



00032565

OPEN FILE REPORT 42-87

April 1987

Effects of Stockpile Storage on Topsoil Characteristics in Arid
Climates

By L. J. Froisland, W. K. Tolley, and M. B. Shirts

MSHA LIBRARY
P. O. BOX 25367
DENVER, CO 80225

OFR
87-42

UNITED STATES DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, SECRETARY

BUREAU OF MINES
ROBERT C. HORTON, DIRECTOR

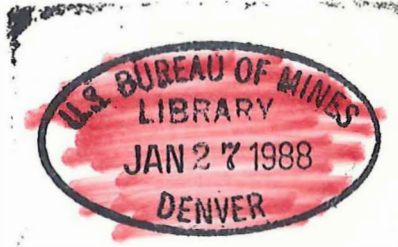
UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	μg/g	microgram per gram of soil
°C	degree Celsius	meq/100g	milliequivalents per 100 grams of soil
diam	diameter	min	minute
ft	foot	mL	milliliter
°F	degree Fahrenheit	mm	millimeter
g	gram	nm	nanometer
10 ³ /g	thousand counts per gram	pct	percent
h	hour	ppm	parts per million
in	inch	s	second
kg	kilogram	yd	yard
L	liter	yr	year
<u>M</u>	molar	μS/cm	micro-Siemen per centimeter

DISCLAIMER

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

REPORT DOCUMENTATION PAGE	1. REPORT NO. OFR 42-87	2.	3. Recipient's Accession No.
4. Title and Subtitle Effects of Stockpile Storage on Topsoil Characteristics in Arid Climate		5. Report Date 10-09-87	
7. Author(s) Lawrence J Froisland, William K. Tolley, and Monte B. Shirts		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Salt Lake City Research Center, BuMines U.S. Department of the Interior 729 Arapeen Drive Salt Lake City, UT 84108		10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)	
12. Sponsoring Organization Name and Address Office of Assistant Director--Minerals and Materials Research BuMines, U.S. Department of the Interior Washington, DC 20241		13. Type of Report & Period Covered Open File Report 1980-1987 14.	
15. Supplementary Notes			
<p>16. Abstract (Limit: 200 words)</p> <p>To aid in minimizing adverse environmental impacts of mining and mineral processing, the Bureau of Mines studied changes in soil characteristics in topsoil stockpiled during mining operations. Topsoil stockpiles in arid areas of New Mexico, Utah, and Wyoming were sampled over a 1- to 2-yr period to determine any changes in physical, chemical, or biological parameters in the top 15 ft of soil. Parameters examined in this study included soil moisture, pH, electrical conductivity, and cation exchange capacity; total nitrogen, organic carbon, carbon to nitrogen ratio, extractable potassium, and soluble phosphorus levels in the soil; general levels of bacteria activity in the soil; and productivity of the soil as measured by shoot yield in growth tests.</p> <p>Data were analyzed by multiple linear regression to determine possible effects of stockpile age and depth. Bacteria population counts, used as an indicator of general bacterial activity, was the only parameter found to be significantly correlated with stockpile age and depth at more than one site. Bacterial activity increased with depth at the two sites where it was measured. Activity increased with age at one site and decreased with age at the second. Significant changes in soil pH, electrical conductivity, and moisture were significantly correlated with stockpile age and depth at single sites. This study did not show significant, consistent deterioration in soil characteristics or growth yield of topsoil stored in stockpiles.</p>			
<p>17. Document Analysis a. Descriptors</p> <p>17 a) Land reclamation Soils Soil fertility, stockpiles, soil properties</p> <p>b. Identifiers/Open-Ended Terms</p> <p>Topsoil storage Fertility loss</p> <p>c. COSATI Field/Group</p>			
18. Availability Statement: Available from Jean Beckstead, Librarian Salt Lake City Research Center, BuMines, 729 Arapeen Dr., Salt Lake City, UT 84108		19. Security Class (This Report)	21. No. of Pages 44
		20. Security Class (This Page)	22. Price



FOREWORD

This report was prepared by the United States Bureau of Mines, U.S. Department of the Interior. The project was initiated under the Minerals Environmental Technology Program. It was administered under the technical supervision of Monte B. Shirts. This report was submitted by the authors in April 1987.

CONTENTS

	<u>Page</u>
Abstract.....	7
Introduction	8
Climate and description of test sites	9
Sampling procedures	11
Soil characteristics	15
Physical analysis	15
Chemical analysis	15
Bulk chemical analysis	16
Soil pH	16
Electrical conductivity	16
Cation exchange capacity	16
Potassium and phosphorus	17
Biological analysis	17
Dehydrogenase	17
Bacteria and fungi populations	18
Growth tests	18
Statistical methods	19
Results and analysis	19
Value ranges	19
Correlations and regressions	20
Farmington, NM	21
Correlations	21
Multiple regressions	21
Kemmerer, WY	21
Correlations	21
Multiple regressions	21
Ticaboo, UT	25
Correlations	25
Multiple regressions	25
Correlation discussion	27
Regression discussion	29
Summary	29
References	31
Appendix A.--Statistical methods	34
Appendix B.--Experimental data	35

ILLUSTRATIONS

1. Topsoil stockpile near Farmington, NM	10
2. Older topsoil stockpile near Kemmerer, WY	12
3. Newer topsoil stockpile near Kemmerer, WY	13
4. Topsoil stockpile near Ticaboo, UT	14

CONTENTS -- Continued

	<u>Page</u>
TABLES	
1. Range of parameter values for each stockpile site	20
2. Simple correlations between measured soil characteristics; shoot yields in 1980, 1981, and 1982 growth tests; and stockpile age and depth for stored topsoil from Farmington, NM.	22
3. Significant multiple-regression equations relating soil characteristics to stockpile age and depth at Farmington, NM	23
4. Simple correlations between measured soil characteristics; shoot yields in 1981 and 1982 growth tests; and stockpile age and depth for stored topsoil from Kemmerer, WY	24
5. Significant multiple-regression equations relating soil characteristics and plant growth to stockpile age and depth at Kemmerer, WY	25
6. Simple correlations between measured soil characteristics; shoot yields in 1981 and 1982 growth tests; and stockpile age and depth for stored topsoil from Ticaboo, UT	26
7. Significant multiple-regression equations relating soil characteristics to stockpile age and depth at Ticaboo, UT	27
B-1. 1980 experimental data from Farmington topsoil samples	36
B-2. 1981 experimental data from Farmington topsoil samples	37
B-3. 1982 experimental data from Farmington topsoil samples	38
B-4. 1981 experimental data from Kemmerer topsoil samples	40
B-5. 1982 experimental data from Kemmerer topsoil samples	41
B-6. 1981 experimental data from Ticaboo topsoil samples	43
B-7. 1982 experimental data from Ticaboo topsoil samples	44

Effects of Stockpile Storage on Topsoil Characteristics
in Arid Climates

By L. J. Froisland,¹ W. K. Tolley,² and M. B. Shirts³

ABSTRACT

To aid in minimizing adverse environmental impacts of mining and mineral processing, the Bureau of Mines studied changes in soil characteristics in topsoil stockpiled during mining operations. Topsoil stockpiles in arid areas of New Mexico, Utah, and Wyoming were sampled over a 1- to 2-yr period to determine any changes in physical, chemical, or biological parameters in the top 15 ft of soil. Parameters examined in this study included soil moisture, pH, electrical conductivity, and cation exchange capacity; total nitrogen, organic carbon, carbon to nitrogen ratio, extractable potassium, and soluble phosphorus levels in the soil; general levels of bacteria activity in the soil; and productivity of the soil as measured by shoot yield in growth tests.

Data were analyzed by multiple linear regression to determine possible effects of stockpile age and depth. Bacteria population counts, used as an indicator of general bacterial activity, was the only parameter found to be significantly correlated with stockpile age and depth at more than one site. Bacterial activity increased with depth at the two sites where it was measured. Activity increased with age at one site and decreased with age at the second. Significant changes in soil pH, electrical conductivity, and moisture were significantly correlated with stockpile age and depth at single sites. This study did not show significant, consistent deterioration in soil characteristics or growth yield of topsoil stored in stockpiles.

¹Group supervisor.

²Metallurgist.

³Research supervisor.

All authors are with the Salt Lake City Research Center, Bureau of Mines, Salt Lake City, UT.

INTRODUCTION

Over 150,000 acres of land in the United States are stripped each year to extract coal and other minerals lying beneath the surface. Because surface mining is usually the most economical method of recovering coal in the Western United States, land-stripping is expected to increase significantly as the United States expands its domestic energy program in the next decade. Large tracts of strippable coal deposits lie west of the Mississippi River, where arid climates and relatively infertile soils can pose significant reclamation problems. Coal surface mining began in the Western United States in the early 1900's; large-scale mined land reclamation began only within the last two decades. By 1980, 4 million acres of land or nearly 0.2 pct of this country's total area, had been disturbed by surface mining; but only 55 pct of the disturbed area had been reclaimed (12).⁴ Unreclaimed areas often remained as barren piles of mine spoils, subject to wind and water erosion, and contributing to air and water pollution.

⁴Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Legislation has been enacted on both state and federal levels to regulate the reclamation of surface-mined lands. A current regulation of the Surface Mining Control and Reclamation Act (PL 95-87) requires surface-mine coal operators to remove topsoil from sites to be mined and to redistribute it over recontoured mine spoils as soon as practical (26). Removed topsoil that cannot be immediately redistributed over regraded spoils is stored in stockpiles for a few weeks up to many years. Stockpiles can vary in depth up to 30 ft and may cover several acres. The buried soil is isolated from moisture and atmospheric conditions encountered in an undisturbed state. Physical structure and biological content can be altered by stripping and stockpiling; and stripping often takes more than the topsoil layer, so that the stockpile may contain a mixture of topsoil and subsoil.

Past experience indicates that productivity of redistributed topsoil can be significantly lower than that of undisturbed topsoil. Studies made in Illinois, Ohio, and Pennsylvania found corn production on reclaimed coal mine lands with redistributed topsoil to be from 4 to 70 pct lower than on undisturbed soils in nearby fields (21). If such productivity decreases occur in the relatively infertile soils found on western mining sites, vast barren areas could result even if the topsoil is managed in accordance with legal requirements.

Previous research on stored topsoil was conducted in North Dakota (15, 24), Wyoming (25), and in England (2, 11). Results showed decreases in biological activity in stored topsoil; but the changes occurred very slowly, sometimes taking 10 yr or more to be noticeable. Other parameters such as cation exchange capacity also tended to be

lower in stored soils than in undisturbed soil. Changes occurring in stored topsoil in these areas where normal annual precipitation is 17 in or more (2, 16, 25), could be different than changes occurring in some parts of the Western United States where annual precipitation is much less.

Since 1965, the Bureau of Mines has researched methods to reclaim mining and mineral processing wastes (6-7, 9-10, 14). A study was initiated in 1980 to determine physical, chemical, or biological changes occurring in topsoil stockpiled in mining of coal or other materials in arid sites in New Mexico, Utah, and Wyoming. This report summarizes laboratory analyses of soil characteristics and plant growth in topsoil samples collected annually from each stockpile site over a 1- to 2-yr period.

CLIMATE AND DESCRIPTION OF TEST SITES

Three sites were selected for topsoil study: two coal strip mines and a uranium mill. One coal mine is near Farmington, NM; the other is near Kemmerer, WY; and the uranium mill is near Ticaboo, UT.

Farmington, NM - The San Juan coal strip mine, owned by Utah International Corp. and operated by San Juan Coal Company, is located about 15 miles west of Farmington in northwest New Mexico. This mine lies in a high desert environment at 5,100-ft elevation. The terrain is rolling, broken hills; the predominant parent rock for the soil is shale. The area is sparsely covered with Atriplex species and native grasses.

The climate in this area is arid with precipitation averaging about 7.5 in annually. Mine officials stated that average annual precipitation at the mine site is 6.6 in. Mean temperatures range from 76° F in the summer to 29° F in the winter (17).

The topsoil stockpile chosen for study at this site was constructed in late 1978 and early 1979, about 18 months before the first sampling in June of 1980. Approximately 25 ft high, the stockpile covers about two acres and is built in an "L" shape, figure 1. The topsoil pile lies on level terrain where water would drain away. Russian thistle and an unidentified species of grass had invaded the stockpile at the time sampling began, but plant cover was still sparse.

Kemmerer, WY - The Kemmerer coal strip mine, Pittsburg and Midway Coal Mining Co., lies approximately 5 miles southwest of Kemmerer. Shale is the predominant parent rock for soil in this area. The elevation is approximately 6,900 ft in a high plains desert with mostly sagebrush and juniper tree vegetation. Sagebrush ground cover is dense except for rocky outcroppings, which are barren.

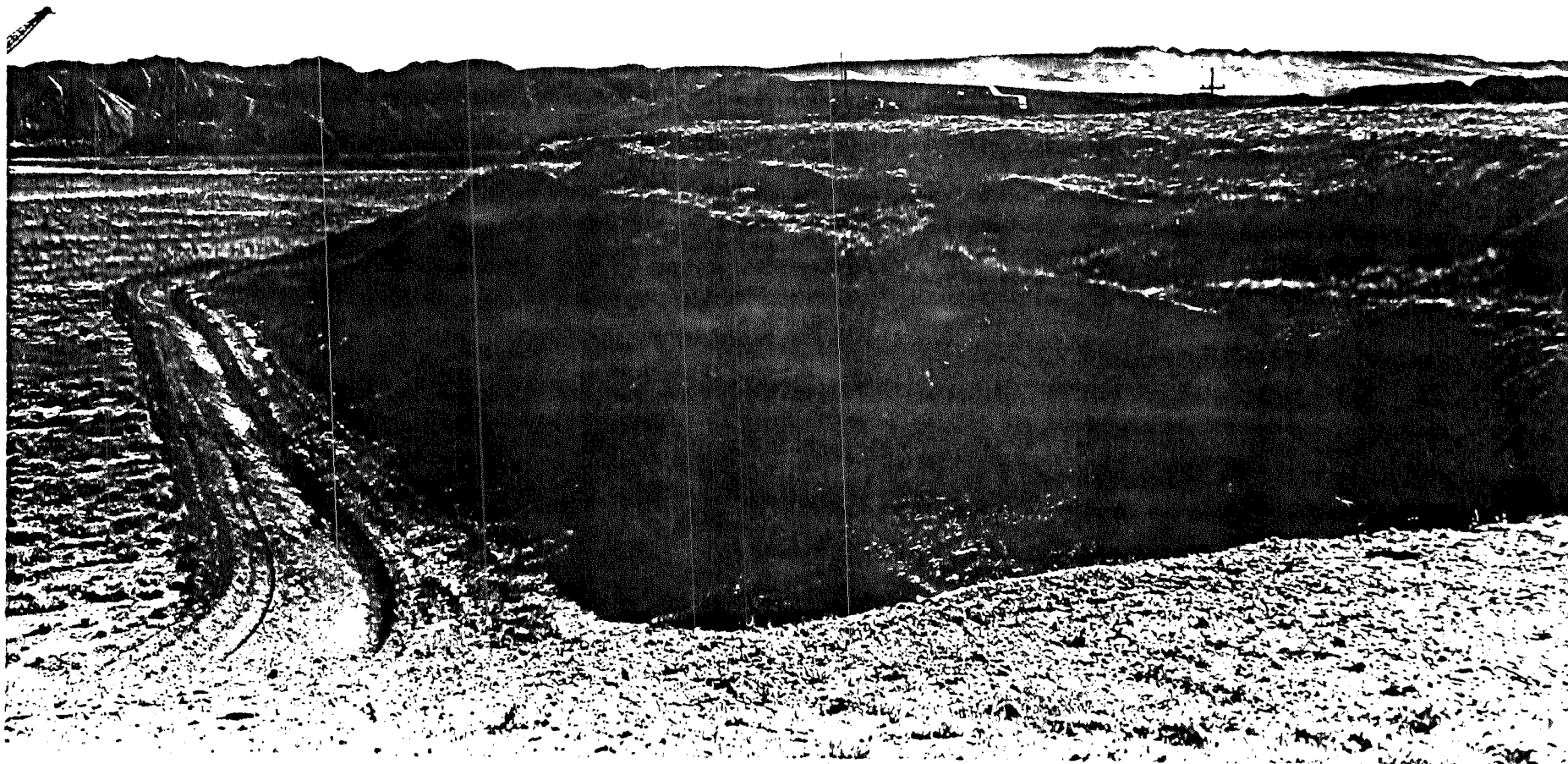


FIGURE 1. - Topsoil stockpile near Farmington, NM.

The climate in this part of Wyoming is arid with precipitation averaging about 9.5 in annually. Mean temperatures range from 63° F in the summer to 17° F in the winter (19).

Two stockpiles were selected for sampling at this site. One had been in place for about 7 yr; the other about 2 months when sampling started. Each stockpile is 20 to 25 ft high and covers about 1 acre. The stockpiles, pictured in figures 2 and 3, are about 400 yd apart and contain soil from the same hillside. Stripping commenced on the hillside in one direction in 1972; 7 yr later, stripping commenced from the same point in the opposite direction. Vegetation on the older stockpile consists of weedy plants and some grasses, while the newer stockpile was barren throughout the study period. Data from the two stockpiles were combined for statistical analysis.

Ticaboo, UT - Located near Ticaboo in southern Utah is Plateau Resources, Limited's Shootaring Canyon uranium mine and mill. This complex is situated at approximately 4,000-ft elevation in an area of sandstone cliffs, which was parent rock for the topsoil. The mill site vegetation is sparse with yucca, sagebrush, blackbrush, and galleta grass being the predominant species.

The climate at this site is arid with precipitation averaging about 8 in annually. Mean temperatures range from 81° F in the summer to 40° F in the winter (18).

Topsoil was stripped from the mill site in 1978 prior to construction and stockpiled in a small "Y" shaped canyon nearby. This topsoil will be spread over the uranium tailing ponds as they are filled and over the mill site after decommissioning and decontamination.

The stockpile varies in depth according to the contours of the canyon and reaches a maximum depth of about 40 ft. The stockpile is shown in figure 4. When sampling started in 1981, the stockpile was devoid of plants. Some revegetation had started the following year through seeding and natural invasion of plants onto the stockpile.

SAMPLING PROCEDURES

Topsoil stockpiles at all three sites were sampled down to 15 or 16 ft. Samples collected at 1-ft intervals were sealed in plastic bags as quickly as possible and kept sealed until tested and analyzed. Sampling in 1980 at the Farmington site was done with a 2-1/2-in-diam hand auger. Later samples were taken with a 4-in-diam hydraulic auger. Several sample holes were drilled at each site to provide mean values for measured characteristics.

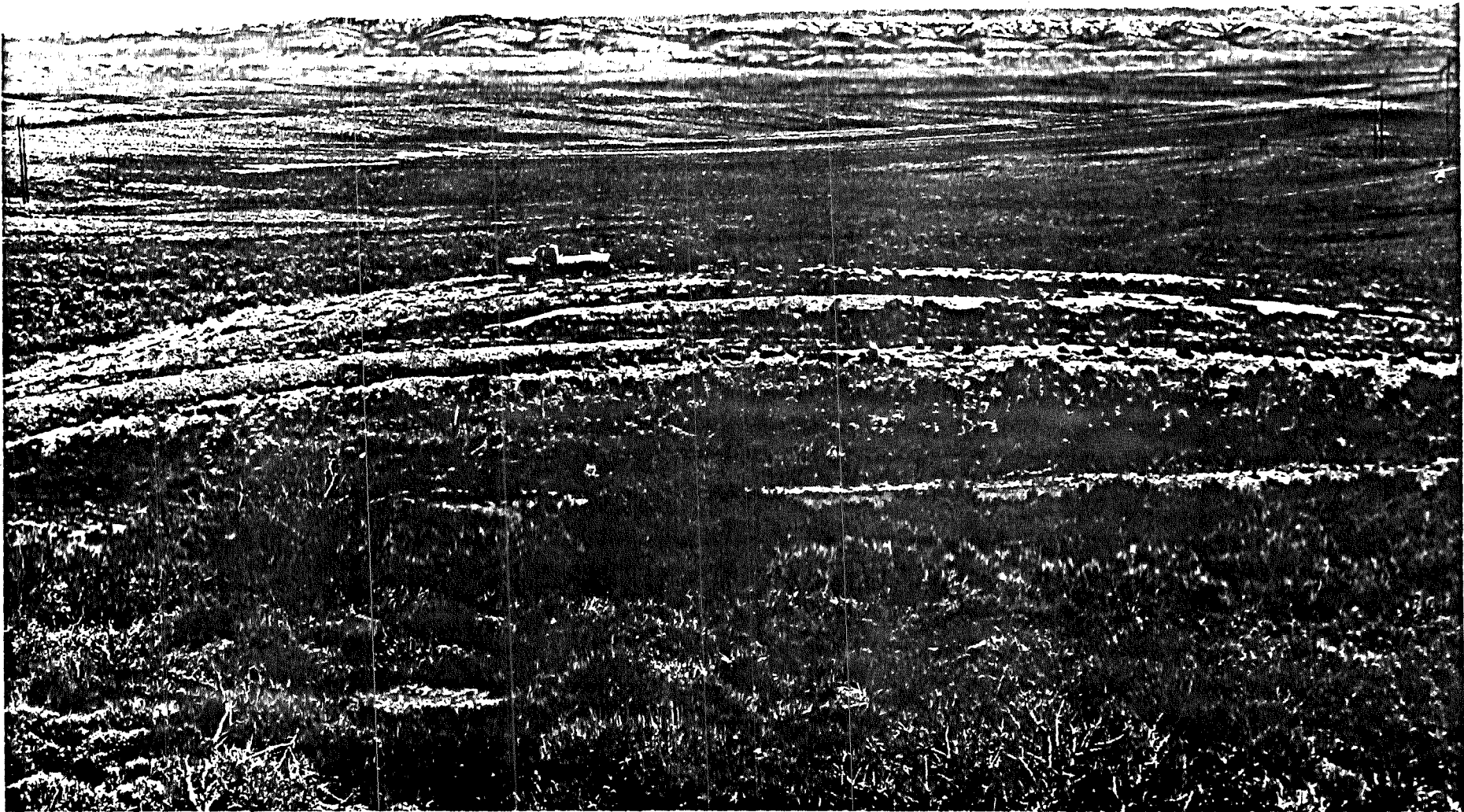


FIGURE 2. - Older topsoil stockpile near Kemmerer, WY.





FIGURE 4. - Topsoil stockpile near Ticaboo, UT.

Farmington - Eleven sets of drill samples were taken and analyzed over a 2-yr period. Two sets were taken in 1980 using the hand auger. Three sets were taken in 1981 using the hydraulic auger, one from each of the same areas as those in 1980, and one from a different area of the pile. In 1982, six holes were drilled, three around each of the two 1980 drill sites. Because the origin of the soil in this stockpile was not known, no undisturbed soil samples were taken from this site.

Kemmerer - Eleven sets of soil samples were taken and analyzed over a 1-yr period. In 1981, two sets of samples from the 7-yr-old stockpile, one set from the 2-month-old stockpile, and one set of undisturbed, native samples were taken. In 1982, three sets from each stockpile and one set of native samples were taken.

Ticaboo - Seven sets of soil samples were taken and analyzed over a 1-yr period. In the spring of 1981, one set of samples from the stockpile and one set of undisturbed, native soil samples were taken. About 4 months later, a second set of samples from the same area of the stockpile and a second set of native samples were taken. The two sets of native samples were considered as a single set for statistical analysis. In 1982, three sets of soil samples from the stockpile and a set of native samples were taken.

SOIL CHARACTERISTICS

Soil characteristics determined annually in this study included physical, chemical, and biological factors known to affect plant growth. Growth tests were conducted each year to determine productivity of the soils. Tall wheatgrass (Agropyron elongatum), a grass which had been used successfully by the Bureau in revegetating several disturbed sites, was used in these growth tests. Results of analyses and growth tests are described in this section.

PHYSICAL ANALYSIS

Moisture content of the soils was monitored over the test period. A sample of soil was weighed, dried overnight at 105° C, and reweighed. The results are reported on a dry weight basis.

Soil texture and compaction were not determined because of the drilling method used to obtain the samples. The auger drill loosened and thoroughly mixed the soil during the sampling operation.

CHEMICAL ANALYSIS

Chemical properties monitored over the test period included bulk chemical analysis, soil pH, electrical conductivity, and cation exchange capacity. Samples for analysis were taken from each of the 1-ft-interval samples.

Bulk Chemical Analysis

Soil samples were analyzed for bulk content of nitrogen and organic carbon. Total nitrogen in the soil was determined by a Kjeldahl analysis. Organic carbon, which includes carbon contained in coal, was determined in a wet-combustion procedure (1). Heavy metals were determined by an inductively-coupled-plasma analysis of soil digested in acid, but the concentrations were very low and were not included in the statistical analysis. Total nitrogen was divided into organic carbon to give a carbon-to-nitrogen ratio (C-N).

Soil pH

Soil pH was determined for each of the 1-ft-interval samples using 0.01M CaCl_2 solution in a 1:2 soil-to-solution ratio. Slurries were agitated for 30 min and then allowed to settle for 30 min. The pH measurements were taken with the electrode tip immersed in the settled sediment. This method has several advantages (22):

1. The pH is independent of dilution over a wide range of soil-to-solution ratios.
2. The observed pH is essentially independent of soluble salts present in the soil. This minimizes variations in pH values from different levels in the stockpiles due to changes in soluble salt content.
3. The soil pH measured in 0.01M CaCl_2 represents more nearly the soil pH under actual field conditions.

Electrical Conductivity

Soil samples were analyzed for electrical conductivity (EC) by adding 10 g of air-dried soil to 50 mL of distilled water. This slurry was agitated for 30 min and then allowed to settle for 30 min. About 40 mL of extract was decanted and centrifuged, and about 35 mL of the clarified extract was placed in the conductivity tube. The EC was measured using a direct-reading, Wheatstone-bridge type conductivity meter and reported as micro-Siemens per centimeter ($\mu\text{S}/\text{cm}$).

The 1:5 soil-to-water ratio was chosen as being most appropriate to follow changes in soluble salt content at various levels in the topsoil stockpiles over time. The 1:5 ratio permits simple removal of the extract and rapid completion of the determinations (3).

Cation Exchange Capacity

Cation exchange capacity (CEC), defined as the amount of exchangeable cations per unit weight of soil, was measured and recorded in milliequivalents per 100 grams of soil (meq/100 g). The CEC was measured using a silver thiourea (AgTU) extraction process followed by chemical analysis of the extract (23). The only cations found to

contribute significantly to the CEC in the soils from the three sites were sodium, potassium, magnesium, and calcium. Tabulated values are based on these four elements.

Potassium and Phosphorus

Available potassium and soluble phosphorus may be determined by extraction with water, weak acids, or salt solutions (8). Exchangeable potassium and soluble phosphorus levels in this investigation were determined in the same AgTU extractions used for cation exchange capacities. Levels of AgTU-extracted potassium and phosphorus provided relative value series for evaluating changes in availability of these elements among samples. Results from these analyses are reported as concentration in the extract.

BIOLOGICAL ANALYSIS

Biological activity in the topsoil stockpiles was monitored by dehydrogenase analysis and by agar plate population counts for both bacteria and fungi. Samples for these determinations were taken from each 1-ft-interval soil sample.

Dehydrogenase

Dehydrogenase activity, or the ability of some microbes to reduce 2, 3, 5-triphenyltetrazolium chloride (TTC) to a red formazan dye in the absence of oxygen, was used as an index of general soil microorganism activity (4). The procedure followed in this study was a modification of a rapid procedure developed to follow microbe activity in disturbed soils (13). Duplicate samples were weighed out and mixed with a solution containing 24 g/L TTC and 50 g/L dextrose, which provided a source of organic carbon for the soil microbes. Soil weights and solution volumes yielding the highest microbial response were determined for each soil type before analyses were begun, and these weights and volumes for each soil were held constant from year to year to permit comparison of the data. Solution volumes were sufficient to immerse the soil samples and thus exclude oxygen from the soil.

The immersed soil samples were then incubated in the dark for 48 h at 28° C. Following incubation, methyl alcohol was added to each sample at a methyl alcohol-to-TTC solution volumetric ratio of 5:1. The mixtures were agitated for 30 sec and returned to the incubator for 2 h to extract the red-colored formazan product of the TTC reduction. Samples were then centrifuged to obtain clear, supernatant solutions. Formazan concentrations were determined spectrophotometrically by measuring absorbances at 485 nm. Results were converted to micrograms of formazan per gram of soil ($\mu\text{g/g}$) by calibration with standard formazan solutions. Generally, increasing absorbance values indicate increasing microbial activity in the soil.

Bacteria and Fungi Populations

Bacteria and fungi population counts using a modified agar pour-plate method (5) was used as a second indicator of biological activity. This procedure does not detect all strains of bacteria or fungi but does yield values which indicate relative levels of microbial activity.

The specific procedure was as follows: Soil, weighed to yield 20 g dry weight equivalent as determined by the soil moisture measurement, was added to 80 g of sterile, demineralized water. The slurry was agitated with a wrist shaker for 4 h. These suspensions were diluted in series as follows: 1:50; 1:250; 1:500; 1:2500; 1:5000; $1:1 \times 10^4$; $1:5 \times 10^4$; $1:1 \times 10^5$; $1:5 \times 10^5$; and $1:1 \times 10^6$. Three replicate pour plates per dilution were prepared for each sample. One milliliter of diluted slurry was pipetted into a sterile 100 by 15 mm Petri dish. Twenty milliliters of sterile peptone-glucose agar were poured into the Petri dish and swirled into the sample. The plates were allowed to solidify, then inverted and placed in an incubator at 28° C for 96 h. Generally, only plates showing 50 to 150 colonies per plate were selected for counting. When the number of colonies did not fall into this range, the lowest dilution was counted. Bacteria and fungi colonies were counted separately. Reported data are the mean values of all replications from each dilution counted.

GROWTH TESTS

Tall wheatgrass was seeded into soil samples as a measure of productivity for the stockpiled topsoil. Undisturbed soil samples from both Kemmerer and Ticaboo sites were included in the growth testing. Undisturbed soil was not available from the Farmington site. The age of these undisturbed samples was taken to be "0" (zero) with respect to the stockpiled soil regardless of the year in which they were collected. Because of the relatively small amount of soil obtained from each 1-ft interval in the sample holes, most samples taken in 1981 and 1982 were combined into 2-ft intervals for the growth tests. Thus, growth testing was done with soil from depths of 0 to 2 ft, 2 to 4 ft, etc. Most of the sample holes extended past 15 ft deep and the excess soil was used in the 15-ft-deep growth test. The two soil samples combined for each test were thoroughly mixed, and approximately 5 kg was placed in a planting box measuring 23 by 17 by 12 cm.

In growth tests performed on soil samples collected in 1980 and 1981, 20 tall wheatgrass seeds were planted in each box. The boxes were placed in a greenhouse and the plants were grown for 8 weeks. At the end of that period, the shoots were clipped, dried, and weighed to determine dry matter production. In 1982, the procedure was modified because there was no greenhouse available. One gram of seeds (approximately 175 seeds) was planted in each box; the boxes were maintained under fluorescent lights in the laboratory; and the growth period was shortened to 5 weeks because of decreased available space.

These procedural changes prevent comparison of 1980 and 1981 productivity data with 1982 productivity data, but correlation of other parameters with growth for each year and correlation of growth data with stockpile depth is still justified.

STATISTICAL METHODS

Linear regression analysis was used to determine simple correlations between soil characteristics, and multiple linear regression was used to determine correlations between soil characteristics and the stockpiling parameters of age and depth. Statistical significance of the regression and individual parameter coefficients were assessed with F-tests and Students' T-tests, respectively. Statistical tests are outlined in more detail in Appendix A.

RESULTS AND ANALYSIS

This section of the report discusses data obtained from various assays and determinations performed on the soil samples. Ranges of data values, simple correlations, and multiple linear regression analyses are presented and discussed here. Raw data obtained during this study is presented in Appendix B.

VALUE RANGES

Table 1 shows the range of values for each parameter at each site and gives some generally accepted values for these parameters in agricultural soil. These value ranges point out some similarities and differences between the soils at the three sites.

- Kemmerer soil contains up to three times as much organic carbon and up to twice as much total nitrogen as do the others. In general, however, nitrogen and carbon contents in all three soils are below the accepted values for agricultural soils.
- Kemmerer soil is slightly acid while Farmington and Ticaboo soils are slightly basic. With few exceptions, however, soil samples from all three sites had pH values within the range of 4 to 8, which is considered to be suitable for plant growth.
- EC levels at all three sites are in the nonsaline classification of less than 4,000 $\mu\text{S}/\text{cm}$.
- CEC values for Ticaboo soils are lower than for the other two, in accordance with the sandy soil texture compared with the loamy soils of Farmington and Kemmerer. All three soils show CEC values below the accepted agricultural values.

- Microbial activity in all three soils is lower than in agricultural soil.
- Shoot yields were lower in the sandy Ticaboo soil under both sets of growth conditions than for either of the other two soils.

TABLE 1. - Range of parameter values for each stockpile site

Parameter	Parameter ranges						Generally accepted agricultural soil values
	Farmington		Kemmerer		Ticaboo		
	High	Low	High	Low	High	Low	
Moisture content...pct..	18.7	3.6	16.4	1.5	10.9	1.2	NA
Total nitrogen.....pct..	.17	.01	.33	.01	(¹)	(¹)	0.05-.25
Organic carbon.....pct..	.9	0	6.6	.2	2.0	0	2-6
Carbon-nitrogen ratio ² ..	50	0	220	1.1	ND	ND	NA
Soil pH.....	8.7	6.9	7.5	3.4	8.1	6.7	4-8
Electrical conductivity, μS/cm.....	3500	115	960	20	220	60	<4,000
Cation exchange capacity ...meq/100 g.....	34.1	7	15.4	4.2	6.5	2.4	50-60
Available potassium,ppm.	61	3	37	2	8	2	NA
Soluble phosphorus,ppm..	1	0	1.3	0	1	0	NA
Dehydrogenase.....mg/g..	18.3	.16	24.3	0	5.3	0.03	NA
Bacteria counts..10 ³ /g..	315	0	2465	.04	29.5	1.3	-4,000
Fungi counts.....10 ³ /g..	223	.4	865	2.4	41.5	2.2	-1,000
Shoot yield, g							
1980.....	5.61	.39	ND	ND	ND	ND	NA
1981.....	6.37	.54	8.14	.93	1.23	.42	NA
1982.....	3.24	.15	3.39	.88	1.15	.51	NA

¹Below detection limits in all samples.

²Obtained by dividing organic carbon content by total nitrogen content.

ND Not determined.

NA Not available.

CORRELATIONS AND REGRESSIONS

Correlations among measured soil characteristics, plant growth, and stockpile parameters of age and depth were determined by statistical analysis of raw data from each site. Each measured characteristic and the plant growth parameter of shoot yield were regressed on stockpile age and depth in a multiple linear regression analysis using age and depth as independent variables. Significance correlation levels of 5 and 1 pct are noted in the tables. Data from each site are presented in this section along with a discussion of similarities among sites.

Farmington, NM

Correlations

Simple linear correlations among soil characteristics, plant growth as measured by shoot yield, and stockpile age and depth for topsoil samples from the Farmington stockpile are shown in table 2. Soil pH had the strongest correlations of any factor in the Farmington samples. The correlation coefficient between pH and age was a negative 0.734, indicating that the pH decreased in this pile over time. Even though the soil pH at the end of the testing period was still approximately 7.5, the decreasing trend may signal future acidity problems if the topsoil is stored over a long period of time.

Multiple Regressions

Data derived from Farmington soil samples yielded only one significant multiple-regression equation. This equation, shown in table 3, relates soil pH to stockpile age and depth and shows that pH decreases with stockpile age and increases with stockpile depth. The overall correlation coefficient of 0.594 indicates that other factors besides age and depth are also affecting the pH level, thus lessening the value of this equation as a predictor of pH in the Farmington stockpile.

Kemmerer, WY

Correlations

Simple correlations among the soil factors, plant growth, and stockpile age and depth for soil samples from Kemmerer, WY, are shown in table 4. Of interest is the positive correlation between shoot yields and stockpile age. This correlation indicates that plant growth increases as soil stockpiles age and does not agree with the hypothesis that fertility decreases from stockpile aging.

TABLE 2. - Simple correlations between measured soil characteristics; shoot yields in 1980, 1981, and 1982 growth tests; and stockpile age and depth for stored topsoil from Farmington, NM

Correlation elements	Stock-pile depth	Stock-pile age	Fungi population counts	Bacteria population counts	Dehydrogenase	Soluble phosphorus	Available potassium	CEC	EC	Soil pH	C-N ratio	Organic carbon	Total nitrogen	Moisture content
Shoot yield, 1980.....	¹ +5	² —	—	—	—	—	—	+1	—	—	—	+1	+5	+5
Shoot yield, 1981.....	—	—	—	—	—	—	—	+1	+5	—	—	—	+5	—
Shoot yield, 1982.....	-1	—	—	+5	—	—	+1	-1	-1	-1	—	—	—	—
Moisture content.....	+1	—	—	—	+5	—	—	—	+1	—	—	+1	+1	—
Total nitrogen.....	+1	-1	—	—	+1	—	+1	—	—	+1	-1	+1	—	—
Organic carbon.....	+5	—	—	—	+5	—	+5	—	—	—	+1	—	—	—
C-N ratio.....	—	+1	—	—	—	—	—	—	—	-5	—	—	—	—
Soil pH.....	+1	-1	—	-1	—	-1	—	+1	+1	—	—	—	—	—
EC.....	+1	—	-5	-5	—	—	-1	+1	—	—	—	—	—	—
CEC.....	+5	-5	—	-5	—	—	-1	—	—	—	—	—	—	—
Available potassium...	—	-1	+1	+5	+1	-5	—	—	—	—	—	—	—	—
Soluble phosphorus....	—	+1	—	—	—	—	—	—	—	—	—	—	—	—
Dehydrogenase.....	+1	—	+1	+1	—	—	—	—	—	—	—	—	—	—
Bacteria population counts.	—	—	+1	—	—	—	—	—	—	—	—	—	—	—
Fungi population counts.	—	—	—	—	—	—	—	—	—	—	—	—	—	—

¹Entries indicate significant level of correlation and whether correlation is positive or negative. For example, the correlation between moisture content and stockpile depth is positive and is significant at the 1 pct level.

²Dashed entry indicates that correlation was not significant at the 5 pct level.

TABLE 3. - Significant multiple-regression equations relating soil characteristics to stockpile age and depth at Farmington, NM

Regression equation	R	F ¹
² Y _{pH} = 8.54 - ³ 0.299 X ₁ + ⁴ 0.0198 X ₂	0.594	113.41

¹Significant at 1 pct level.

²Y = level of subscripted soil characteristic.

³X₁ = stockpile age in years.

⁴X₂ = stockpile depth in feet.

TABLE 4. - Simple correlations between measured soil characteristics; shoot yields in 1981 and 1982 growth tests; and stockpile age and depth for stored topsoil from Kemmerer, WY

Correlation elements	Stock-pile depth	Stock-pile age	Fungi population counts	Bacteria population counts	Dehydrogenase	Soluble phosphorus	Available potassium	CEC	EC	Soil pH	C-N ratio	Organic carbon	Total nitrogen	Moisture content
Shoot yield, 1981.....	¹ +1	+1	² —	—	—	+1	—	-5	-5	—	—	—	—	—
Shoot yield, 1982.....	—	+1	+5	+1	+1	—	—	—	—	—	—	—	—	—
Moisture content.....	+1	—	—	—	—	—	+5	+1	+1	—	—	+1	+1	—
Total nitrogen.....	—	—	+1	—	+1	—	+1	+1	—	-5	-1	+1	—	—
Organic carbon.....	—	-1	—	—	+1	—	—	+1	—	—	+1	—	—	—
C-N ratio.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Soil pH.....	—	+1	—	+1	+1	—	+1	+5	—	—	—	—	—	—
EC.....	+1	-1	—	—	—	—	—	+1	—	—	—	—	—	—
CEC.....	+5	+5	—	—	+1	—	+5	—	—	—	—	—	—	—
Available potassium...	+1	+1	—	—	+5	—	—	—	—	—	—	—	—	—
Soluble phosphorus....	+5	+5	—	—	—	—	—	—	—	—	—	—	—	—
Dehydrogenase.....	—	—	+1	+1	—	—	—	—	—	—	—	—	—	—
Bacteria population counts.	+1	+1	+1	—	—	—	—	—	—	—	—	—	—	—
Fungi population counts.	+1	—	—	—	—	—	—	—	—	—	—	—	—	—

¹Entries indicate significance level of correlation and whether correlation is positive or negative. For example, the correlation between moisture content and stockpile depth is positive and is significant at the 1 pct level.

²Dashed entry indicates that correlation was not significant at the 5 pct level.

TABLE 5. - Significant multiple-regression equations relating soil characteristics and plant growth to stockpile age and depth at Kemmerer, WY

Regression equations	R	¹ F
² Y _{EC} = 174.14 - ³ 21.63X ₁ + ⁴ 13.33X ₂	0.205	20.52
Y _{bacteria} = 29.73 + 41.98X ₁ + 17.29X ₂	.217	22.09
Y _{1981 shoot yield} = 1.52 + 0.29 X ₁ + 0.12X ₂	.426	20.74
Y _{1982 shoot yield} = 1.72 + .057 X ₁ - .026 X ₂	.193	11.92

¹Significant at 1 pct level.

²Y = level of subscripted soil characteristics or plant growth parameter.

³X₁ = stockpile age in years.

⁴X₂ = stockpile depth in feet.

Ticaboo, UT

Correlations

Simple correlations among the soil factors, plant growth, and stockpile age and depth for soil samples from Ticaboo, UT, are shown in table 6. Analyses showed organic carbon to be very low. Total nitrogen in all Ticaboo samples was below detection limits, and no correlations involving nitrogen were possible.

Multiple Regressions

Data derived from the Ticaboo soil samples yielded two significant multiple-regression equations as shown in table 7. Soil moisture contents and bacteria population counts were significantly influenced by stockpile age and depth. These correlations suggest that upper levels of the soil pile protect the underlying layers from excessive heat and dessication, both of which tend to reduce moisture and bacteria levels. The low correlation coefficients again indicate soil changes cannot be explained completely from the parameters studied here.

TABLE 6. - Simple correlations between measured soil characteristics; shoot yields in 1981 and 1982 growth tests; and stockpile age and depth for stored topsoil from Ticaboo, UT

Correlation elements	Stockpile depth	Stockpile age	Fungi population counts	Bacteria population counts	Dehydrogenase	Soluble phosphorus	Available potassium	CEC	EC	Soil pH	Organic carbon	Moisture content
Shoot yield, 1981.....	¹ -1	-1	² -	-	+5	-	-	-5	-1	+1	-	-1
Shoot yield, 1982.....	-	-	-	-	-	-	-	-5	-	-	-	-
Moisture content.....	+1	+1	+5	-	-	-	-	+1	+1	-	-	-
Organic carbon.....	-	-	-	-	-	-	-	-	-	-	-	-
Soil pH.....	-	-	-	-	-	-	-	-	-	-	-	-
EC.....	-	+1	-	-1	-	+5	+1	+1	-	-	-	-
CEC.....	-	+5	-	-	-	-	+1	-	-	-	-	-
Available potassium...	-	-	-	-	+1	-	-	-	-	-	-	-
Soluble phosphorus....	-	-	-	-	-	-	-	-	-	-	-	-
Dehydrogenase.....	-	-1	+1	+1	-	-	-	-	-	-	-	-
Bacteria population counts.	+1	-	+1	-	-	-	-	-	-	-	-	-
Fungi population counts.	+1	-	-	-	-	-	-	-	-	-	-	-

¹Entries indicate significance level of correlation and whether correlation is positive or negative. For example, the correlation between moisture content and stockpile depth is positive and is significant at the 1 pct level.

²Dashed entry indicates that correlation was not significant at the 5 pct level.

TABLE 7. - Significant multiple-regression equations relating soil characteristics to stockpile age and depth at Ticaboo, UT

Regression equations	R	¹ F
² Y _{moisture} = 3.03 + ³ 0.060X ₁ + ⁴ 0.13X ₂	0.527	47.34
Y _{bacteria} = 14.55 - 2.43X ₁ + 92X ₂	.367	18.26

¹Significant at 1 pct level.

²Y = level of subscripted soil characteristics.

³X₁ = stockpile age in years.

⁴X₂ = stockpile depth in feet.

Correlation Discussion

Several similar correlations between two soil parameters were found at all three stockpile sites. These correlations were all positive and most were significant at the 1 pct level at all three sites. The correlations are:

- Soil moisture - EC. This correlation indicates that the soluble salts are following the moisture in the soil.
- Soil moisture - depth. This correlation shows that the surface dries more readily than lower strata. Coupled with the correlation between soil moisture and EC, this indicates that soluble salts are being leached from the surface regions into the lower strata. One may then expect to find a positive correlation between EC and depth, which is the case in the Farmington and Kemmerer data. Data from Ticaboo do not show this EC-depth correlation as significant.
- EC - CEC. This correlation indicates that many of the cation exchange sites are associated with soluble salts.
- Available potassium - dehydrogenase levels. This correlation suggests that potassium may be solubilized from minerals and/or held in the soil by the microbes responsible for dehydrogenase activity.
- Dehydrogenase levels - bacteria population levels.
Dehydrogenase levels - fungi population levels.
Bacteria population levels - fungi population levels. These three correlations suggest that the measures of microbial activity used in this study support each other in their results.

Several other correlations involving total nitrogen content were similar in Farmington and Kemmerer soil samples. These correlations are all positive and significant at the 1 pct level. Because total nitrogen in Ticaboo samples was below detection limits, nitrogen correlations for this soil were not possible. These similar correlations in Farmington and Kemmerer soils are:

- Total nitrogen - soil moisture. This correlation may indicate that nitrogen compounds are following the moisture; however, the total nitrogen - depth correlation to parallel the moisture-depth correlation was found only in the Farmington data.
- Total nitrogen - organic carbon. This correlation suggests that nitrogen in the soil is associated with organic material as a result of plant material inclusion or microbial activity in the stockpile.
- Total nitrogen - available potassium. This correlation together with the associations of dehydrogenase with available potassium and of nitrogen with organic carbon suggests that biological activity accounts for much of the nitrogen and potassium retained by the soils.
- Total nitrogen - dehydrogenase levels. This correlation, like the available potassium - dehydrogenase correlation, may indicate that microbes responsible for the dehydrogenase activity are useful for fixing or holding nitrogen in the soils. Since bacteria and fungi population levels do not correlate significantly to soil nitrogen, microbes measured in the counting procedure may retain less nitrogen than microbes responsible for dehydrogenase activity.

No correlations of shoot yield with other factors were found at all three sites. Only two correlations involving shoot yield were similar from year to year:

1. Shoot yield for Kemmerer samples was positively correlated with stockpile age;
2. Shoot yield for Ticaboo samples was negatively correlated with CEC. The reasons for different correlations in the growth test data were not investigated further.

Regression Discussion

The only parameter having significant multiple-regression equations at more than one site was bacteria population levels. Kemmerer and Ticaboo bacteria levels had positive stockpile depth coefficients indicating that bacteria levels increased with increasing soil depth. Age, however, had contradictory effects on bacteria at the two sites; bacteria counts increased with age in Kemmerer soil but decreased with age in Ticaboo soil. Bacteria population levels in Farmington soil samples were determined in 1982 only and samples of undisturbed soil were unavailable, so multiple regression on age and depth was deemed inappropriate.

The increase of bacteria levels with depth does not agree with results obtained by previous researchers (2, 15); but as has been pointed out, bacteria levels change very slowly in soil, often taking 10 years or more to show significant changes. Since none of the stockpiles at Kemmerer or Ticaboo were over 8 years old and most were less than 2 years old, changes in bacteria populations may not be significant. This factor coupled with the heterogeneous nature of the stockpiles may account for this disagreement.

SUMMARY

Data obtained in this study are not conclusive enough to provide reliable predictors of fertility loss in topsoil stored in arid areas. However, this was a short-term study and data are not applicable to changes requiring several years. Stockpile age and depth did have apparent effects on general bacteria activity levels at the two sites where such determinations were made, but the effects are not in agreement with those reported by previous researchers and may be the result of heterogeneous stacking in the stockpile and very slow changes in bacteria levels. The effect of depth was to increase the bacteria level in soil from both sites. Bacteria levels increased with increasing stockpile age at Kemmerer and decreased slightly at Ticaboo.

Soil pH at Farmington, EC at Kemmerer, and soil moisture content at Ticaboo were significantly affected by stockpile age and depth. Effects on these parameters appear to be site-specific and no general characterization applying to all sites can be made.

At Kemmerer which is furthest north and highest in elevation of the three sites, stockpile age and depth increased plant growth, as measured by shoot yield in laboratory tests; but the multiple regression coefficients are very small and indicate that unmeasured variables also affected growth. Growth data from Ticaboo yielded insignificant relationships, and data from Farmington were insufficient for statistical comparison.

Results from this study show that a much more rigorous study is needed to determine effects of stockpiling topsoil. A study should be done over a 10- to 15-year period that includes laboratory growth tests under closely controlled conditions along with growth tests in the field. Ideally, an area should be sampled before stripping so that the original state of the soil can be determined. Results from such a test would yield a much better understanding of the changes in soil characteristics and resultant changes in soil fertility. With the expected increase in strip mining, both for coal and non-fuel minerals, such understanding is vital to maintaining environmental stability around mining sites.

REFERENCES

1. Allison, L. E. Organic Carbon. Ch. in Methods of Soil Analysis, Part 2, ed. by C. A. Black, D.D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark. Am. Soc. Agronomy, 1965, pp. 1370-1371.
2. Barkworth, H., and M. Bateson. An Investigation Into the Bacteriology of Topsoil Dumps. Plant and Soil, v. 21, No. 3, Dec. 1964, pp. 345-353.
3. Bower, C. A., and L. V. Wilcox. Soluble Salts. Ch. in Methods of Soil Analysis, Part 2., ed. by C. A. Black, D. D. Evans, J. L. White, L. F. Ensminger, and F. E. Clark. Am. Soc. Agronomy, 1965, pp. 933-951.
4. Casida, L. E., Jr. Methods for the Isolation and Estimation of Activity of Soil Bacteria. Ch. in The Ecology of Soil Bacteria, ed. by T. R. G. Grey and D. Parkinson. Liverpool Univ. Press, 1968, pp. 97-122.
5. Clark, F. E. Agar-Plate Method for Total Microbial Count. Ch. in Methods of Soil Analysis, Part 2, ed. by C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark. Am. Soc. Agronomy, 1965, pp. 1460-1466.
6. Dean, K. C., R. Havens, and M. W. Glantz. Methods and Costs for Stabilizing Fine-Sized Mineral Wastes. BuMines RI 7896, 1974, 26 pp.
7. Dean, K. C., R. Havens, and K. T. Harper. Chemical and Vegetative Stabilization of a Nevada Copper Porphyry Mill Tailing. BuMines RI 7261, 1969, 14 pp.
8. Donahue, R. L., R. W. Miller, and J. C. Shickluma. Soils: An Introduction to Soils and Plant Growth. Prentice-Hall, Inc., 1977, pp. 203-204.
9. Froisland, L. J, P. L. Placek, and M. B. Shirts. Restoration of Surface Vegetation on Uranium Wastes at Uravan, Colo. BuMines RI 8653, 1982, 13 pp.
10. Havens, R., and K. C. Dean. Chemical Stabilization of the Uranium Tailings at Tuba City, Ariz. BuMines RI 7288, 1969, 12 pp.
11. Hunter, F., and J. A. Currie. Structural Changes During Bulk Soil Storage. J. Soil Science, v. 17, No. 1, 1956, pp. 75-80.

REFERENCES--Continued

12. Johnson, W., and J. Paone. Land Utilization and Reclamation in the Mining Industry, 1930-80. BuMines IC 8862, 1982, 22 pp.
13. Klein, D. A., T. C. Loh, and R. L. Guilding. A Rapid Procedure to Evaluate the Dehydrogenase of Soils Low in Organic Matter. Soil Bio. Biochem., v. 3, 1971, pp. 385-387.
14. McDonald, W. R., and M. B. Shirts. Progress in Stabilizing Acidic Copper Tailings at Holden Village, Wash. BuMines RI 8314, 1978, 15 pp.
15. Miller, R. M., and R. E. Cameron. Some Effects on Soil Microbiota of Topsoil Storage During Surface Mining. Proc. Fourth Symp. on Surface Mining & Reclamation, Natl. Coal Assoc., Washington, DC, Oct. 1976, pp. 131-139.
16. National Oceanic and Atmospheric Administration (Department of Commerce). Climatology of the United States No. 85 (By State): Monthly Averages of Temperature and Precipitation for State Climatic Divisions 1941-70--North Dakota. National Climatic Center, 1973, 12 pp.
17. _____. Climatology of the United States No. 81 (By State): Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1941-70--New Mexico. National Climatic Center, 1973, 12 pp.
18. _____. Climatology of the United States No. 81 (By State): Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1941-70--Utah. National Climatic Center, 1973, 12 pp.
19. _____. Climatology of the United States No. 81 (By State): Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1941-70--Wyoming. National Climatic Center, 1973, 12 pp.
20. Neville, A. M., and J. B. Kennedy. Basic Statistical Methods for Engineers and Scientists. International Textbook Co., 1964, p. 215.
21. Nielsen, G. A., and E. V. Miller. Crop Yields on Native Soils and Strip Mine Soils: A Comparison. J. Soil and Water Cons. v. 35 No. 1, 1980, pp. 44-46.
22. Peech, M. Hydrogen-Ion Activity. Ch. in Methods of Soil Analysis, Part 2, ed. by C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark. Am. Soc. Agronomy, 1965, pp. 914-926.

REFERENCES--Continued

23. Pleysier, J. L., and A. S. R. Juo. A Single Extraction Method Using Silver Thiourea for Measuring Exchangeable Cations and Effective CEC in Soils With Variable Charges. Soil Sci., v. 129 No. 4, 1980, p. 205.
24. Rives, C. S., M. I. Bajwa, and A. E. Liberta. Effects of Topsoil Storage During Surface Mining on the Viability of VA Mycorrhiza. Soil Sci., v. 129, No. 4, April 1980, pp. 253-257.
25. Singleton, P. C., and S. E. Williams. Effects of Long Term Storage on the Fertility and Biological Activity of Topsoil. Inst. Energy and Environ., Univ. Wyoming, 1979, 36 pp.
26. U.S. Code of Federal Regulations. Title 30 - Mineral Resources: Chapter VII--Office of Surface Mining Reclamation and Enforcement, Department of the Interior; Subchapter K--Permanent Program Performance Standards; Part 816, Permanent Program Performance Standards - Surface Mining Activities, July 1, 1985.

APPENDIX A.--STATISTICAL METHODS

Statistical Tests

Regression equations relating soil characteristics and growth parameters to stockpile parameters were tested for significance with standard F-tests for regression and variance. Coefficients in these equations were tested for significance with Student's T tests.

This study was designed to determine if stockpile age and depth affected the soil characteristics and not necessarily to establish a predictive equation for those parameters. Therefore, these regression equations are useful in interpreting the data even though some of the multiple correlation coefficients are low. An additional statistical test was imposed on these multiple-correlation coefficients to determine if they were significantly different from zero. This was done by comparing the coefficients with critical values based on the number of variables and the number of samples (20). If the calculated coefficient exceeded the critical value, it was accepted as significantly different from zero. Equations yielding multiple-regression coefficients that failed this test were not considered significant.

Regression Equations

Multiple linear regression analysis established some relationships between soil characteristics, growth, stockpile age, and soil depth. All sampling data from each site were combined to determine age and depth equations for soil characteristics. Each year's shoot yield data were analyzed separately because of the different greenhouse conditions from year to year.

In the regression equations, stockpile age is the time in years between construction of the pile and collection of the samples. Fractional parts of years were used if they were known with certainty.

Stockpile or sample depth is the depth in the pile from which the sample was taken. A positive correlation with depth means that the measured value of the parameter increases as the depth gets greater.

The common statistical method of taking growth, as measured by shoot yield, as the dependent variable and soil characteristics as independent variables was not followed in this study because the effects of these characteristics on plant growth has been well established. The purpose of this study was to determine effects of stockpile parameters, age and depth, on the soil characteristics.

APPENDIX B.--EXPERIMENTAL DATA

Tables B-1 to B-3 show experimental data from topsoil samples collected from the Farmington site in 1980, 1981, and 1982, respectively. Tables B-4 and B-5 show experimental data from topsoil samples collected from the Kemmerer site in 1981 and 1982, respectively. Tables B-6 and B-7 show experimental data from the topsoil samples collected from the Ticaboo site in 1981 and 1982, respectively.

In these data tables, stockpile depth is reported in feet. This depth is the bottom of the sampling interval. For example, in table B-1, drill hole No. 1, the soil sample with a listed depth of 9.2 ft contains the soil between the depths of 8.1 and 9.2 ft. All native soil samples were taken from the top foot of soil and are thus listed as having a depth of 1 ft.

Soil moisture is reported on a dry weight basis. Total nitrogen and organic carbon are reported as percent content in the dry soil. Extractable potassium and soluble phosphorus are reported as parts per million in the extraction solution.

Dehydrogenase is reported as micrograms of formazan produced per gram of dry soil ($\mu\text{g/g}$). Bacteria and fungi population counts are reported as thousand counts per gram of dry soil ($10^3/\text{g}$).

TABLE B-1. - 1980 experimental data from Farmington topsoil samples,
1.5-yr stockpile age

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
DRILL HOLE 1													
1.3	6.2	6.9	320	16.50	0.03	0.5	15.0	ND	ND	ND	ND	ND	1.12
2.8	5.1	7.9	280	13.48	.05	.4	8.6	ND	ND	ND	ND	ND	0.75
4.2	ND	7.9	140	11.38	ND	ND	ND	ND	ND	ND	ND	ND	.55
5.5	ND	8.1	210	11.19	ND	ND	ND	ND	ND	ND	ND	ND	1.14
6.9	9.5	8	250	12.97	.05	.5	10.4	ND	ND	ND	ND	ND	.61
8.1	10.5	8	270	8.67	.05	.5	9.6	ND	ND	ND	ND	ND	.39
9.2	ND	8.6	220	9.67	ND	ND	ND	ND	ND	ND	ND	ND	1.01
10.5	10	8.5	420	11.62	.06	.5	8.8	ND	ND	ND	ND	ND	.64
11.7	ND	7.8	210	10.03	ND	ND	ND	ND	ND	ND	ND	ND	1.30
12.8	10.5	8	530	10.81	.06	.5	8.8	ND	ND	ND	ND	ND	1.20
13.9	10.4	8.3	2,260	20.54	.04	.5	13.5	ND	ND	ND	ND	ND	1.84
15.3	ND	7.9	400	20.71	ND	ND	ND	ND	ND	ND	ND	ND	2.49
DRILL HOLE 2													
.4	4.5	8.4	171	ND	.05	.3	6.9	ND	.08	ND	ND	ND	1.42
1.9	6	8.3	298	ND	.05	.4	7.2	ND	.08	ND	ND	ND	1.27
3.3	6.7	8.3	207	ND	.06	.5	8.3	ND	.16	ND	ND	ND	.95
4	6	8.4	170	ND	.05	.6	11.4	ND	.13	ND	ND	ND	.95
5.4	7.9	8.2	770	ND	.04	.3	7.8	ND	.16	ND	ND	ND	.74
6.7	7.4	8.3	146	ND	.04	.3	8	ND	.16	ND	ND	ND	.94
8.1	8.4	8.3	152	ND	.03	.3	9.7	ND	.09	ND	ND	ND	.92
9.4	12.4	8.1	802	ND	.04	.5	11.5	ND	.16	ND	ND	ND	1.09
10.4	10.4	8.4	254	ND	.05	.5	10.4	ND	.07	ND	ND	ND	2.28
11.4	13.5	8.3	355	ND	.09	.8	9.3	ND	.09	ND	ND	ND	5.61
12.7	14.5	8.1	293	ND	.08	.9	11.4	ND	.08	ND	ND	ND	2.14
13.8	9.7	8.5	344	ND	.06	.6	9.3	ND	.07	ND	ND	ND	1.92
14.8	10.3	8.7	442	ND	.17	.6	3.6	ND	.15	ND	ND	ND	2.34

ND Not determined, sample not available.

TABLE B-2. - 1981 experimental data from Farmington topsoil samples,
2.5-yr stockpile age

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
DRILL HOLE 1													
1	3.9	7.9	244	9.52	0.07	0.6	8.8	55	ND	ND	ND	ND	6.37
2	3.9	7.8	257	ND	.07	.4	5.7	ND	ND	ND	ND	ND	6.37
3	4.1	7.8	229	ND	.07	.6	8.5	ND	ND	ND	ND	ND	ND
4	4.5	7.8	243	ND	.04	.5	10.2	ND	ND	ND	ND	ND	ND
5	5.9	7.9	359	ND	.05	.4	7.8	ND	ND	ND	ND	ND	ND
6	6.5	8.1	438	ND	.04	.2	6.4	ND	ND	ND	ND	ND	ND
7	9.1	8	398	ND	.04	.5	10.5	ND	ND	ND	ND	ND	ND
8	10.5	8.1	620	ND	.04	.4	10.8	ND	ND	ND	ND	ND	ND
9	11.3	7.9	1,620	ND	.05	.5	10.2	ND	ND	ND	ND	ND	ND
10	8.5	7.9	1,280	ND	.04	0	0	ND	ND	ND	ND	ND	ND
11	6.8	7.9	269	ND	.04	.8	22.6	ND	ND	ND	ND	ND	ND
12	8.8	7.8	1,990	ND	.04	.4	11.9	ND	ND	ND	ND	ND	ND
13	8.0	8	2,560	ND	.04	.3	9.2	ND	ND	ND	ND	ND	ND
14	9.0	8.1	3,500	ND	.03	.3	9	ND	ND	ND	ND	ND	ND
15	6.7	8.2	3,330	ND	.02	.2	8.6	ND	ND	ND	ND	ND	ND
DRILL HOLE 2													
1	10.4	8.1	162	11.70	.05	.5	10.6	21	0.2	0.64	ND	ND	1.12
2	10	8.1	248	12.10	.05	.6	11.6	25	0	.18	ND	ND	1.12
3	6.6	8.1	168	10.92	.04	.7	17.7	10	0	.16	ND	ND	0.82
4	5.7	8.1	213	10.64	.03	.4	12.9	21	.2	.60	ND	ND	.82
5	7.2	8	171	8.23	.03	.3	10.4	22	0	.72	ND	ND	1.16
6	9	8	219	9.05	.04	.3	8.5	37	0	3.21	ND	ND	1.16
7	10	8	190	8.53	.05	.6	12	11	0	.38	ND	ND	.54
8	9.7	8.1	432	10.55	.03	.4	12.8	17	.2	.68	ND	ND	.54
9	12.6	8.1	960	16.72	.03	.3	9.1	4	.1	1.53	ND	ND	1.70
10	10.4	8.3	495	10.33	.04	.3	7.2	22	.1	1.17	ND	ND	1.70
11	8.2	8.3	340	10.45	.03	.2	48	28	0	1.08	ND	ND	1.37
12	9.8	8.2	186	10.16	.04	.7	16.6	31	.2	2.25	ND	ND	1.37
13	12.4	8.1	392	11.44	.08	.6	7.9	61	.1	2.25	ND	ND	3.16
14	12.6	8.1	1,395	20.63	.05	.5	11	15	0	2.09	ND	ND	3.16
15	9.5	8.3	2,600	34.12	.03	.5	18.6	8	0	1.33	ND	ND	5.12
DRILL HOLE 3													
1	3.6	8.3	210	9.78	.02	.2	9.6	7	0	1.37	ND	ND	.94
3	4.6	8.2	605	13.10	.03	.4	11.2	20	0	.80	ND	ND	1.08
4	6.1	8.1	209	10.78	.04	.5	11.9	15	0	1.04	ND	ND	1.08
5	6.9	8.2	262	11.36	.03	.5	13.2	8	0	.26	ND	ND	.58
6	9.4	8.1	219	10.30	.04	.5	11.2	21	0	1.41	ND	ND	.58
7	8.8	8.1	198	10.03	.04	.4	10.3	41	0	3.01	ND	ND	.80
8	13.6	8	283	10.44	.06	.5	7.4	40	0	2.17	ND	ND	.80
9	13.7	8	270	11.11	.06	.6	9.4	37	0	1.69	ND	ND	ND
10	9.9	8.1	438	13.41	.02	.5	26	20	.6	.88	ND	ND	ND
11	10	8.1	350	11.05	.03	.4	14	13	0	.92	ND	ND	.69
12	7.9	8.1	290	10.64	.04	.5	13	30	0	1.21	ND	ND	.69
13	7.9	8.1	550	11.23	.07	.9	14.2	24	0	.48	ND	ND	.63
14	9.2	8.2	390	12.10	.05	.3	6.2	16	0	.80	ND	ND	.63
15	14.1	8.1	775	16	.05	.7	14	8	0	.80	ND	ND	1.97

ND Not determined, sample not available.

TABLE B-3. - 1982 experimental data from Farmington topsoil samples,
3.5-yr stockpile age

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
DRILL HOLE 1													
1	18.7	7.5	240	8.36	0.05	0.5	10.0	3	0.52	1.53	90	58	2.64
2	9.4	7.5	183	8.97	.05	.5	10	15	.03	2.33	135	80	2.64
3	4.9	7.4	145	11	.04	.7	17.5	25	.45	3.48	70	45	1.41
4	5.7	7.4	170	11.31	.04	.5	12.5	16	.97	2.20	40	26	1.41
5	10.8	7.5	1,300	19.17	.04	.5	12.5	9	.78	1.38	27	21	2.73
6	5.8	7.6	480	9.97	.03	.3	10	11	1	2.60	47	34	2.73
7	6.5	7.5	135	8	.03	.2	6.7	16	.45	2.40	34	29	2.44
8	7.2	7.5	130	7.85	.02	.1	5	18	.51	2.53	35	22	2.44
9	8.3	7.5	115	7.01	.02	.2	10	11	0	2.92	20	29	1.77
10	9.5	7.5	160	7.06	.04	.5	12.5	12	0	2.71	55	31	1.77
11	5	7.5	160	7.82	.03	.4	13.3	15	.20	2.55	38	25	1.15
12	4.2	7.6	215	8.35	.03	.4	13.3	6	0	1.24	10	4	1.15
13	8.4	7.6	300	9.32	.04	.6	15	15	0	3.59	73	38	1.47
14	12.2	7.6	235	9.76	.06	.6	10	18	.46	2.25	50	37	1.47
15	12.2	7.5	275	7.73	.05	.7	14	24	.26	18.33	315	223	1.75
DRILL HOLE 2													
1	16.9	7.7	215	9.29	.03	.4	13.3	4	0	1.07	53	24	1.69
2	5.2	7.6	180	11.76	.03	.5	16.7	19	0	2.53	98	60	1.69
3	4.9	7.7	135	11.42	.04	.6	15	20	0	1.98	29	11	2.36
4	6.6	7.4	180	11.66	.04	.6	15	17	0	2.36	30	12	2.36
5	10.9	7.5	2,450	28.45	.03	.8	26.7	6	0	2.29	16	4	1.73
6	6.8	7.5	1,650	14.07	.04	.4	10	16	0	3.40	38	25	1.73
7	7.7	7.6	160	8.03	.02	.3	15	16	0	3.03	26	20	.83
8	8	7.5	138	7.41	.02	.4	20	16	.33	2.89	36	28	.83
9	10.3	7.5	188	7.40	.01	.5	50	20	0	2.49	13	20	2.28
10	11.2	7.5	260	7.89	.04	.5	12.5	13	0	1.92	32	16	2.28
11	10.4	7.5	330	9.58	.04	.7	17.5	15	0	2.92	32	22	3.24
12	13	7.6	275	8.79	.03	.7	23.3	16	0	2.95	40	20	3.24
13	9.7	7.6	240	7.49	.03	.6	20	17	0	3.11	32	20	2.15
14	13.2	7.5	245	8.13	.05	.6	12	19	.33	2.31	13	14	2.15
15	14.2	7.7	200	7.83	.05	.7	14	21	0	16.56	9	26	1.70
DRILL HOLE 3													
1	6.7	7.3	205	11.85	.01	.2	20	3	.41	.93	28	12	1.72
2	5.5	7.5	175	12.25	.04	.4	10	13	.41	.93	25	20	1.72
3	5.5	7.6	170	11.46	.03	.5	16.7	10	0	1.74	33	22	1.58
4	3.9	7.6	195	12.23	.04	.7	17.5	7	.61	1.26	21	13	1.58
5	5.6	7.6	600	12.76	.02	.6	30	19	0	2.55	35	13	1.80
6	15.9	7.6	740	12.79	.04	.3	7.5	11	0	2.44	20	26	1.80
7	5.7	7.5	235	7.71	.02	.3	15	19	.41	3.38	25	53	2.38
8	5.2	7.6	200	7.31	.02	.2	10	16	.41	2.90	7	28	2.38
9	3.7	7.7	180	7.12	.02	.3	15	17	.51	2.22	24	24	1.70
10	8.9	7.7	185	8.46	.04	.3	7.5	12	.41	1.98	19	10	1.70
11	6.2	7.6	183	8.30	.02	.3	15	16	.81	1.53	14	10	1.86
12	5.9	7.6	208	8.48	.03	.3	10	13	.50	1.96	17	8	1.86
13	8.9	7.6	365	10.83	.04	.5	12.5	16	.10	2.29	9	6	1.44
14	9.5	7.7	255	9.19	.05	.6	12	14	.10	1.10	1	2	1.44
15	13.2	7.7	315	8.04	.04	.3	7.5	10	0	4.40	11	34	1.10

TABLE B-3. - 1982 experimental data from Farmington topsoil samples,
3.5-yr stockpile age--Continued

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
DRILL HOLE 4													
1	15.7	7.4	220	9.81	0.04	0.6	15	11	0.51	2.46	12	14	1.70
2	6.1	7.4	230	11.80	.05	.6	12	14	.38	2.09	27	20	1.70
3	4.7	7.4	115	9.47	.03	.3	10	16	.38	2.24	60	20	1.56
4	6.3	7.6	185	9.26	.03	.5	16.7	14	.38	2.94	40	32	1.56
5	7.4	7.7	135	8.19	.02	.3	15	19	0	4.26	39	26	1.36
6	8.9	7.6	165	7.67	.04	.5	12.5	20	.19	2.87	13	16	1.36
7	8.8	7.6	140	7.83	.03	.4	13.3	9	.38	1.29	25	17	1.47
8	10.6	7.7	235	7.79	.03	.4	13.3	7	.38	1.81	15	15	1.47
9	10.1	7.9	655	11.64	.02	.6	30	5	.76	1.80	73	270	.42
10	10.5	7.9	1,020	15.11	.04	.5	12.5	3	.38	3.38	.1	5	.42
11	10.5	7.9	1,950	21.50	.04	.7	17.5	6	0	1.93	.5	7	.88
12	11.9	7	550	9.44	.05	.8	16	15	0	12.94	22	64	.88
13	13	8	940	11.92	.04	.7	17.5	13	0	2.51	.8	5	.22
14	8.7	8.1	1,260	15.42	.04	.7	17.5	5	0	2.52	.4	2	.22
15	7.4	8.1	2,430	22.65	.03	.5	16.7	6	.38	1.83	0	.4	.34
DRILL HOLE 5													
1	9.4	7.2	100	11.35	.04	.6	15	34	0	1.85	68	65	1.73
2	6.7	7.6	160	11.32	.06	.8	13.3	21	0	2.32	28	50	1.73
3	5.6	7.6	110	11.04	.03	.4	13.3	11	.75	1.77	35	38	1.74
4	3	7.6	160	9.71	.03	.5	16.7	10	0	1.92	40	65	1.74
5	7.9	7.6	130	8.42	.02	.4	20	4	0	.90	13	22	1.93
6	8.1	7.6	135	7.93	.03	.3	10	11	.19	1.69	47	30	1.93
7	7.4	7.5	123	8.91	.03	.3	10	6	0	1.06	35	25	1.83
8	9.8	7.6	260	8.39	.03	.3	10	12	0	1.75	7	11	1.83
9	7.9	7.7	510	10.40	.03	.6	20	15	.19	4.66	.5	5	1.54
10	13.4	7.8	660	11.17	.06	.5	8.3	9	.19	2.23	.5	12	1.54
11	11.5	7.8	1,230	16.85	.04	.8	20	7	.84	2.25	.5	8	.94
12	10.3	7.7	395	8.80	.05	.6	12	20	.93	11.90	8	38	.94
13	16.4	8	1,170	14.79	.07	.8	11.4	13	.93	1.33	.1	3	.65
14	8.8	8	2,100	19.44	.03	.4	13.3	5	.56	1.59	2	3	.65
DRILL HOLE 6													
1	7.6	7.7	115	10.22	.04	.3	7.5	34	.17	3.11	28	110	2.26
2	6.9	7.5	135	10.32	.04	.8	20	31	.56	2.87	25	105	2.26
3	5.0	7.5	130	10.66	.05	.3	6	19	.19	4.04	55	48	2.32
4	5.5	7.6	178	9.49	.05	.7	14	23	.56	5.47	68	68	2.32
5	7.1	7.5	165	8.56	.06	.5	8.3	21	0	4.16	45	73	1.55
6	8	7.6	130	8.35	.05	.3	6	10	0	2.19	26	12	1.55
7	7	7.6	135	8.11	.04	.2	5	8	0	1.58	23	21	1.19
8	9.8	7.6	305	8.35	.08	.6	7.5	12	0	6.57	6	11	1.19
9	8.9	7.7	350	8.79	.05	.5	10	22	0	7.77	5	21	1.64
10	12.4	7.8	440	8.73	.07	.1	1.4	20	0	5.17	2	12	1.64
11	9.9	7.8	1,480	21.24	.05	.4	8	6	0	3.51	1	5	2.01
12	11.8	7.7	370	9.17	.09	.6	6.7	28	0	10.37	23	75	2.01
13	11.8	7.9	800	11.29	.07	.4	5.7	15	.22	6.97	13	51	.61
14	12.8	8.1	2,300	23.25	.05	.3	6	6	.87	3.24	1	2	.61
15	8.6	8.1	2,650	23.44	.04	.1	2.5	5	.50	4.56	.1	1	.15

TABLE B-4. - 1981 experimental data from Kemmerer topsoil samples

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
UNDISTURBED SOIL													
1	6	5.4	67	10.2	0.0	6.6	220.0	16	0.6	7.72	36	16.5	2.30
1	2.8	5.7	27	7.8	.16	4.6	28.8	13	.4	3.63	15.8	5.3	2.30
1	1.8	5.2	22	4.9	.07	1	14.3	11	0	2.04	17.8	4.3	1.92
1	1.5	5.7	27	5.1	.09	.6	6.7	14	0	3.26	14	5	2.03
1	2.8	6	36	8.8	.01	.6	60.0	13	0	5.76	57.5	22.5	2.03
1	9.5	6.7	110	11.7	.01	2.1	210.0	13	0	1.53	11.8	5	1.70
1	3.5	6.2	58	8	.08	6.3	78.8	20	.1	6.77	27.8	3.5	1.70
1	3.3	6.2	44	7.4	.05	.5	10.0	14	.1	2.53	0	2.4	3.24
1	2.4	6.6	90	9.5	.06	2	33.3	26	0	15.35	.8	5.3	3.24
1	6.3	3.7	20	7.7	.07	.7	10.0	15	0	.08	24	13.5	1.68
1	7.7	3.4	34	4.9	.01	1.6	160.0	14	0	.14	7	10.5	1.68
1	1.5	5.7	33	4.3	.07	.7	10.0	9	.1	3.13	47	26.5	2.29
1	1.7	4.9	30	4.8	.05	.6	12.0	9	0	1.13	35.5	5.5	2.29
1	4.7	5.8	38	9.1	.08	.5	6.3	8	0	3.31	29.5	7.5	1.86
1	7.5	6.4	114	11	.14	.7	5.0	12	0	6.21	25	4.8	1.86
DRILL HOLE 1, 7-YR STOCKPILE AGE													
1.5	10.5	6.6	120	9.55	.10	.9	9	10	.3	2.48	255	27.5	.93
3	9	6.1	80	8.02	.09	.9	10	18	.2	2.35	395	65	.93
4	8.1	6	54	8.25	.11	1.1	10	16	0	2.07	112	17.5	3.23
5	8.1	6	100	8.65	.14	1	7.1	19	.6	2.17	30.5	10.5	3.23
6	7	5.8	137	8.18	.15	1.5	10	26	0	1.61	175	155	3.36
7	8.8	6	96	8.33	.17	1.3	7.6	25	0	4.39	160	77.5	3.36
8	9	6.5	82	8.67	.12	1.1	9.2	17	0	2.99	277.5	15	3.36
9	9.5	7	124	8.85	.07	1.2	17.1	22	.4	1.16	20	19	1.70
10	3.1	7	138	8.54	.11	1	9.1	22	.3	1.37	19.5	43	1.70
11	14.3	6.6	129	9.34	.02	1.5	75	37	0	.74	155	196	5.72
12	10	6.3	116	6.93	.13	2	15.4	29	0	.45	82.5	112.5	5.72
13	7.7	6.2	122	6.47	.10	1.2	12	22	0	.21	17.5	17.5	5.28
14	6.9	6.4	88	5.95	.10	.7	7	20	0	.57	13.5	39.5	5.28
15	6.1	6.2	56	5.57	.11	1.2	10.9	16	0	.27	18.5	49.5	4.58
DRILL HOLE 2, 7-YR STOCKPILE AGE													
1	8.4	5.8	79	6.41	.18	1.7	9.4	17	.7	2.53	105	60	2.52
2	10	5.9	66	8.96	.19	.2	1.1	14	0	2.25	52	17	2.52
3	9.2	6.6	103	10.59	.12	.7	5.8	23	0	9.24	442.5	45	5.04
4	6.4	6.1	70	8.95	.17	1.2	7.1	16	.1	3.17	295	32.5	5.04
5	5.7	6	60	7.26	.11	1.4	12.7	15	0	2.89	327.5	50	4.99
6	5.7	5.8	99	6.30	.01	1	100	18	0	1.87	620	85	4.99
7	6.2	6.3	57	8.30	.16	1.2	7.5	13	0	2.11	165	15	4.88
8	6.6	6.4	80	7.69	.14	1.1	7.9	21	0	7.59	102.5	87.5	4.88
9	6.3	6	77	8.20	.17	1.4	8.2	20	.1	5.29	205	67.5	7.80
10	7.3	6.3	107	9.48	.17	1.8	10.6	20	0	4.98	160	42.5	7.80
11	8.1	6.5	118	8.04	.16	1.1	6.9	21	0	1.59	40	37.5	8.14
12	7.7	6.7	156	7.90	.14	1	7.1	25	.8	2.44	200	115	8.14
13	9.8	6.6	96	9.37	.01	1.4	140	21	0	2.11	215	55	4.23
14	9.8	6.7	82	8.65	.09	1.1	12.2	23	.4	2.23	61.5	34.5	4.23
15	10.1	7	167	10.63	.06	1.9	31.7	22	0	.96	39	12.5	7.70
DRILL HOLE 3, 0.2 YR STOCKPILE AGE													
1	9.3	7.0	163	10.8	.16	1.7	10.7	19	0	2.83	38.5	22	1.08
2	10.2	6.8	237	10.7	.17	1.8	10.6	16	0	5.47	48	16.5	1.08
3	10.3	5.8	780	15.4	.02	1.6	80	14	.2	2.45	117.5	47.5	1.39
4	7.3	5.8	545	14.7	.15	1.6	10.7	14	0	2.52	72.5	60	1.39
5	9.5	4.7	750	12.5	.17	1.7	10	16	0	.24	15.5	12.5	.98
6	8.3	4.9	390	9.4	.11	1.2	10.9	14	0	.35	21	9	.98
7	13.5	4.4	184	8.6	.19	2	10.5	13	.3	.20	33.5	14.5	5.70
8	12.8	4.3	146	9	.21	3.4	16.2	12	0	.29	27.5	7.5	5.70
9	13.1	5.8	146	10.8	.28	2.1	7.5	22	.3	6.55	295	380	1.90
10	11.3	6.9	280	11.2	.20	1.6	8	17	0	15.19	485	640	1.90
11	10.4	6.9	260	11	.02	1.9	95	17	.3	10.37	152.5	225	1.28
12	9.6	6.8	360	10.9	.16	1	6.3	17	.1	8.20	145	305	1.28
13	9.6	6.6	618	12.9	.05	1.7	34	19	.3	9.72	110	17.5	1.89
14	9.3	6.4	855	14.3	.08	1.7	21.3	20	.6	6.03	65	95	1.89
15	8.2	6.5	960	14.9	.21	1.6	7.6	21	.6	4.01	32.5	40	1.89

TABLE B-5. - 1982 experimental data from Kemmerer topsoil samples

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
UNDISTURBED SOIL													
1	9.1	5.7	25	7.07	0.09	0.3	3.3	9	0.17	5.39	265	215	1.84
1	7.3	5.9	34	8.51	.13	2.1	16.2	11	0	13.67	235	230	1.84
1	4.9	5.7	24	5.25	.04	2.2	55	12	.34	6.55	155	190	1.56
1	4.2	5.8	31	7.24	.10	1.3	13	10	.18	10.45	325	340	1.56
1	7	6	44	7.92	.08	.8	10	9	0	6.31	95	165	1.41
1	6.2	5.5	20	4.78	.03	.3	10	9	.50	1.09	100	105	1.41
1	5.6	5.8	28	5.37	.04	.3	7.5	8	0	3.74	75	85	1.65
1	5.1	6.3	34	5.19	.05	.4	8	8	0	5.02	80	123	1.65
1	4.1	6.1	31	4.35	.04	.3	7.5	6	0	3.32	105	48	1.45
1	7.1	6.6	70	6.81	.05	.4	8	4	0	5.71	60	45	1.45
1	16.4	6.3	57	8.07	.17	3.2	18.8	21	0	5.79	170	130	2.60
1	14.2	6	39	11.48	.24	3.9	16.3	13	0	11.66	380	205	2.60
1	8.3	6	44	10.85	.32	5.5	17.2	17	0	21.10	375	315	2.23
1	9.8	6.2	45	11.28	.33	5.4	16.4	22	0	24.32	395	415	2.23
1	9.9	5.9	24	6.96	.07	1.3	18.6	11	.16	2.99	68	43	1.31
DRILL HOLE 1, 1.2-YR STOCKPILE AGE													
1	9.9	6.3	465	9.72	.11	1.6	14.5	5	.38	1.43	65	75	2.40
2	7.6	6.3	200	7.60	.08	1.5	18.8	5	.40	1.85	78	95	2.40
3	6	6.6	370	6.65	.03	.5	16.7	5	0	1.00	23	63	1.81
4	6.3	6.3	530	10.54	.11	1.8	16.4	12	.76	10.45	200	210	1.81
5	4.1	6.9	315	10.52	.06	.9	15	9	1.30	7.23	385	175	.98
6	8.4	7	170	10.34	.11	1.8	16.4	16	.96	2.67	75	58	.98
7	10.8	5.2	140	9.52	.16	2.3	14.4	9	.28	0	29	15	1.07
8	7.1	5.7	610	9.35	.09	1.2	13.3	8	.19	2.89	195	115	1.07
9	7.7	5	230	4.19	.17	5	29.4	10	0	1.37	140	125	1.57
10	8.6	5.1	465	10.82	.14	2.6	18.6	11	0	1.97	180	135	1.57
11	9.4	5.6	190	10.78	.18	1.9	10.6	17	.28	3.28	250	230	1.50
12	14.1	4.3	295	8.99	.17	4.1	24.1	9	0	.26	53	50	1.50
13	9	5.6	215	10.26	.17	2.2	12.9	16	.19	9.64	535	435	2.06
14	9	6.5	350	10.58	.12	1.6	13.3	12	.47	7.47	195	150	2.06
15	9.2	6.5	200	9.97	.13	1.3	10	15	.21	10.85	1,620	485	2.15
DRILL HOLE 2, 1.2-YR STOCKPILE AGE													
1	8.6	5.9	125	6.57	.08	1.6	20	5	0	.30	80	23	2.40
2	7.9	6.7	640	8.03	.04	.6	15	4	0	.28	113	73	2.40
3	10.9	6	210	7.67	.05	1.5	30	9	.27	1.69	48	38	1.44
4	7.7	6.5	800	11.08	.16	.6	3.8	8	0	6.99	225	110	1.44
5	6	6.9	260	8.89	.09	2.5	27.8	10	.36	5.02	100	95	1.33
6	7.9	7	130	9.49	.12	1.9	15.8	14	0	2.07	28	14	1.33
7	8.2	5.5	165	10.11	.16	2.6	16.3	10	0	.52	29	19	.88
8	8.3	4.9	550	9.86	.15	3.4	22.7	8	0	1.61	155	135	.88
9	8.6	4.7	470	10.27	.18	3.6	20	10	.36	.72	100	190	1.74
10	8.1	5.4	240	9.53	.11	1.7	15.5	10	0	1.89	160	165	1.74
11	7.7	6.2	115	9.20	.13	1.9	14.6	15	0	3.86	130	110	1.50
12	7.8	5.3	165	9.39	.13	2.2	16.9	13	0	1.29	155	155	1.50
13	10.2	5	260	8.97	.14	2.1	15	11	0	1.11	115	115	1.16
14	8.9	6.4	200	9.31	.13	1.8	13.8	15	0	3.24	345	260	1.16
15	8.6	6.5	215	8.90	.13	1.6	12.3	13	0	12.46	2,025	865	2.05
DRILL HOLE 3, 1.2-YR STOCKPILE AGE													
1	8.5	6.7	125	5.47	.08	1.2	15	5	0	.80	105	35	1.36
2	10.3	7.1	255	6.50	.10	1.1	11	6	0	2.57	75	55	1.36
3	7.2	5.4	60	5.85	.09	1.6	17.8	9	.18	1.23	68	43	1.17
4	6.3	6.1	110	8.82	.12	1.8	15	16	0	2.53	73	20	1.17
5	7.2	7.4	265	12.33	.04	.5	12.5	2	0	1.01	44	6.5	1.43
6	8.3	7.5	150	9.29	.10	1.6	16	13	0	1.09	63	7.5	1.43
7	7.8	6.8	480	11.84	.11	1.7	15.5	11	0	2.01	220	60	1.62
8	6.4	5.8	480	7.95	.08	1	12.5	9	0	2.25	200	58	1.62
9	8.7	5.3	410	10.37	.17	4	23.5	11	.37	1.53	300	95	1.33
10	9	4.7	760	11.06	.10	1.9	19	8	0	.16	165	38	1.33
11	9.5	4.8	275	6.84	.10	2.1	21	7	.27	.32	103	38	1.45
12	14.1	4.2	195	7.40	.19	3.3	17.4	8	.36	.08	55	10	1.45
13	12.3	5	260	9.78	.18	3.1	17.2	12	0	.52	140	43	1.70

TABLE B-5. - 1982 experimental data from Kemmerer topsoil samples--Continued

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct	Organic C, pct	C/N ratio	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield g
DRILL HOLE 4, 8-YR STOCKPILE AGE													
1	6.7	5.7	210	9.55	0.12	3	25	16	0.54	2.73	300	125	2.25
2	7.4	5.7	155	9.25	.11	1.9	17.3	14	.18	3.20	425	115	2.25
3	5.6	6.6	265	9.17	.07	1.1	15.7	11	.27	3.14	640	75	2.11
4	6.5	6.8	135	9.75	.08	.7	8.8	13	0	6.27	710	85	2.11
5	5.8	6.5	65	8	.08	1.2	15	12	0	4.42	555	125	2.14
6	5.7	6.3	75	8.92	.09	1.6	17.8	10	0	4.50	375	50	2.14
7	5.6	6.3	82	9.05	.10	1.9	19	11	0	3.26	325	120	1.56
8	6.2	6.2	74	7.86	.09	1.3	14.4	14	.17	5.47	540	140	1.56
9	5.7	6.2	89	7.37	.07	1.1	15.7	13	0	4.30	875	110	1.79
10	6.2	6.1	120	8.40	.11	1.4	12.7	17	0	4.50	1,590	210	1.79
11	6.7	6.3	110	8.46	.10	1.4	14	14	0	3.78	2,045	165	2.07
12	5.9	6.2	160	7.66	.10	1.3	13	15	.26	3.94	815	175	2.07
13	7.4	6.4	145	7.66	.10	1.3	13	17	.69	3.86	625	140	1.37
14	9	6.5	110	8.80	.10	1.5	15	16	.69	2.41	153	15	1.37
15	8.1	6.6	110	7.74	.10	1.5	15	16	.61	4.50	450	60	2.21
DRILL HOLE 5, 8-YR STOCKPILE AGE													
1	5.9	6.1	215	9.27	.13	3.1	23.8	17	0	5.31	580	185	2.13
2	11.6	5.7	185	7.16	.13	2	15.4	10	.52	3.90	425	145	2.13
3	8.9	6.3	130	8.52	.09	.6	6.7	7	.69	2.21	485	110	3.39
4	6.9	6.2	135	8.26	.10	1.5	15	8	.29	6.35	505	190	3.39
5	6.9	6.2	85	7.07	.08	1.3	16.3	10	.29	4.98	270	55	1.62
6	6.6	6.3	90	8.60	.09	1.9	21.1	12	.26	5.02	550	165	1.62
7	5.2	6.3	93	7.47	.07	1.6	22.9	11	.26	3.10	390	210	2.38
8	5.5	6.4	72	8.62	.09	1.9	21.1	10	.34	3.26	170	100	2.38
9	5.5	6.1	80	7.18	.10	1.5	15	14	.33	4.98	560	185	1.31
10	6.1	6.3	75	7.39	.08	1.1	13.8	14	.33	3.66	970	235	1.31
11	6.8	6.3	73	7.33	.10	1.2	12	13	.42	4.58	1,075	220	1.92
12	6.9	6.5	125	8.04	.08	1.4	17.5	16	.33	5.11	1,800	110	1.92
13	7.5	6.8	155	6.97	.09	1.2	13.3	16	0	3.74	755	235	1.77
14	7.6	7	155	7.59	.09	1.4	15.6	16	0	5.55	2,465	610	1.77
15	8.2	6.9	155	8.13	.12	1.5	12.5	17	0	5.14	415	205	1.49
DRILL HOLE 6, 8-YR STOCKPILE AGE													
1	8.8	6.2	100	9.31	.09	1.8	20	15	.33	1.23	200	53	1.69
2	7	6.5	155	8.22	.07	1	14.3	9	0	4.14	460	70	1.69
3	6	6.2	155	9.96	.10	1.1	11	13	0	2.73	570	135	2.09
4	5.5	6.1	130	8.29	.09	1.5	16.7	13	0	3.98	520	105	2.09
5	5.8	6.2	80	7.67	.07	1	14.3	9	.60	3.42	395	100	2
6	6.3	6.2	74	7.97	.07	1.4	20	14	0	4.70	870	250	2
7	8	6.4	74	10.38	.16	2.5	15.6	9	0	1.65	173	23	1.64
8	5.3	6.3	80	7.59	.10	1.5	15	13	.34	4.06	285	45	1.64
9	5	6.2	96	7.37	.10	1.6	16	15	.26	4.78	1,425	190	2.17
10	6.8	6.3	86	8.33	.10	2.3	23	16	.17	4.42	1,135	245	2.17
11	7.1	6.4	96	8.86	.10	2.2	22	18	0	4.02	530	45	2.55
12	8.9	6.4	148	7.68	.10	1.4	14	17	1	3.90	605	75	2.55
13	7.6	6.6	105	7.12	.09	1.3	14.4	15	.58	4.42	745	65	1.42
14	8.4	6.5	105	7.40	.11	1.5	13.6	17	.58	4.62	385	40	1.42
15	9.6	6.5	80	7.17	.10	1.6	16	13	.84	2.77	175	20	2.20

TABLE B-6. - 1981 experimental data from Ticaboo topsoil samples

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct ¹	Organic C, pct	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield, g
UNDISTURBED SOIL												
1	3.0	7.4	86	3.65	0	0.1	4	0	0.33	11.9	4.3	0.84
1	3	7.3	105	5.30	0	0	5	0	1.57	14.5	6	1.10
1	7	6.7	91	3.85	0	0	4	0	.65	18	14.8	.80
1	2.8	7.6	64	2.70	0	0	3	.4	.25	ND	ND	1.12
1	2.8	7.8	66	2.73	0	0	3	0	.25	ND	ND	1.12
1	3.9	7.9	72	3.29	0	.2	4	.3	.96	ND	ND	1.11
1	2.8	7.7	72	3.29	0	0	4	.7	.32	ND	ND	1.11
1	3.5	7.6	70	2.81	0	2	4	.3	.42	ND	ND	1.03
1	2.8	7.6	78	3.85	0	0	5	0	1.21	ND	ND	1.22
1	2.8	7.6	84	4.78	0	.1	8	0	5.31	ND	ND	1.22
1	3.2	7.7	82	4.28	0	.1	6	.3	2.92	ND	ND	1.18
1	2.9	7.8	72	3.20	0	0	4	.3	.27	ND	ND	1.18
1	3.4	7.5	78	3.84	0	.1	6	.2	1.50	ND	ND	1.23
1	2.9	7.6	66	3.24	0	0	4	0	.56	ND	ND	1.23
DRILL HOLE 1												
1.5	6.4	6.8	220	4.82	0	.01	6	1	.14	1.3	2.2	.71
3	6.9	6.8	152	5.02	0	.01	5	.3	.19	3.5	4.5	.42
4.5	5.7	7.2	97	5.44	0	.02	5	.2	.29	7.8	7.6	.53
6	7.6	7.3	94	4.59	0	0	6	0	.57	5.4	9.9	.84
7	8.2	7.3	96	5.12	0	0	7	0	.88	11.6	19.5	.90
8	8.2	7.1	88	4.94	0	0	5	.1	.96	6.2	10.9	.88
9	10.9	7.3	90	4.95	0	.02	5	.3	.63	13.8	11.5	1
10	7.1	7.3	86	4.81	0	.03	4	0	.36	9.5	3.3	.54
11	8.4	7.4	118	5.15	0	.01	4	.1	.69	19	11	.67
12	7.9	7.4	108	5.40	0	0	4	0	.71	11.8	8.8	.89
13	8.9	7.3	104	4.62	0	0	5	0	.66	17.5	12.5	.86
15	7.7	7.3	120	4.90	0	0	6	0	.92	18.3	12.5	.75
DRILL HOLE 2												
1	3.6	7.6	103	3.81	0	0	5	.3	.03	ND	ND	1.08
2	6.7	7.8	136	4.82	0	.7	6	0	.21	ND	ND	1.08
3	5.5	7.7	121	4.72	0	0	6	.3	.40	ND	ND	.87
4	6.4	7.8	115	6.47	0	.1	6	.4	.27	ND	ND	.87
5	6	7.9	107	4.60	0	.1	5	.4	.57	ND	ND	1.17
6	9.1	8	101	5.81	0	.1	5	.2	.74	ND	ND	1.17
7	6.7	8	101	4.66	0	0	5	.4	.61	ND	ND	.91
8	7.3	8	115	5.51	0	.1	3	.3	.30	ND	ND	1.19
9	7.1	8	100	4.72	0	0	6	.7	1.03	ND	ND	1.02
10	6.5	8.1	108	4.73	0	0	5	.4	.48	ND	ND	1.02
11	5.9	7.8	103	4.54	0	.2	7	.3	.91	ND	ND	.69

¹Nitrogen content was below analytical limits in all samples.

ND Not determined, sample not available.

TABLE B-7. - 1982 experimental data from Ticaboo topsoil samples

Sample depth, ft	Soil moisture, pct	Soil pH	EC, $\mu\text{S}/\text{cm}$	CEC meq/100 g	Total N, pct ¹	Organic C, pct	Extractable K, ppm	Soluble P, ppm	Dehydrogenase, $\mu\text{g}/\text{g}$	Bacteria counts, $10^3/\text{g}$	Fungi counts, $10^3/\text{g}$	Shoot yield, g
UNDISTURBED SOIL												
1	1.4	7.3	74	4.84	0	0.1	4	0.3	1.49	22.5	7.5	0.55
1	2.1	7.5	72	5.03	0	.1	6	0	1.69	17	9.5	.55
1	2	7.4	69	3.96	0	0	3	.2	.90	29.5	8	.55
1	1.6	7.3	63	2.59	0	0	3	0	.31	8.5	2.5	1.02
1	1.3	7.2	73	3.03	0	0	3	.5	.40	18.5	6.5	1.02
1	1.2	7.2	60	2.41	0	0	3	.3	.45	12.3	3	1.02
DRILL HOLE 1												
1	4.6	7.1	130	4.38	0	.1	4	0	.19	2.6	3.6	.86
2	4.5	7.6	135	4.19	0	.1	5	0	.21	2.5	5.5	.86
3	6.2	7.5	150	3.86	0	0	4	0	.19	4.5	4	.73
4	6.5	7.5	115	4.80	0	.5	4	0	.27	7.8	5.3	.73
5	6.3	7.5	85	4.01	0	0	4	0	.49	6.3	3.5	.63
6	6.1	7.4	132	3.64	0	0	5	.1	.58	7.8	3	.63
7	6.9	7.4	76	3.80	0	0	4	.1	.99	12.8	12.8	.69
8	5.8	7.4	72	3.50	0	0	4	0	.68	15	14	.69
9	5.9	7.5	84	4.11	0	0	2	.1	.24	6.3	9.5	.53
10	6.1	7.6	86	4.54	0	0	3	.1	.34	9.8	4.8	.53
11	7.4	7.6	80	4.04	0	0	4	0	.52	12	11.5	.56
12	6.4	7.5	75	3.62	0	0	4	.1	.69	8	11.3	.56
13	6	7.4	81	3.72	0	.2	5	0	1.09	18.5	9.5	.53
14	6.1	7.6	70	3.74	0	0	4	0	.88	12.5	12.5	.53
15	4.8	7.5	68	3.67	0	.1	5	0	.96	20.3	6.5	.51
DRILL HOLE 2												
1	4.3	7.2	85	3.68	0	0	3	0	.03	5	3	.53
2	6	7.4	89	3.94	0	0	4	.2	.15	7.3	3	.53
3	5.6	7.5	85	3.79	0	.1	5	.4	.09	12	4.5	.65
4	5.3	7.5	82	4.12	0	0	4	.4	.10	19.3	8.5	.65
5	6.6	7.5	84	3.70	0	0	4	.2	.17	12.5	6.8	.87
6	7.5	7.5	87	3.91	0	0	4	0	.20	9.3	3.3	.87
7	5.5	7.6	85	3.30	0	.2	4	0	.26	10.5	4.3	.77
8	5.8	7.7	90	4.02	0	.1	3	0	.17	11.3	3.3	.77
9	6.4	7.7	89	3.88	0	.1	3	.5	.33	20.5	6	.83
10	7.8	7.7	83	3.75	0	.1	4	.1	.61	14.5	4	.83
11	6.5	7.6	81	3.48	0	0	4	0	.52	28.5	10.5	1.15
12	5.7	7.6	102	4.21	0	.1	5	.4	.52	14	7.5	1.15
13	7	7.7	93	3.77	0	0	3	.7	.82	28	18	.98
14	6	7.6	81	3.72	0	.1	5	.1	.71	20.5	7	.98
15	7.2	7.7	86	3.83	0	.2	4	.5	1.07	22.1	10.5	ND
DRILL HOLE 3												
1	4.1	7.6	95	3.74	0	0	4	.6	.08	6	9.3	.82
2	3.6	7.6	165	4.89	0	0	4	.4	.28	10	2.9	.82
3	5.5	7.8	123	4.33	0	.1	4	.3	.19	7.8	10	.73
4	5.9	7.6	90	3.93	0	.1	4	.4	.33	8.3	9.8	.73
5	6.3	7.5	91	3.19	0	.1	4	.6	.65	13	6	.66
6	7.2	7.4	96	4.57	0	0	4	.4	.48	20	8	.66
7	6.8	7.5	85	4.28	0	.2	5	.2	.92	20.5	41.5	1.09
8	6.4	7.6	75	3.87	0	.1	4	.5	.63	13	4.5	1.09
9	5.5	7.6	75	3.65	0	.1	3	.5	.42	8.3	7.5	.96
10	5.5	7.5	78	3.68	0	0	2	.5	.26	12	4	.96
11	6.1	7.5	75	3.44	0	.1	3	.2	.59	15	10	.97
12	5.9	7.5	80	4.03	0	0	4	0	.53	14.5	38	.97
13	5.6	7.6	80	3.90	0	.1	4	.1	.52	15	8.8	.90
14	5.8	7.5	79	3.59	0	0	5	0	.76	19.8	12	.90
15	5.2	7.6	84	3.72	0	.2	6	.3	.64	25	14	.70

¹Nitrogen content in all samples was below analytical limits.

ND Not determined.