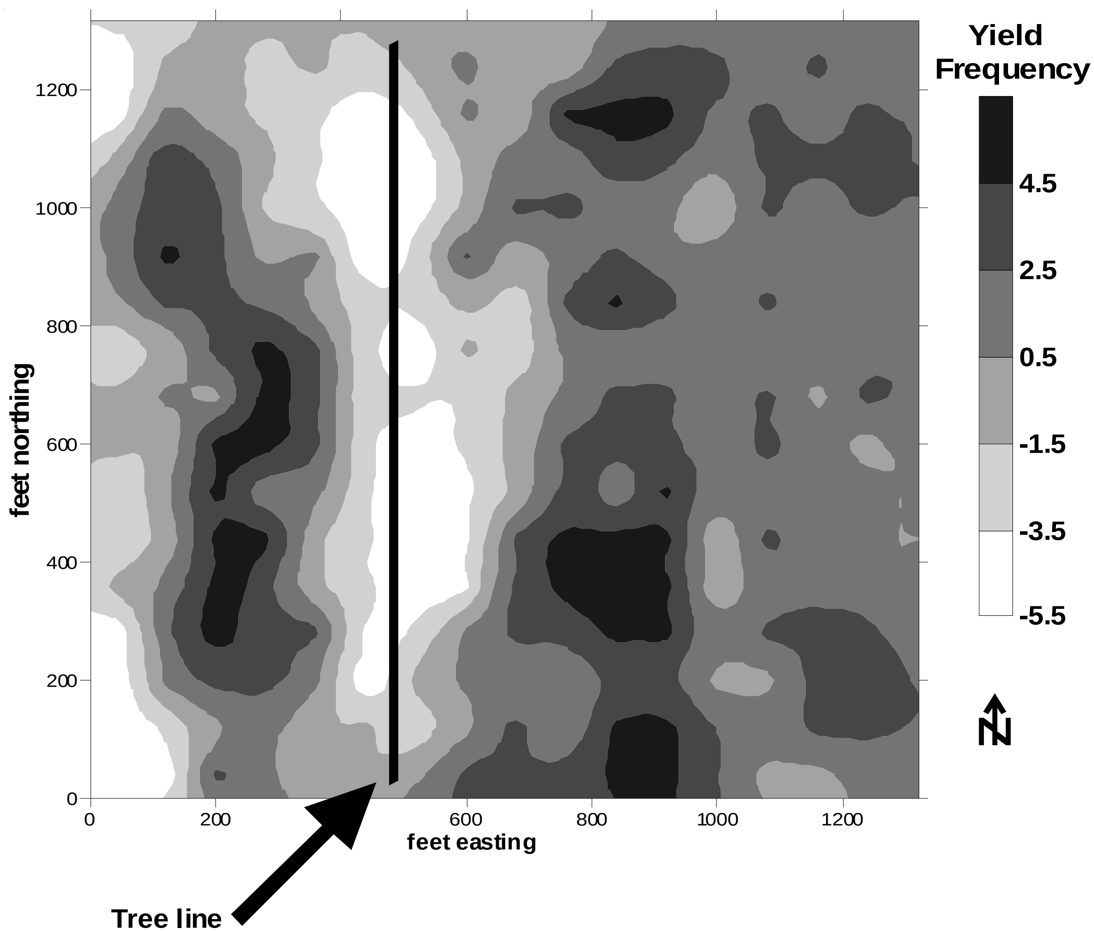


Figure 4-6. Thomasboro yield frequency, from 1992, 1994, 1995, 1996 and 1999 data. Note how the tree line influences yield on both the east and west sides of the trees. Also, trees that line the west boundary of the field appear to have a negative effect on yield.

Peck always was somewhat frustrated because of the lack of a relationship between yields and soil nutrient levels. The regressions in the past were conducted on individual yield years with each year's nutrient level. Table 3 shows the correlation value (r) for the comparisons of Mansfield, 1991 and 1992, and Thomasboro 1992 among soil pH, P, K and yield.

The results of the correlation are not consistent; sometimes a relationship exists between yield and nutrient and sometimes it does not. The problem with trying to correlate nutrient level with yield in one year on a field scale is that the exercise assumes nutrients are the only factors that influence yield. On a small-plot experiment, this, researchers hope, is true. Blocking and even spatial statistics are used to take out any nonuniformity in the less-than-1-acre space of a small-plot nutrient experiment. However, a field is seldom uniform, so differences in soils, landscape patterns and other phenomena result in yield differences in every year.

In an attempt to circumvent the effects of within-field crop productivity variability of the Mansfield and Thomasboro sites, a yield frequency dataset was established. Each individual yield year average was computed, then each yield was given a +1 if higher than average, -1 if lower than average or 0 if the yield was average. The years of each data point were totaled, resulting in a relative yield frequency dataset. By correlating the yield frequency dataset with nutrient levels and changes in the nutrient levels, a much better relationship is seen (Table 4).

Soil P in 1987 and 1992 and the changes between years were significantly correlated with Thomasboro yield frequency. Soil K was correlated in 1992 and K changes were correlated between years with yield frequency. Soil pH in 1987 and 1992 was correlated with yield frequency at Thomasboro, but pH changes between those years were not.

At Mansfield, all comparisons were correlated, except for 1988 K, following years of buildup K fertilizer.

What this suggests is that soil pH, P and K influence yields, but detecting those in a field may be better conducted using a measurement of relative yield through time instead of single yields. Changes in P and K also are related to relative yield through time, which is logical given the crop removal of these nutrients from the field.

Table 3. Correlation (r) among soil pH, P and K with yield, Thomasboro, 1992; Mansfield, 1991 and 1992.

Comparison	Thomasboro 1992	Mansfield 1991	Mansfield 1992
Soil pH and yield	0.30*	0.20*	NS
P and yield	0.42*	NS	NS
K and yield	NS	NS	NS

* denotes significance at least at the P > 0.01 level.

Table 4. Correlation (r) among soil pH, P and K with yield frequency data, Thomasboro 1987, 1992 and changes 1987-1992, and Mansfield 1988, 1992 and changes 1988-1992.

Nutrient	Thomasboro 1987		Thomasboro 1992		Thomasboro changes 1987-1992		Mansfield 1988		Mansfield 1992		Mansfield changes 1988-1992	
	r	P>	r	P>	r	P>	r	P>	r	P>	r	P>
Soil pH	0.21	0.001	0.21	0.001	0.06	0.33	0.56	1×10^{-3}	0.53	1.1×10^{-22}	0.24	1×10^{-4}
P	0.25	7.6×10^{-5}	0.10	0.11	0.19	2×10^{-3}	0.25	4.8×10^{-5}	0.006	0.93 NS	0.42	2.4×10^{-12}
K	0.02	0.78 NS	0.12	0.05	0.14	0.03	0.04	0.48 NS	0.16	0.01	0.27	1.5×10^{-5}

Zone delineation tools

The recurrence of soil pH, P and K patterns from early sampling to late P and K drawdown and the persistence of soil pH patterns within a few years of liming at Mansfield and each year at Thomasboro suggest that these patterns are not due to random chance, nor are they the product of arbitrary signatures of individual applications of lime, P or K. If so, the patterns would not revert with drawdown and time.

Zone delineation tools are instruments that may be used to generate data that are used to create patterns that are similar to patterns of soil nutrients seen in soil sampling. These tools have been shown to reduce the number of soil samples required to reveal nutrient levels in a field. The zone delineation is used to direct soil sampling. After sampling, the boundaries of the zone delineation data are used to form the polygons that contain the nutrient analysis obtained by zone sampling.

Zone delineation tools include the Order 1 scale soil survey, yield maps or yield frequency maps, soil EC, aerial photography, satellite imagery and topography. Combinations of tools, or data layering, have been shown to produce more consistent, reliable zones than any single tool.

The following are the delineation tools used in modern analysis of the Thomasboro and Mansfield data:

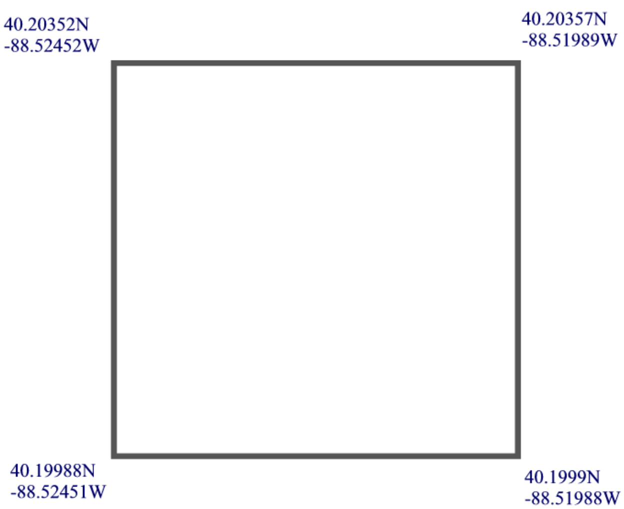


Figure 5-1.
Global Positioning System (GPS) coordinates for field corners at Mansfield.

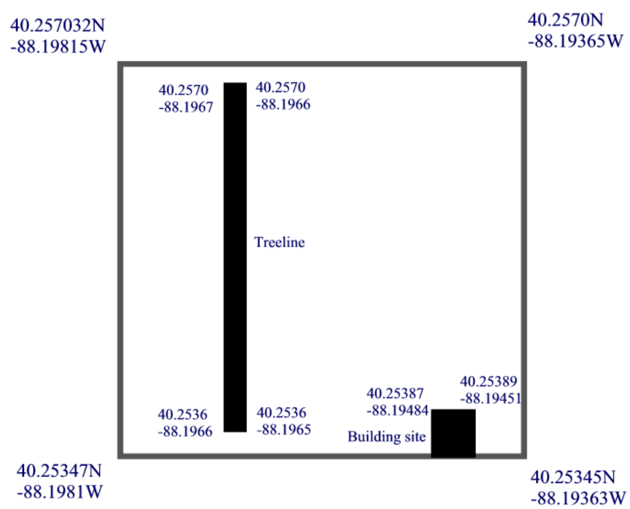


Figure 5-2.
GPS coordinates for field corners and internal spatial objects at Thomasboro.

GPS coordinates for Mansfield and Thomasboro, respectively, are provided in Figures 5-1 and 5-2. These coordinates may help future researchers in registering imagery or other data in these two fields.

Soil type maps on an Order 1 scale were developed by Peck, who had soil survey experience in Wisconsin prior to his employment at the University of Illinois.

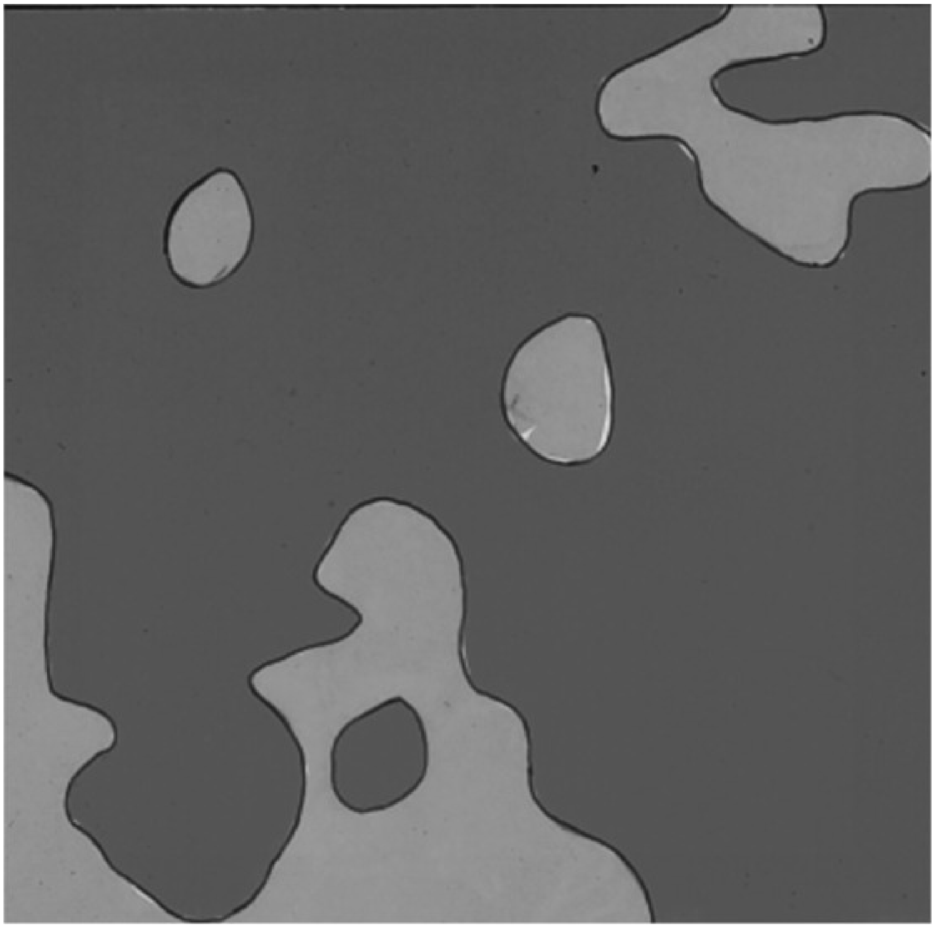


Figure 5-3.
Soil types – Thomasboro.
Darker = Drummer sicl,
lighter = Harpster sicl.

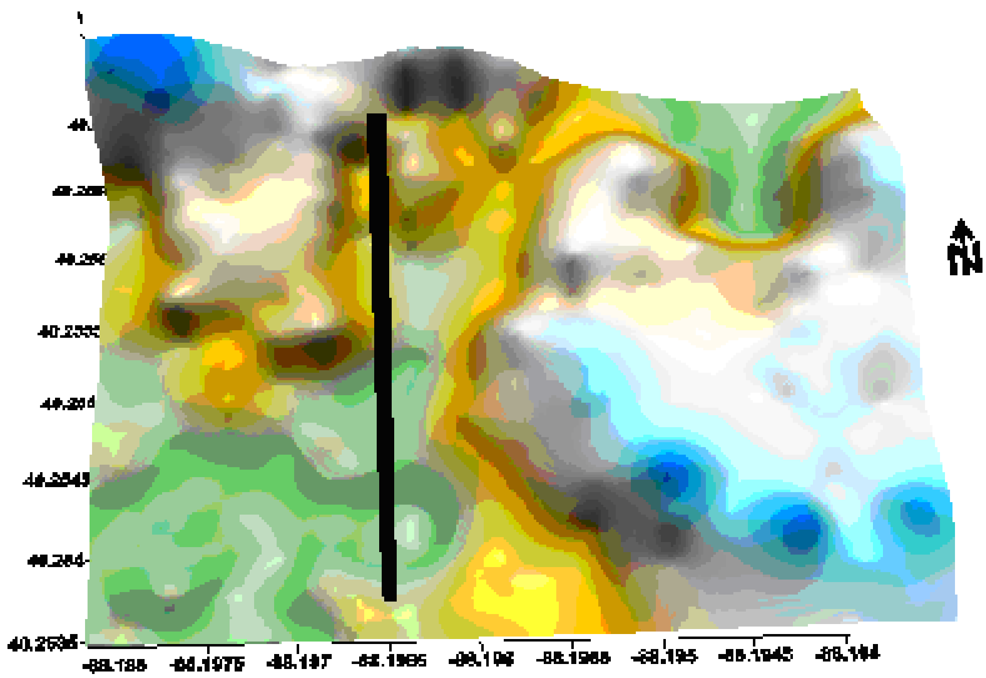


Figure 5-4.
Elevation surface, Thomasboro. The dark line is the tree line. East of the tree line, the higher elevations are the Drummer. The depressions are Harpster. West of the tree line, the depressions are Harpster. The soil survey incorrectly identifies a Harpster soil in the northwest. This area is identified as a higher elevation in that area. That area likely was filled in or leveled before 1982. Soil in that area does not lie in a depression, but nonetheless stays wetter longer than anywhere else in the field and is siltier in texture than any other soil in the field.

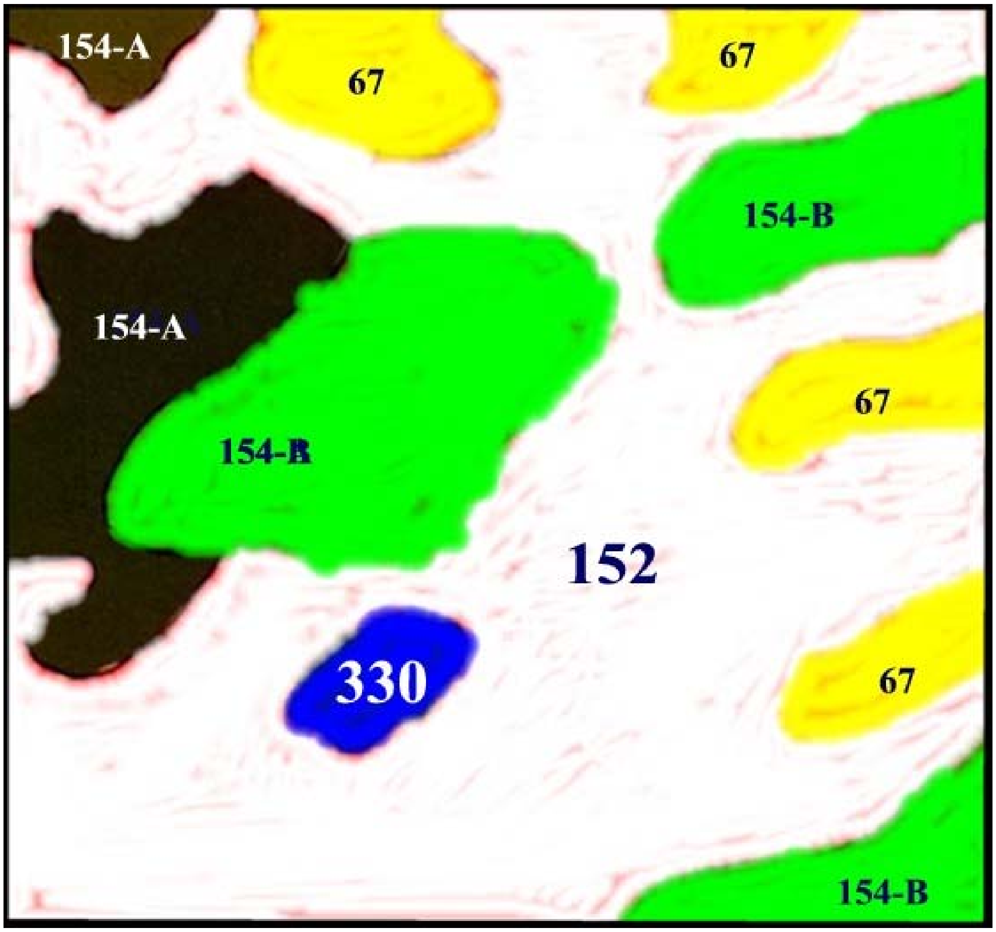


Figure 5-5.
Soil types – Mansfield.
67 – Harpster sicl;
152 – Drummer sicl;
154-A – Flanagan sil, A slopes;
154-B – Flanagan sil, B slopes.
330 – Peotone sicl.

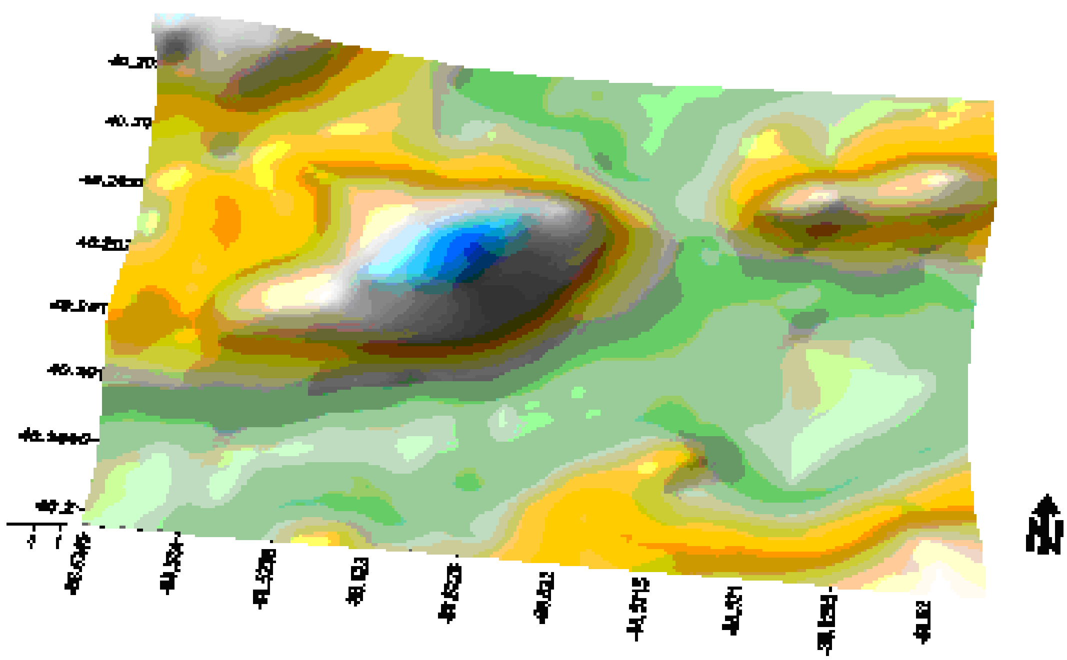


Figure 5-6.
Elevation surface, Mansfield. Flanagan soil types are associated with higher landscapes. Harpster soils occupy the depressions on the north and east side. The Peotone soil is located in the depression directly south of the highest elevation. The Drummer soil occupies the remaining landscape. The higher landscapes also are associated with the highest yields, the lowest pH, and the greatest pH, P and K changes.

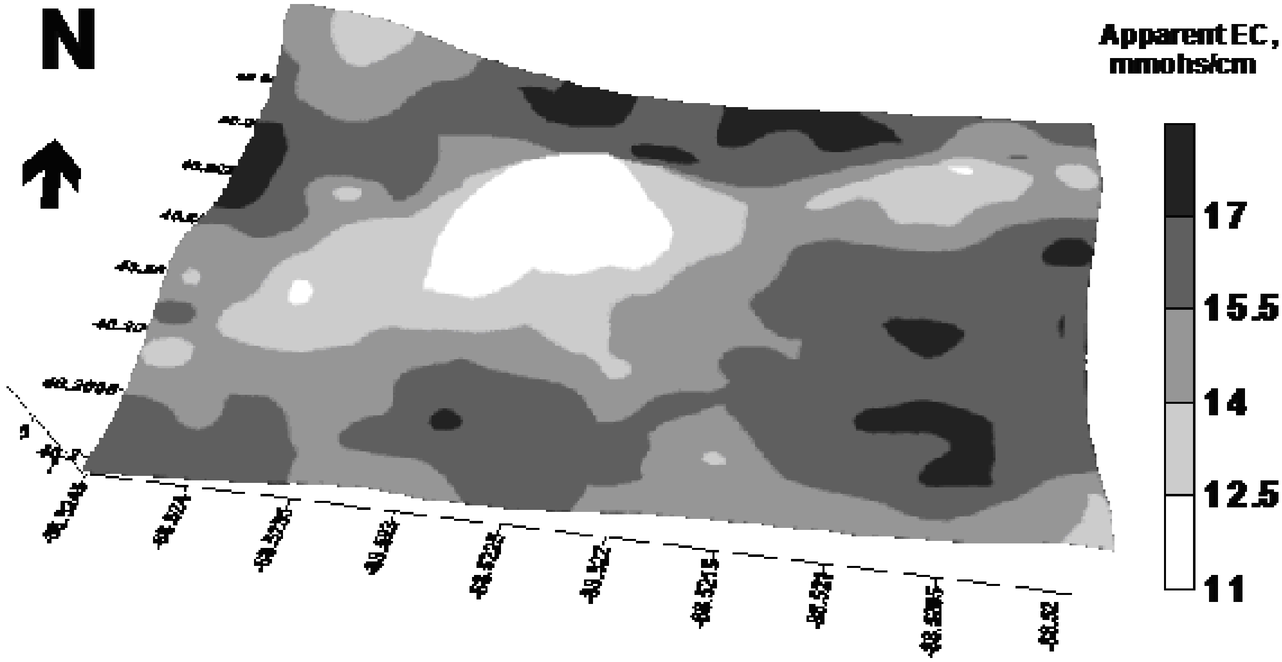


Figure 5-7.
Mansfield EM (electromagnetic)-38 readings (EC) over elevation. Lower EC corresponds with higher elevations. Higher EC readings are found in depressions, which are higher in both clay and organic matter, and also moisture.

Figure 5-8.
EM-38 readings (EC) over elevation, Thomasboro. Higher EC is associated mostly with lower elevations. Some darker areas in the northwest are artifacts of shading to better reveal landscape differences.

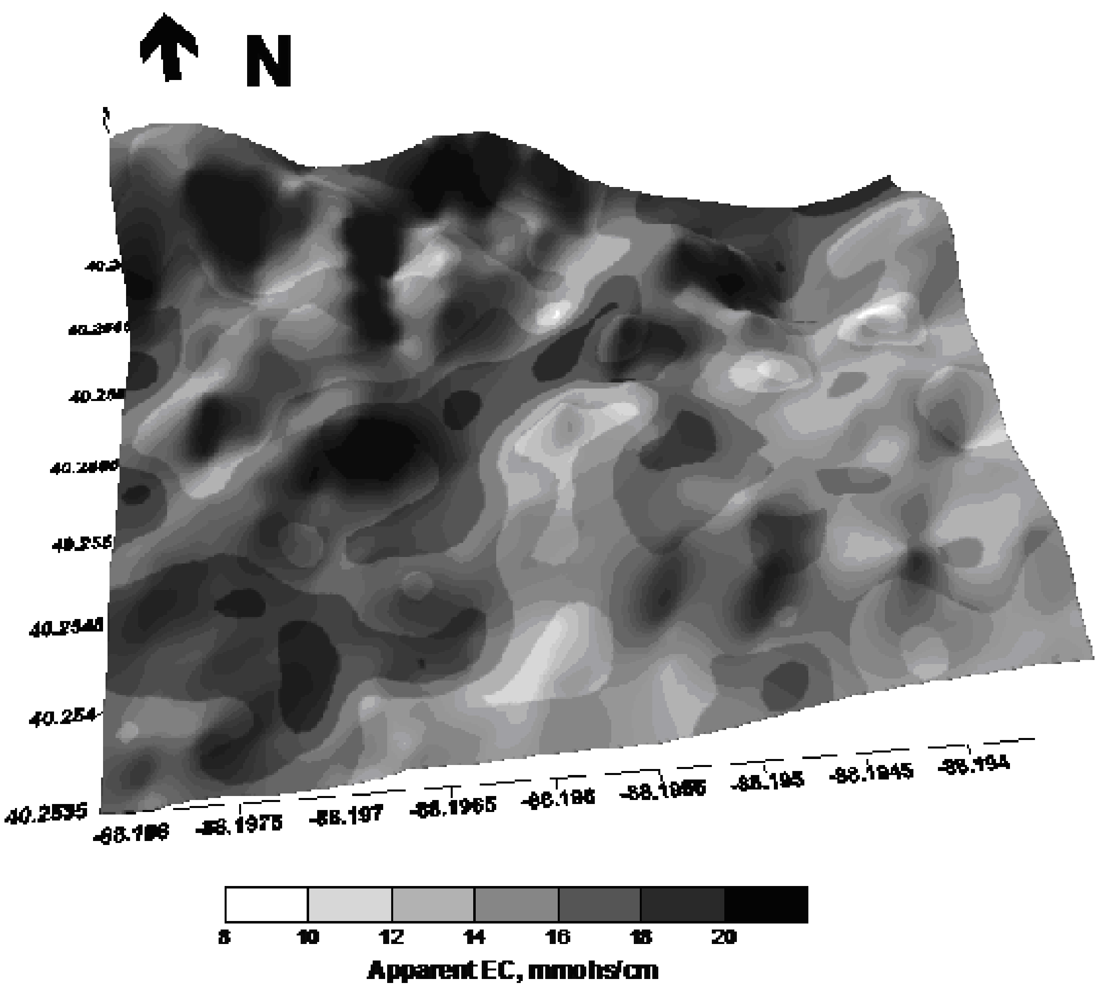


Figure 5-9.
Layered and clustered zones derived from elevations and EM readings, Mansfield. This image was derived using a combination of ArcMap to register the elevation and EM maps, then was imported into ERDAS Imagine as a .img file. The files were layered and the layers were subjected to unsupervised classification using the isodata clustering method embedded within Imagine. This map shows the higher landscape positions being segregated from the rest of the field.

Figure 5-10.
Layered and clustered map of Thomasboro with EM readings combined with elevations. This map was developed using the same procedure as explained in Figure 5-9.

Tables 6 through 9 contain correlations among zones of EM and elevation and their combination at both Thomasboro and Mansfield. In comparison, Table 5 contains correlations among grid sizes evaluated in Franzen and Peck (1995). Most significant comparisons of zones with nutrient values compare favorably with dense grid sampling.

Table 5. Comparison of a 330-foot grid (1 sample per 2.5 acres) and a 220-foot grid (1 sample per acre) with original sampling values, Thomasboro and Mansfield, 1992.

		Sampling grid	
		330 ft	220 ft
Location	Soil test	r	
Mansfield	pH	0.54	0.70
	P	0.16	0.42
	K	0.17	0.41
Thomasboro	pH	0.46	0.51
	P	0.47	0.53
	K	0.41	0.59

Table 6. Comparisons of electromagnetic and elevation zones with soil pH, P and K, Mansfield, 1961.

Comparison	r	P
EM vs pH	0.51	4.6×10^{-18}
EM vs P	0.17	0.006
EM vs K	0.46	1.6×10^{-14}
El vs pH	0.41	9.1×10^{-12}
El vs P	0.10	0.13 NS
El vs K	0.37	1.7×10^{-9}
EM + El vs pH	0.25	4.8×10^{-5}
EM + El vs P	0.07	0.26 NS
EM + El vs K	0.17	0.007

Table 7. Comparisons of electromagnetic and elevation zones with soil pH, P and K, Mansfield 1991.

Comparison	r	P
EM vs pH	0.64	1.7×10^{-30}
EM vs P	0.01	0.92 NS
EM vs K	0.25	6.5×10^{-5}
El vs pH	0.53	6.4×10^{-20}
El vs P	0.02	0.78 NS
El vs K	0.32	1.5×10^{-7}
EM + El vs pH	0.28	4.8×10^{-6}
EM + El vs P	0.08	0.23 NS
EM + El vs K	0.14	0.02

Table 8. Comparisons of electromagnetic and elevation zones with soil pH, P and K, Thomasboro, 1982.

Comparison	r	P
EM vs pH	0.18	0.003
EM vs P	0.07	0.24 NS
EM vs K	0.02	0.76 NS
El vs pH	0.41	8.4×10^{-12}
El vs P	0.04	0.52 NS
El vs K	0.12	0.05
EM + El vs pH	0.15	0.01
EM + El vs P	0.12	0.06 NS
EM + El vs K	0.20	0.001

Table 9. Comparisons of electromagnetic and elevation zones with soil pH, P and K, Thomasboro, 1991.

Comparison	r	P
EM vs pH	0.08	0.22 NS
EM vs P	0.42	2.2×10^{-12}
EM vs K	0.13	0.04
El vs pH	0.33	6.1×10^{-8}
El vs P	0.31	7.4×10^{-7}
El vs K	0.13	0.03
EM + El vs pH	0.15	0.02
EM + El vs P	0.22	0.0005
EM + El vs K	0.07	0.25 NS

Satellite imagery was available for each of these fields. The imagery patterns of early to mid-July crop growth were similar to patterns in each field of soil EC and topography patterns. These images can be imported into a program, such as Erdas Imagine, and layered with yield frequency, soil EC and topography data.

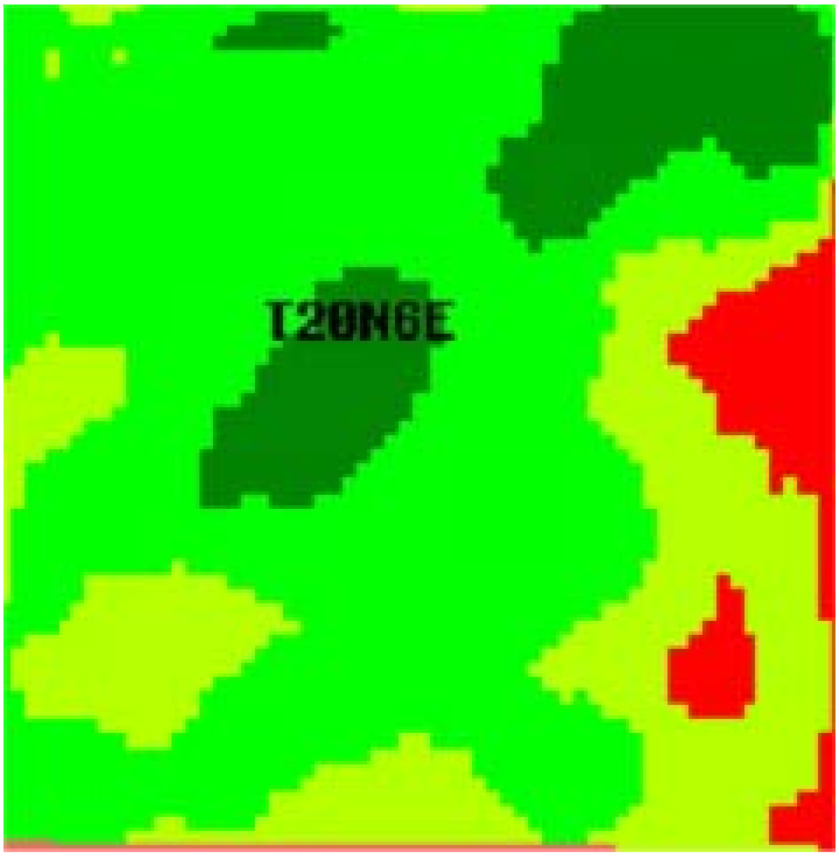


Figure 5-11.
Mansfield Landsat image,
July 4, 1999.
The growing crop image shows
similar patterns as landscape,
EC and native pH, P and K patterns.

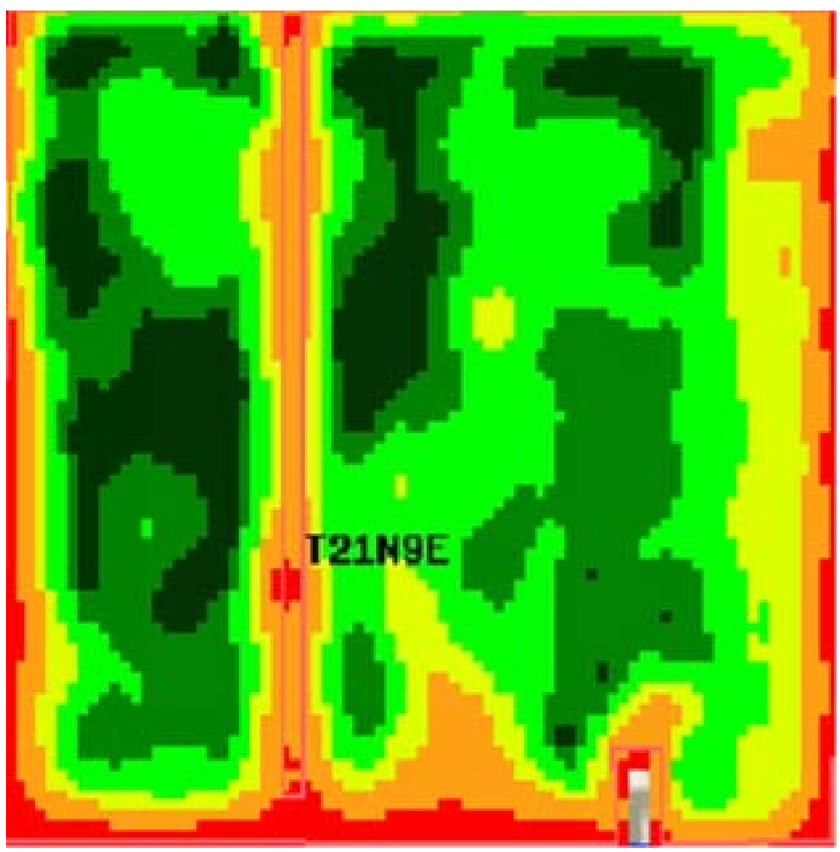


Figure 5-12.
Thomasboro Landsat image,
July 16, 2006, 15-m resolution.
Dark green areas are high
productivity; red areas indicate
roadside or tree lines/building site.
Lighter green to yellow
indicates lower productivity.
Areas of high and low productivity
are similar in pattern to topography
and soil EC measurements.

Small-scale variability plots

Three plot areas, two in the northwest and one in the northeast, were singled out by Peck for closer investigation. Most of the grid values varied only a small amount between consecutive years. However, at least one nutrient, sometimes soil pH, sometimes P, varied greatly between years. Each plot was sampled in an 8-foot grid in an 18-by-18 sample configuration. The results showed that sometimes the boundaries between high and low levels of nutrients were abrupt and large. In plots 4-4 and 15-4, soil pH levels varied from about 8 to 5 within 20 feet. The locations were random, with no evidence of misapplication of lime. However, especially in 4-4, this area probably was filled with soil from some unknown source. Having subsoil high in carbonates is common in the area north of Champaign. Use of fill from these subsoil areas to level a depression or from a burial of refuse or other materials may be the reason for the small-scale variability in soil pH.

In all three plots, misapplication appears to be the problem with soil P values and sometimes K. North-south streaks of high and low P and K are evident about 40 feet apart in all three plots. A distance of 40 feet is about the spread from older spinner pull-behind spreaders and older-style spinner applicators used in the early 1980s when large buildup applications of P and K were made.

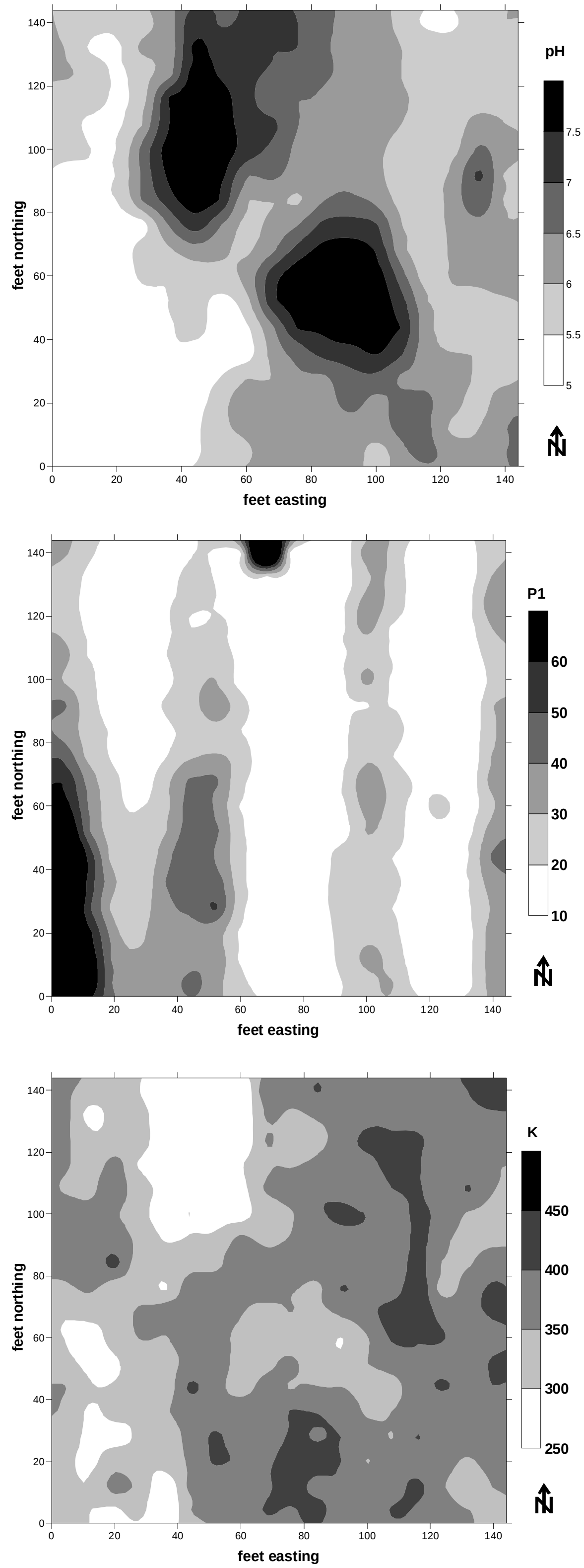


Figure 6-1.
Plot 4-4, 8-foot grid, soil pH, P and K, 1991.
Note P streaking about 50 feet apart, probably due to improper adjustment of a fertilizer applicator.

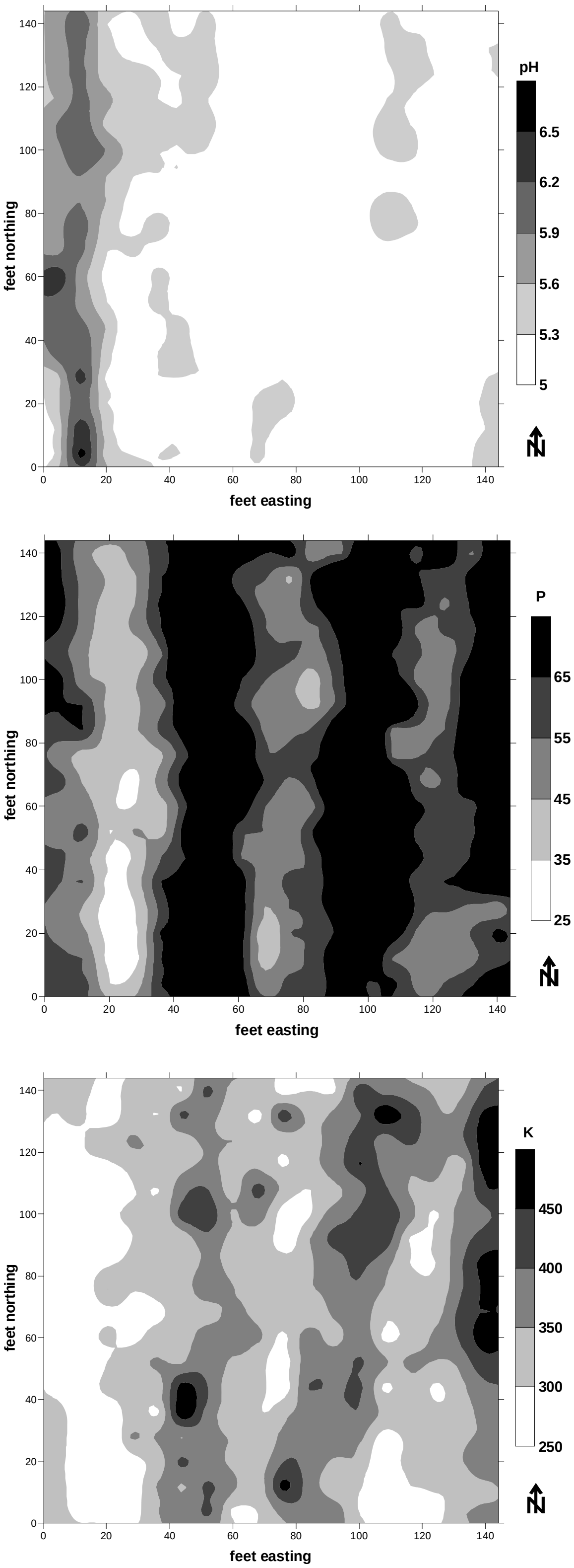


Figure 6-2.
Thomasboro plot 4-8, 8-foot grid, soil pH, P and K, 1991. Note P and K streaking about 50 feet apart.

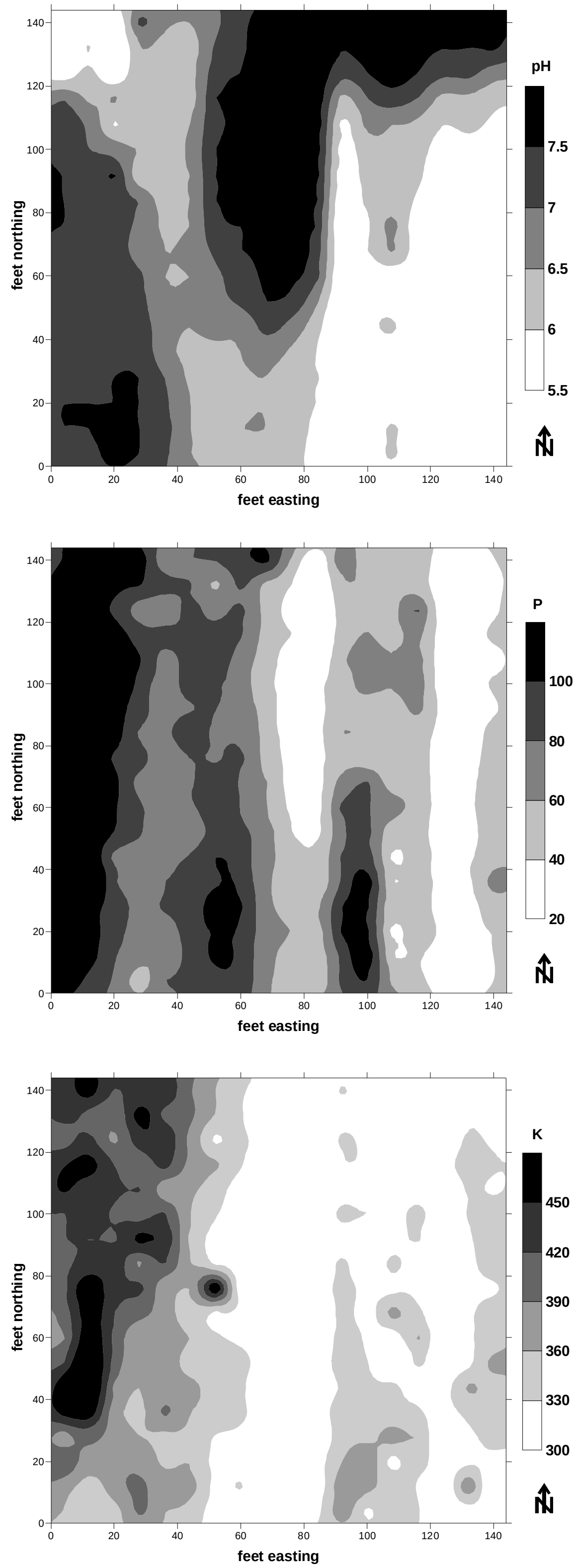


Figure 6-3.
Thomasboro plot 15-4, 8-foot grid soil pH, P and K, 1991. Note abrupt pH differences, probably naturally occurring. Also note P and K streaking.

Summary

This technical publication documents the tremendous dataset begun by Melsted and Peck in 1961 and continued by Peck until 2002. The following are conclusions that have been reached due to analysis of this dataset:

1. Soil pH, P and K patterns were persistent when not obscured by lime, P or K applications.

2. When P and K applications were discontinued, yields remained high and total P and K removal at both sites exceeded P and K inputs, while P and K levels remained high. The rate of P soil test drawdown was slower than fertilization buildup rates. The rate of K soil test drawdown was faster than buildup rates.

3. Nutrient difference maps did not generally represent historic nutrient patterns within two to three years of each sampling; however, long-term difference maps tended to be similar in pattern to soil/landscape.

4. Yield frequency mapping more consistently represented nutrient patterns and was more related to nutrient levels than single-year yield maps.

5. Simulated zone sampling using topography and soil EC generally was similar in pattern to dense (one sample per acre) grid sampling for pH, P and K.

6. Satellite imagery of July-growing crops showed similar patterns as nutrients, soil EC, yield frequency maps and topography.

7. Small-scale nutrient sampling (8-foot grids) showed that attention needs to be paid to fertilizer application to avoid streaking. The small-scale sampling also shows that although zone and grid sampling maps suggest long transitions between nutrient levels, the transition also can be abrupt.