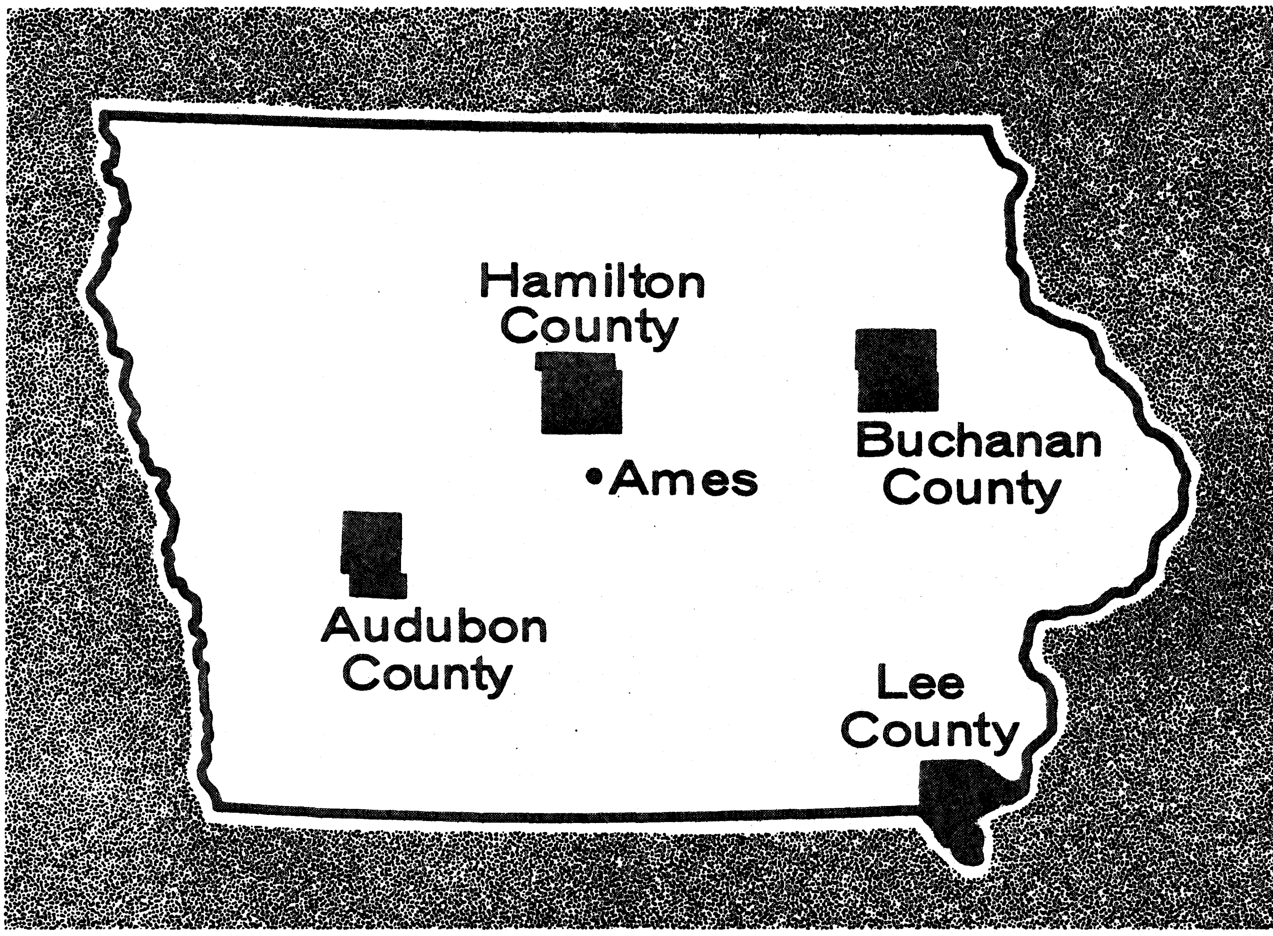
Fifth Annual Report, 1981
and
Project Summary: HR-186

EVALUATION OF CHANGES IN PRODUCTIVITY RESULTING FROM REMOVAL OF SOIL FOR HIGHWAY CONSTRUCTION



Iowa Agricultural and
Home Economics Experiment Station
and
Iowa Department of Transportation

FIFTH ANNUAL REPORT AND SUMMARY, 1981 : HR-186

EVALUATION OF CHANGES IN PRODUCTIVITY RESULTING FROM REMOVAL OF SOIL FOR HIGHWAY CONSTRUCTION

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TABLE OF CONTENTS

Background

Borrow areas are created where soil is removed to provide needed fill material for highway and other construction projects. Where these areas are located beyond the highway right-of-way, they must be restored and returned to useful purposes. In Iowa, borrow areas are often developed on agricultural lands and therefore, it is necessary to return them to agricultural uses whenever possible. This research project was established to evaluate the changes in row crop productivity where borrow is removed for highway construction. Secondly, several reclamation techniques were selected to be applied to borrow area research sites and the response of crops to each treatment will be evaluated.

Four type locations representative of a range of major soil materials in Iowa were designated for the study:

1. Coarse textured (sandy) material

   (Buchanan County - NE 1/4, SE 1/4 sec. 24, T88N, R9W)

2. Calcareous loess in western Iowa

   (Audubon County - NW 1/4, NE 1/4 sec 7., T79N, R35W)

3. Late Wisconsin glacial till in north central Iowa

   (Hamilton County - SE 1/4, NE 1/4 sec 2, T88N, R26W)

4. Weathered loess or glacial till in eastern or southern Iowa

   (Lee County - W 1/2, NE 1/4 sec 2, T67N, R6W)

The four type locations are listed according to increasing clay content. Clay content is an important factor in considering the usefulness and management of a soil material for agricultural production.

The following reclamation techniques were selected to be tested at the four type locations:

1. Thickness of restored topsoil - 0, 6, and 12 inches
2. Subsoil tillage - none and 24 inches deep
3. Manure application - none and 10 tons per acre
4. Crops - alfalfa (first two years only), corn and soybeans
5. Tile drainage (at the Hamilton County site only) - 1 to 4 feet deep.

Of the treatments selected, the depth of topsoil restored is probably the most important factor in reclaiming the borrow area. It is also the most expensive treatment because it must be removed and stockpiled before borrowing and then retrieved and spread after borrowing is completed. These operations have cost as much as $3000 per acre to remove and restore one foot of topsoil. This cost can be expected to increase in the future.

Subsoil tillage was selected as a means to loosen compacted or dense subsoil horizons. This treatment is usually carried out before topsoil is replaced. On sloping land, it provides an excellent scarification treatment which prevents mass movement of restored topsoil. The cost of this treatment is slight and depends on the size tractor used to undertake the operation. Where large crawlers are used, costs may be several hundred dollars per acre.

Manure application is probably the oldest known treatment used to improve soil. It adds essential plant nutrients and organic matter which are beneficial to the soil. However, finding manure in Iowa is not always easy as farmers are decreasing their livestock herds or utilizing liquid manure systems. The organic matter content of manures from liquid systems is greatly diminished because little or no bedding is used. In addition, the cost of transporting manure to a borrow area site can be large because of the mass involved and specialized equipment needed.

Row crops consisting of corn and soybeans were selected to be grown in rotation for this study. These are the primary cash crops of Iowa and it is logical that a productivity study should be concerned with them. Alfalfa was selected to be grown for the first two years after a borrow area was restored. This amounted to a pre-treatment which allowed a comparison of row crop production that was not preceded by alfalfa growth. Alfalfa is a very important legume that has soil building capabilities such as increasing soil nitrogen and organic matter while protecting the soil from erosion. Besides those capabilities, alfalfa can provide a hay crop which is relatively inexpensive to produce compared to row crops.

Drainage is the last factor considered for borrow area treatment. Both surface and subsurface drainage or a combination of both should be considered. In this experiment, all borrow area research sites were to be graded to insure removal of excess surface water by surface drainage. Tile drains were to be installed at one research site to determine if there would be an advantage from subsurface drainage.

Changes in productivity and responses to reclamation techniques required a comparison with a selected baseline of productivity. This was accomplished by utilizing yearly and 5-year county production values where the respective borrow area research sites were located. This information is compiled by the Iowa Crop and Livestock Reporting Service (Iowa Department of Agriculture and Economic and Statistics Service - USDA).

Progress

All borrow area research sites were selected in 1977 from Iowa Department of Transportation construction plans. The Audubon and Buchanan County sites were completed in the fall of 1977 and May 1978, respectively. Both were used for research in 1978, 1979, and 1980. The two remaining sites in Hamilton and Lee Counties were completed in the fall of 1978 and research was conducted at these sites in 1979, 1980, and 1981.

In this report, the 1981 results from the Hamilton and Lee County borrow sites will be presented. Secondly, a summary of the three years of research from each borrow area will be presented along with specific and general conclusions from the research project.

1981 Results

Late Wisconsin Glacial Till - Hamilton County

The Hamilton County site was located on the southwest edge of Webster City. The subsoil exposed in the borrow area is a calcareous, unweathered, and unoxidized (blue) glacial till of Cary age (deposited approximately 14,000 years ago). Three years of crop production research have been completed at the site. Additional research is being undertaken to study soybean response to topsoil depth and subsoil characteristics. This latter research is funded by the Iowa Soybean Promotion Board.

Preparations for the 1981 crop season were begun in the fall of 1980. Alfalfa plots were sprayed with 2,4-D herbicide at a rate of two pints per acre in 20 gallons of water. After the corn and soybeans were harvested, all plots were chisel plowed in November. In the spring of 1981, soil samples for pH and plant available phosphorus and potassium were obtained from all depths of topsoil plots. Sampling was done in 6-inch increments to a depth of 24 inches. The 18-24 inch increment was dry at the time of sampling. Because of the dry conditions of the soil, a decision was made to plant both corn and soybeans after adequate moisture had wetted the soil profile to at least the two foot depth. This would require about three inches of rain during May.

A second application of 2,4-D herbicide was applied on April 24 to all research plots to destroy surviving alfalfa plants and emerging broadleaf weeds. The research plots were disked twice on June 2 and an excellent seedbed resulted. Corn and soybeans were planted in 30-inch wide rows on June 3. O's Gold 6880 hybrid seed corn was planted at 20,900 seeds per acre and certified Corsoy soybean seed was planted at one bushel per acre. Phosphorus and potassium fertilizer as 0-26-25 liquid was applied with the planter in a band 4 inches from the corn or soybean seed row. Three rates of fertilizer were used: (1) 0, (2) 40 lb P_2O_5 and 39 lb K_2O, and (3) 80 lb P_2O_5 and 78 lb K_2O per acre. These rates were applied within existing plots. Nitrogen fertilizer as 28-0-0 liquid was broadcast applied with an agricultural sprayer at a rate of 200 lb N per acre to all corn plots except the tile drainage-continuous corn plots which received 300 lb N per acre.

Pesticides were applied to all plots. Corn pesticides consisted of Bladex and Lasso herbicides at 2 and 3 quarts per acre, respectively, and Lorsban insecticide at 3 pints per acre. These pesticides were applied with the nitrogen fertilizer solution. Soybean pesticides consisted of Amiben and Lasso herbicides at 4 and 3 quarts per acre, respectively, and Lorsban insecticide at 3 pints per acre applied with 50 gallons of water per acre. The threat of cutworm activity to these late planted crops required the application of an insecticide.

Climatological data for the Hamilton County research site is given in Table 1. April and May were drier than normal although rain in May was adequate for seed germination. The rains in June were one inch above normal but did not provide a reserve to be carried into July. Drought stress became evident in early July on the plots receiving no topsoil and by July 15, was evident on all plots. Fortunately, corn pollination did not occur until the second week of August when there was adequate moisture and cooler temperatures. After pollination, the remainder of the growing

Table 1. Monthly average temperature and precipitation at the Hamilton County borrow area research center - 1981.

Month	Temperature				Number of days temperature reached 90° or above	Precipitation		
	Average maximum	Average minimum	Daily average	Departure from normal[1/]		Number of days	Total	Departure from normal[1/]
	°F						inches	
April	67.0	39.4	53.2	4.7	1	7	2.08	-0.71
May	70.4	44.9	57.7	-2.3	0	7	3.00	-1.08
June	83.8	57.5	70.7	1.6	5	8	5.94	1.01
July	85.0	63.7	74.3	1.1	12	5	3.33	-0.67
August	81.3	58.5	69.9	-1.7	1	8	5.47	2.10
September	76.9	48.3	62.6	0.0	0	3	4.80	2.14

[1/] Calculated from Climatological Data, Webster City used for "normal", National Oceanic and Atmospheric Administration, National Climate Center, Asheville, N.C.

season was wetter than normal.

Corn and soybean yields were obtained by harvesting 20 feet each of the two interior rows of the four-row plots. Corn was hand picked in the harvest area, collected in burlap sacks, weighed and sampled for moisture content. The number of plants and ears in each plot harvest area were also counted. Yields were calculated on the basis of the area harvested, adjusted to 15.5 percent moisture and reported as bushels per acre. Before the soybean plots were harvested, a count of plant density was obtained. This was accomplished by counting the number of plants bearing pods in 3-foot increments at four locations in the harvest area of each plot. These counts were then used to determine an average number of plants per foot of row. Harvesting was carried out by cutting the plants slightly above the ground surface with a circular bladed mower. The samples were collected and carried to a stationary thresher where seed was separated, collected and sacked. Each sample was weighed and yields were calculated on the basis of the area harvested and reported as bushels per acre.

Corn yield data from the corn-soybean rotation plots and first-year corn following alfalfa is summarized by treatment in Table 2. The yields of individual plots are given in the Appendix. Statistical analyses were conducted on these data using Iowa State University's Computation Center facility. A discussion of the statistical procedures is also presented in the Appendix. There were no significant differences in yield due to alfalfa treatment, subsoil tillage, manure application, and phosphorus fertilization. An analysis of variance indicated that topsoil depth had a highly significant effect on corn yield. Table 3 presents a summary of

Table 2. Third year corn yields at a late Wisconsin till borrow site in north central Iowa, Hamilton County - 1981.

Treatment	Topsoil depth	Check	Manured	Subsoil tilled	Manured & subsoil tilled	Average
No alfalfa	inches	bushels per acre				
	0	105.9	101.7	99.7	97.6	101.2
	6	110.9	113.3	121.3	103.0	111.1
	12	136.6	116.6	123.3	134.4	127.3
Average		117.8	110.5	114.8	111.7	113.2
2 years alfalfa						
	0	98.2	104.0	110.1	112.1	106.1
	6	114.4	126.5	117.3	108.5	117.4
	12	125.9	124.4	122.4	128.1	125.2
Average		112.8	118.3	116.6	116.2	116.2

Table 3. Corn yield response to topsoil depth, Hamilton County - 1981.

Topsoil depth	Yield[1/]
inches	Bushels per acre
0	105.7 a
6	113.5 ab
12	126.5 b

$LSD_{0.05}$ = 14.9 bushels/acre

1/ Different letters indicate significantly different yields.

corn yield response to topsoil depth and the means are separated using a Least Significant Differences Test (LSD). This additional test indicated that the yields measured at the 0 and 12-inch topsoil depths were different due to the depth of topsoil replacement. Yields at the intermediate depth of topsoil were not significantly different from the 0 or 12-inch depths.

Soybean yield and plant density data from the corn-soybean rotation plots and first-year soybeans following alfalfa are summarized by treatment in Tables 4 and 5, respectively. The yields of individual plots are given in the Appendix. Statistical analyses were computed on these data. (See the discussion concerning statistics in the Appendix.) There were no significant differences in yield or plant density due to subsoil tillage, manure application, or phosphorus fertilization. The depth of topsoil and two years of previous alfalfa growth had highly significant effects on yield, but only topsoil depth affected plant density. Table 6 presents a summary of soybean yield and plant density response to topsoil depth and alfalfa treatment. (Figure 1 graphically presents the same information). LSD's were calculated to determine if mean responses to treatments were statistically different. These computations showed that yield and plant density were significantly greater where 6 inches of topsoil was restored to the borrow area but that the difference between 6 and 12 inches of topsoil were not. Alfalfa treatment, however, had a significant effect on yield but not on plant density even though the data shows a strong trend toward increasing plant density after alfalfa treatment.

A possible explanation for the responses to restored topsoil and alfalfa treatment lay in the occurrence of Phytophthora root rot infection. This

Table 4. Third year soybean yields at a late Wisconsin till borrow site in north central Iowa, Hamilton County - 1981.

Treatment	Topsoil depth	Check	Manured	Subsoil tilled	Manured & subsoil tilled	Average
No alfalfa	inches	bushels per acre				
	0	4.3	8.0	9.6	10.1	8.0
	6	24.8	20.9	18.6	20.7	21.6
	12	30.9	26.2	26.9	28.9	27.9
Average		20.0	18.4	18.5	19.9	19.2
2 years alfalfa						
	0	22.9	26.1	23.8	29.8	25.2
	6	38.7	27.8	36.5	43.4	37.3
	12	40.6	41.8	43.9	45.9	43.1
Average		34.1	31.9	34.7	39.7	35.2

Table 5. Third year soybean plant density at a late Wisconsin till borrow site in north centra Iowa, Hamilton County - 1981.

Treatment	Topsoil depth	Check	Manured	Subsoil tilled	Manured & subsoil tilled	Average
No alfalfa	inches			plants per foot		
	0	1.7	2.9	2.7	3.1	2.6
	6	4.2	4.2	4.0	4.4	4.2
	12	4.4	5.0	4.1	4.4	4.5
Average		3.4	4.0	3.6	4.0	3.8
2 years alfalfa						
	0	5.9	5.6	5.8	5.9	5.8
	6	7.2	7.2	7.9	7.4	7.5
	12	7.7	7.2	7.2	7.9	7.5
Average		6.9	6.7	7.0	7.1	6.9

Table 6. Summary of soybean yield and plant density response to alfalfa treatment and restored topsoil at a late Wisconsin glacial till borrow area in Hamilton County, Iowa -- 1981.

	Yield[1/]			Plant density[2/]		
	No alfalfa	2 years alfalfa	Average	No alfalfa	2 years alfalfa	Average
Inches	-------- bushels per acre --------			--------- plants per foot --------		
0	7.7 a	25.4 g	16.6 a	2.6 a	5.7 c	4.2 a
6	21.9 b	35.9 c	28.9 b	4.2 b	7.4 d	5.8 b
12	28.2 b	42.9 c	35.5 b	4.5 bc	7.6 d	6.0 b
Average	19.3 x	34.7 6		3.8 x	6.9 x	

[1/] Yield LSD's at 0.05 level: 8.2 (a,b,c) and 12.7 (x,y) bushes per acre.

[2/] Plant density LSD's at 0.05 level: 1.3 (a,b,c,d) and 5.2 (x) plants per foot.

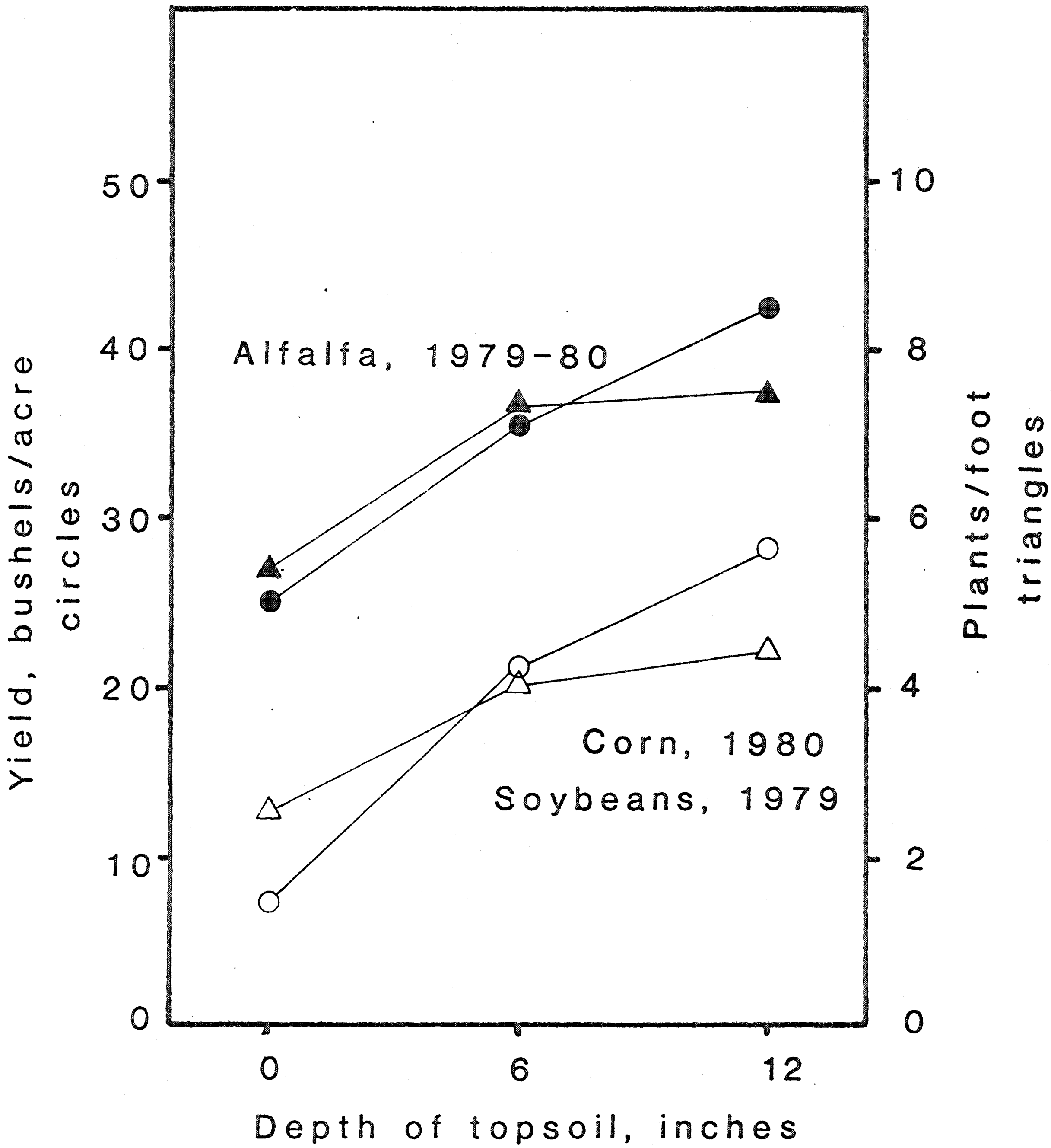

Figure 1. Soybean yield and plant density response to replaced topsoil and alfalfa treatment at a late Wisconsin glacial till borrow area in Hamilton County, Iowa - 1981.

disease was diagnosed to be severe in subsoil plots where soybeans had grown two years before. The addition of topsoil diminished the occurrence of the disease and alfalfa treatment seemed beneficial too. The effect of alfalfa may be in its ability to improve the internal drainage of the subsoil by the development of its tap-rooted growth habit. The old root channels in the soil will carry away excessive water which would otherwise provide an ideal growth medium for the Phytophthora fungi.

The remaining research concerned the tile drainage experiment. Yields were determined from plots located at various depths and distances from each tile. (Table 7). (See Appendix Figure 6 for a plan of this experiment.) A statistical analysis of variance showed that there was no significant difference in yield due to depth or distance from the tile drains. Yields from the tile drainage plots were comparable to those measured from the rotation plots where corn was grown without topsoil. The tile drainage plots were also without topsoil. There also appeared to be no benefit from the application of 300 pounds of nitrogen per acre. The rate of 200 pounds applied to the rotation plots was adequate.

An additional observation after the corn was harvested, indicated that tile drainage may have a beneficial effect where machinery had to traverse the plots. The mechanical combine harvester left wheel tracks approximately one foot deep where the tile drains were placed at a depth of 2 feet or less. Where the tile drains were 3 or more feet deep, the combine tires did not sink into the plots. By lowering the water table below 2 feet, the tile drain allowed the soil to support the combine harvester. In the spring of the year, this same factor may allow more timely planting of tile drained plots. However, the previous springs have not been wet nor was the experiment designed to allow differential planting among plots.

Table 7. Corn yield response to tile drainage at a late Wisconsin till borrow site in north central Iowa, Hamilton County.

Depth to tile	Year	Distance from tile, feet 0	20	40	Average
		----- bushels per acre ------			
One	1979	61	75	80	73
	1980	30	67	40	42
	1981	105	113	116	112
Two	1979	38	46	60	48
	1980	50	45	54	49
	1981	105	115	108	110
Three	1979	34	70	62	59
	1980	49	49	47	48
	1981	117	120	116	118
Four	1979	60	52	62	57
	1980	49	50	61	53
	1981	111	111	116	112
Average	1979	48	61	66	
	1980	45	53	51	
	1981	110	114	114	

Soil test analyses for pH, buffer pH (lime requirement), and plant available phosphorus and potassium were obtained and the results are presented in Table 8. These additional analyses were conducted as a part of the Iowa Soybean Promotion Board research project. Each soil test value in Table 8 is the average of samples obtained from each of the 12 main plots assigned to different cropping sequences and replications. Where no topsoil was replaced, soil test values for the glacial till subsoil remain fairly constant throughout the sampled profile with respect to pH and plant available phosphorus. Replaced topsoil caused a reduction in pH and both phosphorus and potassium were available to plants at very high levels. Changes in pH and soil test phosphorus and potassium values seem to accurately reflect the depth of restored topsoil. Chisel plow tillage has caused some mixing of soil materials which accounts for gradual changes in soil test values.

In previous years, marked symptoms of manganese toxicity were noted in soybeans grown on plots where topsoil was replaced. The symptoms were slight and spotted within the plots with a row crop history. No symptoms were noted where soybeans were grown on plots receiving topsoil and 2 years of alfalfa treatment. This may have been another beneficial effect from alfalfa.

Table 8. Average soil test values for Hamilton County borrow area research site.

Depth of Topsoil	Sample Depth	pH	Buffer pH	Available P	Available K
	inches			---------- lb per acre	----------
No Topsoil					
	0-6	7.7	7.4	2.5	340
	6-12	7.6	7.1	2.3	256
	12-18	7.6	7.5	2.2	261
	18-24	7.6	7.4	2.2	280
6" Topsoil					
	0-6	6.7	6.8	87.7	445
	6-12	6.8	6.9	43.3	360
	12-18	7.4	7.3	9.2	304
	18-24	7.4	7.4	2.1	300
12" Topsoil					
	0-6	6.7	6.8	104.9	555
	6-12	6.5	6.7	52.0	437
	12-18	7.1	7.2	20.5	381
	18-24	7.3	7.3	2.2	308

Weathered Loess or Glacial Till - Lee County

This borrow area research site is located two miles east of Donnellson, Iowa. The original soils in the borrow area developed from wind deposited loess but the exposed subsoil consisted of calcareous, unweathered, and oxidized glacial till of Kansan age (deposited approximately 500,000 years ago). During construction and restoration of the borrow area, a gray, clay paleosol was removed from the site and thus exposed the unweathered glacial till.

All plots were moldboard plowed in the fall of 1980 with a three-bottom, two way plow. Soil was thrown up slope and only one dead furrow resulted at the south border of each row of plots. On April 3, all plots were disked twice and then disked again on May 30 prior to planting. An excellent seedbed resulted where topsoil had been restored but the seedbed was cloddy on the subsoil plots. Excess moisture and a lack of organic matter hindered seedbed preparation in the latter plots. Planting was greatly delayed in southeast Iowa because an above normal amount of rain fell during May.

Both corn and soybeans were planted in 30-inch wide rows on May 30. Lester Pfister 75 hybrid seed corn was planted at 20,900 seeds per acre and certified Oakland soybean seed was planted at one bushel per acre. Solution fertilizers were applied in a band four inches from the seed row. The corn plots received 180 lb N, 83 lb P_2O_5, and 81 lb K_2O per acre from 28-0-0 and 0-26-25 solutions. The soybean plots received the same rates of P_2O_5 and K_2O only. Corn pesticides consisted of Bladex and Lasso herbicides at 2 and 3 quarts per acre, respectively, and Lorsban insecticide at 3 pints per acre. All corn pesticides were broadcast applied in a tank mix with 50 gallons of water per acre. The soybean plots received the same tank mix except Amiben at 4 quarts per acre was substituted for Bladex.

Climatological data for the Lee County research site is presented in Table 9. The growing season was characterized by excessive rain in April, May, June, and July. Nearly normal rainfall occurred in August and September. The entire growing season was cooler than normal and both corn and soybeans were slow to mature.

Corn yields are summarized by treatment in Table 10. There were no significant yield differences due to alfalfa treatment, subsoil tillage, or manure application. The addition of 6 inches of topsoil caused a significant yield increase but there was no significant difference between the 6 and 12-inch topsoil applications. Much of the yield increase from topsoil replacement was caused by an increase in plant density. A summary of corn yield and plant density response to topsoil replacement is presented in Table 11. Much of the improved plant density can be attributed to the superior seedbed which was attained where topsoil was replaced.

Soybean yields are given in Table 12. This was the first year that soybeans were successfully grown and yields measured. There were no significant differences in soybean yield due to alfalfa treatment, subsoil tillage, or manure application. The soybean crop also responded significantly to the first 6-inch addition of topsoil and there was not a significant yield difference between the 6 and 12-inch topsoil applications. Plant density counts were not made of soybean plants at harvest. There also appeared to be no Phytophthora root rot infection in soybeans grown on any of the plots at this research site.

Table 9. Monthly temperature and precipitation records for the Lee County borrow area research site, 1981.

Month	Temperature				Number of days temperature reached 90° or above	Precipitation		
	Average Maximum	Average Minimum	Daily Average	Departure from Normal 1/		Number of days	Total	Departure from Normal 1/
	F°						inches	
May	68.2	47.4	57.8	-6.1	0	15	5.79	+2.27
June	82.7	61.5	72.1	-1.0	0	18	7.04	+2.50
July	83.0	65.3	74.2	-3.1	4	21	8.21	+3.82
August	82.1	62.3	72.2	-3.3	1	10	3.66	+0.50
September	76.8	51.7	64.3	-3.0	0	10	3.36	-0.50

1/ Calculated from Climatological Data, Keokuk Lock and Dam 19 record used for "normal", National Oceanic and Atmospheric Administration, National Climate Center, Asheville, N.C.

Table 10. Lee County Corn Yields, 1981

	Topsoil Depth, inches			
	0	6	12	Average
No Alfalfa		Bushels per Acre		
Check	63.5	95.2	86.8	81.8
Manured	56.4	77.5	82.3	72.1
Subsoiled	46.2	88.6	86.6	73.8
Manured & Subsoiled	51.7	115.1	95.2	87.3
Average	54.5	94.1	87.7	78.8
2 yrs Alfalfa				
Check	50.6	127.7	112.1	96.8
Manured	76.5	131.8	116.7	108.3
Subsoiled	79.0	94.7	94.7	89.5
Manure & Subsoiled	89.8	87.6	88.8	88.7
Average	74.0	110.5	103.1	95.8

Table 11. Effect of topsoil replacement on corn yield and plant density at the Lee County borrow area research site, 1981.

Depth of topsoil inches	Yield bushels/acre	Plant density Number plnts/acre
0	64.8 a[1/]	12,300 e
6	102.3 b	16,700 d
12	97.0 b	16,400 d
LSD 0.05	21.0	1,800

[1/] Different letters indicate significantly different means.

Table 12. Lee County Soybean Yields, 1981

	Topsoil Depth, inches			
	0	6	12	
No Alfalfa		Bushels per Acre		Average
Check	20.1	41.8	35.0	32.3
Manured	27.8	37.3	33.4	32.8
Subsoiled	12.9	43.4	42.7	33.0
Manure & Subsoiled	21.6	37.9	-	29.8
Average	20.6	40.1	37.0	32.2
2 yrs Alfalfa				
Check	22.2	34.4	30.0	28.9
Manured	23.8	32.3	32.0	29.4
Subsoiled	23.3	31.4	29.1	27.9
Manured & Subsoiled	21.6	30.7	26.0	26.1
Average	22.7	32.2	29.3	28.1

SUMMARY

Three years of research data have been collected at each of the four borrow sites selected to be representative of major soil materials in Iowa. A summary will be presented concerning productivity, reclamation methods, and general recommendations based on observations throughout the study period.

Productivity

Figures 2-9 give histogram presentations of yearly corn and soybean grain yields at each of the borrow area research sites. The nonsignificant treatments were dropped from the figures and generally the responses to topsoil depth and alfalfa treatment are shown.

At the Audubon County borrow site, corn and soybean yields have exceeded or equaled county average yields during the last two years of the three year study. This was done without any restored topsoil at the borrow area. It is also interesting to note that in the last year of the study, a severe drought hindered the county average yield of both corn and soybeans and that the borrow area nevertheless achieved the county average (See Climatological Data in Appendix Table 1.)

Corn and soybean yields exceeded county average yields in only one of three years at the Buchanan County borrow site. During the first year of the study, yields were greatly reduced. Much of this yield reduction resulted from the poor seedbed that was prepared only a few days after the site was completed. The yields in 1979 were excellent and average county corn and soybean yields were exceeded. The results of the third year of the study were disappointing because heavy rains, wind, and hail greatly damaged the corn and soybeans at this site. A secondary effect of these

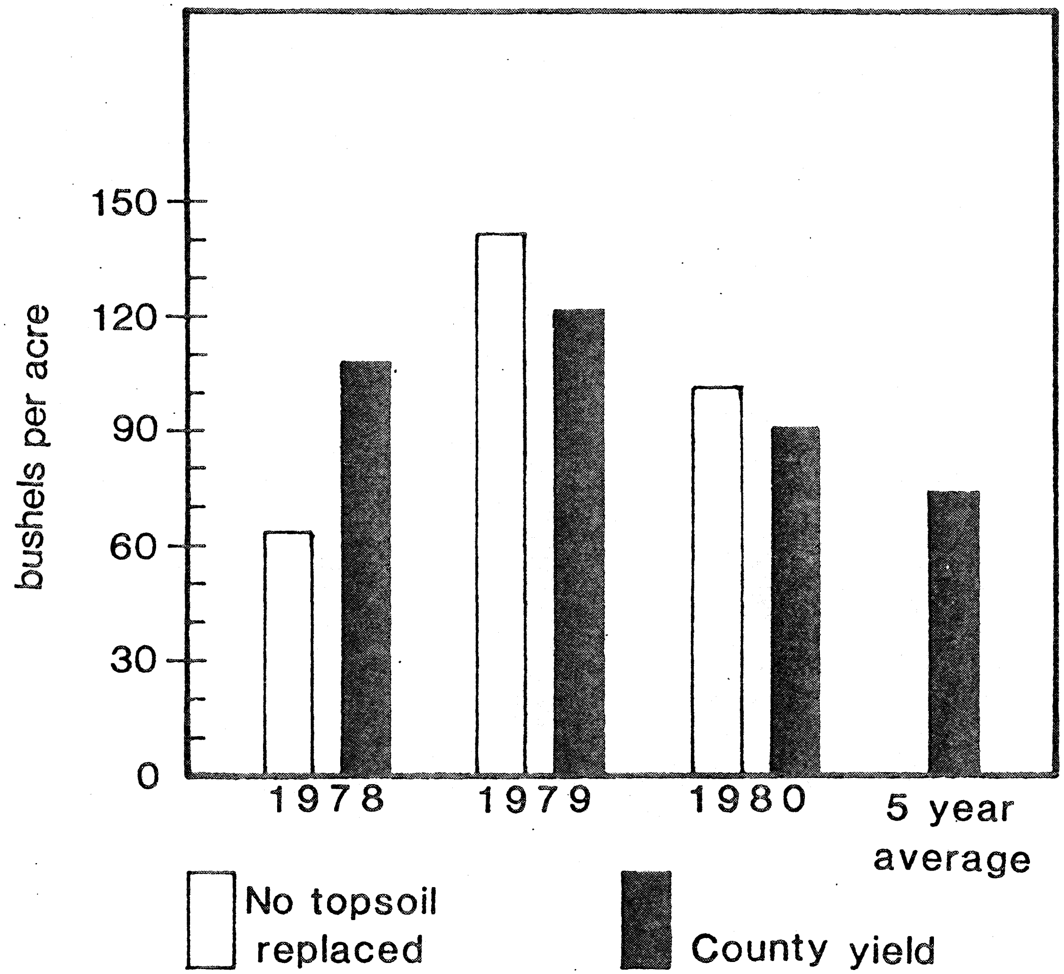

Figure 2. Corn yield response at a loess borrow area in Audubon County, Iowa.

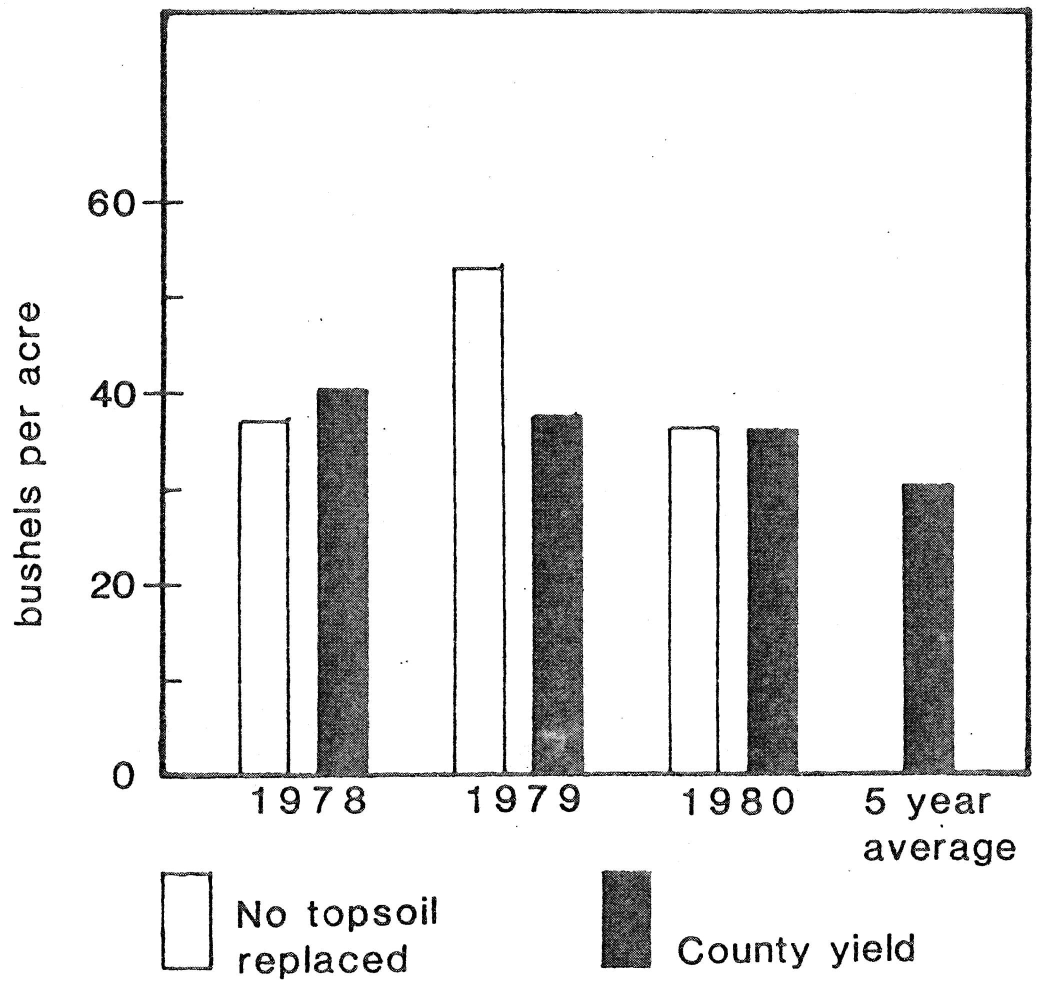

Figure 3. Soybean yield response at a loess borrow area in Audubon County, Iowa.

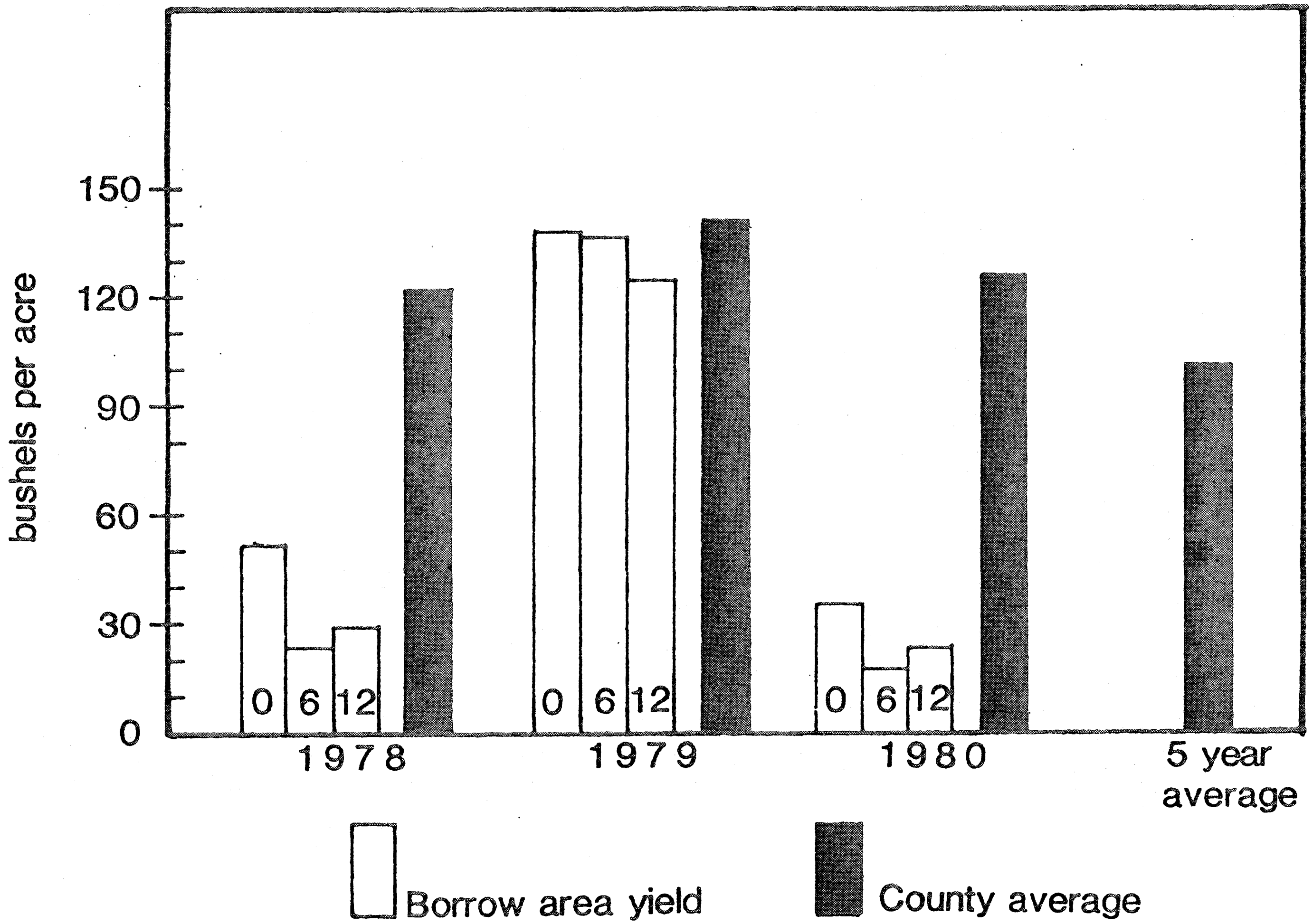

Figure 4. Corn yield response to restored topsoil at a coarse-textured borrow area in Buchanan County, Iowa.

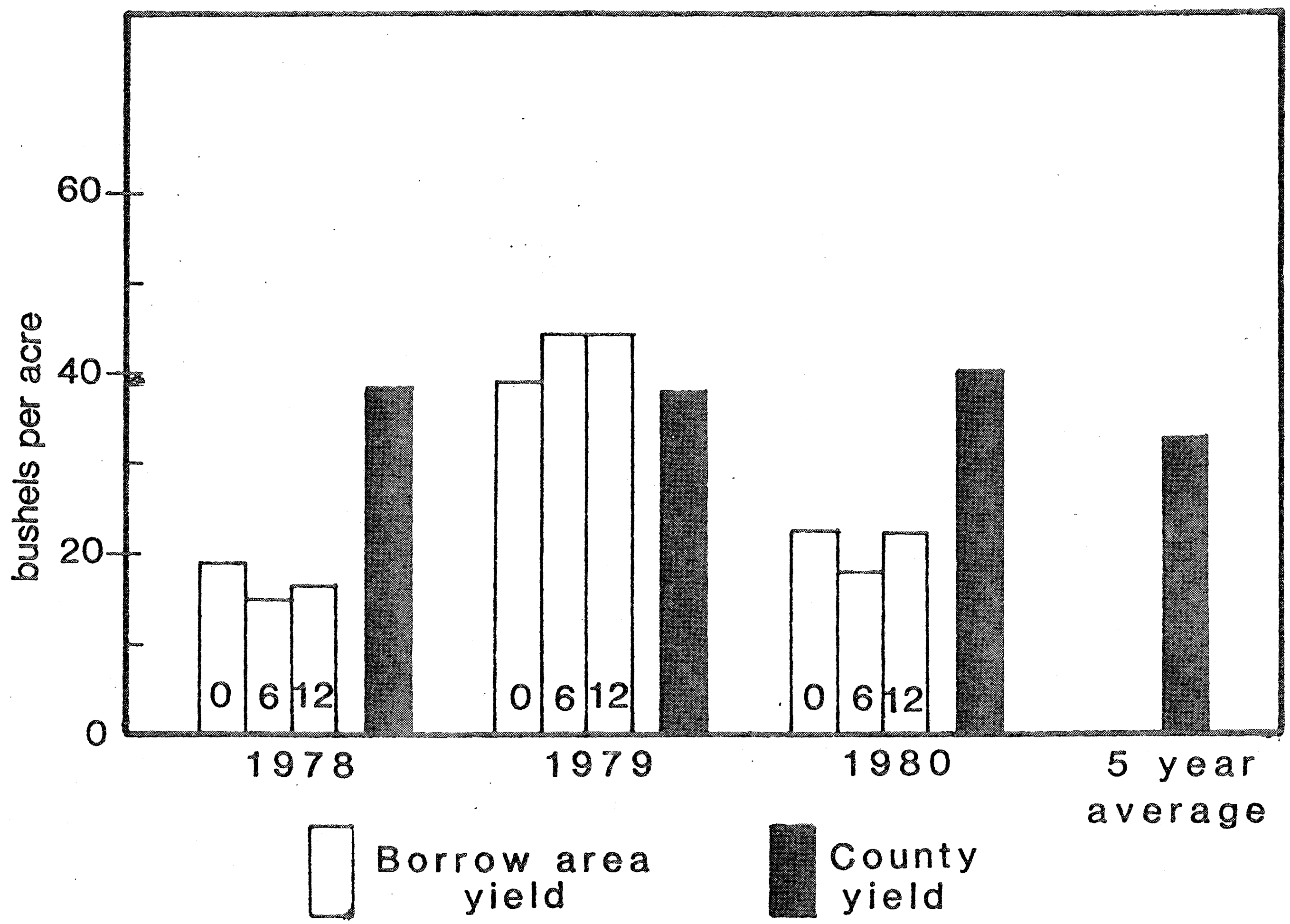

Figure 5. Soybean yield response to restored topsoil at a coarse-textured borrow area in Buchanan County, Iowa.

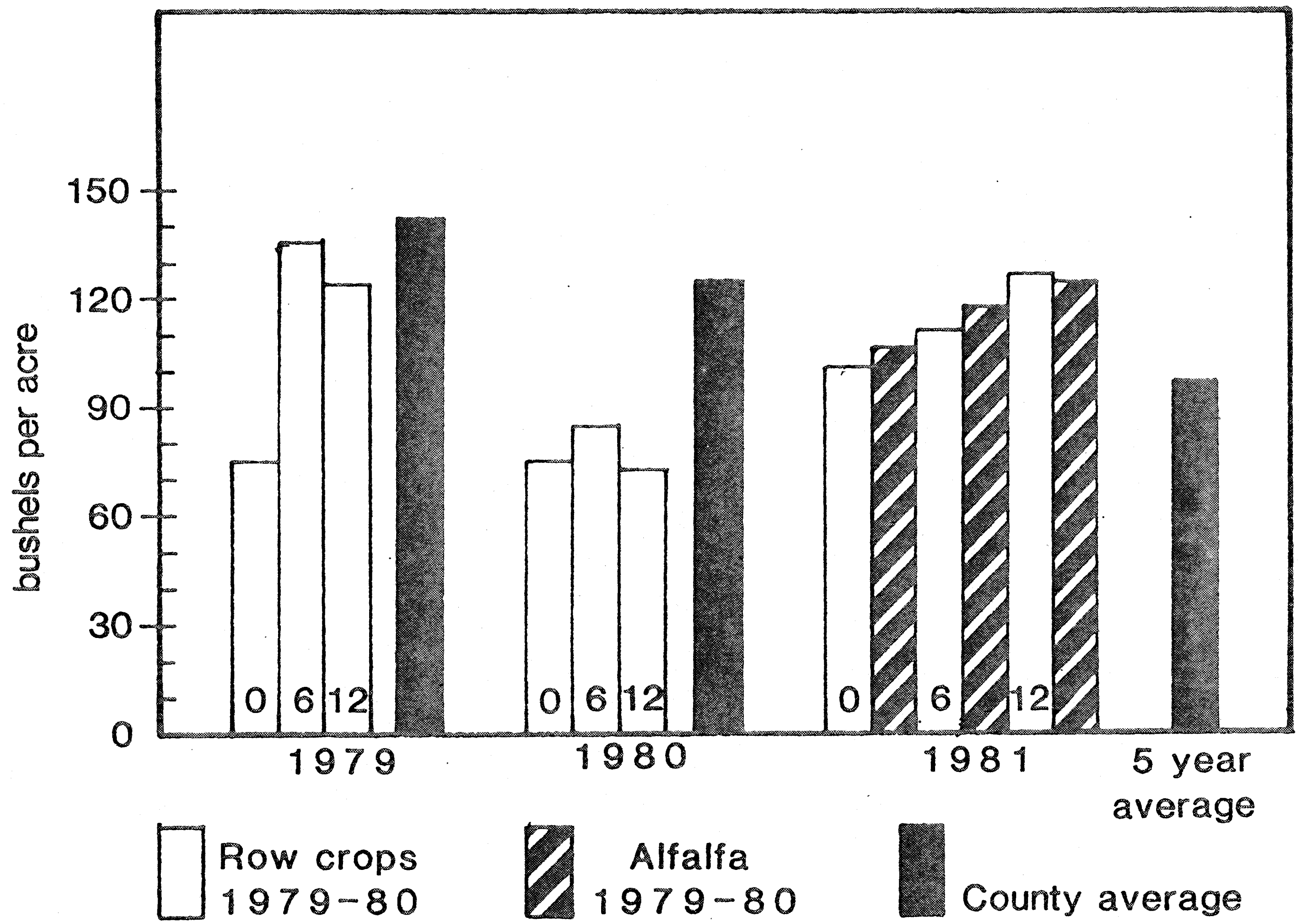

Figure 6. Corn yield response to restored topsoil and alfalfa treatment at a late Wisconsin glacial till borrow area in Hamilton County, Iowa.

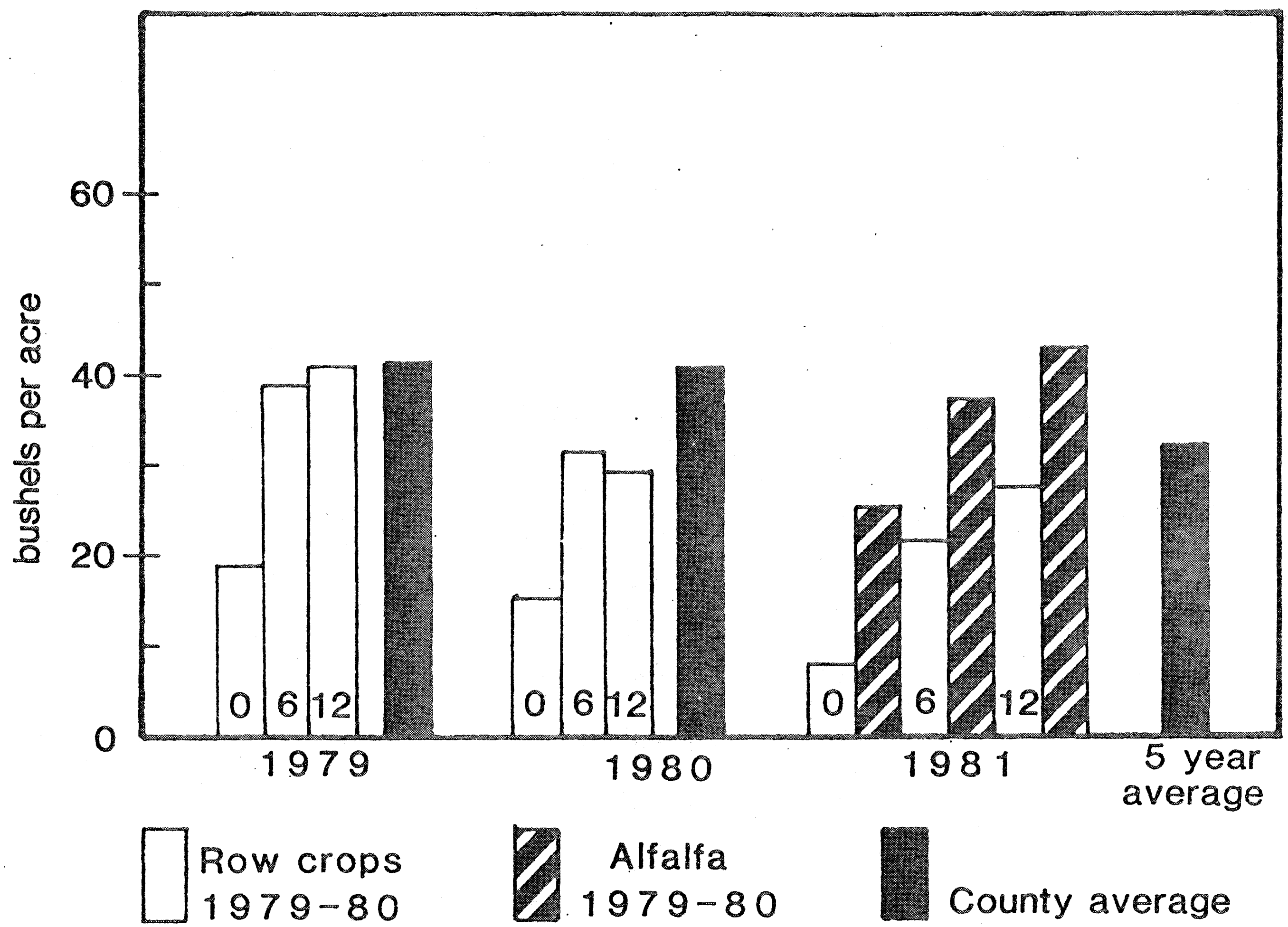

Figure 7. Soybean yield response to restored topsoil and alfalfa treatment at a late Wisconsin glacial till borrow area in Hamilton County, Iowa.

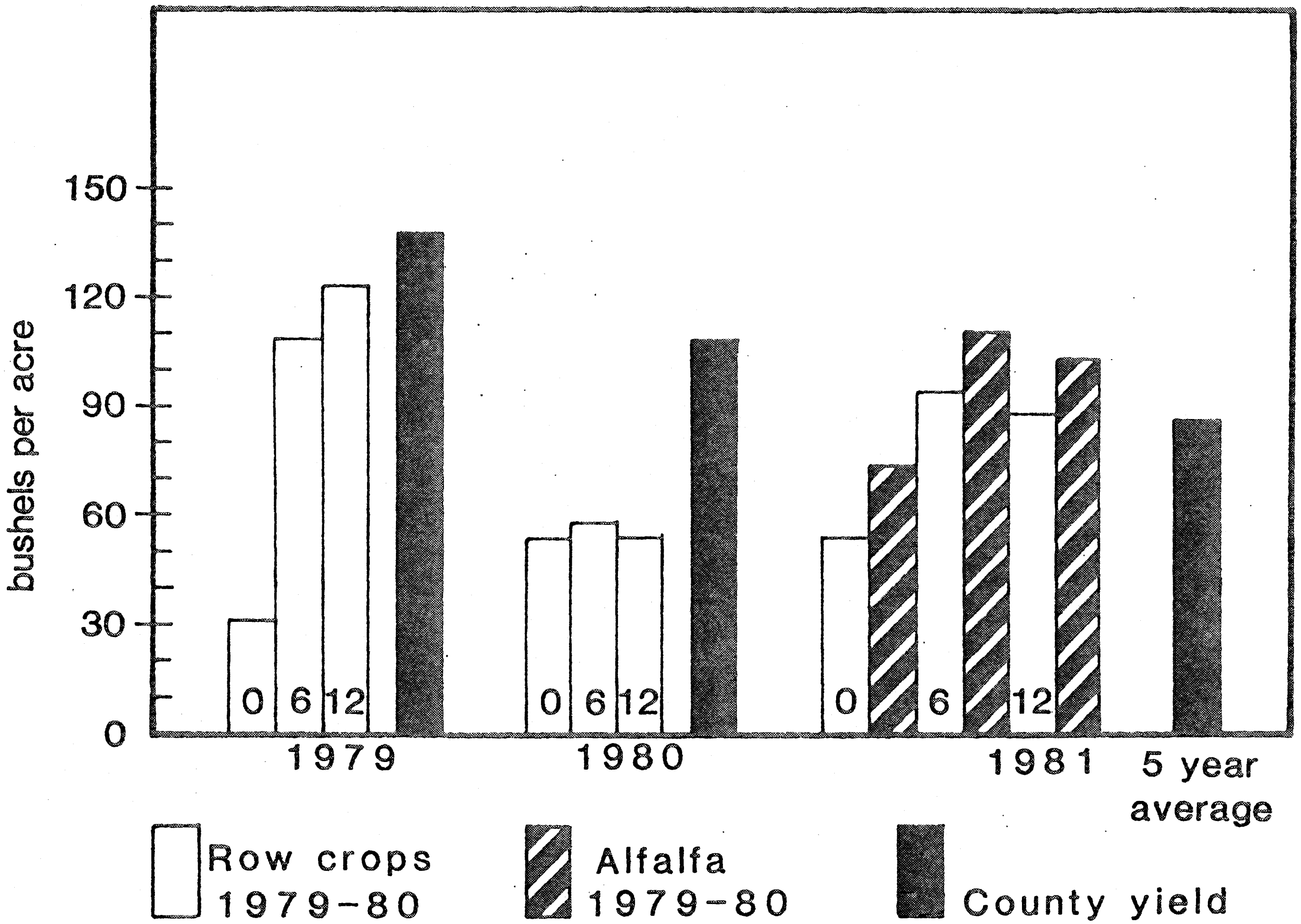

Figure 8. Corn yield response to restored topsoil and alfalfa treatment at a Kansan glacial till borrow area in Lee County, Iowa.

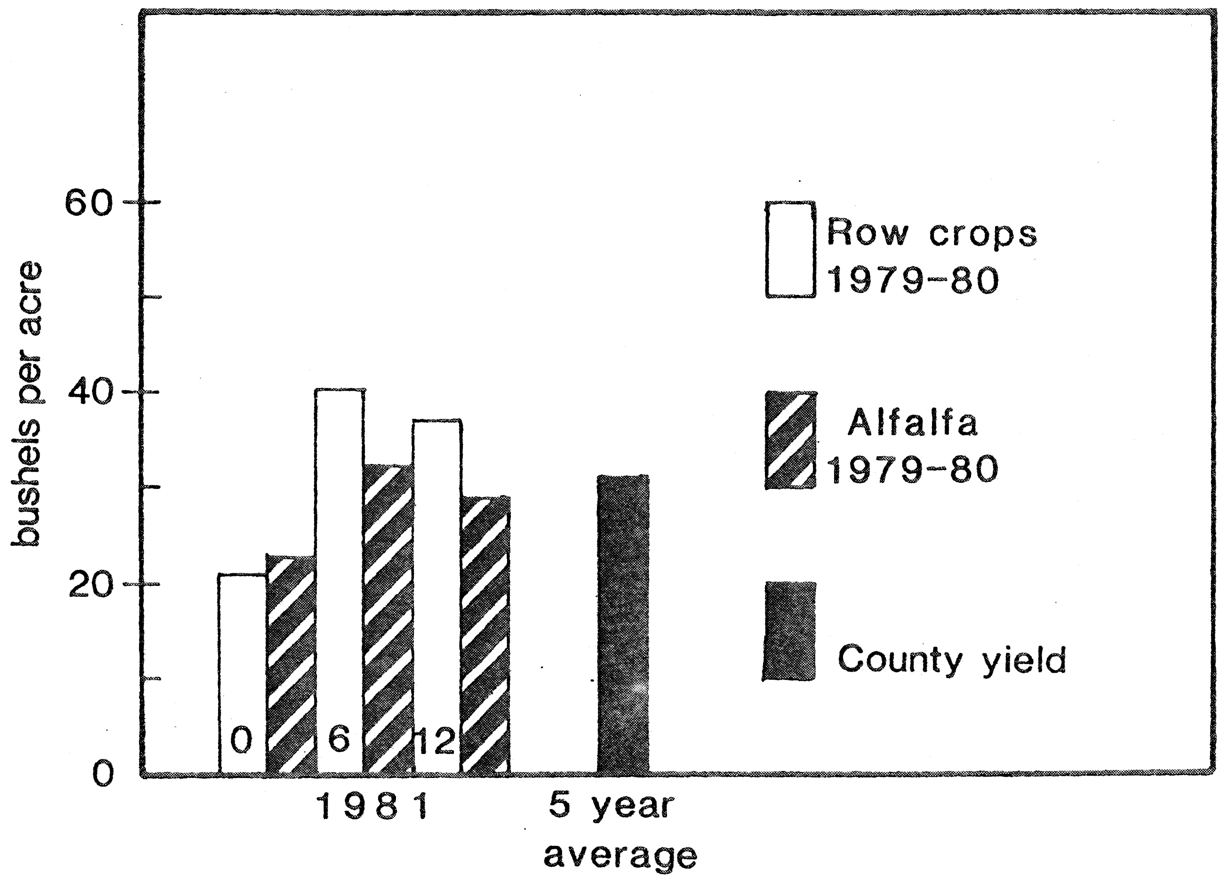

Figure 9. Soybean yield response to restored topsoil and alfalfa treatment at a Kansan glacial till borrow area in Lee County, Iowa.

storms was the loss of herbicides through leaching and erosion. This resulted in a severe weed infestation which further reduced yields. The most important result from this research site was the lack of response by corn or soybeans to restored topsoil. Other observations at this site indicated that alfalfa was poorly suited to the conditions that prevailed. Although the seed germinated, most seedlings died early in the summer of the seeding year, especially where topsoil was replaced. Consequently, the alfalfa plots became infested with weeds and grasses. However, these same plots were less subject to erosion in 1980 than were the plots that had been in continuous row cropping since 1978.

Corn yields have equaled county yield averages at the Hamilton County borrow site in two out of three years where topsoil was restored. The second year's yield results showed no response to restored topsoil and yields were much reduced compared to the county average. Drought and differential pollination of corn among depth of topsoil plots greatly confounded the results of 1980. Soybean yield data showed some interesting responses. In the first year of the study, yields from topsoiled plots equaled the county average but there was no significant difference between the 6 and 12-inch depths of topsoil. In 1980, drought greatly limited soybean yields although plots with restored topsoil had yields twice as great as those without topsoil. In 1981, the most important results occurred. Soybean yields were greatly reduced when the second soybean crop was grown on the corn-soybean rotation plots were compared with soybeans grown following two years of alfalfa. The primary explanation for this result was the occurrence of Phytophthora root rot infection which reduced yields. This disease organism became established when the first soybean crop was grown and rapidly infected the second crop grown in 1981. Restoration of topsoil appeared to lessen the disease to some extent. Both corn and soybeans responded significantly to restored topsoil but little or no difference in yield could be found between the 6 or 12-inch depths.

Corn yields have been disappointing at the Lee County borrow site. There has been a significant response to topsoil replacement but little difference has been found between yields from the 6 and 12-inch depths. Two years of alfalfa growth appeared to increase corn yields but the response was not significantly greater than where row crops were grown. Soybean yields from the first two years of research were not obtained and only the results from the third year can be discussed. There was a significant yield increase from the addition of topsoil but the difference between 6 and 12-inch depths was not significant. Two years of alfalfa growth did not improve soybean yields at this site. There was no infection of soybeans by Phytophthora root rot at this site.

Reclamation methods

a. Depth of topsoil - Restoration of topsoil showed no yield advantage at the coarse-textured borrow site in Buchanan County. No topsoil was restored at the loess borrow site in Audubon County and excellent yields were achieved which equaled or surpassed county averages. However, topsoil replacement increased crop yields at the glacial till borrow sites in Hamilton and Lee Counties. Little difference in crop yield was measured between plots with 6 or 12 inches of topsoil. The yield increase due to topsoil replacement could partially be attributed to the preparation of a superior seedbed compared to plots where topsoil was not replaced. In some years, corn plant density was greatly reduced because of poor seedbed conditions on the latter plots. Also, topsoil held enough moisture to allow uniform and rapid germination in a drought year as was evident at the Hamilton County site in 1980. An unexpected benefit from topsoil was the reduction of Phytophthora root rot infection in soybeans. The dense, poorly drained glacial till subsoil at the Hamilton County site was an ideal growth medium for the disease organism when soybeans were grown. It is likely that spores from this fungi will persist and infect subsequent soybean crops unless resistant cultivars are planted or experimental chemicals prove effective for controlling this disease.

b. Alfalfa treatment - Alfalfa growth was vigorous at all borrow sites except in Buchanan County. A late planting date and excessive moisture contributed greatly to the problems of establishing alfalfa at the borrow site. Alfalfa did become established on plots where no topsoil was replaced because these plots were not as wet nor was there any weed competition. This pointed out the need to match a legume with the site. Where excessive moisture is likely to occur, clovers or trefoils should be planted because they are more tolerant of wetness. Late planting of alfalfa and other small seeded legumes should also be avoided. This was demonstrated at the Lee County borrow site where failure occurred on subsoil plots which did not receive a manure application. The manure provided a mulching effect that allowed alfalfa seedlings to survive in spite of a late planting date.

c. Subsoil tillage - Generally there was no yield response to subsoil tillage. A yield increase occurred in the first year at the Buchanan County site but did not persist in later years. Subsoil tillage may be beneficial where construction equipment traffic is excessive as appeared to be the case at the Audubon County site. Yields were always reduced in plots which were located where equipment converged as it exited the borrow area. An explanation for the lack of response to subsoil tillage or persistence of response may be the effectiveness of natural weathering forces such as freeze-thaw and wetting and drying. These forces will be very effective in the zone tilled to a depth of 24 inches. Subsoil tillage may be beneficial if it is carried out to modify factors limiting plant root penetration. Therefore, subsoil tillage recommendations should be made on a site-by-site basis.

d. Manure application - Corn generally responded to manure application in the first growing season after manure was applied. This is to be expected but any carryover effect of manure in the following year will be minimal. Manure also served as a very effective mulch which greatly aided alfalfa establishment where planting was delayed in the spring. The greatest problem with manure was availability. Animal manure other than liquids is not readily available in all areas of Iowa. If manure is available to the land manager, it should be applied to the borrow area as it is to other fields. Crop residues may be substituted for manure to some extent and should be considered where mulching is needed. Conservation cropping which leaves significant amounts of residue on the land surface should be utilized on borrow areas as well as other agricultural lands.

e. Tile drainage - The tile drainage study was hampered by relatively dry field conditions in the spring during each year. Only in the fall of 1981 could a benefit be seen from tile installations deeper than 2 feet.

This depth of installation allowed harvest equipment to traverse the site without sinking into the field. Water has always flowed from the tile drains after heavy rainfall events, which should control water table elevations. However, shallow tile installations appear to allow the water table level to remain too high and support for farm machinery is lessened.

General Recommendations

Recommendations for restoring borrow areas to agricultural uses are based on the results of this research and observations while field research was being conducted.

1. Topsoil replacement is not always necessary. At coarse-textured sites which include loess and sandy materials, excellent yield may be obtained with no topsoil replacement. Fertility levels at these sites can be built up rapidly with commercial fertilizer. Soil crusting may be a problem which can be overcome with proper residue management either through no-tillage or other conservation tillage methods. Where clay content is greater as at the glacial till sites, one foot of topsoil should be removed and stockpiled before borrowing. Replacement of the saved topsoil will yield at least a six-inch depth of topsoil. There will be some loss of topsoil through handling and shrinkage. This amount of restored topsoil will insure good seedbed preparation and preserve plant nutrients.

2. Alfalfa treatment should be considered for the first years following reclamation of a borrow pit. In some instances, other legumes such as red clover or birdsfoot trefoil should be used instead of alfalfa. Where topsoil is not restored, a legume treatment should be mandatory to reduce

soil erosion. When row crop production is initiated, a strong conservation tillage program should be followed to insure that sufficient crop residues remain at the surface to control erosion and minimize soil crust problems. Secondly, alfalfa treatment also appears to lessen the severity of phytophthora root rot infection in soybeans. This benefit from alfalfa is still being examined at the Hamilton County borrow area research site.

3. Subsoil tillage generally was not beneficial for row crops. The tillage equipment used in this research could not penetrate beyond 20 inches into the soil. This same zone is also most greatly affected by natural forces resulting from freezing and thawing and wetting and drying. Any advantage from subsoil tillage was seen in the early years after reclamation and during dry years. Tillage may be needed where construction equipment traffic was intense but specialized equipment such as the slip plow may prove more useful than agricultural tillage equipment. The former tillage tool is presently being tested on reclaimed minelands in Iowa. In conclusion, a site by site evaluation should be made of subsoil tillage needs at borrow areas and the results of other research may demonstrate that new, specialized equipment may be better suited to this operation.

4. Manure application was beneficial to corn grown in the first year after its application. This is generally expected. However, excellent corn yields could be achieved without manure. The availability of manure will determine if it is to be used. Farmers with available manure will generally apply it to any lands they wish to improve and borrow areas are no exception. Many of the benefits of manuring may be duplicated

with a good conservation tillage program where crop residues are left at the surface. Manures can also provide a mulching effect but other materials can serve equally well where mulch is needed.

5. Tile drainage appeared to improve the support for harvest equipment where the drains were placed deeper than 2 feet. There was no yield advantage from tile drains that could be measured at the one site where they were installed. Many of the problems of drainage could be solved by proper design of a surface drainage system. In fact, the greatest difficulty in conducting this research was poor surface drainage at the Buchanan and Lee County sites. In Buchanan County, sand lenses and channels came to the surface in some plots and seeps were a problem. At the Lee County site, the contractor had a limited area in which to work and the construction of research plots further restricted the finishing of the borrow area. The best recommendation to provide drainage at borrow areas is to develop a drainage plan and carry it out according to specification. This will eliminate ponded water and safely carry away excess precipitation with minimal erosion hazard.

A conclusion concerning productivity may also be drawn from this research. Yields were greatly reduced if row crop production was initiated immediately after reclamation without the benefit of a winter's freezing and thawing. After a period of one or two years, yields from reclaimed borrow areas may equal county wide yields if at least 6 inches of topsoil were restored to glacial till sites. At coarse-textured or loess sites, topsoil may not be necessary to achieve county yield averages.

APPENDIX

In this experiment, the significance of a treatment effect was tested by analysis of variance procedures (ANOVA). The procedure consists of six steps:

1. Outline the ANOVA table for the experiment by listing the sources of variation and degrees of freedom.
2. Compute the sum of squares and mean square for variates.
3. Compute the total sum of squares.
4. Compute the sum of squares and mean square for the error.
5. Calculate F ratio for variates.
6. Look up F values for the levels of significance chosen for the experiment (usually at the 0.05 and 0.01 levels are used).

To outline the ANOVA table, the treatments, replications and experimental design must be known. The borrow area experiment had the following treatments:

1. Alfalfa (2 levels) - 2 years growth and none
2. Topsoil depth (3 levels) - 0, 6, and 12 inches
3. Subsoil tillage (2 levels) - none and tilled
4. Manure application (2 levels) - none and 10 tons/A.

Three replications were used at each of the borrow area research sites. The experimental design was a split-split-split plot. Alfalfa treatments were assigned to main plots which consisted of one-half of each replication growing alfalfa for 2 years or growing row crops immediately after restoration. Each of the two halves of the main plot were divided into 3 split main plots which received 0, 6, or 12 inches of topsoil. The split main plots were divided again to yield split-split main plots and subsoil tillage treatments were assigned to the new divisions. Finally, manure treatments were randomly assigned within each split-split main plot. This ANOVA was used in the third year of the experiment after row crops were harvested from the alfalfa treated main plots. The ANOVA process did not include different counties, years, or crops. This was justified because each county was selected to represent a unique soil material. Similarly, corn and soybean are different crops and many comparisons of their yields would be meaningless. Finally, each year's crop yield data reflected the soil and climatological condition prevailing during that growing season.

The ANOVA table had the following form:

Source of variation	Degrees of freedom
Total	71
Main Plots (alfalfa treatments-A)	5
Replications (R)	2
A	1
R * A (Error A)	2
Split main plots (Topsoil treatments-%)	12
T	2
T * A	2
R * T + R(T * A) (Error B)	8
Split-split main plots (subsoil tillage treatments - S)	18
S	1
S * T	2
S * A	1
S * T * A	2
R * S + R(S * T) + R(S * A) + R(S * T * A) (Error C)	12
M - manure treatments	1
M * S	1
M * T	2
M * A	1
M * S * T	2
M * S * A	1
M * T * A	2
M * S * T * A	2
R * M + R(M * S) + R(M * T) + R(M * A) + R(M * S * T) + R(M * S * A) + R(M * T * A) + R(M * S * T * A) (Error D)	24

The appearance of the ANOVA is a systematic presentation of variates and their interactions arranged according to the experimental design. Computation of sum of squares and mean squares is the next step in the ANOVA process. At this point of the ANOVA process, a computer generally is used to complete the necessary calculations. It is important to note that mean squares for variates or error terms are obtained by dividing the sum of squares by the degrees of freedom given for the term. Therefore, the greater the degrees of freedom, the smaller will be the mean square.

Calculation of the F ratio is needed for the F test. The F test is defined as a ratio between two variances and is used to determine whether two independent estimates of variance can be assumed to be estimates of the same variance. In the ANOVA table, an F ratio is calculated by dividing the mean square of the variate by the mean square of the appropriate error term. Therefore, F ratio of the alfalfa treatment, A, is obtained by dividing its mean square by the mean square by the mean square of error A. The F test is completed by using an F-table where numerical values of F ratios at different probability levels are given. Degrees of freedom for the numerator mean square and demoninator mean square are used to locate the specific F ratio value which must be exceeded in order for a significant response to have occurred.

The process of F testing is carried out using the appropriate error term. In the above example, error A tested the alfalfa variate; error B can be used to test the topsoil variate and the interaction of topsoil with alfalfa treatment; error C can be used to test the subsoil tillage variate and its interactions with the topsoil and alfalfa variates; and error D can be used to test the manure variate and its interactions.

After significance of variate effects are tested, a second test may be used to determine if means from different levels of a variate are significantly different from one another. This is accomplished using the least significant difference to test for significant differences (LSD) among treatment means. In this experiment, LSD's were used to determine if the mean yield of corn or soybeans grown on various depths of topsoil were different. Calculation of an LSD was based on using the error mean square which also was in the denominator that yielded the F ratio. The calculation of LSD's is given in many statistical references.

Table 1. Audubon County climatological record.[1/]

	Temperature						Precipitation					
	Total			Departure from normal			Total			Departure from normal		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
	degrees Fahrenheit						inches					
January	10.9	7.3	22.5	-8.3	-11.3	3.3	.24	1.53	.96	- .74	.55	.02
February	14.8	13.1	21.7	-9.4	-11.1	- 2.5	1.19	.43	.41	.12	- .64	- .66
March	33.4	33.5	34.0	- .2	- .1	.4	.80	4.88	.84	-1.32	2.76	-1.28
April	49.9	46.4	51.7	.5	- 3.0	2.3	4.84	3.28	.90	1.71	.15	-2.23
May	60.6	59.9	62.1	.1	- .6	1.6	2.82	2.56	3.07	-1.51	-1.77	-1.26
June	71.8	70.4	71.5	2.3	.9	2.0	1.65	3.26	4.07	-3.53	-1.92	-1.11
July	75.3	73.6	78.7	1.0	- .7	4.4	4.90	7.71	1.98	.98	3.79	-1.94
August	73.9	72.8	75.3	1.2	.1	2.6	2.69	2.34	7.22	-1.72	-2.07	2.81
September	69.8	66.3	67.1	6.6	3.1	3.9	9.05	1.27	.34	5.91	-1.87	-2.80
October	52.5	53.0	50.3	-1.0	- .5	-3.2	.87	3.61	1.61	-1.14	1.60	- .40
November	36.2	36.1	41.0	- .6	- .7	4.2	1.92	1.84	.15	.70	.62	-1.07
December	21.0	30.9	26.2	-3.5	6.4	1.7	1.07	.13	.45	.08	- .86	- .54
ANNUAL	47.5	46.9	50.2	-1.0	- 1.6	1.7	32.04	32.84	22.00	- .46	.34	-10.50

[1/] Climatological Data, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, NC.

Table 2. Buchanan County climatological record.[1/]

	Temperature						Precipitation					
	Total			Departure from normal			Total			Departure from normal		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
	degrees Fahrenheit						inches					
January	5.8	3.3	19.0	-11.8	-14.3	1.4	.49	1.66	1.56	- .51	.66	.56
February	8.4	7.9	16.3	-13.6	-14.1	-5.7	.25	.51	.53	- .65	- .39	- .37
March	27.3	29.6	28.2	- 5.3	- 3.0	-4.4	.31	1.90	.70	-1.93	- .34	-1.54
April	46.3	43.1	47.3	- 1.8	- 5.0	- .8	4.94	3.18	1.09	1.90	.14	-1.95
May	58.4	57.5	60.6	- .8	- 1.7	1.4	3.26	2.89	6.05	- .97	-1.34	1.82
June	68.2	67.2	68.1	- .3	- 1.3	- .4	5.28	4.29	7.52	- .28	-1.27	1.96
July	70.3	69.8	73.0	- 2.2	- 2.7	.5	4.86	4.57	2.77	.90	.61	-1.19
August	68.0	67.0	71.2	- 2.9	- 3.9	.3	1.76	11.06	8.42	-1.97	7.33	4.69
September	66.4	60.8	62.8	4.3	- 1.3	.7	3.64	.58	4.42	- .47	-3.53	.31
October	47.9	49.8	45.7	- 4.2	- 2.3	-6.4	2.35	2.84	1.72	.03	.52	- .60
November	35.2	34.3	37.0	- 1.1	- 2.0	.7	3.46	1.20	.69	1.84	- .42	- .93
December	18.0	26.9	22.7	- 5.0	3.9	- .3	.59	.58	.45	- .65	- .66	- .79
ANNUAL	43.4	43.1	46.0	- 3.7	- 4.0	-1.1	31.19	35.26	35.92	-2.76	1.31	1.97

[1/] Climatological Data, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, NC.

Table 3. Hamilton County climatological record.[1/]

	Temperature						Precipitation					
	Total			Departure from normal			Total			Departure from normal		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
	degrees Fahrenheit						inches					
January	4.5	20.6	22.8	-12.9	3.2	5.4	1.06	1.09	T	.30	.32	- .76
February	10.3	19.0	27.8	-11.3	-3.2	5.6	.32	.52	.85	- .60	- .40	- .07
Marcy	30.9	32.2	40.2	- 1.7	- .4	7.6	3.39	.62	.49	1.49	-1.28	-1.41
April	44.3	49.9	53.2	- 4.2	1.4	4.7	3.06	1.10	2.08	.27	-1.69	- .71
May	58.8	61.8	57.7	- 1.2	1.8	-2.3	3.17	1.83	3.00	- .91	-2.25	-1.08
June	69.0	69.9	70.7	- .1	.8	1.6	3.38	4.26	5.94	-1.55	- .67	1.01
July	72.3	77.1	74.3	- .9	3.9	1.1	6.41	2.04	3.33	2.41	-1.96	- .67
August	71.1	73.1	69.9	- .5	1.5	-1.7	9.00	5.58	5.47	5.63	2.21	2.10
September	64.4	65.3	62.6	1.8	2.7	0.0	1.19	1.92	4.80	-1.47	- .72	2.14
October	51.3	48.4	49.0	- 1.3	-4.2	-3.6	2.96	1.67	2.73	.97	- .32	.74
November	34.9	39.2		- .9	3.4		2.27	.25		1.15	- .87	
December	28.6	23.8		5.6	.8		.40	.48		- .53	- .45	
ANNUAL	45.0	48.4		-2.4	1.0		36.61	21.35		7.16	-8.10	

[1/] Climatological Data, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, NC.

Table 4. Lee County climatological record.[1/]

	Temperature						Precipitation					
	Total			Departure from normal			Total			Departure from normal		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
	degrees Fahrenheit						inches					
January	12.2	27.5	28.1	-13.6	1.7	2.3	2.44	.74	.09	.78	- .92	-1.57
February	18.9	24.1	33.1	-11.2	-6.0	3.0	.67	1.09	.79	- .65	- .23	- .53
March	41.0	37.7	43.6	1.6	-1.7	4.2	4.07	1.87	.83	1.41	- .79	-1.83
April	50.8	52.8	60.9	- 2.4	- .4	7.7	4.25	1.63	5.16	.59	-2.03	1.50
May	64.5	65.9	57.8	.6	2.0	-6.1	2.36	3.28	5.79	-1.16	- .24	2.27
June	74.4	73.1	72.1	1.3	.0	-1.0	2.54	7.55	7.04	-2.00	3.01	2.50
July	76.2	81.9	74.2	- 1.1	4.6	-3.1	4.11	1.90	8.21	- .28	-2.49	3.82
August	76.2	79.1	72.2	.7	3.6	-3.3	2.48	5.93	3.66	- .68	2.77	.50
September	68.7	69.4	64.3	1.4	2.1	-3.0	T	8.76	3.36	-3.68	4.90	- .50
October	57.3	53.4	54.9	- .3	- 4.2	-2.7	2.34	1.52	3.62	- .67	-1.49	.61
November	42.0	43.9		- .4	1.5		2.10	.61		.50	- .99	
December	35.3	31.5		4.9	1.1		1.24	3.07		- .32	1.51	
ANNUAL	51.5	53.4		- 1.5	.4		28.60	37.95		-6.34	3.01	

[1/] Climatological Data, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, NC.

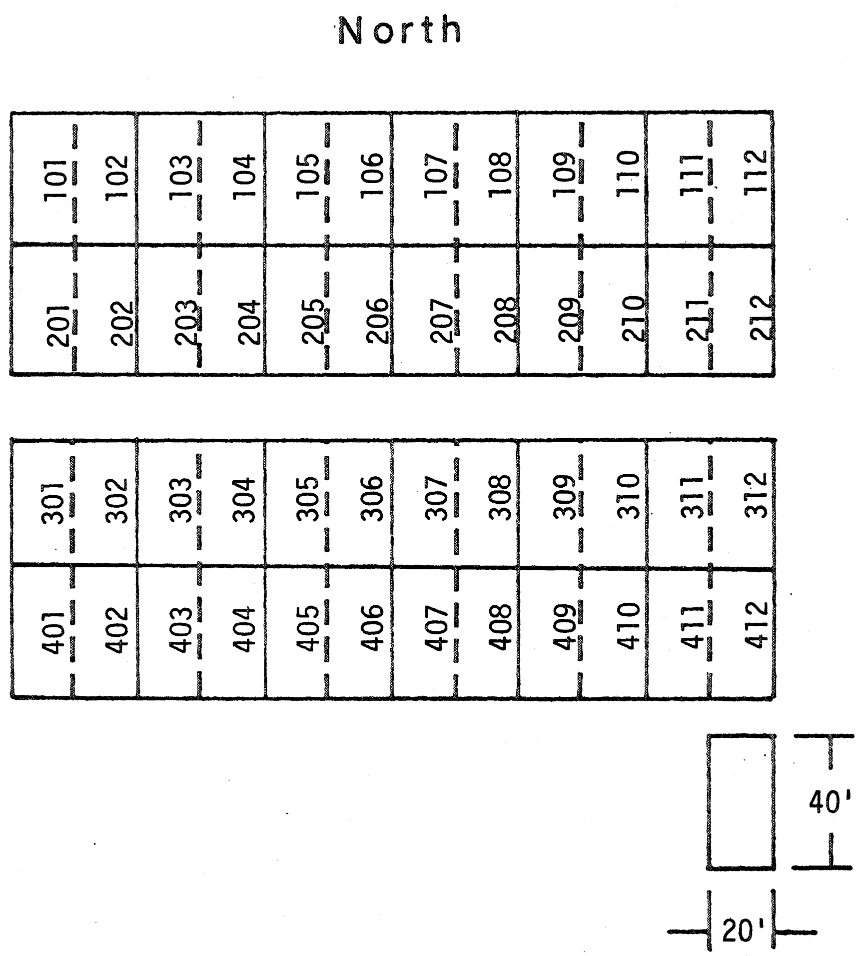

Figure 1. AUDUBON COUNTY BORROW AREA PLOT LAYOUT, HR-186

Audubon County borrow area corn yields, 1978-80.

PLOT	TILLAGE	MANURE	CORN78	CORN79	CORN80
101	2	2	77	0	73
102	1	1	48	0	80
103	2	2	62	0	109
104	1	2	56	0	113
105	1	1	0	146	0
106	2	1	0	155	0
107	2	2	0	131	0
108	1	2	0	136	0
109	1	2	92	0	110
110	2	1	73	0	114
111	1	1	0	102	0
112	2	1	0	129	0
201	2	1	64	0	100
202	1	2	67	0	93
203	2	1	52	0	102
204	1	1	26	0	102
205	1	2	0	169	0
206	2	2	0	166	0
207	2	1	0	144	0
208	1	1	0	151	0
209	1	1	59	0	108
210	2	2	73	0	112
211	1	2	0	115	0
212	2	2	0	155	0

Audubon County borrow area soybean yields, 1978-80.

PLOT	TILLAGE	MANURE	BEANS78	BEANS79	BEANS80
101	2	2	0	58	.
102	1	1	0	56	.
103	2	2	0	58	.
104	1	2	0	57	.
105	1	1	39	0	40
106	2	1	32	0	41
107	2	2	43	0	43
108	1	2	39	0	37
109	1	2	0	50	0
110	2	1	0	51	0
111	1	1	42	0	28
112	2	1	29	0	26
201	2	1	0	55	0
202	1	2	0	57	0
203	2	1	0	53	0
204	1	1	0	57	0
205	1	2	39	0	38
206	2	2	35	0	50
207	2	1	42	0	43
208	1	1	41	0	38
209	1	1	0	49	0
210	2	2	0	45	0
211	1	2	39	0	27
212	2	2	36	0	27

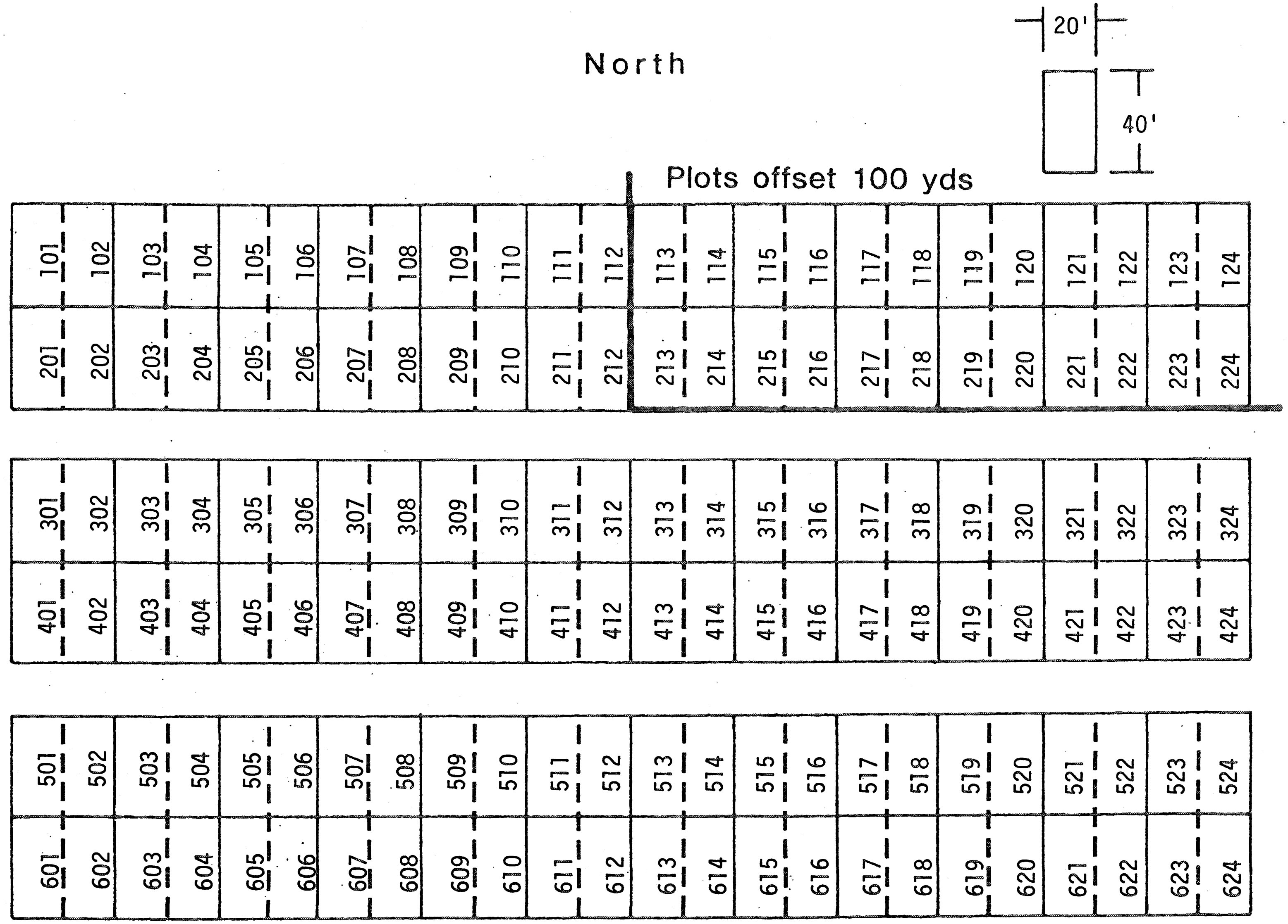

Figure 2. BUCHANAN COUNTY BORROW AREA PLOT LAYOUT, HR-186

Buchanan County borrow area corn yields, 1978-80.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	CORN78	CORN79	CORN80
101	2	3	2	2	0	0	0
102	2	3	1	1	0	0	0
103	2	1	2	1	0	0	0
104	2	1	1	1	0	0	0
105	2	2	1	2	0	0	0
106	2	2	2	2	0	0	0
107	1	3	2	1	1	0	26
108	1	3	1	2	26	0	6
109	1	2	1	2	24	0	23
110	1	2	2	2	24	0	18
111	1	1	1	1	6	0	44
112	1	1	2	1	3	0	34
113	2	3	2	2	0	0	0
114	2	3	1	1	0	0	0
115	2	2	2	2	0	0	0
116	2	2	1	2	0	0	0
117	2	1	1	2	0	0	0
118	2	1	2	1	0	0	0
119	2	3	1	2	0	0	37
120	2	3	2	2	0	0	39
121	2	1	1	1	0	0	31
122	2	1	2	2	0	0	33
123	2	2	2	2	0	0	30
124	2	2	1	2	0	0	27
201	2	3	2	1	0	0	0
202	2	3	1	2	0	0	0
203	2	1	2	2	0	0	0
204	2	1	1	2	0	0	0
205	2	2	1	1	0	0	0
206	2	2	2	1	0	0	0
207	1	3	2	2	26	0	17
208	1	3	1	1	21	0	17
209	1	2	1	1	38	0	24
210	1	2	2	1	25	0	20
211	1	1	1	2	52	0	64
212	1	1	2	2	32	0	34
213	2	3	2	1	0	0	0
214	2	3	1	2	0	0	0
215	2	2	2	1	0	0	0
216	2	2	1	1	0	0	0
217	2	1	1	1	0	0	0
218	2	1	2	2	0	0	0
219	2	3	1	1	0	0	36
220	2	3	2	1	0	0	42
221	2	1	1	2	0	0	40
222	2	1	2	1	0	0	50
223	2	2	2	1	0	0	58
224	2	2	1	1	0	0	39
301	1	3	1	2	0	126	0
302	1	3	2	2	0	83	0
303	1	1	2	1	0	124	0
304	1	1	1	2	0	118	0
305	1	2	1	2	0	87	0
306	1	2	2	2	0	150	0
307	2	3	1	2	0	0	52
308	2	3	2	1	0	0	47
309	2	2	2	2	0	0	30
310	2	2	1	2	0	0	19
311	2	1	2	1	0	0	52
312	2	1	1	1	0	0	36
313	2	3	1	1	0	0	0
314	2	3	2	1	0	0	0
315	2	2	2	2	0	0	0
316	2	2	1	2	0	0	0
317	2	1	2	2	0	0	0
318	2	1	1	2	0	0	0
319	2	3	2	1	0	69	0
320	1	3	1	2	0	107	0
321	1	1	1	1	0	146	0
322	1	1	2	2	0	156	0
323	1	2	2	1	0	122	0
324	1	2	1	1	0	152	0

Buchanan County borrow area corn yields, 1978-80 (continued)

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	CORN78	CORN79	CORN80
401	1	3	1	1	0	134	0
402	1	3	2	1	0	117	0
403	1	1	2	2	0	119	0
404	1	1	1	1	0	109	0
405	1	2	1	1	0	87	0
406	1	2	2	1	0	109	0
407	2	3	1	1	0	0	55
408	2	3	2	2	0	0	42
409	2	2	2	1	0	0	11
410	2	2	1	1	0	0	21
411	2	1	2	2	0	0	47
412	2	1	1	2	0	0	36
413	2	3	1	2	0	0	0
414	2	3	2	2	0	0	0
415	2	2	2	1	0	0	0
416	2	2	1	1	0	0	0
417	2	1	2	1	0	0	0
418	2	1	1	1	0	0	0
419	1	3	2	2	0	103	0
420	1	3	1	1	0	138	0
421	1	1	1	2	0	135	0
422	1	1	2	1	0	130	0
423	1	2	2	2	0	132	0
424	0	2	1	2	0	146	0
501	1	3	2	1	57	0	54
502	1	3	1	1	27	0	38
503	1	1	1	2	91	0	65
504	1	1	2	2	95	0	62
505	1	2	2	2	13	0	25
506	1	2	1	1	18	0	42
507	1	3	2	1	0	152	0
508	1	3	1	1	0	170	0
509	1	2	1	2	0	161	0
510	1	2	2	1	0	162	0
511	1	1	2	2	0	163	0
512	1	1	1	1	0	121	0
513	1	3	1	1	18	0	10
514	1	3	2	2	66	0	0
515	1	2	1	1	15	0	7
516	1	2	2	1	29	0	6
517	1	1	1	1	30	0	8
518	1	1	2	2	57	0	15
519	2	3	2	1	0	0	18
520	2	3	1	2	0	0	14
521	2	1	2	1	0	0	19
522	2	1	1	1	0	0	40
523	2	2	2	2	0	0	14
524	2	2	1	2	0	0	14
601	1	3	2	2	59	0	36
602	1	3	1	2	41	0	12
603	1	1	1	1	71	0	48
604	1	1	2	1	88	0	54
605	1	2	2	1	30	0	21
606	1	2	1	2	42	0	26
607	1	3	2	2	0	142	0
608	1	3	1	2	0	155	0
609	1	2	1	1	0	165	0
610	1	2	2	2	0	161	0
611	1	1	2	1	0	187	0
612	1	1	1	2	0	140	0
613	1	3	1	2	33	0	30
614	1	3	2	1	14	0	3
615	1	2	1	2	10	0	0
616	1	2	2	2	21	0	0
617	1	1	1	2	56	0	0
618	1	1	2	1	59	0	0
619	2	3	2	2	0	0	17
620	2	3	1	1	0	0	26
621	2	1	2	2	0	0	57
622	2	1	1	2	0	0	55
623	2	2	2	1	0	0	19
624	2	2	1	1	0	0	8

Buchanan County borrow area soybean and hay yields, 1978-80

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	BEANS78	BEANS79	BEANS80	HAY79
101	2	3	2	2	0	0	0	0.00
102	2	3	1	1	0	0	0	0.30
103	2	1	2	1	0	0	0	0.90
104	2	1	1	1	0	0	0	0.75
105	2	2	1	2	0	0	0	0.00
106	2	2	2	2	0	0	0	0.00
107	1	3	2	1	0	41	0	0.00
108	1	3	1	2	0	45	0	0.00
109	1	2	1	2	0	46	0	0.00
110	1	2	2	2	0	45	0	0.00
111	1	1	1	1	0	33	0	0.00
112	1	1	2	1	0	32	0	0.00
113	2	3	2	2	0	0	0	0.00
114	2	3	1	1	0	0	0	0.00
115	2	2	2	2	0	0	0	1.13
116	2	2	1	2	0	0	0	1.37
117	2	1	1	2	0	0	0	0.69
118	2	1	2	1	0	0	0	0.00
119	2	3	1	2	0	0	0	1.27
120	2	3	2	2	0	0	0	1.49
121	2	1	1	1	0	0	0	0.67
122	2	1	2	2	0	0	0	1.05
123	2	2	2	2	0	0	0	0.00
124	2	2	1	2	0	0	0	0.00
201	2	3	2	1	0	0	0	0.00
202	2	3	1	2	0	0	0	0.86
203	2	1	2	2	0	0	0	1.05
204	2	1	1	2	0	0	0	1.49
205	2	2	1	1	0	0	0	0.00
206	2	2	2	1	0	0	0	0.00
207	1	3	2	2	0	44	0	0.00
208	1	3	1	1	0	44	0	0.00
209	1	2	1	1	0	46	0	0.00
210	1	2	2	1	0	47	0	0.00
211	1	1	1	2	0	38	0	0.00
212	1	1	2	2	0	37	0	0.00
213	2	3	2	1	0	0	0	0.00
214	2	3	1	2	0	0	0	0.00
215	2	2	2	1	0	0	0	1.27
216	2	2	1	1	0	0	0	0.97
217	2	1	1	1	0	0	0	0.00
218	2	1	2	2	0	0	0	0.00
219	2	3	1	1	0	0	0	1.27
220	2	3	2	1	0	0	0	1.63
221	2	1	1	2	0	0	0	1.63
222	2	1	2	1	0	0	0	0.53
223	2	2	2	1	0	0	0	0.00
224	2	2	1	1	0	0	0	0.00
301	1	3	1	2	18	0	29	0.00
302	1	3	2	2	24	0	31	0.00
303	1	1	2	1	29	0	28	0.00
304	1	1	1	2	19	0	22	0.00
305	1	2	1	2	18	0	16	0.00
306	1	2	2	2	15	0	14	0.00
307	2	3	1	2	0	0	0	0.00

Buchanan County borrow area soybean and hay yields, 1978-80 (continued)

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	BEANS78	BEANS79	BEANS80	HAY79
308	2	3	2	1	0	0	0	0.35
309	2	2	2	2	0	0	0	1.02
310	2	2	1	2	0	0	0	0.95
311	2	1	2	1	0	0	0	1.05
312	2	1	1	1	0	0	0	1.62
313	2	3	1	1	0	0	0	0.55
314	2	3	2	1	0	0	0	0.69
315	2	2	2	2	0	0	0	0.73
316	2	2	1	2	0	0	0	0.91
317	2	1	2	2	0	0	0	1.05
318	2	1	1	2	0	0	0	0.72
319	2	3	2	1	15	0	0	0.00
320	1	3	1	2	9	0	23	0.00
321	1	1	1	1	17	0	22	0.00
322	1	1	2	2	25	0	13	0.00
323	1	2	2	1	15	0	15	0.00
324	1	2	1	1	9	0	24	0.00
401	1	3	1	1	22	0	27	0.00
402	1	3	2	1	20	0	23	0.00
403	1	1	2	2	18	0	25	0.00
404	1	1	1	1	16	0	32	0.00
405	1	2	1	1	15	0	23	0.00
406	1	2	2	1	17	0	19	0.00
407	2	3	1	1	0	0	0	0.00
408	2	3	2	2	0	0	0	1.62
409	2	2	2	1	0	0	0	0.39
410	2	2	1	1	0	0	0	0.77
411	2	1	2	2	0	0	0	0.83
412	2	1	1	2	0	0	0	1.49
413	2	3	1	2	0	0	0	0.77
414	2	3	2	2	0	0	0	0.66
415	2	2	2	1	0	0	0	0.50
416	2	2	1	1	0	0	0	0.75
417	2	1	2	1	0	0	0	0.48
418	2	1	1	1	0	0	0	0.58
419	1	3	2	2	14	0	0	0.00
420	1	3	1	1	10	0	20	0.00
421	1	1	1	2	10	0	0	0.00
422	1	1	2	1	16	0	15	0.00
423	1	2	2	2	13	0	13	0.00
424	0	2	1	2	9	0	17	0.00
501	1	3	2	1	0	45	0	0.00
502	1	3	1	1	0	46	0	0.00
503	1	1	1	2	0	51	0	0.00
504	1	1	2	2	0	51	0	0.00
505	1	2	2	2	0	44	0	0.00
506	1	2	1	1	0	31	0	0.00
507	1	3	2	1	16	0	16	0.00
508	1	3	1	1	16	0	21	0.00
509	1	2	1	2	12	0	16	0.00
510	1	2	2	1	13	0	16	0.00
511	1	1	2	2	18	0	20	0.00
512	1	1	1	1	17	0	31	0.00
513	1	3	1	1	0	42	0	0.00
514	1	3	2	2	0	50	0	0.00

Buchanan County borrow area soybean and hay yields, 1978-80 (continued)

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	BEANS78	BEANS79	BEANS80	HAY79
515	1	2	1	1	0	38	0	0.00
516	1	2	2	1	0	57	0	0.00
517	1	1	1	1	0	31	0	0.00
518	1	1	2	2	0	34	0	0.00
519	2	3	2	1	0	0	0	0.00
520	2	3	1	2	0	0	0	1.62
521	2	1	2	1	0	0	0	1.16
522	2	1	1	1	0	0	0	1.13
523	2	2	2	2	0	0	0	0.00
524	2	2	1	2	0	0	0	0.00
601	1	3	2	2	0	43	0	0.00
602	1	3	1	2	0	36	0	0.00
603	1	1	1	1	0	39	0	0.00
604	1	1	2	1	0	47	0	0.00
605	1	2	2	1	0	44	0	0.00
606	1	2	1	2	0	38	0	0.00
607	1	3	2	2	19	0	17	0.00
608	1	3	1	2	12	0	19	0.00
609	1	2	1	1	23	0	18	0.00
610	1	2	2	2	23	0	26	0.00
611	1	1	2	1	20	0	23	0.00
612	1	1	1	2	24	0	20	0.00
613	1	3	1	2	0	46	0	0.00
614	1	3	2	1	0	46	0	0.00
615	1	2	1	2	0	50	0	0.00
616	1	2	2	2	0	49	0	0.00
617	1	1	1	2	0	38	0	0.00
618	1	1	2	1	0	28	0	0.00
619	2	3	2	2	0	0	0	0.00
620	2	3	1	1	0	0	0	0.83
621	2	1	2	2	0	0	0	2.43
622	2	1	1	2	0	0	0	2.73
623	2	2	2	1	0	0	0	0.00
624	2	2	1	1	0	0	0	0.00

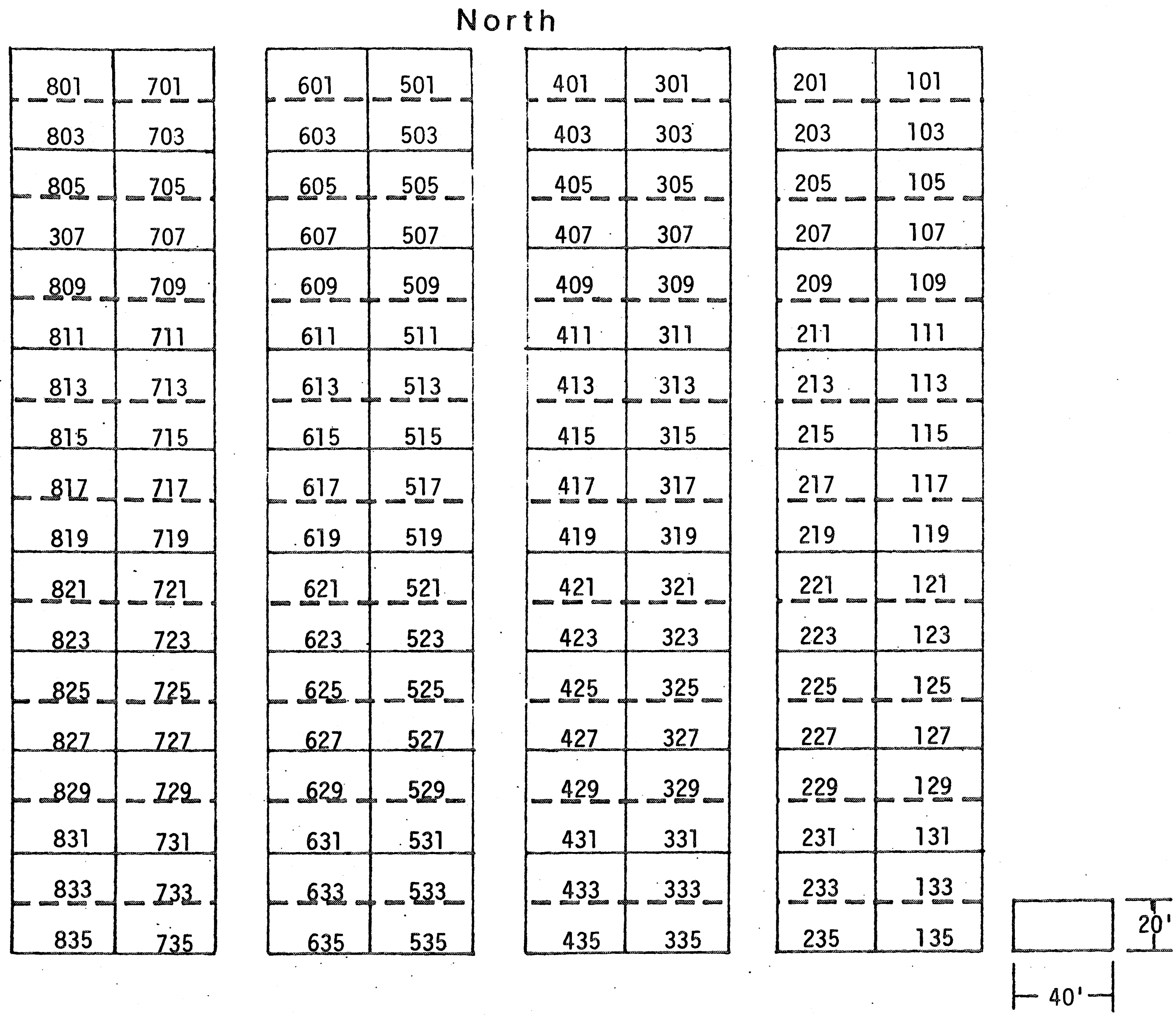

Figure 3. HAMILTON COUNTY BORROW AREA PLOT LAYOUT, HR-186

Hamilton County borrow area corn yields, 1979-80.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD79	YIELD80
113	1	3	2	1	116	
115	1	3	1	1	103	
117	1	1	1	2	80	
119	1	1	2	1	84	
121	1	2	2	2	149	
123	1	2	1	1	125	
125	1	2	1	2		83
127	1	2	2	1		91
129	1	3	2	1		57
131	1	3	1	1		52
133	1	1	2	1		78
135	1	1	1	1		78
213	1	3	2	2	128	
215	1	3	1	2	149	
217	1	1	1	1	86	
219	1	1	2	2	75	
221	1	2	2	1	141	
223	1	2	1	2	131	
225	1	2	1	1		85
227	1	2	2	2		92
229	1	3	2	2		62
231	1	3	1	2		50
233	1	1	2	2		82
235	1	1	1	2		72
301	1	1	2	2	95	
303	1	1	1	1	85	
305	1	2	2	2	146	
307	1	2	1	1	136	
309	1	3	2	1	84	
311	1	3	1	2	124	
325	1	2	1	1	118	
327	1	2	2	2	156	
329	1	3	1	2	153	
331	1	3	2	2	120	
333	1	1	1	1	71	
335	1	1	2	2	61	
401	1	1	2	1	72	
403	1	1	1	2	77	
405	1	2	2	1	116	
407	1	2	1	2	132	
409	1	3	2	2	117	
411	1	3	1	1	137	
425	1	2	1	2	141	
427	1	2	2	1	146	
429	1	3	1	1	143	
431	1	3	2	1	123	
433	1	1	1	2	69	
435	1	1	2	1	53	
513	1	3	1	2		85
515	1	3	2	1		75
517	1	1	2	2		92
519	1	1	1	2		39
521	1	2	1	2		92
523	1	2	2	2		83
613	1	3	1	1		87
615	1	3	2	2		76
617	1	1	2	1		65
619	1	1	1	1		76
621	1	2	1	1		67
623	1	2	2	1		72
701	1	1	1	1		93
703	1	1	2	1		92
705	1	2	2	2		78
707	1	2	1	2		67
709	1	3	2	2		97
711	1	3	1	2		84
801	1	1	1	2		47
803	1	1	2	2		88
805	1	2	2	1		94
807	1	2	1	1		67
809	1	3	2	1		78
811	1	3	1	1		80

Hamilton County borrow area soybean yields, 1979

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD79
125	1	2	1	2	36
127	1	2	2	1	31
129	1	3	2	1	38
131	1	3	1	1	29
133	1	1	2	1	14
135	1	1	1	1	16
225	1	2	1	1	37
227	1	2	2	2	34
229	1	3	2	2	37
231	1	3	1	2	47
233	1	1	2	2	20
235	1	1	1	2	17
513	1	3	1	2	44
515	1	3	2	1	45
517	1	1	2	2	19
519	1	1	1	2	11
521	1	2	1	2	46
523	1	2	2	2	46
613	1	3	1	1	39
615	1	3	2	2	45
617	1	1	2	1	22
619	1	1	1	1	18
621	1	2	1	1	48
623	1	2	2	1	40
701	1	1	1	1	.
703	1	1	2	1	24
705	1	2	2	2	52
707	1	2	1	2	17
709	1	3	2	2	45
711	1	3	1	2	35
801	1	1	1	2	24
803	1	1	2	2	29
805	1	2	2	1	55
807	1	2	1	1	24
809	1	3	2	1	44
811	1	3	1	1	40

Hamilton County borrow area soybean yields, 1980.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	Yield 80
113	1	3	2	1	31
115	1	3	1	1	38
117	1	1	1	2	18
119	1	1	2	1	17
121	1	2	2	2	34
123	1	2	1	1	40
213	1	3	2	2	24
215	1	3	1	2	40
217	1	1	1	1	14
219	1	1	2	2	13
221	1	2	2	1	27
223	1	2	1	2	34
301	1	1	2	2	20
303	1	1	1	1	14
305	1	2	2	2	36
307	1	2	1	1	37
309	1	3	2	1	30
311	1	3	1	2	27
325	1	2	1	1	33
327	1	2	2	2	26
329	1	3	1	2	23
331	1	3	2	2	31
333	1	1	1	1	13
335	1	1	2	2	11
401	1	1	2	1	18
403	1	1	1	2	19
405	1	2	2	1	28
407	1	2	1	2	36
409	1	3	2	2	30
411	1	3	1	1	13
425	1	2	1	2	28
427	1	2	2	1	24
429	1	3	1	1	34
431	1	3	2	1	28
433	1	1	1	2	15
435	1	1	2	1	11

Hamilton County borrow area alfalfa hay yields, 1980.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD80
101	2	1	1	2	4.65
103	2	1	2	2	4.39
105	2	2	2	1	4.00
107	2	2	1	1	4.39
109	2	3	1	1	5.22
111	2	3	2	1	4.88
201	2	1	1	1	3.81
203	2	1	2	1	3.58
205	2	2	2	2	3.58
207	2	2	1	2	4.48
209	2	3	1	2	4.44
211	2	3	2	2	4.27
313	2	3	1	1	4.97
315	2	3	2	2	5.49
317	2	1	1	2	3.20
319	2	1	2	2	4.91
321	2	2	1	2	5.23
323	2	2	2	2	4.16
413	2	3	1	2	4.14
415	2	3	2	1	4.04
417	2	1	1	1	3.73
419	2	1	2	1	4.04
421	2	2	1	1	4.00
423	2	2	2	1	3.87
501	2	1	1	1	3.58
503	2	1	2	2	3.73
505	2	2	2	2	4.53
507	2	2	1	1	4.30
509	2	3	1	2	4.57
511	2	3	2	1	2.10
525	2	2	1	2	3.60
527	2	2	2	1	3.96
529	2	3	1	1	4.77
531	2	3	2	2	4.70
533	2	1	1	1	3.88
535	2	1	2	2	3.50
601	2	1	1	2	4.69
603	2	1	2	1	3.93
605	2	2	2	1	4.22
607	2	2	1	2	4.39
609	2	3	1	1	3.45
611	2	3	2	2	2.40
625	2	2	1	1	4.31
627	2	2	2	2	3.59
629	2	3	1	2	4.20
631	2	3	2	1	4.28
633	2	1	1	2	3.30
635	2	1	2	1	3.82
713	2	3	1	1	4.09
715	2	3	2	2	4.54
717	2	1	1	2	4.38
719	2	1	2	2	4.04
721	2	2	1	2	6.41
723	2	2	2	1	4.42
725	2	2	1	1	4.85
727	2	2	2	2	4.56
729	2	3	1	2	4.81
731	2	3	2	1	4.43
733	2	1	2	2	3.80
735	2	1	1	2	3.67
813	2	3	1	2	3.86
815	2	3	2	1	5.12
817	2	1	1	1	4.66
819	2	1	2	1	3.34
821	2	2	1	1	5.07
823	2	2	2	2	4.42
825	2	2	1	2	4.61
827	2	2	2	1	3.90
829	2	3	1	1	6.12
831	2	3	2	2	4.76
833	2	1	2	1	3.68
835	2	1	1	1	3.55

North

801	701	601	501	401	301	201	101
802	702	602	502	402	302	202	102
803	703	603	503	403	303	203	103
804	704	604	504	404	304	204	104
805	705	605	505	405	305	205	105
806	706	606	506	406	306	206	106
807	707	607	507	407	307	207	107
808	708	608	508	408	308	208	108
809	709	609	509	409	309	209	109
810	710	610	510	410	310	210	110
811	711	611	511	411	311	211	111
812	712	612	512	412	312	212	112
813	713	613	513	413	313	213	113
814	714	614	514	414	314	214	114
815	715	615	515	415	315	215	115
816	716	616	516	416	316	216	116
817	717	617	517	417	317	217	117
818	718	618	518	418	318	218	118
819	719	619	519	419	319	219	119
820	720	620	520	420	320	220	120
821	721	621	521	421	321	221	121
822	722	622	522	422	322	222	122
823	723	623	523	423	323	223	123
824	724	624	524	424	324	224	124
825	725	625	525	425	325	225	125
826	726	626	526	426	326	226	126
827	727	627	527	427	327	227	127
828	728	628	528	428	328	228	128
829	729	629	529	429	329	229	129
830	730	630	530	430	330	230	130
831	731	631	531	431	331	231	131
832	732	632	532	432	332	232	132
833	733	633	533	433	333	233	133
834	734	634	534	434	334	234	134
835	735	635	535	435	335	235	135
836	736	636	536	436	336	236	137

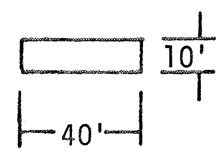

Figure 4. HAMILTON COUNTY BORROW AREA PLOT LAYOUT, HR-186
(Plots divided for phosphorus treatments)

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	PRATE	YIELD81
101	2	1	1	2	2	84.3
102	2	1	1	2	1	95.3
103	2	1	2	2	3	112.2
104	2	1	2	2	1	107.6
105	2	2	2	1	3	106.6
106	2	2	2	1	1	115.8
107	2	2	1	1	2	110.6
108	2	2	1	1	1	100.2
109	2	3	1	1	2	116.6
110	2	3	1	1	1	104.5
111	2	3	2	1	3	114.3
112	2	3	2	1	1	106.8
113	1	3	2	1	1	125.8
114	1	3	2	1	2	104.5
115	1	3	1	1	3	118.9
116	1	3	1	1	1	101.6
117	1	1	1	2	2	90.1
118	1	1	1	2	1	85.5
119	1	1	2	1	3	83.7
120	1	1	2	1	1	99.4
121	1	2	2	2	1	104.8
122	1	2	2	2	2	88.0
123	1	2	1	1	3	90.4
124	1	2	1	1	1	125.7
201	2	1	1	1	1	86.0
202	2	1	1	1	2	85.5
203	2	1	2	1	3	94.8
204	2	1	2	1	1	80.2
205	2	2	2	2	2	89.2
206	2	2	2	2	1	98.5
207	2	2	1	2	3	103.7
208	2	2	1	2	1	107.7
209	2	3	1	2	3	105.6
210	2	3	1	2	1	106.2
210	1	1	2	2	3	79.6
211	2	3	2	2	1	78.5
212	2	3	2	2	2	101.6
213	1	3	2	2	3	118.3
214	1	3	2	2	1	97.5
215	1	3	1	2	2	103.9
216	1	3	1	2	1	92.9
217	1	1	1	1	2	87.8
218	1	1	1	1	1	94.8
219	1	1	2	2	1	84.3
221	1	2	2	1	2	106.0
222	1	2	2	1	1	84.6
223	1	2	1	2	3	88.0
224	1	2	1	2	1	108.3
301	1	1	2	2	1	108.1
302	1	1	2	2	2	102.9
303	1	1	1	1	3	116.9
304	1	1	1	1	1	112.2
305	1	2	2	2	2	110.6
306	1	2	2	2	1	100.2
307	1	2	1	1	1	114.1
308	1	2	1	1	3	117.6
309	1	3	2	1	2	116.0
310	1	3	2	1	1	129.8
311	1	3	1	2	3	116.0
312	1	3	1	2	1	122.9
325	1	2	1	1	1	109.5
326	1	2	1	1	2	112.4
327	1	2	2	2	3	111.2
328	1	2	2	2	1	90.9
329	1	3	1	2	1	131.0
330	1	3	1	2	3	144.3
331	1	3	2	2	1	171.4
332	1	3	2	2	2	157.0
333	1	1	1	1	3	116.9
334	1	1	1	1	1	132.0
335	1	1	2	2	1	115.7
336	1	1	2	2	2	118.0

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	PRATE	YIELD81
401	1	1	2	1	2	98.3
402	1	1	2	1	1	102.9
403	1	1	1	2	3	107.6
404	1	1	1	2	1	100.0
405	1	2	2	1	1	122.8
406	1	2	2	1	2	135.0
407	1	2	1	2	1	118.7
408	1	2	1	2	3	134.4
409	1	3	2	2	2	136.2
410	1	3	2	2	1	146.0
411	1	3	1	1	1	162.2
412	1	3	1	1	3	178.9
425	1	2	1	2	1	110.1
426	1	2	1	2	3	119.9
427	1	2	2	1	1	130.9
428	1	2	2	1	2	148.3
429	1	3	1	1	1	147.7
430	1	3	1	1	3	110.2
431	1	3	2	1	1	136.8
432	1	3	2	1	2	127.0
433	1	1	1	2	2	105.2
434	1	1	1	2	1	114.5
435	1	1	2	1	1	117.4
436	1	1	2	1	3	104.6
501	2	1	1	1	1	100.0
502	2	1	1	1	3	125.6
503	2	1	2	2	2	116.9
504	2	1	2	2	1	125.0
505	2	2	2	2	2	108.3
506	2	2	2	2	1	130.3
507	2	2	1	1	3	129.2
508	2	2	1	1	1	123.4
509	2	3	1	2	1	122.3
510	2	3	1	2	2	132.7
511	2	3	2	1	3	116.0
512	2	3	2	1	1	165.6
601	2	1	1	2	1	109.9
602	2	1	1	2	3	137.2
603	2	1	2	1	2	129.6
604	2	1	2	1	1	122.7
605	2	2	2	1	1	119.3
606	2	2	2	1	3	132.6
607	2	2	1	2	1	141.3
608	2	2	1	2	2	158.1
609	2	3	1	1	3	135.0
610	2	3	1	1	1	129.8
611	2	3	2	2	1	147.2
612	2	3	2	2	2	152.9
713	2	3	1	1	2	124.1
714	2	3	1	1	1	132.2
715	2	3	2	2	1	125.2
716	2	3	2	2	3	140.8
717	2	1	1	2	3	106.4
718	2	1	1	2	1	112.2
719	2	1	2	2	1	105.2
720	2	1	2	2	2	106.4
721	2	2	1	2	1	113.5
722	2	2	1	2	3	97.3
723	2	2	2	1	1	112.4
724	2	2	2	1	2	116.4
813	2	3	1	2	1	135.0
814	2	3	1	2	3	132.7
815	2	3	2	1	1	132.7
816	2	3	2	1	2	117.1
817	2	1	1	1	3	93.6
818	2	1	1	1	1	112.8
819	2	1	2	1	2	129.6
820	2	1	2	1	1	115.1
821	2	2	1	1	3	111.8
822	2	2	1	1	1	112.8
823	2	2	2	2	2	110.6
824	2	2	2	2	1	114.1

Hamilton County borrow area soybean yields, 1981

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	PRATE	YIELD81
125	1	2	1	2	1	23.7
126	1	2	1	2	2	23.8
127	1	2	2	1	3	10.7
128	1	2	2	1	1	20.1
129	1	3	2	1	2	25.1
130	1	3	2	1	1	31.9
131	1	3	1	1	3	26.9
132	1	3	1	1	1	24.0
133	1	1	2	1	1	3.9
134	1	1	2	1	2	3.9
135	1	1	1	1	1	6.4
136	1	1	1	1	3	3.0
225	1	2	1	1	3	21.8
226	1	2	1	1	1	16.0
227	1	2	2	2	2	18.7
228	1	2	2	2	1	21.6
229	1	3	2	2	1	29.1
230	1	3	2	2	2	32.3
231	1	3	1	2	1	26.6
232	1	3	1	2	3	23.4
233	1	1	2	2	2	9.5
234	1	1	2	2	1	12.0
235	1	1	1	2	3	10.6
236	1	1	1	2	1	9.8
313	2	3	1	1	2	39.7
314	2	3	1	1	1	52.5
315	2	3	2	2	3	51.5
316	2	3	2	2	1	52.2
317	2	1	1	2	2	25.1
318	2	1	1	2	1	27.2
319	2	1	2	2	3	30.9
320	2	1	2	2	1	37.0
321	2	2	1	2	2	42.4
322	2	2	1	2	1	24.6
323	2	2	2	2	3	51.3
324	2	2	2	2	1	44.9
413	2	3	1	2	2	30.7
414	2	3	1	2	1	32.5
415	2	3	2	1	1	45.4
416	2	3	2	1	3	50.5
417	2	1	1	1	1	22.5
418	2	1	1	1	3	14.0
419	2	1	2	1	2	26.4
420	2	1	2	1	1	27.4
421	2	2	1	1	1	34.3
422	2	2	1	1	3	44.6
423	2	2	2	1	1	44.3
424	2	2	2	1	2	39.1
513	1	3	1	2	2	25.2
514	1	3	1	2	1	32.7
515	1	3	2	1	3	26.5
516	1	3	2	1	1	35.7
517	1	1	2	2	3	9.1
518	1	1	2	2	1	5.8
519	1	1	1	2	2	7.0
520	1	1	1	2	1	3.6
521	1	2	1	2	3	.
522	1	2	1	2	1	22.9
523	1	2	2	2	2	29.0
524	1	2	2	2	1	28.4
525	2	2	1	2	1	5.1
526	2	2	1	2	2	29.2
527	2	2	2	1	3	31.4
528	2	2	2	1	1	33.6
529	2	3	1	1	3	35.8
530	2	3	1	1	1	43.2
531	2	3	2	2	1	37.4
532	2	3	2	2	2	39.1
533	2	1	1	1	2	26.7
534	2	1	1	1	1	23.2
535	2	1	2	2	1	21.4
536	2	1	2	2	3	32.0

Hamilton County borrow area soybean yields, 1981 (continued)

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	PRATE	YIELD81
613	1	3	1	1	1	19.5
614	1	3	1	1	3	42.6
615	1	3	2	2	2	42.6
616	1	3	2	2	1	41.4
617	1	1	2	1	1	5.8
618	1	1	2	1	3	14.8
619	1	1	1	1	1	3.7
620	1	1	1	1	2	4.9
621	1	2	1	1	1	42.0
622	1	2	1	1	2	30.6
623	1	2	2	1	3	29.7
624	1	2	2	1	1	7.5
625	2	2	1	1	3	39.4
626	2	2	1	1	1	34.9
627	2	2	2	2	2	40.7
628	2	2	2	2	1	36.7
629	2	3	1	2	1	46.5
630	2	3	1	2	3	45.4
631	2	3	2	1	1	44.6
632	2	3	2	1	2	40.5
633	2	1	1	2	2	25.1
634	2	1	1	2	1	21.7
635	2	1	2	1	1	22.1
636	2	1	2	1	3	24.0
701	1	1	1	1	1	3.0
702	1	1	1	1	3	4.0
703	1	1	2	1	1	10.9
704	1	1	2	1	2	10.2
705	1	2	2	2	3	13.6
706	1	2	2	2	1	24.0
707	1	2	1	2	2	18.0
708	1	2	1	2	1	15.9
709	1	3	2	2	2	13.4
710	1	3	2	2	1	14.7
711	1	3	1	2	3	31.5
712	1	3	1	2	2	17.9
725	2	2	1	1	3	33.4
726	2	2	1	1	1	45.7
727	2	2	2	2	1	29.6
728	2	2	2	2	2	42.9
729	2	3	1	2	2	45.0
730	2	3	1	2	1	47.5
731	2	3	2	1	1	44.0
732	2	3	2	1	3	42.7
733	2	1	2	2	1	31.3
734	2	1	2	2	3	26.1
735	2	1	1	2	1	28.2
736	2	1	1	2	2	29.3
801	1	1	1	2	3	6.3
802	1	1	1	2	1	12.2
803	1	1	2	2	2	13.8
804	1	1	2	2	1	11.3
805	1	2	2	1	1	22.2
806	1	2	2	1	3	23.0
807	1	2	1	1	2	24.5
808	1	2	1	1	1	16.6
809	1	3	2	1	3	21.2
810	1	3	2	1	1	27.7
811	1	3	1	1	1	34.1
812	1	3	1	1	1	30.0
825	2	2	1	2	1	34.2
826	2	2	1	2	2	31.0
827	2	2	2	1	1	35.1
828	2	2	2	1	3	33.7
829	2	3	1	1	1	34.0
830	2	3	1	1	3	41.7
831	2	3	2	2	2	46.4
832	2	3	2	2	1	40.5
833	2	1	2	1	2	25.0
834	2	1	2	1	1	15.7
835	2	1	1	1	3	23.4
836	2	1	1	1	1	23.8

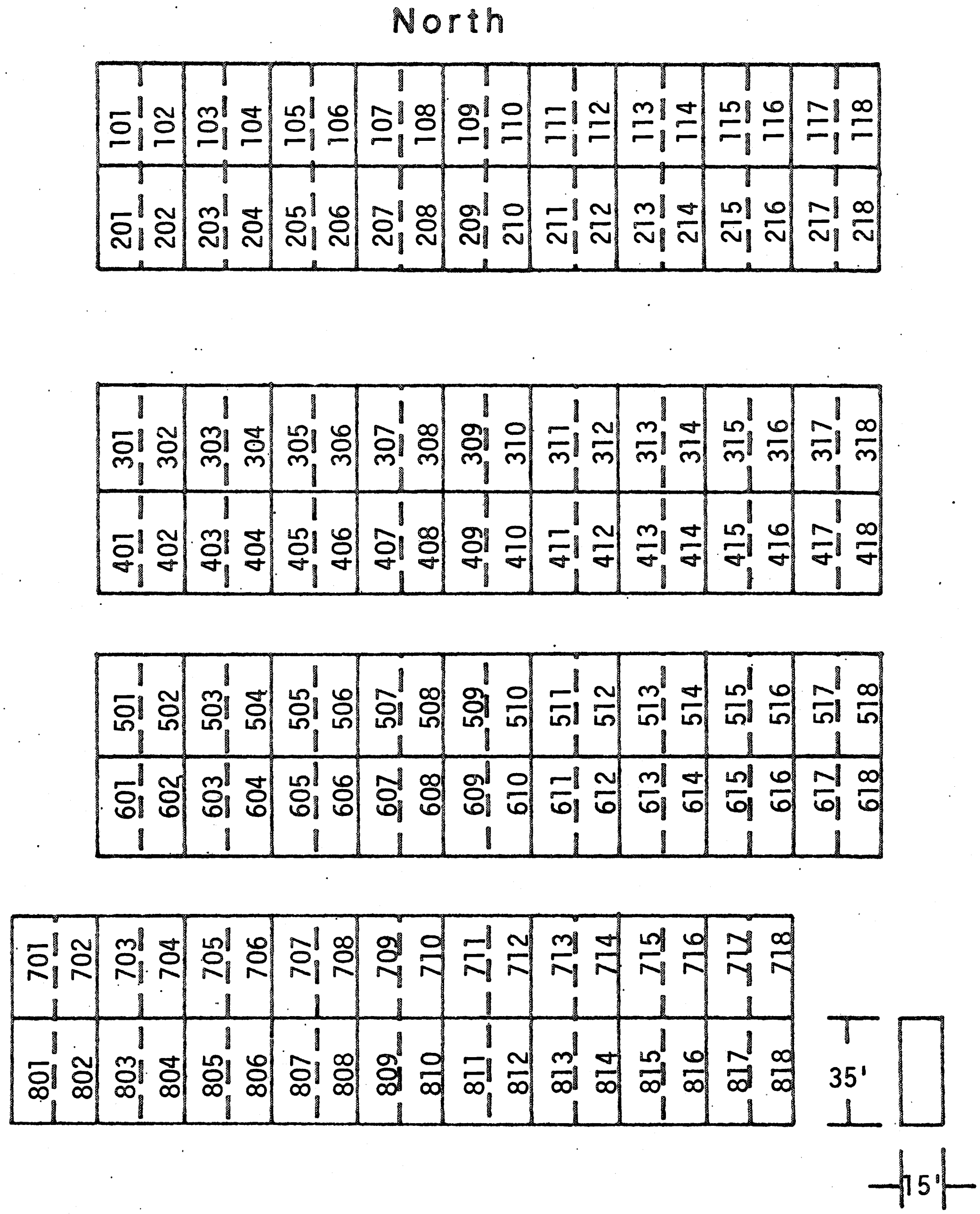

Figure 5. LEE COUNTY BORROW AREA PLOT LAYOUT, HR-186

Lee County borrow area corn yields, 1979.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD79
107	1	1	2	2	51.0
108	1	1	1	2	32.0
109	1	2	2	1	122.0
110	1	2	1	2	113.0
111	1	3	2	2	94.0
112	1	3	1	2	125.0
207	1	1	2	1	16.0
208	1	1	1	1	7.0
209	1	2	2	2	107.0
210	1	2	1	1	114.0
211	1	3	2	1	113.0
212	1	3	1	1	118.0
301	1	3	2	1	119.0
302	1	3	1	1	110.0
303	1	1	2	1	36.0
304	1	1	1	1	21.0
305	1	2	2	1	101.0
306	1	2	1	1	107.0
401	1	3	2	2	162.0
402	1	3	1	2	143.0
403	1	1	2	2	69.0
404	1	1	1	2	47.0
405	1	2	2	2	131.0
406	1	2	1	2	9.4
501	1	3	2	2	79.0
502	1	3	1	2	70.0
503	1	1	1	2	71.0
504	1	1	2	2	53.0
505	1	2	1	2	55.0
506	1	2	2	2	45.0
513	1	1	2	2	49.0
514	1	1	1	1	40.0
515	1	2	2	2	62.0
516	1	2	1	2	56.0
517	1	3	2	1	72.0
518	1	3	1	1	47.0
601	1	3	2	1	81.0
602	1	3	1	1	65.0
603	1	1	1	1	75.0
604	1	1	2	1	55.0
605	1	2	1	1	55.0
606	1	2	2	1	58.0
613	1	1	2	1	47.0
614	1	1	1	2	44.0
615	1	2	2	1	47.0
616	1	2	1	1	67.0
617	1	3	2	2	83.0
618	1	3	1	2	62.0
709	1	1	1	2	16.0
710	1	1	2	2	41.0
711	1	2	2	2	88.0
712	1	2	1	2	107.0
713	1	3	2	2	87.0
714	1	3	1	1	39.0
809	1	1	1	1	16.0
810	1	1	2	1	31.0
811	1	2	2	1	108
812	1	2	1	1	116
813	1	3	2	1	38
814	1	3	1	2	2

Lee County borrow area corn yields, 1980.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD80
307	1	1	2	2	64
308	1	1	1	1	39
309	1	2	1	2	68
310	1	2	2	2	82
311	1	3	2	2	61
312	1	3	1	1	77
407	1	1	2	1	56
408	1	1	1	2	53
409	1	2	1	1	44
410	1	2	2	1	65
411	1	3	2	1	69
412	1	3	1	2	65

Lee County borrow area corn yields, 1981.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD81
107	1	1	2	2	68.9
108	1	1	1	2	44.1
109	1	2	2	1	111.4
110	1	2	1	2	94.7
111	1	3	2	2	120.1
112	1	3	1	2	97.8
113	2	1	1	1	.
114	2	1	2	1	85.6
115	2	2	1	2	148.4
116	2	2	2	2	92.2
117	2	3	2	2	102.8
118	2	3	1	2	130.2
207	1	1	2	1	79.5
208	1	1	1	1	61.3
209	1	2	2	2	127.1
210	1	2	1	1	114.0
211	1	3	2	1	103.3
212	1	3	1	1	85.6
213	2	1	1	2	78.0
214	2	1	2	2	86.6
215	2	2	1	1	147.9
216	2	2	2	1	87.6
217	2	3	2	1	90.2
218	2	3	1	1	110.4
301	1	3	2	1	69.9
302	1	3	1	1	88.1
303	1	1	2	1	49.1
304	1	1	1	1	65.9
305	1	2	2	1	76.5
306	1	2	1	1	87.1
313	2	1	1	2	102.3
314	2	1	2	1	97.8
315	2	2	1	2	135.2
316	2	2	2	2	77.0
317	2	3	2	2	73.5
318	2	3	1	1	93.7
401	1	3	2	2	72.4
402	1	3	1	2	66.9
403	1	1	2	2	50.7
404	1	1	1	2	75.5
405	1	2	2	2	127.1
406	1	2	1	2	76.5
413	2	1	1	1	64.3
414	2	1	2	2	107.4
415	2	2	1	1	114.0
416	2	2	2	1	60.3
417	2	3	2	1	100.8
418	2	3	1	2	100.8
507	2	1	2	2	75.5
508	2	1	1	1	37.0
509	2	2	2	2	93.7
510	2	2	1	2	111.9
511	2	3	2	2	90.2
512	2	3	1	2	119.0
607	2	1	2	1	53.7
608	2	1	1	2	49.1
609	2	2	2	1	136.3
610	2	2	1	1	121.1
611	2	3	2	1	93.2
612	2	3	1	1	132.2
709	1	1	1	2	49.6
710	1	1	2	2	35.5
711	1	2	2	2	91.2
712	1	2	1	2	61.3
713	1	3	2	2	.
714	1	3	1	1	.
809	1	1	1	1	63.3
810	1	1	2	1	10.0
811	1	2	2	1	78.0
812	1	2	1	1	84.6
813	1	3	2	1	.
814	1	3	1	2	.

PLOT	ALFALFA	TOPSOIL	TILLAGE	MANURE	YIELD81
101	2	3	1	2	24.0
102	2	3	2	2	32.2
103	2	1	1	2	20.1
104	2	1	2	2	17.9
105	2	2	2	2	35.6
106	2	2	1	1	28.5
201	2	3	1	1	20.1
202	2	3	2	1	32.5
203	2	1	1	1	17.8
204	2	1	2	1	17.2
205	2	2	2	1	27.1
206	2	2	1	2	22.0
307	1	1	2	2	20.2
308	1	1	1	1	23.3
309	1	2	1	2	40.9
310	1	2	2	2	33.7
311	1	3	2	2	.
312	1	3	1	1	30.0
407	1	1	2	1	11.6
408	1	1	1	2	15.7
409	1	2	1	1	44.7
410	1	2	2	1	51.8
411	1	3	2	1	42.7
412	1	3	1	2	26.4
501	1	3	2	2	.
502	1	3	1	2	40.3
503	1	1	1	2	47.9
504	1	1	2	2	25.8
505	1	2	1	2	33.1
506	1	2	2	2	43.2
513	1	1	2	2	18.9
514	1	1	1	1	15.4
515	1	2	2	2	36.7
516	1	2	1	2	38.0
517	1	3	2	1	.
518	1	3	1	1	.
601	1	3	2	1	.
602	1	3	1	1	40.1
603	1	1	1	1	21.6
604	1	1	2	1	17.2
605	1	2	1	1	45.7
606	1	2	2	1	42.0
613	1	1	2	1	9.9
614	1	1	1	2	19.8
615	1	2	2	1	36.5
616	1	2	1	1	35.0
617	1	3	2	2	.
618	1	3	1	2	.
701	2	3	2	1	25.4
702	2	3	1	1	33.2
703	2	3	1	1	36.8
704	2	3	2	1	29.5
705	2	1	1	2	27.5
706	2	1	2	1	29.4
707	2	2	1	2	42.6
708	2	2	2	2	25.8
715	2	1	2	2	.
716	2	1	1	1	.
717	2	2	2	2	.
718	2	2	1	2	.
801	2	3	2	2	19.9
802	2	3	1	2	37.1
803	2	3	1	2	35.0
804	2	3	2	2	.
805	2	1	1	1	26.6
806	2	1	2	2	25.4
807	2	2	1	1	40.4
808	2	2	2	1	35.7
815	2	1	2	1	.
816	2	1	1	2	.
817	2	2	2	1	.
818	2	2	1	1	.

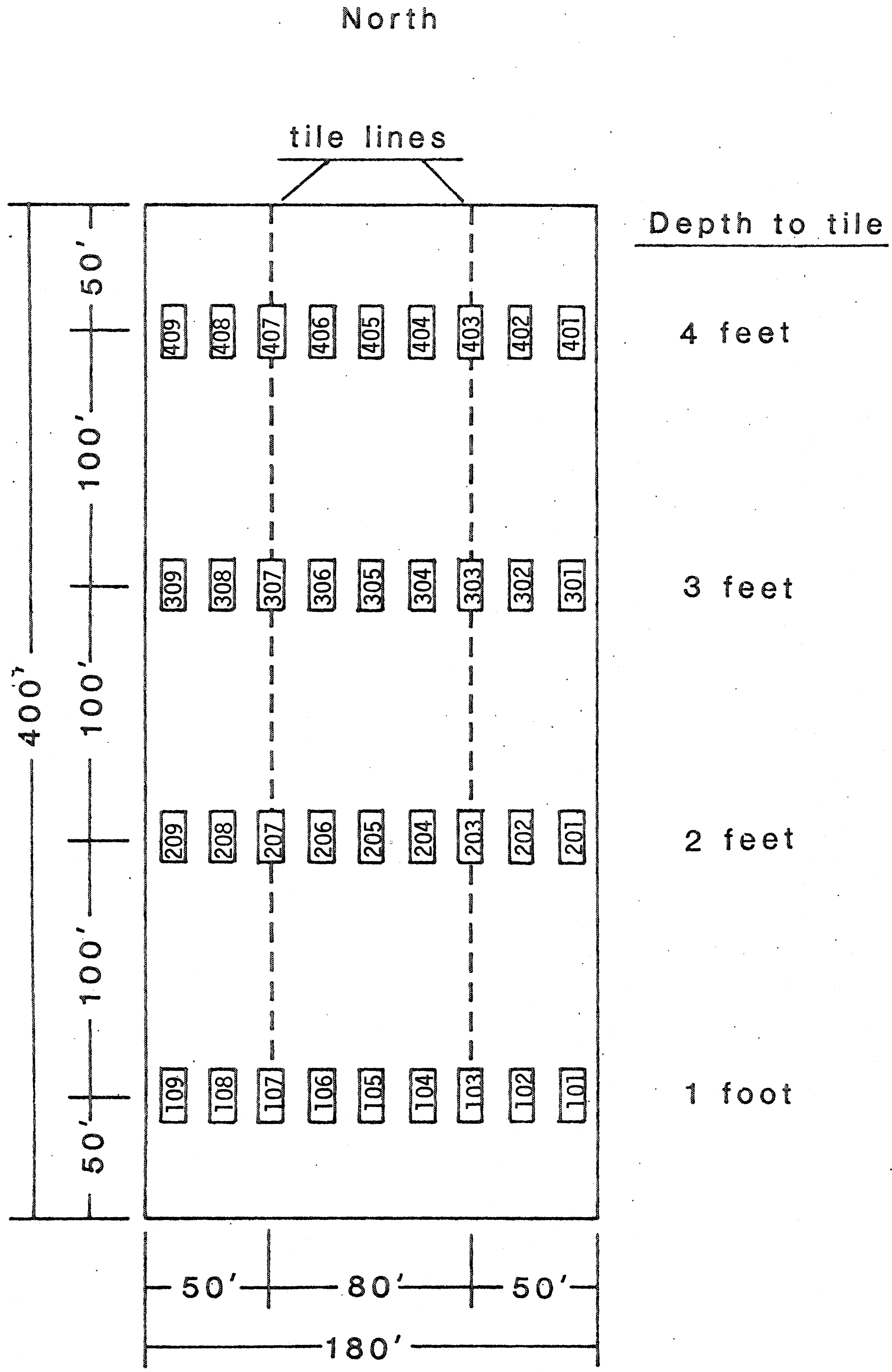

Figure 6. HAMILTON COUNTY BORROW AREA TILE DRAINAGE PLOT SAMPLING LAYOUT, HR-186