

The influence of soil series on cereal grain yield
by Michael Herbert Larson

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Soils
Montana State University
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Abstract:
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Fertilizer recommendations based on soil test values were made for individual soil series compared to the entire field, This analysis provides evidence of the benefit of managing individual soil series according to their potential. Soil performance data can be applied to soil survey maps, aerial photographs, and other types of yield maps to assist the producer in managing soils according to their potentials.

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MICHAEL HERBERT LARSON

A thesis submitted in partial fulfillment
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in

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Knowledge of the productivity potential of each soil in a field can assist land managers in making management decisions. Producers can realize greater returns on their investments if they use soil performance data to set realistic yield goals, recognize yield limiting soil properties, and learn to farm soils instead of fields.

We collected and compared soil performance data for twenty-one important agricultural soils in Montana. Within a given field, five plots were located for each of two or three different soil series. Each plot was evaluated for grain yield and selected chemical, physical, and morphological characteristics.

Yield differences between soil series in the same field ranged from 0.07 to 1.88 Mg/ha (1 to 28 Bu/A). Following harvest, soils were analyzed to a depth of 120 cm for nitrogen, phosphorus, potassium, organic matter, electrical conductivity, and pH. Morphological properties measured included depth to calcium carbonate, available water holding capacity, water use, and clay content. Depth to calcium carbonate, organic matter content (0-15 cm), and soil pH (0-15 cm) proved to be the most yield-limiting soil properties according to stepwise regression analysis (r^2 = .83). It appears that these properties in turn are related to available soil phosphorus (0-15 cm) and available water holding capacity of soil profiles.

Fertilizer recommendations based on soil test values were made for individual soil series compared to the entire field. This analysis provides evidence of the benefit of managing individual soil series according to their potential. Soil performance data can be applied to soil survey maps, aerial photographs, and other types of yield maps to assist the producer in managing soils according to their potentials.

INTRODUCTION

To realize optimum crop production for a crop-soil system, it is necessary to characterize soil and plant growth relationships. The influence of soil nutrients, water and other soil characteristics on crop production have been studied for decades. Recently, the importance of the interrelationships among plant characteristics and population, soil moisture and fertility, soil morphological properties, temperature, topography and many other variables which can influence crop yield and quality has been recognized.

Only a limited number of quantitative investigations of cereal grain yield in relation to soil series have been undertaken. This kind of information can help farmers make decisions about cropping systems, tillage, and fertilizer application based on each soil's yield capabilities and properties.

Collecting soil performance data makes it possible to set realistic crop yield goals for important agricultural soils. The data can become an integral part of soil survey reports, providing farm managers a means for improving their management decisions. Overall usefulness of a soil survey will be increased from an agronomic standpoint.

The objectives of this study were to: 1) obtain soil performance data for 21 agricultural soils in Montana, 2) identify soil properties related to yield performance of soil series occurring in sequence in a

single field, and 3) evaluate opportunities for managing soil series differently.

L I T E R A T U R E R E V I E W

This section reviews research findings of four areas: 1) soil performance studies, 2) topographical influence on crop yield, 3) calcium carbonate influence on crop yield and, 4) soil variability.

SOIL PERFORMANCE STUDIES

Soil performance studies are directed toward two objectives simultaneously: 1) to provide crop yield data for representative soils and 2) to determine soil properties related to yield. Although some soil performance studies have been completed, most fail to provide adequate information on the yield of the same crop on different soils and few attempt to identify yield-limiting soil properties.

Difficulties that arise in quantifying soil productivity are partially due to crop yields being a product of various management, genetic, and climatic factors as well as soil properties. In Montana and other dryland production areas, yearly moisture differences have the greatest influence on year-to-year differences in soil productivity.

Odell (1958) suggests that most soil performance studies are based on one of three methods which include: 1) producer surveys, 2) experiment station or farm record data and, 3) small plot experiments. The third method is the most precise method of gathering soil performance data.

Sampling crop yields on various soil series within the same field eliminates the variability associated with management and climatic factors so that yield differences can be attributed to soil properties associated with specific soil series. This type of experiment reduces the number of experimental variables. Management and climatic interactions and differences can be removed, so that the important chemical and morphological soil properties can be examined.

Many studies have been conducted to relate soil and crop productivity to soil type (Rennie and Clayton, 1960; Bennett, et al., Munn, et al., 1982; and Webb, et al., 1983).

Rennie and Clayton (1960) studied the significance of four local soil types to soil fertility in Saskatchewan. The criteria used to assess soil productivity included grain yield with and without fertilization, uptake of applied phosphorus fertilizer, and extractable phosphorus. Their data showed variability in yield and response to phosphorus even within small distances in a single field due to the soil variability. They suggested that differences in productivity were closely associated with pedogenic differences used to classify soils.

Bennett et al. (1980) found that soils distinguished by differing depths of fine textured material over gravels produced significantly different yields of spring barley under dryland conditions.

Munn et al. (1982) studied the effectiveness of the paired design compared to nonpaired sampling to establish yield differences between two soils developed on glacial till in northern Montana. Their findings showed that percent calcium carbonate was highly negatively correlated

with spring wheat yields on the Scobey-Kevin complex, but more so on the Kevin soil than the Scobey soil.

Webb et al. (1983) concluded through regression analysis that available water holding capacity increased with depth of fine textured material over gravels (r^2 = .92). Consequently, a strong linear relationship (r^2 = .90) exists between yield and depth to gravels. They suggest the practice of mapping and defining soils according to their depth to underlying gravels.

TOPOGRAPHICAL INFLUENCE ON CROP YIELDS

Many of the agricultural soils in northern Montana were formed from calcareous glacial till parent material. An undulating to strongly rolling topography with slopes of 2% to 15% is characteristic of soils formed in glacial till. A catena or toposequence contains a continuum of soil profiles which have developed under a range of micro-environments caused by localized changes in relief (Bushnell, 1942). To a great extent, soil properties are influenced by landscape position. Lower slope positions are usually associated with better moisture, greater plant growth, increased water infiltration and percolation, greater organic matter content, and increased degree of horizon differentiation. On the other extreme, soils located at knoll positions are usually shallow, droughthy, and much more prone to severe erosion. In this study, the effect of soil properties and associated micro-climate was examined by sampling toposequences in each of several fields.

According to Larson (1981) erosion reduces productivity through the loss of plant-available water capacity. This subjects the crops to more frequent and severe water stress. He also states that erosion reduced root zone depth and is partially responsible for plant nutrient losses, degradation of soil structure, and ineffectiveness of pesticides.

Malo and Worcester (1975) noted the relationships of crop growth to landscape position in North Dakota. Sunflower response was studied at various landscape positions under uniform management. The shoulder and footslope positions showed decreases in plant heights, later blossoming dates, lower yields and smaller seed sizes when compared to the responses of the toeslope. Barley responses showed similar relationships to landscape position in 1973. They suggested the responses observed on the shoulder slope reflect the erosional and moisture stress conditions at this landscape position. They concluded that differences in plant responses to landscape position exist primarily because of changes in soils and their associated properties.

Webb (1983) used regression analysis to show that for every 1 cm increase in depth of fine material there was, on the average, a 36 kg/ha increase in the yield of oats and a 31 kg/ha increase in the yield of wheat.

In a study on the growth of winter wheat on a toposequence, in Washington, Ciha (1984), found differences in mean grain yield ranging from 0.45 to 1.90 Mg/ha when compared across slope positions. He concluded that in the Palouse, slope steepness can influence soil temperature, levels of soil erosion within a single year, quantity of snow present on the surface for protection against winter injury, and

available soil moisture. He noted that it may become important in the future to identify specific cultivars for a slope position.

Ferguson and Gorby (1967) report that 15 kg of fertilizer P was needed for optimum production on well-drained soils but twice as much was needed for poorly drained soils. They thought this was due to the changes in microclimatic factors as affected by the slope shape, size and aspect.

Spratt and McIver (1972) initiated a study in Saskatchewan to determine whether fertilizer recommendations, based on soil tests, should be modified for various soils due to their topographical characteristics. They reported that, with or without fertilizer, the grain yields were lower at the crown of the hill and increased progressively down slope. Fertilizers did not increase the yield potential of the crown and midslope positions to the level of the lower slopes. They reported that basic soil factors of the soil catena affect yields of wheat more than the soil fertility and that fertilizers would not eliminate the large yield variation.

CALCIUM CARBONATE INFLUENCE ON CROP YIELD

The mineral calcite ($CaCO_3$) is present in soils that have developed in arid to humid climates. It may occur either in the original soil parent material or as a result of pedogenic processes. With increasing rainfall, soil parent material is the important factor in determining geographic distribution. Harper (1957) reports that with increasing rainfall, the presence of calcic horizons are more confined to areas with strongly calcareous parent materials.

Many of Montana's soils have strongly calcareous parent material and limited moisture. Soil series are commonly distinguished by soil scientists on the basis of depth to calcium carbonate. Where soil moisture deficits occur in most seasons, soils with greater depth to calcium carbonate (higher water holding capacities) will usually support higher yielding crops.

The longer a parent material has been exposed to processes of soil formation, the greater the soil profile development. The estimated time for development of a calcium carbonate enriched Ck horizon is approximately 10,000 years (Buol, et al., 1973).

Calcium carbonate horizons are thought to roughly indicate the average annual depth of water penetration, that is, the depth to which salts are leached. Although water sometimes passes through $CaCO_3$-enriched horizons, these are the layers that tend to dry out last and therefore become the place where relatively insoluble calcium carbonate precipitates from the soil solution.

Soils with shallow carbonate depth are common in semiarid regions especially where they have been subject to severe erosion due to cultivation. Erosive sites are prone to a number of environmental and soil factors that reduce productivity. They include high soil temperature, lower available soil moisture, low organic matter content, and shallow depth of mineral horizons (A and B horizons).

Plant nutrient availability is often suppressed by an abundance of free calcium carbonate in the soil (Larsen, 1967; Spratt and McIver, 1972; Mortvedt, 1976; Karathanasis et al., 1980; Webb, 1983; Munn et al., 1982).

Larsen (1967) suggests the P labile pool is constantly transferred to non-labile pools in the presence of $CaCO_3$. He postulates that as P fertilizer is added to the soil in the monocalcium phosphate form, it moves as a concentrated solution of dicalcium phosphate. As it moves, soluble P may react with $CaCO_3$ to form a precipitate of phosphate minerals.

Spratt and McIver (1972) studied crop response to P fertilizer on eroded sites in Manitoba. They suggested that soils high in Ca content may either limit plant nutrient uptake or rooting tendency. Their findings also indicate that basic pedological and microclimatological factors of the soil catena affect yields of wheat more than soil fertility and fertilizers.

Mortvedt (1976) postulates that shallow depth to $CaCO_3$ may cause stunted plant growth as a result of P and micronutrient immobilization. Karathanasis et al. (1980) studied grain yields at international sites. Their results showed low yields on highly calcareous soils.

In evaluating selected soil and climatic variables in Montana Burke (1982) reported depth to calcium carbonate as positively correlated with cereal grain yield. Dry consistence of the Ck horizon was also positively correlated with yield, due to its positive correlation with greater depth to Ck and fine texture.

SOIL VARIABILITY

Commonly, in fields one observes plant responses to soil differences. Such "spots" in fields are a problem for farmers, because these areas need different management than other parts of the field.

Soil surveyors attempt to group similar soil areas together as mapping units, in which the soil is expected to be homogenous or is at least easily recognized from slope position or other features. However, many inclusions of other soils cannot be shown in standard soil survey reports because areas smaller than about 5 acres are too small to show on standard aerial photographs and maps.

An important consideration for any soil-site study is the physical and chemical variability, either within a soil series (Wilding et al., 1965; Cipra et al., 1972; Lee et al., 1975), or within a soil cartographic unit (mapping unit) (Adams and Wilde, 1976; Beckett and Webster, 1971; Bascomb and Jarvis, 1976).

Wilding et al., (1965) and Adams and Wilde, (1976) discussed that with the increasing variety of uses which soil surveys now serve in both urban and rural areas, a greater emphasis must be placed on more accurate and quantitative definitions of the basic interpretative elements of surveys.

In a study of the Richfield silt loam, Cipra et al., (1972), determined soil fertility variation among pedons separated by 3 m, 90 m, and from 8 to 145 km. They report that variation among pedons 3 m apart contributed only slightly to total variation while pedons 90 m apart contributed substantially to total variation within the soil series.

They contend that to estimate the soil series mean by ±10%, some fertility tests would require as many as 175 fields; others only two fields.

Assessment of the soil factor can be complicated by variations in climate, fertility levels, and rotation effects according to Lee et al., (1975) when studying wheat yields from four soil series. They concluded that for more accurate predictions of soil cropping potential, a subdivision into soil types and phases would be desirable.

Beckett and Webster (1971) studied the variability of soil properties within mapping units. They separated soil properties into three groups: 1) Those which are only slightly affected by management, such as sand, silt, and clay, plastic and liquid limits, thickness of horizon, and total P, 2) properties such as organic matter, cation exchange capacity, and nitrogen and 3) properties most affected by management such as available P, Mg, Ca, and K. Those properties most affected by management were consistently more variable than the others.

Bascomb and Jarvis (1976) examined the variability in three areas of the Denchworth soil map unit in England. They also reported that the properties influenced by management were the most variable. They suggested that Denchworth soils can be managed uniformly for land uses dependent upon physical properties of soil. But, the variability of soluble phosphorus precluded the use of a soil map as a guide to fertilizer application and little was achieved for that aspect of management. They suggested mapping soluble phosphorus distribution within fields.

MATERIALS AND METHODS

LOCATION

The study sites are located in Chouteau County, in north central Montana (Fig.1). It is presently being mapped under the National Cooperative Soil Survey program and is scheduled for completion in about 1990. Most of the economy is based on cereal grain agriculture. This county was selected for study because 1) there were many fields with at least two contrasting soil series within its boundaries 2) the area ranks within the top two counties in the state for wheat and barley production, and 3) the soil survey crew was particularly interested in assisting with the initial mapping and interpretation of the respective soil series.

SOIL FORMING FACTORS

The factors affecting soil formation in this area include: 1) geologic parent material, 2) climate, 3) topography, 4) plants and animals, and 5) time.

Parent materials of the study sites in Chouteau County were deposited by the Laurentide continental ice sheet. The resultant glacial till is derived from the soft black shale unit of the Colorado Shale. The till is predominately calcareous loam and clay loam.

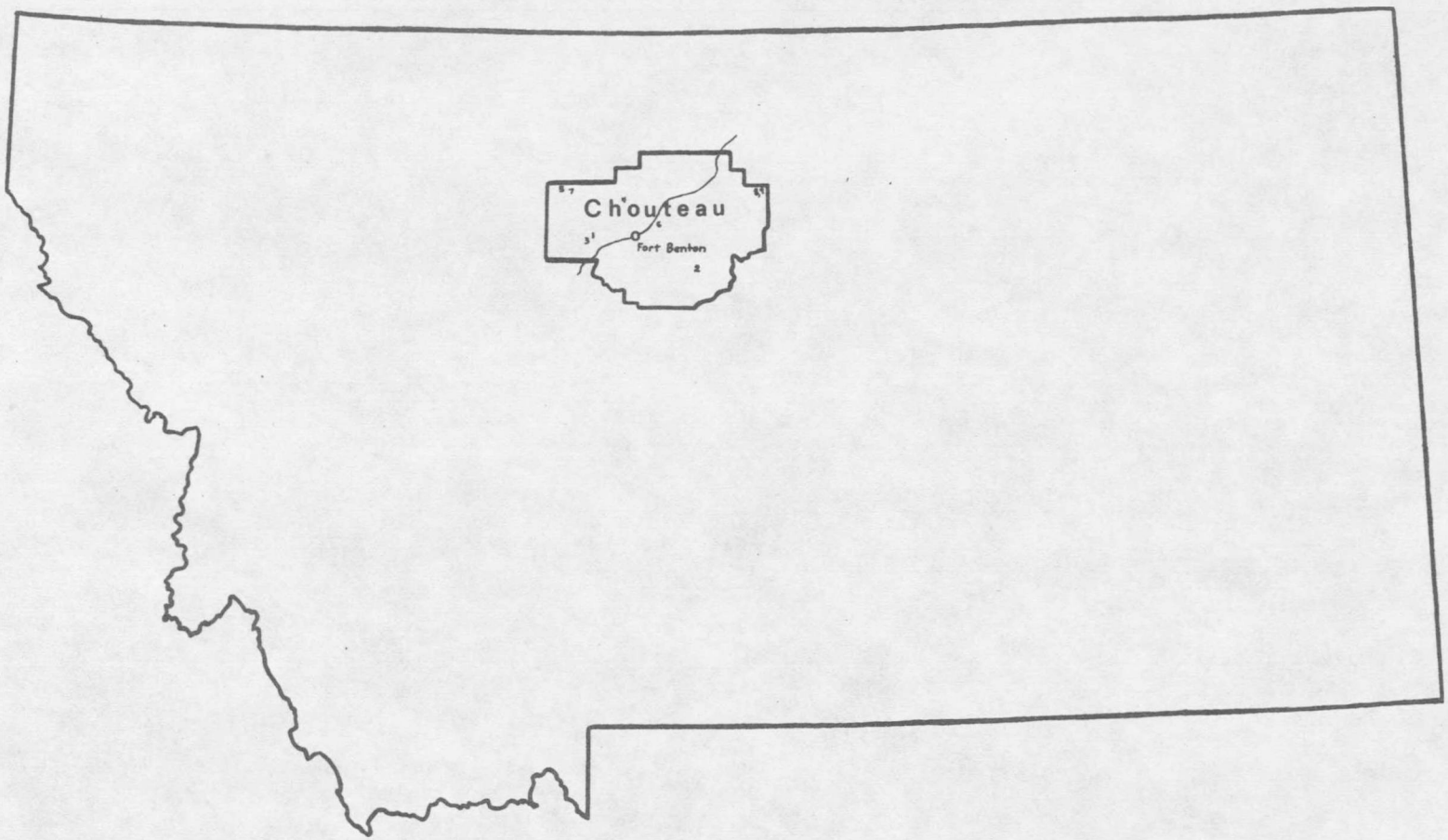


Figure 1. Location of Study Sites.

The climate of Chouteau County is continental characterized by long, cold winters and warm summers although warm chinook-like winds are common during the winter months. The average annual precipitation ranges from 30 to 40 cm (12-18 inches). The mean annual temperature ranges from 6^{o} C to 7^{o} C (42^{o}-45^{o} F). The length of growing season averages 125 days during which time 60% of the total annual rainfall falls (Caprio et al., 1980).

The topography of Chouteau County results from the glacial advance of the Laurentide Continental ice sheet. The ice rounded the topography, smoothing hills, leaving depressions, and burying former valleys. During the past century, intensive agriculture and resultant soil erosion, have further influenced the natural topography.

Native climax vegetation was dominated by green needlegrass, western wheatgrass, needleandthread, blue gramma, and little bluestem (Soil Conservation Service, 1976). Vegetation influences soil properties in several ways. Organic acids reduce soil pH and increase chemical weathering. Organic matter increases with amount of vegetation undergoing microbial decomposition.

Parent materials of the study soils were deposited about 15,000 years ago as glacial till, outwash, and lake sediments (Klages and Montagne, 1985). The minerology of glacial deposits is determined by the kinds of rock formations from which they have been derived. Many of the northern Montana deposits are calcareous, which indicates that limestone has been one of the important source rocks.

DESCRIPTION OF SOIL SERIES STUDIED

Soil series are soils that are grouped together because they have similar profile characteristics with the exception of Ap texture. The primary use of soil series in the classification system is to relate the polypedons represented on detailed soil maps to soil taxa and to the interpretations that may follow (Soil Taxonomy, 1975). This and the following sections describe the soil series used in this study. Appendix A contains the complete Soil Conservation Service Soil Interpretation Record for each soil series. Table 1 shows the soil series studied and their classification according to Soil Taxonomy, 1975.

Soils at sites 1-4 were studied in detail whereas sites 5-8 were examined less intensively to provide a larger data base for yield comparisons between soil series. Sites 5-8 provide excellent opportunities for future related research.

The following groups of associated soils were studied in detail and will be discussed by site. Information about each soil association is based on field observation and personal communication with SCS Soil Survey party leader, Neal Svendsen.

Site number	Soil Association
1	Ethridge - Lonna
2	Bearpaw - Vida - Zahill
3	Scobey - Kevin - Hillon
4	Telstad - Joplin - Hillon

Table 1. Classification of Soil Series Studied.*

Site	Soil Series	Subgroup	Family
1	Ethridge	Aridic Argiborolls	fine, montmorillonitic
	Lonna	Borollic Camborthids	fine-silty, mixed
2	Bearpaw	Typic Argiborolls	fine, montmorillonitic
	Vida	Typic Argiborolls	fine-loamy, mixed
	Zahill	Typic Ustorthents	fine-loamy, mixed (calcareous)
3	Scobey	Typic Argiborolls	fine, montmorillonitic
	Kevin	Aridic Argiborolls	fine-loamy, mixed
	Hillon	Ustic Torriorthents	fine-loamy, mixed (calcareous)
4	Telstad	Aridic Argiborolls	fine-loamy, mixed
	Joplin	Aridic Argiborolls	fine-loamy, mixed
	Hillon	(see site 3)	
5	Kobar	Borollic Camborthids	fine, montmorillonitic
	Marvan	Ustertic Torriorthents	fine, montmorillonitic (calcareous)
6	Chinook	Aridic Haploborolls	coarse-loamy, mixed
	Yetull	Ustic Torripsamments	mixed, frigid
7	Ethridge	(see site 1)	
	Marias	Udorthentic Chromusterts	fine, montmorillonitic (calcareous) frigid
8	Attewan	Aridic Argiborolls	fine-loamy, mixed
	Telstad	(see site 4)	
9**	Attewan	(see site 8)	
	Telstad	(see site 4)	

* Classification according to Soil Taxonomy (Soil Survey staff, 1975).
**Irrigated site

Site 1 soils are not as extensive in North-Central Montana as the glacial till soils of sites 2-4. Ethridge and Lonna were chosen to compare soils with differences that are primarily related to morphology instead of topography.

Sites 2-4 include glacial till soils that are very extensive in cereal grain producing areas of Montana. Figure 2 illustrates a block diagram of a typical glacial till landscape. Topography and landscape position play a major role in the development of these soils. Soil morphological expressions of development include differences in water holding capacity, depth to calcium carbonate, and clay content.

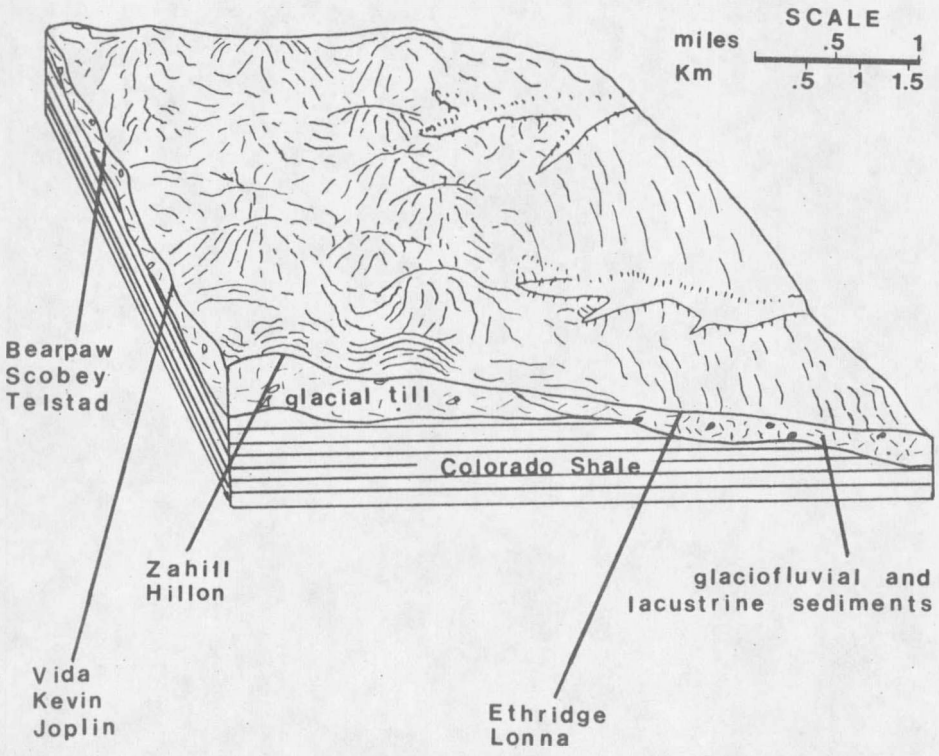
Ethridge-Lonna (Site 1)

The Ethridge-Lonna soils are primarily in the southwest part of the county. The average annual precipitation is about 30 cm (12 inches), the frost free period averages 120 days, and the mean annual air temperature (MAAT) is 44° F. The Ethridge samples were from an area of Ethridge silty clay loam, on 0-2% slopes. The Lonna was sampled in an adjacent area of Lonna silty clay loam with similar slope. Both soils formed in glaciofluvial or glaciolacustrine deposits quite possibly associated with glacial lake Great Falls.

Ethridge soils are deep, well-drained, fine, montmorillonitic Aridic Argiborolls. They are generally silty clay loam throughout with a well-developed argillic horizon. Calcium carbonate accumulations are typically at depths of 25 to 35 cm (10 to 14 inches).

Lonna soils are deep, well-drained, fine-silty, mixed Borollic Camborthids. They are also silty clay loams throughout but have a

Figure 2. Typical Glacial Till Landscape.



calcareous cambic horizon rather than an argillic horizon.

The morphological differences in these soils are difficult to explain. They are both on smooth, nearly level and stable landscapes, about the same age and formed in the same parent material, yet the Ethridge soil has a mollic epipedon and argillic horizon while the Lonna soil is ochric with a cambic horizon. Erosion processes combined with mixing of the Bk horizon may have changed the Lonna from a Mollisol to the present calcareous Camborthid. The Lonna soils are significantly lower in organic matter and do not have the desirable soil structure of the Ethridge soils.

Bearpaw-Vida-Zahill (Site 2)

These soils were sampled in the south-central part of the county near Geraldine, Montana where the average annual precipitation is about 40 cm (16 inches), the frost free season is about 125 days, and MAAT is about 45° F. The parent material is undulating and gently rolling clay loam continental glacial till. The samples were taken from areas of Bearpaw and Vida clay loams, 0-4% slopes and 4-8% slopes respectively. The Zahill soil is an important inclusion in these mapping units, particularly where slopes range from 4-8%.

Bearpaw soils are deep, well-drained, fine, montmorillonitic Typic Argiborolls. They occur in low-lying smooth, depositional areas. Calcium carbonate accumulations are at depths of 25-40 cm (10-16 inches).

Vida soils are deep, well-drained, fine-loamy, mixed, Typic Argiborolls. They occur on intermediate to upper slope positions. Calcium carbonate accumulations are at depths of 15-25 cm (6-10 inches).

Zahill soils are deep, well-drained, fine-loamy, mixed (calcareous), frigid, Typic Ustorthents. They occupy the knoll and ridge positions of the landscape. Calcium carbonate is present at the soil surface and throughout.

The Bearpaw-Vida-Zahill association is very similar to the Scobey-Kevin-Hillon association except the latter occurs in higher rainfall areas (Ustic moisture regime vs. Aridic).

Scobey-Kevin-Hillon (Site 3)

These soils were sampled in the southwestern part of the county. Climatic conditions are similar to the Ethridge-Lonna site. These soils developed in clay loam continental glacial till. The plots were selected from an area of Scobey-Kevin clay loams, with 0-4% slopes. Hillon is an inclusion in this mapping unit.

Scobey soils are deep, well-drained, fine, montmorillonitic, Aridic Argiborolls. They are on the lower, depositional slopes. Depth to calcium carbonate ranges from 25-40 cm (10-16 inches).

Kevin soils are deep, well-drained, fine-loamy, mixed, Aridic Argiborolls. Its landscape position ranges from lower to intermediate slopes. Calcium carbonate accumulates below the 15-25 cm (6-10 inches) depth.

Hillon soils are deep, well-drained, fine-loamy, mixed (calcareous), frigid, Ustic Torriorthents. They occur on the knoll positions and eroded upper sideslopes. Hillon soils are calcareous at the surface.

Telstad-Joplin-Hillon (Site 4)

These soils were sampled in the west central part of Chouteau county. The average precipitation is about 33 cm (13 inches), the frost free period about 120 days, and the MAAT is about 44° F. The parent material is loam or clay loam continental glacial till on an undulating to gently rolling landscape. Sample plots were in areas mapped as Telstad-Joplin loams with 0-4% and 4-8% slopes. Much like Site 3, Hillon soils are major inclusions in this mapping unit.

Telstad soils are deep, well-drained, fine-loamy, mixed, Aridic Argiborolls. They are on lower slopes and smooth areas. Calcium carbonate accumulations are at depths of 25-40 cm (10-16 inches).

Joplin soils are deep, well-drained, fine-loamy, mixed, Aridic Argiborolls. They occur on upper side slopes of knolls and occasionally on knoll tops. Calcium carbonate accumulations are at depths of 15-25 cm (6-10 inches).

Hillon soils are similar to those described for site 3 except they are mainly loams rather than clay loams throughout the soil profile.

FIELD METHODS

Field Selection

Four key soil performance sites (sites 1-4), plus four additional sites (sites 5-8) were selected in April of 1984 with the assistance of SCS soil survey party leader for Chouteau County, Neal Svendsen and retired soil scientist, June Haigh.

A single field-single producer approach was used to ensure uniform management of each soil performance site. At the time of field

selection, management data questionnaires were filled out for each cooperator. A sample questionnaire appears in Appendix B. Management questionnaires are summarized in Appendix C. All sites were commercial cereal grain production fields that received recommended fertilizer rates, crop varieties, plant population, and pesticides. Crop rotation was generally winter wheat-fallow-spring wheat or barley with an occasional crop of sunflower or safflower. Management and climate were assumed to be constant throughout the respective fields so that soil effects on crop yields could be examined.

A goal of this study was to discover an efficient and effective method of collecting soil performance data. The method must accurately assess soil series' yield performance under Montana conditions. The method must also allow for collection of chemical and morphological data so that the yield-limiting properties of a particular soil series can eventually be understood.

Plot Selection

Following verification of the soil series by field investigation, small plots were staked out along transects. Plots were chosen by selecting an area of the designated soil series that was apparently within the range of characteristics defined by SCS. Morphological properties such as depth to calcium carbonate, presence of an argillic horizon, and clay percentage of the Ap and B horizons were important means of identification.

For each soil series, five plots (replications) were marked with dimensions dependent on row width. Plot size was 100 cm wide x 240 cm long, for 25 cm row width, 120 cm wide x 240 cm long for 30 cm rows, and

140 cm wide x 240 cm long for 35 cm rows. Plot size was measured with a steel tape. Figure 3 illustrates plot locations for sites 1-4.

Field Measurements

At the beginning of the growing season, depth of spring soil water was determined for all plots using the Brown soil moisture probe. Measurements of slope percent, aspect, and landscape position (concave or convex) were made for each plot.

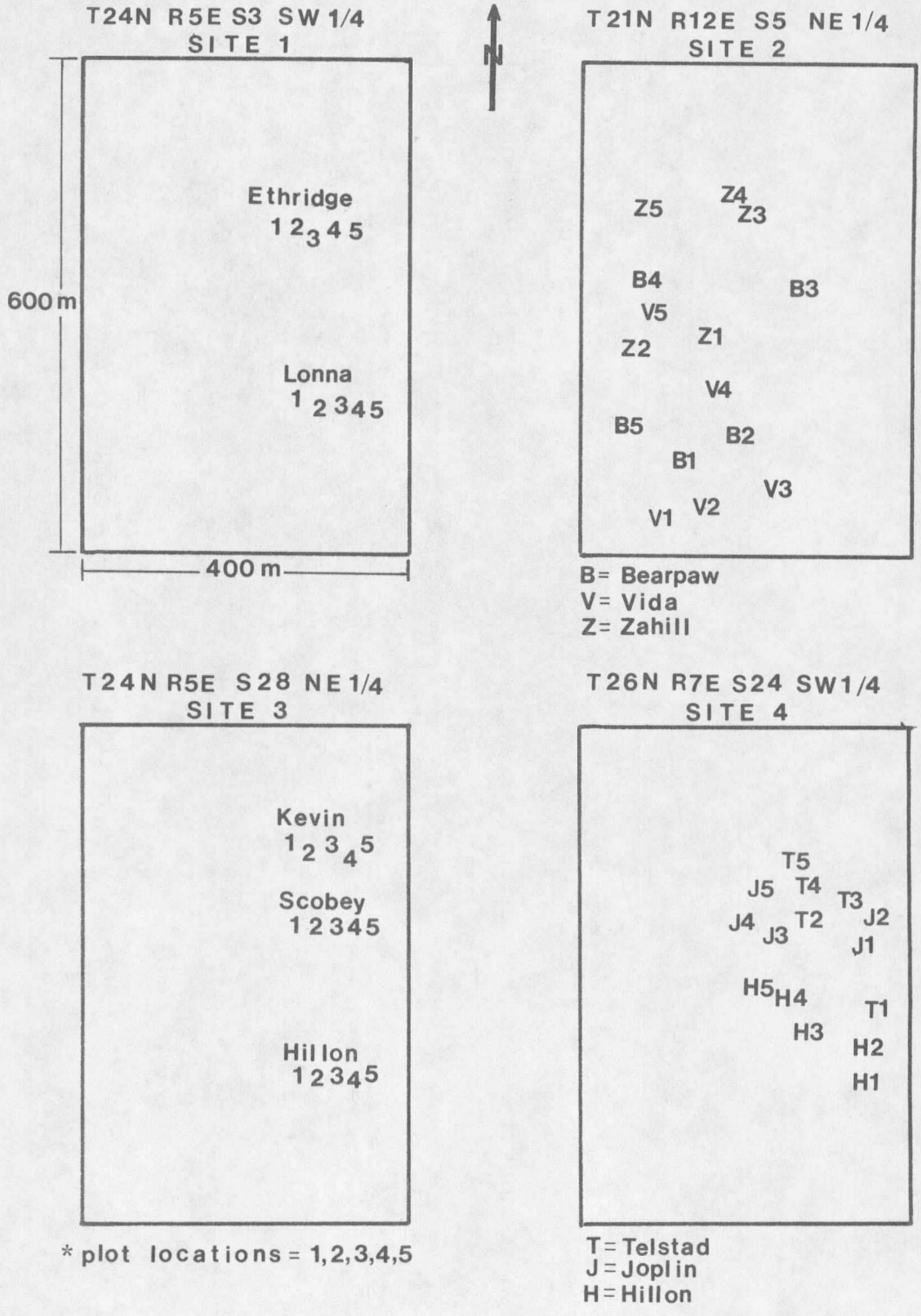
Crop Sampling

Crop samples were collected to study the influence of soil series on crop yield. In most cases, differences in crop density and overall vigor were observable in the field and reflected influences of the contrasting soil series.

Wheat samples were collected in late July of 1984 to determine yield differences between soils. Percent protein, test weight, and number of plants per plot were also measured. Test weight for individual samples was used to calculate yield. These data are presented in Appendix E for general information and future reference.

The entire plot area was hand-harvested with an electric clipper. Samples were bagged for each respective plot, tagged, and returned to Montana State University storage. After allowing the grain to dry, it was threshed, cleaned, and weighed to determine grain yield for each plot.

Figure 3. Plot Locations* for Sites 1-4.



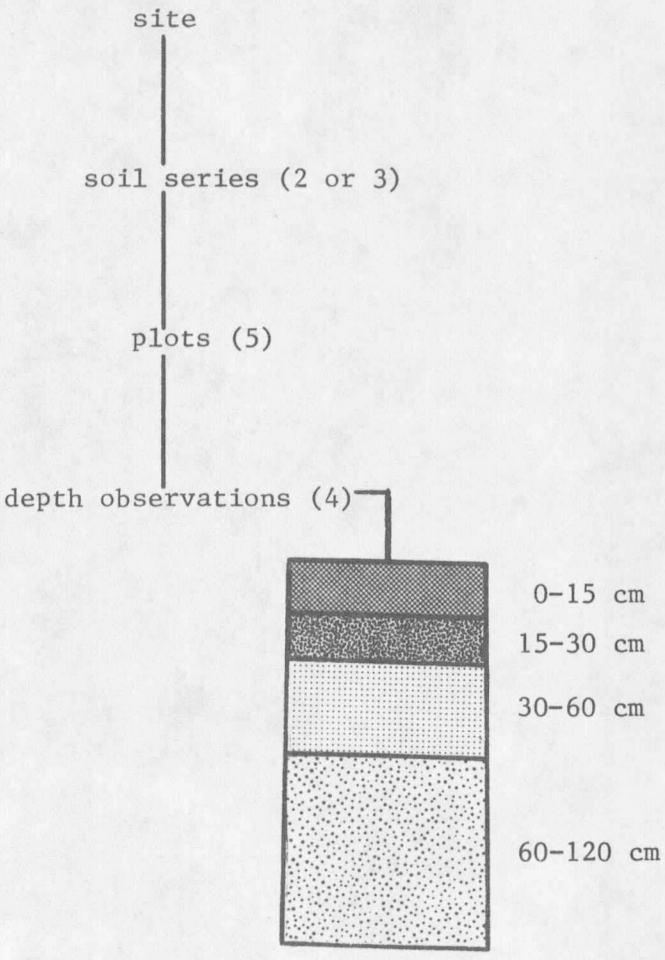
Soil Sampling

Following crop harvest of all plots, the sites were revisited and soil samples were taken with a Giddings soil hydraulic probe to a depth of 120 cm, using a 7.5 cm diameter probe. The probe was inserted at several locations within each plot to obtain a composite sample.

For chemical analysis, composite samples (1 quart) were taken from each of four depth increments of 0-15 cm, 15-30 cm, 30-60 cm, and 60-120 cm. Thus, there were samples from five plots, with four depth increments per plot totaling 20 samples for each soil series (Figure 4). Samples were bagged, and returned to Montana State University soil testing lab for chemical analysis including pH (2:1), organic matter, Olsen-phosphorus, extractable potassium, nitrate-nitrogen, and electrical conductivity.

Soil morphological properties were measured for each plot at the time of soil sampling. Measurements included depth to calcium carbonate as determined by effervescence with a ten percent solution of hydrocholoric acid (HCl), depth of respective soil horizons, and estimated clay percentage of the Ap and B horizons. Additional analysis of clay percentage and gravimetric water content was carried out at the Montana State soil classification laboratory.

Figure 4. Soil Sampling Design.



LABORATORY METHODS

Soil Chemical Analysis

All soil samples were air dried in a forced-air oven at 55°-60° C for 48 hours. Samples were crushed with a mechanical mortar and passed through a ten mesh sieve. Standard Montana soil testing laboratory procedures for field soils were used in determining soil pH, extractable phosphorus, extractable potassium, nitrate, organic matter, and electrical conductivity. Brief descriptions of each analysis follow:

Soil pH. Soil reaction was measured in a 1:2 soil to water paste after a 30 minute equilibration. The determination was made by glass electrode.

Electrical Conductivity. Filtrate from the soil reaction test was used for electrical conductivity measurement by conductivity bridge. Results were converted to saturated paste values by the equation: $Y = 3X + .07$ for X above 7 mmhos/cm and $Y = 4X$ for X below 7 mmhos/cm; Y = estimated saturated paste value and X = EC values.

Soil Phosphorus. Extractable phosphorus was determined by the Olsen method as described by Olsen et al. (1954). This method consists of extracting soil samples with 0.5 N $NaHCO_3$ buffered at pH 8.5. The extract was treated according to the phosphomolybdate blue method of Murphy and Riley (1962).

Soil Potassium. The determination of extractable potassium was made by extracting soil samples with 1 N acetate solution buffered at pH 7.0. The sample was shaken for 30 minutes and the filtered extract is analyzed by flame emission on an atomic absorption spectrophotometer (Bower et al., 1952).

Soil Nitrogen. Nitrate-nitrogen was determined by cadmium reduction and colorimetric analysis as detailed by Sims and Jackson (1971).

Soil Organic Matter. Soil organic matter was determined by the modified Walkley-Black method as described by Sims and Haby (1970).

Soil Physical Analysis

At the time of oven drying, soil samples from the 30-60 cm and 60-120 cm depths were analyzed for gravimetric water content. This measurement provides some indication of any plant available water remaining in each soil profile after harvest. The 0-15 cm samples were not weighed because all were clearly too dry to contain available water. In addition, clay contents for each depth increment were determined by hand texturing and hydrometer method as described by Bouyoucos, (1936). This information was necessary to estimate available water holding capacity (AWHC) and water use for each profile.

Available Water Holding Capacity. The Decker equation as described by Decker (1972) was used to estimate AWHC. The equation is as follows:

$$\text{AWHC (weight)} = 2 + 0.33\ (\text{clay \%}) + 0.5\ (\text{organic matter \%})$$

Total AWHC for the 120 cm profile was then adjusted by adding growing season precipitation and subtracting 10 cm for plant emergence. AWHC by weight was converted to a volume basis using estimated bulk densities reported by Evans (1982).

Water Use. Water use was defined as profile AWHC minus water in the same profile at harvest according to gravimetric water measurements, plus growing season precipitation. The profile depth was assumed to be 120 cm at all sites.

Plant Analysis

Percent Protein. Grain samples taken at harvest were used to determine percent protein in grain by Technicon Near Infrared Analyzer (Infra Analyzer 400) method.

MANAGEMENT RECOMMENDATION PROCEDURE

To determine possible advantages of fertilizing by soil rather than on a field basis, fertilizer recommendations for winter wheat were taken from the Montana Small Grain Guide (Extension Bulletin 364). Recommendations of phosphorus (P_2O_5), potassium (K_2O), and nitrogen (N) are given in Tables 12-14 (page 55). These data make it possible to determine if soil series require different fertility levels to achieve their respective yield goals.

Soil series yield goals from SCS Soil Interpretation Records (10 year estimates) are reported in Appendix A. The author also

communicated with SCS State Soil Scientist Staff concerning their yield value determinations. For comparison, actual average crop yields obtained during this project for the 1983-84 growing season were included.

STATISTICAL METHODS

Analyses of data were accomplished using Montana State University Statistical Analysis Program (MSUSTAT) (Lund, 1985) and Statistical Analysis System (SAS) (Helwig, 1978).

Soil Analysis

The experimental design for the soil properties measured was a nested design. There were four fields, two or three soil series per field, five sampling plots (replications) representing each soil series, and four depth observations at each sampling plot. Soil pH, extractable phosphorus, extractable potassium, nitrate-nitrogen, organic matter, and electrical conductivity were analyzed at 0-15, 15-30, 30-60, and 60-120 cm depths giving rise to 20 observations per soil series. Morphological properties described by depth increment include: estimated clay percentage available water holding capacity, and water use. Depth to calcium carbonate was determined for each soil during field plot selection.

Means, standard deviation, range, mean difference, standard error difference, and t-statistics were obtained from the MSUSTAT T-Grouped program. A one way analysis of variance was used to determine if there

were significant differences in the means of soil properties between soil series within a single field.

To determine which of the soil variables contribute most to the dependent variable, yield, SAS stepwise multiple regression procedures were used for all eleven soil series combined and for individual soil series. Apart from this procedure, SAS maximum correlation coefficient (Max R) and Pearson's correlation matrix (Proc Corr) were conducted for all soil series to measure strength of relationship and multicollinearity effects between the means of all 29 soil variables studied. Significance levels were based on tables in Statistical Methods (Snedecor and Cochran, 1980).

Plant Analysis

To identify significant differences in the means of the crop yields among soil series pairs, a one way analysis of variance was used. The experimental design for crop yields was based on the assumption that the mean yield from five plots represents the soil series.

A T test (MSUSTAT T GROUPED) was used to determine if significant differences occurred between soils for crop yield.

Sample Number

In order to establish the number of experimental plots needed, one would need a preliminary study to determine the amount of variability within individual soil properties .

Sample number (n) is then calculated from the standard statistical equation: $n = \frac{t^2 s^2}{d^2}$ where n is the number of samples required; t

is the tabulated t value for the desired confidence level; s is the standard deviation; and d is the allowable error.

For purpose of this study, it was decided that five plot areas per soil series would provide statistical significance for major variables and would be a workable sample size for the number of soil series examined.

Standard Statistics

To measure the variability of soil properties within a soil series, the mean, standard deviation, range and coefficient of variation of the properties measured was calculated. The mean is a measurement of central tendency, an average of all plots analyzed. The range includes the minimum and maximum value for each determination. Standard deviation (Snedecor and Cochran, 1980), is defined as:

$$sd = \sqrt{\frac{1}{n-1} \sum_{i}^{n} (xi - \bar{x})^2}$$

The coefficient of variation is the sample standard deviation expressed as a percentage of the sample mean.

$$cv = \frac{sd}{\bar{x}}$$

While the standard deviation is in the same units as the observations, coefficient of variation is a relative measure of variation (%).

RESULTS AND DISCUSSION

Results and discussion of the influence of soil series on cereal grain yield are presented in three sections; 1) soil performance data, 2) soil properties related to yield and 3) management opportunities. Cereal grain yield differences for all soil series are presented. A statistical evaluation of soil chemical and morphological data to determine the most important yield-limiting properties is given for Sites 1-4. The third section describes management opportunities for farming soils instead of fields based on soil test and fertilizer recommendations for Sites 1-4.

SOIL PERFORMANCE DATA

Crop Yield Comparisons Between Soil Series

One of the greatest benefits of a soil peformance study is that it provides a summary of actual cereal grain yields on various soil series. Yield differences between soil series for wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) are presented in Table 2. Yield differences ranged from only 0.04 Mg/ha (0.6 Bu/a) between the Bearpaw and Vida soil series, to a high of 1.86 Mg/ha (27.6 Bu/a) between Kobar and Marvan.

Of a total of 15 soil series comparisons, eight had significant differences at the 0.01 level with one additional soil series comparison being significantly different at the 0.05 level. Six of the total nine

Table 2. Grain Yield Differences Between Soil Series for All Sites.

Site	Soil Series	Yield Mg/ha	Yield Bu/a	Significance
1	Ethridge	2.85	42.3	**
	Lonna	2.49	36.9	
2	Bearpaw	4.05	60.2	**Z
	Vida	4.01	59.6	**Z
	Zahill	2.34	34.8	
3	Scobey	2.65	39.3	*K, **H
	Kevin	2.26	33.5	**H
	Hillon	1.92	28.5	
4	Telstad	2.49	37.0	
	Joplin	2.40	35.7	
	Hillon	2.17	32.2	
5	Kobar	2.66	39.5	**
	Marvan	0.80	11.9	
6	Chinook	2.29	34.1	
	Yetull	1.99	29.6	
7	Marias	2.45	36.2	
	Ethridge	2.36	35.1	
8	Telstad	1.67	24.9	**
	Attewan	0.69	10.2	
9¶	Telstad	6.54	97.2	**
	Attewan	6.08	90.4	

*, ** Significant differences between means at the 0.05 and 0.01 levels, respectively; letter indicates soil series comparison were significantly different.

¶ = irrigated site

soil performance sites had significantly different yields at the 0.05 level between soil series in the same field.

Compared to average growing season (May-July) rainfall data for these sites (20 to 30 cm), rainfall was approximately 12 cm below normal. Visual observations indicated greater water stress for soils occupying the shoulder and knoll positions of the landscape where the soil water regime is influenced by slope, runoff, and wind.

Figures 5 and 6 show the plot locations and soil profile characteristics in relation to crop yield for site 1 and sites 2-4 respectively.

Crop Yield Variability Within Soil Series

The variation in yield for a particular soil series may have been affected by microclimatological factors. Some of the variability may be due to variations in slope, aspect, and shape of plot area (concave or convex). Table 3 presents the mean yields with their standard deviation, range, and coefficient of variation for soil series at sites 1-4.

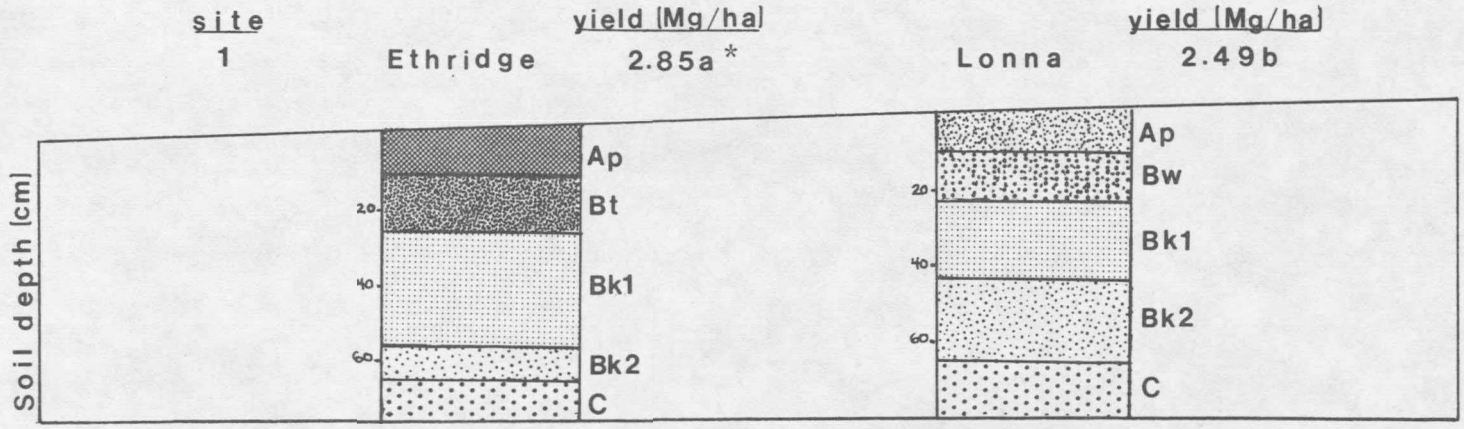
The Bearpaw, Scobey and Telstad glacial till soils occupying the toeslope landscape positions showed little plant water stress. On the other hand, plants on the Zahill and Hillon soils expressed plant water stress even though post-harvest soil water content determinations indicated they had greater subsoil water content (30-120 cm depth) than the depositional and midslope soil series. This suggests that plants grown on knoll positions may be incapable of taking up subsoil water, even though it exists.

Table 3. Means, Standard Deviations, Range, and Coefficient of Variation for Crop Yields at Sites 1-4.

Site	Soil Series	X	SD	Range	CV
		----------Mg/ha----------			%
1	Ethridge	2.85	0.19	2.64-3.07	6.66
	Lonna	2.49	0.23	2.21-2.65	9.24
2	Bearpaw	4.05	0.30	3.62-4.43	7.41
	Vida	4.01	0.61	3.37-4.71	15.21
	Zahill	2.34	0.56	1.88-2.96	23.93
3	Scobey	2.65	0.39	2.17-3.02	14.72
	Kevin	2.26	0.16	2.02-2.46	7.07
	Hillon	1.92	0.13	1.80-2.13	6.77
4	Telstad	2.49	0.31	2.10-2.83	12.45
	Joplin	2.40	0.23	2.15-2.73	9.58
	Hillon	2.17	0.37	1.66-2.51	17.05

X = mean
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation (%)

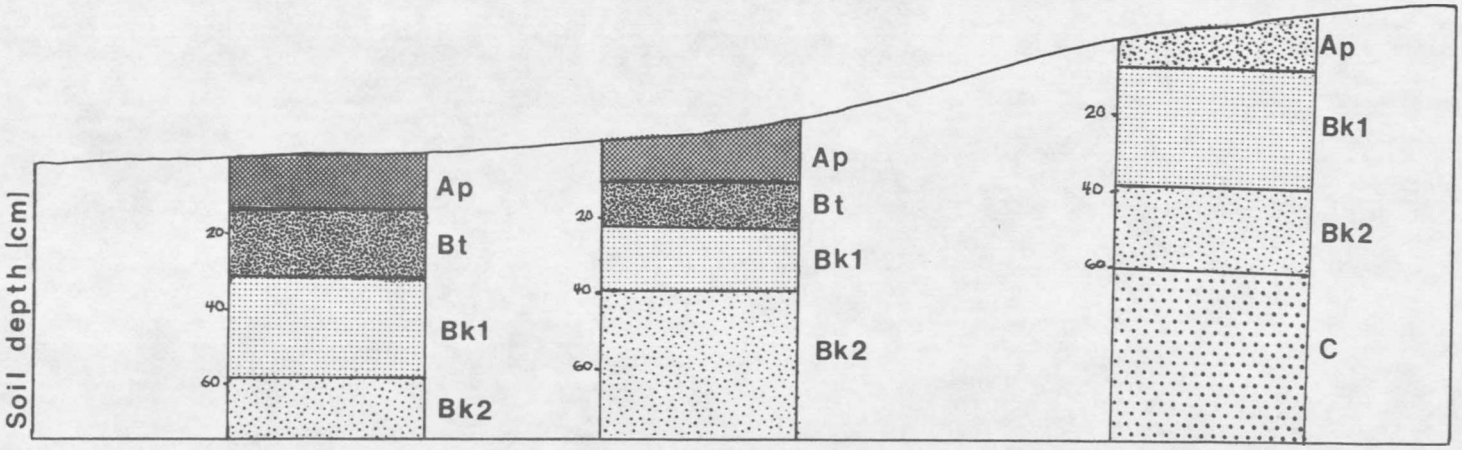
Figure 5. Wheat Yield at Site 1 in Relation to Soil Depth and Characteristics of Toposequence.



* Yield values followed by the same letter are not significantly different at p = 0.01.

Figure 6. Wheat Yield at Sites 2,3, and 4 in Relation to Soil Depth and Characteristics of Toposequence*.

site		yield (Mg/ha)		yield (Mg/ha)		yield (Mg/ha)
2	Bearpaw	4.04a**	Vida	4.01a	Zahill	2.34 b
3	Scobey	2.65a	Kevin	2.26a' †	Hillon	1.92 b
4	Telstad	2.49	Joplin	2.40	Hillon	2.17



* Soil series found at sites 2,3, and 4 have similar soil depths and landscape positions; see Appendix A for more detailed descriptions.

** Yield values followed by the same letter are not significantly different at p = 0.01.

† Yield values followed by the same letter ' are significantly different at p = 0.05.

Percentage yield differences were surprisingly similar between the Ethridge and Lonna (16%), Kevin and Hillon (19%), and Joplin and Hillon (13%). This may suggest that given similar landscape position and parent material, soils with calcium carbonate accumulation at or near the surface will yield about 16% less than soils with noncalcareous plow layers. This shows the importance of keeping the top 15-25 cm of a noncalcareous soil in place.

An evaluation of yield differences within individual soil series is beyond the scope of this study. However, more accurate assessment of soil series yield potentials may require closer examination of microclimatological factors. For example, soil series plots could be selected according to similar hydrological characteristics (slope, aspect, plot shape). Analysis of these characteristics might help explain yield differences within the same soil series.

Soil Performance Data Collection Methodology

The collection of soil performance data in this study systematically provided 1) realistic yield goals for soils, 2) information on the effects of soil properties on crop yield, and 3) a basis for management according to soil conditions.

Data collection plots were located across landscapes (toposequential testing) for which grain yield was measured and soil properties evaluated at each plot. Plots can be set up along a transect deliberately traversing soil boundaries.

To effectively measure soil performance data, uniform procedures are essential. The methodology used for this study proved to be an

accurate and effective means of assessing crop yields across varying soil conditions. Although it was designed specifically for Montana conditions (Appendix B), the data can be implemented into the USDA Soil-Crop Yield Data Base (National Bulletin 430-3-12).

It may become important in the future to identify other important soil and crop variables that will improve the overall usefulness of this data.

SOIL PROPERTIES RELATED TO GRAIN YIELD

The second objective of this study was to determine the most important soil properties related to grain yield. This section uses two statistical methods of identifying soil properties related to yield differences between soil series at sites 1-4.

The means, standard deviations, ranges, coefficients of variation, and significance levels for soil chemical and morphological properties are presented in Appendix F. Soil factors that probably limited yield were selected on the basis of logic and common knowledge gained from the literature and personal communication. Although factors other than those discussed were also significantly different they are not discussed here because their roles as yield-limiting factors are not understood.

Selected Yield-Limiting Soil Properties

Ethridge - Lonna

Table 4 shows five soil properties related to yield differences between the Ethridge and Lonna soil series. Solum thickness is a soil

feature which indicates a degree of profile development and/or weathering. Ethridge has a greater solum thickness and has undergone more development of profile and soil structure than Lonna. Lonna is subject to high wind erosion hazard whereas the hazard is moderate for Ethridge (Lonna is in wind erodibility group 4L, Ethridge in group 7). Ethridge soils have deeper depth to $CaCO_3$ and an argillic horizon (Bt) development which provides greater AWHC and water retention in the profile.

Ethridge has more favorable nutrient conditions for wheat growth. As shown in Table 4, Ethridge has three times more available phosphorus and double the extractable potassium in the Ap horizon. As previously mentioned, calcium carbonate is known to limit the availability of soil phosphorus in calcareous soils. Although the depth to $CaCO_3$ for Lonna was about 14 cm, field evidence of some $CaCO_3$ mixing within the Ap horizon by cultivation, may have further influenced nutrient availability. Differences in extractable potassium might be attributed to clay fixation or available water characteristics.

The significant differences in pH at the 0-15 cm depth reflect the addition of some $CaCO_3$ to this layer.

Table 4. Selected Factors (5 of 14*) Related to Yield Differences Between Ethridge and Lonna Soil Series at Site 1.

Soil Properties	Depth(cm)	Ethridge	Lonna
AWHC (cm)	0-120	23	18
$CaCO_3$ Depth (cm)		23	14
Olsen-P (mg/kg)	0-15	18	6
Extr-K (mg/kg)	0-15	596	287
pH 2:1	0-15	7.9	8.5
Yield (Mg/ha)		2.85	2.49
(Bu/a)		42.3	36.9

*minimum significance level = 0.05
N = 5
AWHC = available water holding capacity

Bearpaw - Zahill

Table 5 shows four soil properties related to yield differences between the Bearpaw and Zahill. Site 2 is a good example of rolling glacial till topography with approximately a 15 m variation in relief and with steepness of slope exceeding 15% in some areas.

Bearpaw occupies depositional areas and has a deep mollic epipedon. It is among the top yielding cereal grain producing soils in Montana. Bearpaw's high productivity potential is influenced by high Ap clay content, high phosphorus and potassium availability in the Ap, and depth to $CaCO_3$. In high rainfall years, runoff of soil and nutrients from the

upper slope positions is likely to have a positive influence on Bearpaw's productivity.

Table 5. Selected Factors (4 of 12*) Related to Yield Differences Between Bearpaw and Zahill Soil Series at Site 2.

Soil Properties	Depth(cm)	Bearpaw	Zahill
Clay (%)	0-15	26	21
$CaCO_3$ Depth (cm)		41	0
Olsen-P (mg/kg)	0-15	21	11
Extr-K (mg/kg)	0-15	278	174
Yield (Mg/ha)		4.1	2.3
(Bu/a)		60.2	34.8

*minimum significance level = .05
N = 5

Zahill soils are calcareous and occupy knoll landscape positions. Fertilizer phosphorus in calcareous soils can precipitate to form relatively insoluble compounds that deposit on surfaces of $CaCO_3$, or phosphate can be retained by clays saturated with $CaCO_3$ (Tisdale and Nelson, 1975). Under native conditions, the Zahill soils have shallow depth to $CaCO_3$ and low organic matter content in the Ap horizon. With cultivation of these erosion-prone areas, calcareous C horizon is mixed into the Ap horizon. This is probably detrimental to plant nutrient relationships. Whether yields are reduced by gains in $CaCO_3$ or the associated losses in soil organic matter is still unknown. Larson

(1981) and Gillespie (1984) conclude that erosion reduces productivity through loss of plant-available water capacity, reduced root zone depth, plant nutrient losses, and degradation of soil structure.

Vida-Zahill

Vida and Zahill were also compared at Site 2 as shown in Table 6.

Table 6. Selected Factors (4 of 11*) Related to Yield Differences Between Vida and Zahill Soil Series at Site 2.

Soil Properties	Depth(cm)	Vida	Zahill
$CaCO_3$ Depth (cm)		21	0
Olsen-P (mg/kg)	0-15	18	11
Extr-K (mg/kg)	0-15	339	174
OM (%)	15-30	1.8	1.2
Yield (Mg/h)		4.0	2.3
(Bu/a)		59.6	34.8

*minimum significance level = .05
N = 5

Surprisingly, the Vida series yielded nearly as much as the Bearpaw even though it was expected to yield intermediately between the Bearpaw and Zahill due to its landscape position. The high fertility program and favorable precipitation at this site may have "masked" differences in yield potential in 1984.

Selected factors related to yield differences between the Vida and Zahill are very similar to the Bearpaw and Zahill comparison. One

exception was significantly different organic matter content at the 15-30 cm depth.

Scobey-Hillon and Kevin-Hillon

Scobey, Kevin and Hillon soil series were studied at Site 3. It became evident that these glacial till soils vary considerably over short distances as a result of topographic position. Scobey and Kevin soils occupy the depositional and midslope landscape positions that receive additional materials while Hillon soils lose materials because of erosion by wind and water.

Significant yield differences occurred between Scobey and Hillon, Kevin and Hillon, and Scobey and Kevin soil pairs. Five soil factors related to yield differences were identical and are presented in Tables 7 and 8.

Scobey and Kevin may yield greater amounts of winter wheat due to more favorable water and nutrient conditions. Scobey has the greatest depth to calcium carbonate, Kevin, the intermediate depth to calcium carbonate, and Hillon is calcareous at the soil surface. Based on the average values obtained in this study, the Scobey and Kevin soils had more available phosphorus and potassium than the Hillon soil in the 0-15 and 15-30 cm depths. This demonstrates the depressing effect that calcium carbonate seems to have on phosphorus and potassium availability.

Significant differences in surface horizon pH and organic matter occur between Hillon and the other two soils. The low organic matter

Table 7. Selected Factors (5 of 18*) Related to Yield Differences Between Scobey and Hillon Soil Series at Site 3.

Soil Properties	Depth (cm)	Scobey	Hillon
AWHC (cm)	0-120	21	11
$CaCO_3$ Depth (cm)		36	0
Exch-K (mg/kg)	15-30	395	165
pH 2:1	0-15	6.9	8.3
OM (%)	0-15	2.1	1.8
Yield (Mg/h)		2.7	1.9
(Bu/a)		39.3	28.5

*minimum significance level = .05
N = 5

Table 8. Selected Factors (5 of 18*) Related to Yield Differences Between Kevin and Hillon Soil Series at Site 3.

Soil Properties	Depth (cm)	Kevin	Hillon
AWHC (cm)	0-120	16	11
$CaCO_3$ depth (cm)		22	0
Exch-K (mg/kg)	15-30	341	165
pH 2:1	0-15	6.9	8.3
OM (%)	0-15	2.1	1.8
Yield (Mg/h)		2.3	1.9
(Bu/a)		33.5	28.5

*minimum significance level = .05
N = 5

content and high pH level of the Hillon suggest that topsoil losses by wind and water are rapid compared with soil development processes.

Scobey - Kevin

Significant yield differences at the .05 level occurred between the Scobey and Kevin soils (Table 9) even though the respective plots were located less than 50 m apart (Figure 3, pg. 24). It is interesting to note that these two soils differ chemically from the Hillon soil in a nearly identical manner. However, the selected soil factors related to yield differences between Scobey and Kevin are quite different.

Table 9. Selected Factors (3 of 8*) Related to Yield Differences Between Scobey and Kevin Soil Series at Site 3.

Soil Properties	Depth (cm)	Scobey	Kevin
Water Use (cm)	0-120	28	16
$CaCO_3$ Depth (cm)		36	22
EC (d/Sm)	60-120	2.6	7.1
Yield (Mg/h)		2.7	2.3
(Bu/a)		39.3	33.5

*minimum significance level = .05
N = 5

Scobey had more clay in the 15 to 30 cm depth and significantly greater depth to calcium carbonate accumulation. These two factors

facilitate greater water retention in the Scobey profile. In years with low rainfall, such as was the case during 1984, Scobey may yield more than Kevin solely due to more favorable soil moisture supplies.

Another possible explanation for yield differences might be the significant difference in electrical conductivity in the 60-120 cm depth. Several saline seeps at various stages of development were present on this farm. Perhaps the Kevin soils had subsoil and moisture characteristics conducive to saline conditions that limited crop response.

Telstad-Joplin-Hillon

Although there were yield differences between the Telstad, Joplin, and Hillon soil series, they were not statistically significant (Table 2, pg. 34). Soil identification was more difficult at this site than at any other.

Factors that most influenced the yield differences between these soils are associated with landscape position. The knoll positions of the Hillon and to a lesser degree the Joplin are exposed to wind erosion. Snow blows off these positions in the winter and accumulates in the lower areas occupied by Telstad, provided enough crop residues are present.

Depth to calcium carbonate and available soil water are perhaps the most important factors related to yield differences at this site. This site illustrates how high fertility management can "mask" soil performance differences. As seen in Appendix C, this farm manager applied fertilizer to meet a 50+ bushel per acre yield goal for all soils. This provided excessive nutrient levels for the Telstad and

Joplin. On the other hand, this level was wasteful for the Hillon because of its shallow depth to $CaCO_3$ and usual lack of enough water to support a 50+ bushel per acre yield.

Regression Analysis

To determine which of the soil variables contribute the most to the dependent variable, yield, SAS stepwise regression procedures (Helwig, 1978) were used to obtain the best regression model.

The stepwise regression technique used for this analysis begins with no variables in the model. The variables are then added one by one according to their calculated F statistic. The higher the F-statistic, the greater the variable's contribution to the model.

A stepwise model was generated for soil series means of dependent variable, yield, and the following independent variables: pH, organic matter content, Olsen phosphorus, extractable potassium, nitrate-nitrogen, electrical conductivity, available water holding capacity, water use, and depth to calcium carbonate. All variables (29) were taken at four depth increments (0-15, 15-30, 30-60, and 60-120 cm) except depth to calcium carbonate.

Based on stepwise regression, the three most important soil variables influencing cereal grain yield at sites 1-4 were depth to calcium carbonate, pH (0-15 cm), and organic matter content (0-15 cm). These three soil variables contributed r-square values of 0.297, 0.232, and 0.305 respectively, toward a coefficient of determination of 0.834

for the prediction equation (Table 10). The stepwise regression model equation for all soils at sites 1-4 is:

$$\text{Yield} = CaCO_3 \text{ depth } (0.04) + \text{pH } 0\text{-}15 \text{ cm } (0.88) + \text{Organic matter } 0\text{-}15 \text{ cm } (1.64) - 8.37$$

$$R^2 = .83$$

Where depth to $CaCO_3$ is reported in cm and organic matter in %.

Table 10. Summary of Stepwise Regression Model for All Soils.

Variable	R Square	R Square Increase
$CaCO_3$ depth (cm)	.296	
pH, 0-15 cm	.529	.232
Organic matter %, 0-15 cm	.834	.305

Significance probability F-value = 0.004

Stepwise models were also developed for each soil series using the same soil independent variables against the dependent variable, yield. A summary of the results for the best fit regression model by soil series appears in Table 11. The sample size (N=5) may be insufficient to conclude which soil property affects grain yield for a particular soil series. However, this approach needs further research to determine how reliable it would be if an adequate sample size was used.

Table 11. Summary of Stepwise Regression Model by Individual Soils.

Soil Series	1st Best/R^2	2nd Best/R^2	3rd Best/R^2
Ethridge	K2	K1 + pH1**	K1 + pH1 + pH3
	0.738	0.998	0.999
Lonna	P2	P2 + K4**	P2 + P3 + K4
	0.914	0.996	0.999
Bearpaw	OM3 *	OM3 + pH3**	OM3 + pH3 + EC1
	0.808	0.981	0.999
Vida	OM1 *	OM1 + P1*	OM1 + OM2 + P1
	0.809	0.978	0.999
Zahill	OM3	OM3 + P1**	OM3 + pH3 + P1
	0.700	0.996	0.999
Scobey	H203 *	H202 + pH1**	K1 + K2 + H204
	0.853	0.998	0.999
Kevin	K1*	K1 + K2**	K1 + K2 + H204
	0.859	0.995	0.999
Hillon	EC1*	EC1 + EC3*	EC3 + N4 + OM1**
	0.811	0.993	1.0
Telstad	H204*	H204 + OM4**	H204 + OM4 + EC4
	0.860	0.999	0.999
Joplin	H204	H204 + pH1	P1 + OM4 + pH1*
	0.718	0.967	0.999
Hillon	K4 *	K4 + H204**	K4 + H204 + P2
	0.955	0.999	1.0

* = significant level .05
** = significant level .01
N = 5 (sample size)
K = extractable potassium (mg/kg)
P = $NaHCO_3$ phosphorus (mg/kg)
OM = organic matter (%)
H_2O = available water holding capacity (cm)
EC = electrical conductivity (d/Sm)
1, 2, 3, 4 = depth increments 0-15, 15-30, 30-60, 60,120 cm respectively

A correlation analysis using the SAS PROC CORR procedure (Helwig, 1978) was used to measure how strongly correlated the means of any two independent variables might be for all soils. The resulting correlation coefficients appear in Appendix G with the highest coefficients being 0.99 between nitrogen at all four depth increments. Several other variables have high correlation coefficients that are difficult to explain. They include organic matter (0-15 cm) and P (15-30 cm) at 0.98; organic matter (0-15 cm) and P (60-120 cm) at -0.98; and organic matter (15-30 cm) and K (0-15 cm) at -0.98.

Helwig, (1978) suggests that two variables may appear to be highly correlated when, in fact, they are not directly associated with each other but are both highly correlated with a third variable. This is the case with the high correlation coefficients stated in the preceding paragraph. The strong correlations between independent variables are without logic. These findings suggest that multicollinearity has little effect on which independent soil variables were related to yield.

Of the variables appearing in the regression model for all soils, greater depth to calcium carbonate and increased organic matter content influenced yield as expected whereas yield increased as pH increased. This is contradictory to what is expected for Montana soils where pH values of 6.5 to 8.5 are common. According to Helwig, (1978) a drawback of regression analysis is the literal interpretation of the values within the model.

As shown in the individual soil series' regression models (Table 11), the most important soil variables affecting grain yield vary from soil to soil. Some of the variation is due to natural soil factors;

parent material, climate and topography. Other variation may be induced by erosion severity and management.

As mentioned in the literature review section, Beckett and Webster (1971) separated soil properties into three groups from least to most affected by management. The third and most variable group includes soil properties like available phosphorus and potassium which are most likely affected by management. Based on the results of this study, significant differences of phosphorus and potassium between soil series suggests that management opportunities exist. Finding the best combination and amount of fertilizer to apply to a particular soil could be prompted by soil test recommendations for individual soils within the same field.

The next section examines management opportunities by comparing fertility recommendations of individual soils with uniform field applications.

MANAGEMENT OPPORTUNITIES

Agricultural production is entering an age of "fine-tuned fertility." Fertility technology developed by Soil Teq Inc., allows blending and spreading at prescribed rates, on-the-go, using computerized soil maps and radar guidance. The greatest benefit of this system is the ability to apply economic levels of fertilizer according to a soil's yield potential.

The following section discusses possible advantages and implications for fertility management by soil series compared to uniform field application. This approach lends itself well to modern developments in fertilizer technology. It can also be a useful tool in showing producers and others involved in agricultural production how to get the highest return for their fertilizer dollar.

Soil test values and recommended fertilizer rates of phosphorus, potassium, and nitrogen are presented in Tables 13-15. Phosphorus and potassium recommendations were based on the 0-15 cm depth increment soil test values and for nitrogen, the 0-60 cm sample depth was used. Recommended nitrogen fertilizer rates vary for each soil depending upon the expected yield. With greater expected yield, more nitrogen fertilizer is required. Phosphorus and potassium fertilizer amounts are dependent upon the respective soil test levels rather than the expected yield.

Soil test values and recommendations for individual soils are reported separately and for comparison are also averaged to determine fertility recommendations on a field basis (Tables 16-20). The values given by field are probably close to what the farmer would receive,

Table 12. Phosphorus Soil Fertility Recommendations.*

Olsen phosphorus level	Recommended P205
-------mg/kg-------	-------lb/a-------
0 - 4	45 - 60
4 - 8	35 - 45
8 - 12	25 - 35
12 - 16	10 - 25
16 - 20	0 - 10

*Based on The Montana Small Grain Guide, Ext. Bull. 364.

Table 13. Potassium Soil Fertility Recommendations.*

Potassium level	Recommended K20
-------mg/kg-------	-------lb/a-------
0 - 75	50 - 60
75 - 125	35 - 50
125 - 250	25 - 35
250+	0 - 25

*Based on The Montana Small Grain Guide, Ext. Bull. 364.

Table 14. Nitrogen Fertility Recommendation Equation.*

(2.5 lb N) (GYG) - Spring soil NO_3-N = Recommended N (lb/a)

*Based on The Montana Small Grain Guide, Ext. Bull. 364.
N = Nitrogen
GYG = Grain Yield Goal (bu/a)

because samples were taken to represent the entire field, not individual soils. Standard English units (lb/a) were used rather than metric units (kg/ha) because grower fertility recommendations are still reported this way.

Limitations of the "fertilizer by soil" approach might include: 1) soil identification, 2) soil variability, and 3) ability to vary management practices. Many landscapes are composed of soil complexes, phases, and inclusions that are difficult to effectively delineate and map. These conditions might warrant the use of aerial infared photographs to identify soil differences. Preliminary aerial photography research at Montana State has shown that remotely sensed data can be useful in evaluating soil conditions.

In addition, the variability of phosphorus, potassium, and nitrogen levels for some soil series may be too large for accurate fertilizer recommendations. In this case, there is no benefit from sampling and fertilizing by soil series.

Finally, soil fertility and fertilizer recommendations depend in part on past and present soil management practices. Heavy past applications for example, can hide some natural differences in soil fertility.

Fertilizer Recommendations

Site 1. Table 15 presents soil test levels and fertilizer recommendations for the Ethridge and Lonna soil series. Ethridge requires 10 lb/a of additional phosphorus fertilizer (P_2O_5) Lonna requires 40 lb/a.

Potassium levels are high (greater than 300 mg/kg) for the Ethridge. No fertilizer is required for this soil but the Lonna soils need 25 lb/a (K_2O).

More nitrogen fertilizer (N) is required for the Ethridge soil due to a 10 bushel difference in expected yield.

For comparison, the fertilizer recommendations by field show that adequate amounts of phosphorus and potassium fertilizer would be applied to the Ethridge soil. On the other hand, insufficient amounts would be available for the Lonna. Nitrogen recommendations on a field basis would limit the Ethridge yield potential. The Lonna soils would have sufficient nitrogen levels for its expected yield.

Based on the results of fertilizing by soil and by field, it may be presumed that fertilizer management by soil could effectively reduce the cost of production at site 1. Soil survey maps and aerial photographs could be used to develop a fertilizer management map, based on the respective soil series boundaries. This map of average phosphorus, potassium, and nitrogen distribution would show that the Ethridge soils require different amounts than the Lonna.

Sites 2-4. Fertilizer recommendations according to soil test levels for sites 2-4 were very similar (Tables 16-18) and will be discussed together. The landscape relationships of these glacial till soils have a major influence on both fertility requirements and crop response.

Table 15. Mean Soil Test Values (mg/Kg) and Corresponding Fertility Recommendations (lb/a) for the Ethridge and Lonna Soils.

Management	Yield goal	Actual yield	Soil test values			Recommendations		
			P	K	NO3-N	P2O5	K2O	N
	----------bu/A----------		----mg/kg----			-----lb/a-----		
By Soil								
Ethridge	45	42.3	18	596	6	10	0	100
Lonna	35	36.9	6	287	3	40	25	80
By Field*	40	----	12	442	4	25	0	90

*Values based on average of Ethridge and Lonna soils.

Typically, the depositional soils (Bearpaw, Scobey, and Telstad), did not require phosphorus and potassium fertilizer, but required the highest amounts of nitrogen to obtain expected yields.

Soils on the mid-slope landscape positions (Vida, Kevin, and Joplin) required 0 or 5 lb/a of P_2O_5 and 0 or 25 lb/a of K_2O. Nitrogen requirements reflect an intermediate yield goal between those of soils on depositional and knoll positions.

For soils on knoll positions (Zahill and Hillon), P_2O_5 recommendations were 20 or 25 lbs/a.

Potassium requirements for Zahill and Hillon (site 4) were 25 and 30 lb/a K_2O per acre respectively. Hillon (site 3) contained sufficient levels of potassium for the expected yield.

Nitrogen requirements of 55-65 lb of N per acre for the knoll position soils are indicative of 25 and 26 bu/a yield goals.

Based on field observations and soil mapping, sites 2 and 3 have soil differences for which differential fertilizer management would be practical. A fertility map would show increasing phosphorus and potassium requirements from the depositional and mid-slope landscape positions to the knoll areas. The need for nitrogen fertilizer would increase from the knoll and mid-slope positions to the depositional, high producing soils.

If differential fertility management were desirable at site 4, (Table 18) Telstad and Joplin might warrant similar management due to their morphological similarities. According to SCS Soil Scientist, Neal

Table 16. Mean Soil Test Values (mg/Kg) and Corresponding Fertility Recommendations (lb/a) for the Bearpaw, Vida, and Zahill Soils.

Management	Yield goal	Actual yield	Soil test values			Recommendations		
			P	K	NO3-N	P2O5	K2O	N
	----------bu/A----------		----mg/kg----			-----lb/a-----		
By Soil								
Bearpaw	45	60.2	21	365	3	0	0	105
Vida	40	59.6	18	339	2	5	0	95
Zahill	26	34.8	11	270	3	25	25	60
By Field*	37	--	17	325	3	0	0	85

*Values based on average of Bearpaw, Vida, and Zahill soils.

Svendsen, these two soils could be mapped as a complex (personal communication). Hillon, occupying the knoll landscape positions, might possibly be managed differently.

Table 17. Mean Soil Test Values (mg/Kg) and Corresponding Fertility Recommendations (lb/a) for the Scobey, Kevin, and Hillon Soils.

Management	Yield goal - Actual yield		Soil test values			Recommendations		
			P	K	NO3-N	P2O5	K2O	N
	----------bu/A----------		----mg/kg----			-----lb/a-----		
By Soil								
Scobey	40	39.3	20	482	10	0	0	80
Kevin	35	33.5	19	591	13	5	0	65
Hillon	25	28.5	14	342	3	20	0	60
By Field*	33	--	18	472	9	5	0	70

*Values based on average of Scobey, Kevin, and Hillon soils.

Table 18. Mean Soil Test Values (mg/Kg) and Corresponding Fertility Recommendations (lb/a) for the Telstad, Joplin and Hillon Soils.

Management	Yield goal - Actual yield		Soil test values			Recommendations		
			P	K	NO3-N	P2O5	K2O	N
	----------bu/A----------		----mg/kg----			-----lb/a-----		
By Soil								
Telstad	35	37.0	29	358	1	0	0	85
Joplin	33	35.7	23	295	2	0	25	80
Hillon	25	32.2	13	211	4	25	30	55
By Field*	31	--	22	288	2	0	25	75

*Values based on average of Telstad, Joplin, and Hillon soils.

The question of whether the benefits of fertilizing by soil outweigh the cost of doing it is still unanswered. Luellen (1985) noted that matching the right fertilizer prescription to the soil condition will allow a grower to realize a net gain of from $5.00 to $15.00 per acre in additional yield and in savings of fertilizer not oversupplied. Depending on equipment, soil mapping, and field conditions, the increased cost amortized across four years, is between $1.50 and $2.50 per acre more than present custom applicator costs. The computerized fertilizer applicators are obviously more expensive than present-day conventional spreaders. In addition, soil mapping and/or aerial photography will be required to assess soil conditions across every field.

Differences in grain yield within a single field such as the above mentioned was partially due to variation in soil fertility between soils. These findings suggest that to more fully maximize grain yields across soil conditions, it may be beneficial to manage differentially. At present, researchers are working to further develop the technical, economical, and practical components of the "manage by soil" technology.

SUMMARY

A soil performance study was carried out during the 1983-84 cereal grain growing season in Chouteau County, Montana. Actual crop yields were collected for twenty-one soil series to determine the actual differences between either two or three soil series within the same field. Soil chemical and morphological properties were evaluated to identify possible yield-limiting factors. Average values for soil phosphorus, potassium, and nitrogen were used as a basis for investigating the possible benefits of fertility management by soil rather than by field.

All sites chosen for study were farmer-operated fields. Soils were compared within a single field so that management and climatic effects were minimized. Yield, percent protein, and test weights were determined on five plots for each soil series to study the differences in crop response.

Following harvest, soils were sampled at four depth increments (0-15, 15-30, 30-60, and 60-120 cm) directly below each plot harvested. The samples were analyzed for nitrogen, phosphorus, potassium, organic matter, electrical conductivity, and pH. Soil morphological properties measured included depth to calcium carbonate, available water holding capacity, water use, and clay content. Data were analyzed by paired-t test and multiple stepwise regression to determine likely yield-limiting factors for each soil.

Finally, fertilizer recommendations based on soil test values were made for individual soil series and were compared with recommendations for entire fields.

C O N C L U S I O N S

1. Sampling two or more soils in a field provides soil performance data that essentially eliminates climate and management as variables.
2. Cereal grain yields between soil series within a single field were significantly different at six of nine sites.
3. stepwise linear regression and paired-t statistical methods were employed to identify soil properties related to grain yield.
4. According to stepwise linear regression, based on eleven soil series (sites 1-4), depth to calcium carbonate, organic matter (0-15 cm), and pH (0-15 cm) were the three most important soil properties related to yield.
5. In several soils, it appeared that these properties were in turn related to phosphorus and potassium availability and available water holding capacity.
6. Further research is needed to show the relative importance of calcium carbonate depth versus organic matter content on yield.
7. Soil test variations and corresponding fertilizer recommendations suggest that management opportunities exist for fertilizing by soil rather than by field.

Hopefully, this thesis has conveyed some new messages concerning effects of soil series on crop yield and possible management opportunities for cereal crop production in Montana.

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A P P E N D I C E S

Appendix A. Soil Series Interpretation Records

MT0580 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 43, 44
MLB, 3-83
ARIDIC ARGIBOROLLS, FINE-LOAMY OVER SANDY OR SANDY-SKELETAL, MIXED

ATTEHAN SERIES
STONY

THE ATTEHAN SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN ALLUVIUM. TYPICALLY THESE SOILS HAVE A COBBLY LOAM SURFACE LAYER 6 INCHES THICK. THE SUBSOIL IS CLAY LOAM. THE UPPER PART OF THE SUBSTRATUM IS LOAM AND THE LOWER PART IS VERY GRAVELLY LOAMY SAND TO A DEPTH OF 60 INCHES. THIS SOIL IS ON FANS AND TERRACES IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 90 TO 105 DAYS. SLOPES RANGE FROM 2 TO 8 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	CB-L	CL-ML, GH-GC, SM-SC	A-4	15-25	70-95	65-90	55-85	40-70	20-30	5-10
0-6	STV-L	CL-ML, GH-GC, SM-SC	A-4	25-50	70-85	65-80	55-75	40-60	20-30	5-10
6-15	CL, SCL, GR-L	CL-ML,CL,SM-SC,GH-GC	A-4, A-6, A-2	0-10	70-90	65-85	50-85	25-70	25-40	5-15
15-25	CL, GR-L, SIL	CL-ML,CL,GM-GC,SM-SC	A-4, A-6	0-10	65-90	60-85	50-85	35-75	20-35	5-15
25-60	GRV-LS, GRX-LS, GRV-S	GP, GP-GM, GM	A-1	0-25	20-55	15-50	10-40	0-15	-	NP

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	10-20	-	0.6-2.0	0.12-0.14	6.6-7.3	-	LOW	.20	3	5	2-4	HIGH	LOW
0-6	10-20	-	0.6-2.0	0.08-0.10	6.6-7.3	-	LOW	.15	3	5	2-4		
6-15	20-35	-	0.6-2.0	0.12-0.15	6.6-7.8	-	MODERATE	.32					
15-25	15-30	-	0.6-2.0	0.12-0.14	7.4-8.4	<2	LOW	.32					
25-60	0-10	-	>6.0	0.02-0.03	7.4-8.4	<2	LOW	.05					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60				B	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	PASTURE (AUM) NIRR	PASTURE (AUM) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS-LEGUME HAY (TONS) NIRR	GRASS-LEGUME HAY (TONS) IRR.	OATS (BU) NIRR	OATS (BU) IRR.
CB	4E	4E	30	70	25	70	40	80	1.5	7.0	-	5.0	-	3.5		100
STV	7S															

MT0170 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 58A, 43, 44, 46, 58D
REV. MLB, 6-83
ARIDIC ARGIBOROLLS, FINE-LOAMY OVER SANDY OR SANDY-SKELETAL, MIXED

ATTEHAN SERIES

THE ATTEHAN SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN ALLUVIUM. TYPICALLY THEY HAVE A LOAM SURFACE LAYER, A CLAY LOAM SUBSOIL AND UPPER SUBSTRATUM, AND A VERY GRAVELLY LOAMY SAND LOWER SUBSTRATUM. VERY GRAVELLY MATERIAL IS AT A DEPTH OF 20 TO 40 INCHES. THEY ARE ON TERRACES AND FANS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 90 TO 130 DAYS. SLOPES RANGE FROM 0 TO 8 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	L	ML, CL-ML	A-4	0-5	85-100	80-100	70-90	55-75	20-30	NP-10
0-6	SL	SM	A-4, A-2	0-5	85-100	80-100	60-80	30-50	15-25	NP-5
0-6	GR-L	SM-SC, SM, GM-GC, GM	A-4	0-10	60-80	55-75	45-65	35-50	20-30	NP-10
6-15	CL, SCL, GR-L	CL, SC	A-6	0-5	75-100	70-100	55-85	35-70	30-40	10-20
15-25	CL, GR-L, SCL	CL, SC, GC	A-6	0-5	70-100	65-100	50-85	35-65	30-40	10-20
25-60	GRV-LS, GRX-LS, GRV-S	GP, GP-GM, GM, SM	A-1	0-15	25-55	15-50	5-20	0-15	-	NP

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	10-20	-	0.6-2.0	0.16-0.20	6.6-7.3	-	LOW	.37	3	5	1-3	HIGH	LOW
0-6	10-15	-	2.0-6.0	0.13-0.16	6.6-7.3	-	LOW	.24	3	3	1-3		
0-6	10-20	-	0.6-2.0	0.13-0.16	6.6-7.3	-	LOW	.24	3	5	1-3		
6-15	20-35	-	0.6-2.0	0.14-0.17	6.6-7.8	-	MODERATE	.32					
15-25	15-30	-	0.6-2.0	0.13-0.15	7.4-8.4	<2	MODERATE	.32					
25-60	0-10	-	>6.0	0.02-0.03	7.4-8.4	<2	LOW	.05					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		B	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	CORN SILAGE (TONS) NIRR	CORN SILAGE (TONS) IRR.	SUGAR BEETS (TONS) NIRR	SUGAR BEETS (TONS) IRR.
0-4% WARM,L,GR-L	3E	3E	30		25	50	40	80	56	100	1.3	4.0		25		22
4-8% WARM,L,GR-L	3E	3E	28		22		38		52		1.1					
0-8% COOL,L,GR-L	3E	3E	30	70	25	70	40	80		100		5.0				
0-8% WARM,SL	4E															
0-8% COOL,SL	4E															

MT0139 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 53B
REV. HLB. 3-83
TYPIC ARGIBOROLLS, FINE, MONTMORILLONITIC

BEARPAW SERIES

THE BEARPAW SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY, THESE SOILS HAVE A CLAY LOAM SURFACE, AND CLAY LOAM SUBSOIL AND UNDERLYING MATERIALS. THEY OCCUPY GLACIAL TILL UPLANDS IN A 13 TO 19 INCH PRECIPITATION ZONE. THE NATIVE VEGETATIO IS MAINLY MID AND SHORTGRASSES. THE FROST FREE SEASON IS 100 TO 130 DAYS. THE SLOPES ARE 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	CL	CL	A-6, A-7	0-5	85-100	80-100	70-100	55-80	30-45	10-20
0-5	L	CL-ML, CL	A-4, A-6	0-5	90-100	80-100	70-95	50-75	25-35	5-15
0-5	SIL	CL-ML, CL	A-4, A-6	0-5	100	100	90-100	70-90	25-35	5-15
5-23	CL, C	CL, CH	A-7	0-5	85-100	80-100	70-100	60-90	40-65	15-40
23-39	CL, SICL, C	CL, CH	A-6, A-7	0-5	85-100	80-100	70-100	55-85	35-60	15-35
39-60	CL, SICL, C	CL, CH	A-6, A-7	0-5	85-100	80-100	70-100	55-85	35-60	15-35

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-5	27-35	-	0.2-0.6	0.15-0.18	6.1-7.8	-	MODERATE	.37	5	6	1-3	HIGH	MODERATE
0-5	20-27	-	0.2-0.6	0.16-0.20	6.1-7.8	-	MODERATE	.43	5	6	1-3		
0-5	20-27	-	0.2-0.6	0.16-0.20	6.1-7.8	-	MODERATE	.43	5	6	1-3		
5-23	35-50	-	0.2-0.6	0.15-0.18	6.6-8.4	-	HIGH	.37					
23-39	35-45	-	0.2-0.6	0.15-0.18	7.4-8.4	2-4	HIGH	.37					
39-60	30-45	-	0.06-0.2	0.15-0.18	7.4-9.0	2-8	HIGH	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	NIRR	IRR.	(A) ALFALFA HAY (TONS) NIRR	(A) ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.
0-4% PE<34	3E	2E	45	70	35	65	50	90	50	90			2.0	5.5	1.0	
4-8% PE<34	3E	3E	40		35		50		50				2.0		1.0	
8-15% PE<34	4E	4E														
9-15% PE>34	4E															
0-3% PE>34	2C				29		49		58				2.0			
3-6% PE>34	2E				27		46		54				2.0			
6-9% PE>34	3E				30		34		40				1.5			

MT0065 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 44, 52, 54, 58A, 60B
REV. HLB, 3-83
ARIDIC HAPLOBOROLLS, COARSE-LOAMY, MIXED

CHINOOK SERIES

THE CHINOOK SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN MATERIAL WEATHERED FROM SANDY ALLUVIUM OR AEOLIAN MATERIAL. TYPICALLY THESE SOILS HAVE A FINE SANDY LOAM SURFACE AND SUBSOIL AND THE UNDERLYING MATERIAL IS FINE SANDY LOAM OR LOAMY FINE SAND. THEY OCCUPY FANS, TERRACES AND UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 110 TO 135 DAYS. SLOPES ARE 0 TO 35 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	FSL	SM	A-4, A-2	0	80-100	75-100	65-85	30-50	15-25	NP-5
0-6	SL	SM	A-4, A-2	0	80-100	75-100	55-75	30-50	15-25	NP-5
6-52	FSL, SL	SM	A-4, A-2	0	80-100	75-100	55-85	30-50	15-25	NP-5
52-66	FSL, LFS, SL	SM	A-4, A-2	0	80-100	75-100	60-80	25-45	15-25	NP-5

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	5-18	-	2.0-6.0	0.13-0.16	6.6-8.4	<2	LOW	.20	5	3	1-2	HIGH	LOW
0-6	5-18	-	2.0-6.0	0.12-0.15	6.6-8.4	<2	LOW	.20	5	3	1-2		
6-52	5-18	-	2.0-6.0	0.12-0.15	6.6-9.0	<2	LOW	.20					
52-66	5-15	-	2.0-6.0	0.11-0.12	7.4-9.0	<2	LOW	.20					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		B	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	SUGAR BEETS (TONS) NIRR	SUGAR BEETS (TONS) IRR.	POTATOES, IRISH (CWT) NIRR	POTATOES, IRISH (CWT) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.
0-4%	4E	4E	32		25	55	36	80		17		400	1.0	4.5	1.2	3.0
4-8%	4E	4E	28		22	50	34	72		15		375	0.8	3.5	1.0	3.0
8-15%	4E		24		18		24						0.6		0.8	
15-35%	6E															
GULLIED	6E															

MT0093 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 44, 46, 52, 53A, 54, 58A, 60B
REV. MLB, 4-83
ARIDIC ARGIBOROLLS, FINE, MONTMORILLONITIC

ETHRIDGE SERIES

THE ETHRIDGE SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN ALLUVIUM. TYPICALLY, THESE SOILS HAVE A SILTY CLAY LOAM SURFACE LAYER, SILTY CLAY AND SILTY CLAY LOAM SUBSOIL, AND THE UNDERLYING MATERIAL IS SILTY CLAY LOAM. THEY OCCUPY TERRACES, FANS, AND FOOT SLOPES IN A 10 TO 14 INCH PRECIPITATION ZONE. NATIVE VEGETATION IS MID GRASSES. THE FROST FREE SEASON IS 115 TO 135 DAYS. SLOPES RANGE FROM 0 TO 25 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	CL	CL	A-6	0	100	95-100	85-100	70-80	25-40	10-20
0-6	SICL	CL	A-6, A-7	0	100	95-100	90-100	85-95	25-45	10-20
0-6	L, SIL	CL-ML	A-4	0	100	95-100	70-90	60-80	20-30	5-10
6-28	SIC, SICL, C	CL	A-7	0	100	95-100	95-100	90-95	40-50	20-30
28-63	SICL, CL, SIL	CL	A-6, A-7	0	100	95-100	95-100	85-95	30-50	10-25

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	27-35	-	0.2-0.6	0.14-0.18	6.1-7.8	-	MODERATE	.37	5	6	1-3	HIGH / LOW
0-6	27-35	-	0.2-0.6	0.16-0.20	6.1-7.8	-	MODERATE	.37	5	7	1-3	
0-6	20-27	-	0.6-2.0	0.18-0.22	6.1-7.8	-	LOW	.43	5	6	1-3	
6-28	35-45	-	0.06-0.2	0.12-0.15	6.6-8.4	-	HIGH	.32				
28-63	25-40	-	0.06-0.2	0.16-0.20	7.4-9.0	2-4	MODERATE	.37				

FLOODING: FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE: DEPTH (FT)	KIND	MONTHS	CEMENTED PAN: DEPTH (IN)	HARDNESS	BEDROCK: DEPTH (IN)	HARDNESS	SUBSIDENCE: INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		C	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	NIRR	IRR.
0-4%	3E	3E	45		26	50	42	65	1.5	5.5	1.2	3.0	58	76		
4-8%	3E	3E	40		25		40		1.5		1.0		56			
8-15%	4E		35		20		25		1.2		0.8		44			
15-25%	6E															

MT0103 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 53A, 58A
REV. RER, 4-83
USTIC TORRIORTHENTS, FINE-LOAMY, MIXED (CALCAREOUS), FRIGID

HILLON SERIES

THE HILLON SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A LOAM SURFACE LAYER AND LOAM UNDERLYING MATERIAL. THEY OCCUPY UPLANDS IN A 10 TO 14 INCH PERCIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE GROWING SEASON IS 105 TO 135 DAYS. SLOPES ARE 0 TO 70 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	CL	CL	A-6	0-5	85-100	85-100	85-95	70-80	25-35	10-20
0-5	L	ML, CL, CL-ML	A-4, A-6	0-5	85-100	80-100	80-90	65-75	20-35	NP-15
5-60	L, CL	CL	A-6	0-5	85-100	80-100	80-90	65-80	25-35	10-20

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-5	27-35	-	0.6-2.0	0.15-0.18	7.4-8.4	<2	MODERATE	.37	5	4L	.5-2	HIGH / LOW
0-5	20-27	-	0.6-2.0	0.18-0.20	7.4-8.4	<2	LOW	.43	5	4L	.5-2	
5-60	20-35	-	0.06-0.2	0.15-0.18	7.9-9.0	<2	MODERATE	.43				

FLOODING: FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE: DEPTH (FT)	KIND	MONTHS	CEMENTED PAN: DEPTH (IN)	HARDNESS	BEDROCK: DEPTH (IN)	HARDNESS	SUBSIDENCE: INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		C	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-8%	4E	4E	25		27		40		1.5							
8-15%	4E	4E	21		22		38		1.3							
15-35%	6E															
35+%	7E															

MT0289

S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52
REV. RER, 4-83
ARIDIC ARGIBOROLLS, FINE-LOAMY, MIXED

JOPLIN SERIES

THE JOPLIN SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY THEY HAVE A LOAM SURFACE LAYER 4 INCHES THICK, A LOAM SUBSOIL AND A LOAM SUBSTRATUM. THEY OCCUPY UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 105 TO 130 DAYS. SLOPES ARE 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-4	L	CL-ML, ML	A-4	0-5	95-100	95-100	85-90	60-75	25-35	5-10
0-4	CL	CL	A-6	0-5	95-100	95-100	90-100	70-80	30-40	10-15
4-31	L, GR-L	CL-ML, CL, GM-GC, GC	A-4, A-6, A-2	0-5	55-95	50-95	45-90	30-75	25-40	5-15
31-60	L, GR-L	CL-ML, CL, GM-GC, GC	A-4, A-6, A-2	0-5	55-95	50-95	45-90	30-75	25-40	5-15

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-4	10-27	-	0.6-2.0	0.16-0.20	6.6-7.8	-	LOW	.43	5	5	1-3	HIGH	LOW
0-4	28-35	-	0.6-2.0	0.14-0.18	6.6-7.8	-	MODERATE	.37	5	5	1-3		
4-31	18-27	-	0.6-2.0	0.14-0.18	6.6-8.4	<2	MODERATE	.28					
31-60	18-27	-	0.06-0.2	0.13-0.16	7.4-8.4	2-8	MODERATE	.28					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.				
0-4%	3E	2E	33		28	55	42	75	50	85	1.5	5.5				
4-8%	3E	3E	31		26		40					5.0				
8-15%	4E		28		24		37									

MT0105

S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52
REV. WLB, 3-84
ARIDIC ARGIBOROLLS, FINE-LOAMY, MIXED

KEVIN SERIES

THE KEVIN SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A CLAY LOAM SURFACE LAYER, SUBSOIL AND UNDERLYING MATERIAL. THEY OCCUPY UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 105 TO 135 DAYS. THE SLOPES ARE 0 TO 35 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-7	L	ML, CL-ML	A-4	0-5	90-100	85-100	80-95	60-75	20-30	NP-10
0-7	CL	CL	A-6	0-5	90-100	85-100	80-95	70-80	25-40	10-20
7-30	CL	CL	A-6	0-5	90-100	85-100	80-95	70-80	25-40	10-20
30-60	CL	CL	A-6, A-7	0-5	90-100	85-100	80-95	70-80	30-45	10-20

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-7	20-27	1.20-1.40	0.6-2.0	0.16-0.20	6.6-7.8	-	LOW	.43	5	5	1-3	HIGH	LOW
0-7	27-32	1.20-1.40	0.6-2.0	0.14-0.18	6.6-7.8	-	MODERATE	.37	5	6	1-3		
7-30	27-35	1.30-1.60	0.2-0.6	0.14-0.18	7.4-8.4	<2	MODERATE	.37					
30-60	27-35	1.50-1.80	0.06-0.2	0.14-0.18	7.9-9.0	<2	MODERATE	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.						
0-2%	3E	3E	35		35		40		1.5	4.0						
2-8%	3E	3E	25		25		35		1.0	3.8						
8-15%	4E	4E	20		20		30									
15-35%	6E															
25+%	7E															

MT0106 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 58A, 48A
REV. HLB, 1-84
BOROLLIC CAMBORTHIDS, FINE, MONTMORILLONITIC

KOBAR SERIES

THE KOBAR SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN ALLUVIUM AND GLACIOLACUSTRINE MATERIALS. TYPICALLY THESE SOILS HAVE A SILTY CLAY LOAM SURFACE LAYER ABOUT 6 INCHES THICK, SILTY CLAY LOAM SUBSOIL AND THE SUBSTRATUM IS SILTY CLAY LOAM AND SILTY CLAY. THEY OCCUPY TERRACES AND FANS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 115 TO 135 DAYS. SLOPES ARE 0 TO 40 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	SIC, C	CL	A-7, A-6	0	95-100	90-100	90-100	85-100	35-50	15-25
0-6	SICL	CL	A-7, A-6	0	95-100	90-100	85-100	80-95	30-45	10-20
0-6	CL	CL	A-6, A-7	0	95-100	90-100	60-100	55-80	30-45	10-20
6-22	SICL, SIC, C	CL	A-7, A-6	0	95-100	90-100	85-100	75-95	35-50	15-25
22-60	SICL, SIC, C	CL	A-7, A-6	0	95-100	90-100	85-100	75-95	35-50	15-25

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	40-45	-	0.2-0.6	0.14-0.18	6.6-8.4	<2	HIGH	.32	5	4	1-2	HIGH / LOW
0-6	27-40	-	0.2-0.6	0.16-0.20	6.6-8.4	<2	MODERATE	.37	5	6	1-2	
0-6	27-40	-	0.2-0.6	0.14-0.18	6.6-8.4	<2	MODERATE	.37	5	5	1-2	
6-22	35-45	-	0.06-0.2	0.14-0.18	7.4-8.4	<2	HIGH	.37				
22-60	35-45	-	0.06-0.2	0.14-0.18	7.9-9.0	<4	HIGH	.37				

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		C	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.	CORN SILAGE (TONS) NIRR	CORN SILAGE (TONS) IRR.
0-2% SICL,CL	3E	3E	35		30	50	40	65	1.0	5.0	56	76	1.2	3.0		25
2-4% SICL,CL	3E	3E	33		27	40	40	65	1.0	5.0	56	76	1.2	3.0		
4-8% SICL,CL	3E	3E	30		25		35		0.8		52		1.0			
0-8% SIC,C	4E	4E	28		24	40	32	60	1.0	4.5	50	70	1.2	3.0		20
8-15%	4E	4E							0.6				0.8			
15-35%	6E															
35+%	7E															
GULLIED	7E															

MT0156 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 58A, 52
REV. HLB, 3-83
BOROLLIC CAMBORTHIDS, FINE-SILTY, MIXED

LONNA SERIES

THE LONNA SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN ALLUVIUM. TYPICALLY THESE SOILS HAVE A SILT LOAM SURFACE LAYER, A SILT LOAM SUBSOIL AND UPPER PART OF THE SUBSTRATUM, AND A STRATIFIED SILT LOAM AND LOAM LOWER SUBSTRATUM. THEY ARE ON TERRACES, FANS, AND UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 90 TO 120 DAYS. SLOPES RANGE FROM 0 TO 25 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-8	SIL, L	CL-ML	A-4	0	100	100	90-100	75-90	25-30	5-10
0-8	SICL	CL	A-6	0	100	100	95-100	85-95	30-35	10-15
8-12	SIL, SICL	CL-ML, CL	A-6, A-4	0	100	100	95-100	75-95	25-40	5-15
12-32	SIL, SICL	CL-ML, CL	A-6, A-4	0	100	100	95-100	75-95	25-40	5-15
32-60	SR-L-SICL	CL-ML, CL	A-6, A-4	0	100	100	95-100	75-90	25-35	5-15

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-8	18-27	-	0.6-2.0	0.18-0.22	6.6-8.4	<2	LOW	.37	5	6	1-3	HIGH / LOW
0-8	27-35	-	0.6-2.0	0.16-0.20	6.6-8.4	<2	MODERATE	.32	5	7	1-3	
8-12	18-35	-	0.6-2.0	0.16-0.20	6.6-8.4	<2	MODERATE	.37				
12-32	18-35	-	0.6-2.0	0.16-0.20	7.9-9.0	<4	MODERATE	.37				
32-60	18-35	-	0.6-2.0	0.15-0.19	7.9-9.0	<4	MODERATE	.37				

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		B	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS-LEGUME HAY (TONS) NIRR	GRASS-LEGUME HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.
0-2%	3E	2E	35		26	50	40	60	55	75	1.5	5.5	1.3	5.0	1.1	3.5
2-4%	3E	2E	32		25	46	38	55	52	70	1.5	5.0	1.3	4.5	1.1	3.5
4-8%	3E		30		23		36		50		1.3		11		10	
8-15%	4E		26		20		30		45		1.0		0.8		0.8	
15-25%	6E															
0-25% GULLIED	6E															

MT0013 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 32, 43, 46, 52, 53A, 58A
REV. MLB,RER, 4-83
UDORTHENTIC CHROMUSTERTS, FINE, MONTMORILLONITIC, FRIGID

MARIAS SERIES

THE MARIAS SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN CLAYEY ALLUVIUM. TYPICALLY THESE SOILS HAVE A CLAY TEXTURE THROUGHOUT THE PROFILE. THEY OCCUPY TERRACES AND UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 115 TO 135 DAYS. SLOPES RANGE FROM 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	C	CL, CH	A-7	0	100	100	90-100	75-95	40-70	25-50
0-6	SIC	CL, CH	A-7	0	100	100	95-100	90-95	40-60	20-40
0-6	SICL	CL	A-6, A-7	0	100	100	95-100	85-95	30-45	10-20
6-27	C, SIC	CL, CH	A-7	0	100	100	90-100	75-95	40-70	25-50
27-74	C, SIC	CL, CH	A-7	0	100	100	90-100	75-95	40-70	25-50

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	40-60	-	0.06-0.2	0.14-0.18	7.4-8.4	2-4	HIGH	.37	5	4	.5-2	HIGH	LOW
0-6	40-60	-	0.06-0.2	0.14-0.18	7.4-8.4	2-4	HIGH	.37	5	4	.5-2		
0-6	27-40	-	0.2-0.6	0.16-0.20	7.4-8.4	2-4	MODERATE	.43	5	4	.5-2		
6-27	40-60	-	<0.06	0.12-0.16	7.9-9.0	2-4	HIGH	.37					
27-74	40-60	-	<0.06	0.12-0.16	7.9-9.0	2-8	HIGH	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		D	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	CORN SILAGE (TONS) NIRR	CORN SILAGE (TONS) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	SUGAR BEETS (TONS) NIRR	SUGAR BEETS (TONS) IRR.
0-2% HARM	4E	4E	35		26		54	75	38	60	3	24	1.2	5.0		16
2-8% HARM	4E		32		24		50		35				1.0			
8-15%	4E		25		20		45		30				0.8			
0-8% COOL	4E	4E	35	70	30	75		100	50	80				5.0		

MT0114 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 58A, 60B
REV. MLB, 3-84
UDORTHENTIC CHROMUSTERTS, FINE, MONTMORILLONITIC, FRIGID

MARVAN SERIES

THE MARVAN SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN ALLUVIUM. TYPICALLY THESE SOILS HAVE A CLAY SURFACE LAYER, AND THE UNDERLYING MATERIAL IS CLAY. THEY OCCUPY TERRACES, FANS AND FOOTSLOPES IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE GROWING SEASON IS 115 TO 135 DAYS. SLOPES ARE 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-4	C	CL, CH	A-7	0	100	100	90-100	75-95	40-70	25-50
0-4	SIC	CL, CH	A-7	0	100	100	95-100	85-100	40-65	20-45
0-4	SICL	CL	A-6, A-7	0	100	100	95-100	85-95	35-45	15-20
4-35	C, SIC	CL, CH	A-7	0	100	100	90-100	75-100	45-70	25-50
35-60	C, SIC	CL, CH	A-7	0	100	100	90-100	75-100	45-70	25-50

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-4	40-60	-	0.06-0.2	0.14-0.18	7.4-8.4	<4	HIGH	.37	5	4	.5-1	HIGH	MODERATE
0-4	40-60	-	0.06-0.2	0.14-0.18	7.4-8.4	<4	HIGH	.37	5	4	.5-1		
0-4	35-40	1.25-1.45	0.2-0.6	0.16-0.20	7.4-8.4	<4	MODERATE	.43	5	4	.5-1		
4-35	45-60	1.30-1.50	<0.06	0.11-0.13	7.9-9.0	2-8	HIGH	.37					
35-60	45-60	1.30-1.50	<0.06	0.09-0.11	7.9-9.0	8-16	HIGH	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		D	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	NIRR	IRR.
0-2%	4S	4S	18		15	35	26	45	0.5	2.0	0.6	1.8	40	55		
2-8%	4E	4E	15		13		23	35	0.5		0.5		35			
8-15%	4E															

MT0124 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 46
REV. SGV,RER, 1-84
ARIDIC ARGIBOROLLS, FINE, MONTMORILLONITIC

SCOBEY SERIES

THE SCOBEY SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A CLAY LOAM SURFACE LAYER, CLAY AND CLAY LOAM SUBSOIL, AND THE UNDERLYING MATERIAL IS CLAY LOAM. THEY OCCUPY UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. NATIVE VEGETATION IS MAINLY MID GRASSES. FROST FREE SEASON IS 105 TO 135 DAYS. SLOPES ARE 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	L	CL-ML, ML, SM, SM-SC	A-4	0-5	85-100	75-95	65-85	45-75	25-35	5-10
0-6	CL	CL	A-6	0-5	85-100	75-95	70-90	65-80	25-40	10-20
0-6	SL	SM	A-4, A-2	0-5	85-100	75-95	50-70	25-45	20-25	NP-5
6-19	C, CL	CL	A-7, A-6	0-5	85-100	85-95	80-95	65-90	35-50	15-30
19-60	CL	CL	A-6, A-7	0-5	85-100	75-95	70-90	65-80	35-45	15-25

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	20-27	-	0.6-2.0	0.16-0.18	6.1-7.8	-	LOW	.43	5	5	1-3	HIGH	LOW
0-6	27-35	-	0.6-2.0	0.16-0.18	6.1-7.8	-	MODERATE	.37	5	6	1-3		
0-6	10-20	-	0.6-2.0	0.13-0.15	6.1-7.8	-	LOW	.32	5	3	1-3		
6-19	35-45	-	0.2-0.6	0.12-0.15	6.6-8.4	<2	HIGH	.32					
19-60	30-40	-	0.06-0.2	0.12-0.15	7.4-9.0	<2	MODERATE	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.				
0-2%	3E	2E	40		33		46		1.5					
2-4%	3E	2E	35		33		46		1.5					
4-8%	3E	3E	33		31		42		1.3					
8-15%	4E	4E	30		28		37		1.1					

MT0233 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 53A, 58A
REV. MLB,SGV, 6-83
ARIDIC ARGIBOROLLS, FINE-LOAMY, MIXED

TELSTAD SERIES

THE TELSTAD SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A LOAM SURFACE LAYER, A CLAY LOAM SUBSOIL, AND A CLAY LOAM AND LOAM SUBSTRATUM. THEY ARE ON GLACIATED UPLANDS IN A 10 TO 14 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 105 TO 130 DAYS. SLOPES RANGE FROM 0 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-7	L	CL-ML	A-4	0-5	85-100	80-100	65-90	50-70	25-30	5-10
0-7	GR-L	CL-ML, GM-GC, SM-SC	A-4	0-10	70-85	65-75	55-70	40-60	25-30	5-10
0-7	CL	CL	A-6	0-5	90-100	85-100	70-95	55-80	30-35	10-15
7-14	CL, L	CL	A-6	0-5	95-100	90-100	80-95	60-80	30-40	10-20
14-32	CL, L	CL-ML, CL	A-6, A-4	0-5	95-100	90-100	80-95	60-80	25-35	5-15
32-60	L, CL	CL-ML, CL	A-6, A-4	0-5	95-100	90-100	75-90	55-75	25-35	5-15

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-7	18-27	-	0.6-2.0	0.16-0.20	6.6-7.8	-	LOW	.43	5	6	1-3	HIGH	LOW
0-7	18-27	-	0.6-2.0	0.13-0.16	6.6-7.8	-	LOW	.24	5	6	1-3		
0-7	27-32	-	0.6-2.0	0.15-0.18	6.6-7.8	-	MODERATE	.37	5	6	1-3		
7-14	25-35	-	0.2-0.6	0.14-0.17	6.6-8.4	-	MODERATE	.37					
14-32	20-32	-	0.2-0.6	0.14-0.17	7.9-8.4	2-4	MODERATE	.37					
32-60	20-32	-	0.06-0.2	0.14-0.17	7.9-9.0	2-4	MODERATE	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, WINTER (BU) NIRR	WHEAT, WINTER (BU) IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.	GRASS-LEGUME HAY (TONS) NIRR	GRASS-LEGUME HAY (TONS) IRR.
0-4%	3E	3E	35		30		42		58		1.5	5.0	1.1	3.5	1.3	4.5
4-8%	3E	3E	33		28		40		56		1.3	4.5	1.1	3.0	1.2	4.0
8-15%	4E		28		22		35		50		1.1		1.0		1.1	

MT0024 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 53A, 53B, 54, 58A
REV. MLB, 1-84
TYPIC ARGIBOROLLS, FINE-LOAMY, MIXED

VIDA SERIES

THE VIDA SERIES CONSISTS OF DEEP WELL DRAINED SOILS FORMED IN CALCAREOUS GLACIAL TILL OF MIXED ORIGIN. TYPICALLY THESE SOILS HAVE A CLAY LOAM TEXTURE THROUGHOUT THE PROFILE. THEY OCCUPY GLACIATED PLAINS IN A 12 TO 17 INCH PRECIPITATION ZONE. NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST FREE SEASON IS 105 TO 130 DAYS. SLOPES ARE 0 TO 35 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	CL	CL	A-6	0-10	90-100	85-100	75-95	60-80	25-35	10-15
0-5	L	CL-ML	A-4	0-10	90-100	85-95	70-90	55-75	20-30	5-10
5-22	CL, L	CL	A-6	0-10	90-100	85-100	70-95	50-85	30-40	10-20
22-60	CL, L	CL	A-6	0-10	90-100	85-100	70-95	50-80	25-40	10-20

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-5	27-30	-	0.6-2.0	0.14-0.18	6.6-8.4	<2	MODERATE	.37	5	6	1-3	HIGH	LOW
0-5	15-27	-	0.6-2.0	0.16-0.20	6.6-8.4	<2	LOW	.43	5	6	1-3		
5-22	25-35	-	0.2-0.6	0.14-0.18	6.6-8.4	<2	MODERATE	.37					
22-60	25-35	-	0.06-0.2	0.14-0.18	7.9-9.0	<2	MODERATE	.37					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		C	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT) (A)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	WHEAT, SPRING (BU) NIRR	WHEAT, SPRING (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	BARLEY (BU) NIRR	BARLEY (BU) IRR.			ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS HAY (TONS) NIRR	GRASS HAY (TONS) IRR.		
0-4% PE<34	3E	2E	40		62		46				2.0		1.1			
4-8% PE<34	3E	3E	38		58		42				1.8		1.0			
8-15% PE<34	4E		32		53		38				1.4		0.9			
15-35% PE<34	6E															
2-6% PE>34	3E		21		39						1.7					
6-9% PE>34	3E		16		35						1.5					
9-15% PE>34	4E		12		30						1.3					
15-35% PE>34	6E															

MT0068 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 58A, 44, 53A
REV. MLB, 1-84
USTIC TORRIPSAMMENTS, MIXED, FRIGID

YETULL SERIES

THE YETULL SERIES CONSISTS OF DEEP, SOMEWHAT EXCESSIVELY DRAINED SOILS FORMED IN ALLUVIUM OR EOLIAN MATERIAL. TYPICALLY THESE SOILS HAVE A LOAMY SAND SURFACE LAYER ABOUT 5 INCHES THICK, AND THE UNDERLYING MATERIAL IS LOAMY COARSE SAND AND SAND. THEY ARE ON FANS, TERRACES, AND UPLANDS IN A 10 TO 15 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID GRASSES. THE FROST FREE SEASON IS 105 TO 135 DAYS. SLOPES RANGE FROM 0 TO 30 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	LS, LCOS	SM	A-1, A-2, A-4	0-5	95-100	95-100	40-65	15-40	-	NP
0-5	FS, LFS	SM	A-2	0-5	95-100	95-100	50-75	10-30	-	NP
0-5	FSL, SL	SM, ML	A-4	0-5	95-100	95-100	70-90	35-55	-	NP
5-60	LCOS, S, LS	SM, SP-SM	A-1, A-3, A-2	0-5	95-100	95-100	45-70	5-30	-	NP

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-5	0-10	-	6.0-20	0.07-0.10	6.6-7.8	-	LOW	.17	5	2	1-2	HIGH	LOW
0-5	0-10	-	6.0-20	0.05-0.08	6.6-7.8	-	LOW	.17	5	1	1-2		
0-5	0-10	-	2.0-6.0	0.11-0.15	6.6-7.8	-	LOW	.20	5	3	1-2		
5-60	0-10	-	6.0-20	0.05-0.07	7.4-8.4	<4	LOW	.17					

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD GRP	POTENT'L FROST ACTION
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)		
NONE			>6.0			-		>60		-		A	LOW

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	ALFALFA HAY (TONS) NIRR	ALFALFA HAY (TONS) IRR.	GRASS-LEGUME HAY (TONS) NIRR	GRASS-LEGUME HAY (TONS) IRR.	PASTURE (AUM) NIRR	PASTURE (AUM) IRR.								
0-8%	6E															
0-8% COOL	6E	4E		4.5		3.2		6.5								
8+%	6E															

MT0025 S O I L I N T E R P R E T A T I O N S R E C O R D

MLRA(S): 52, 53A, 53B, 58A
REV. WLB, 3-83
TYPIC USTORTHENTS, FINE-LOAMY, MIXED (CALCAREOUS), FRIGID

ZAHILL SERIES

THE ZAHILL SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS FORMED IN CALCAREOUS CLAY LOAM GLACIAL TILL. TYPICALLY THESE SOILS HAVE A CLAY LOAM TEXTURE THROUGHOUT THE PROFILE. THEY OCCUPY HILLS, RIDGES AND KNOLLS ON GLACIATED TILL PLAINS IN A 12 TO 17 INCH PRECIPITATION ZONE. THE NATIVE VEGETATION IS MAINLY MID AND SHORT GRASSES. THE FROST-FREE SEASON IS 100 TO 130 DAYS. SLOPES ARE 2 TO 65 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-6	CL	CL, CL-ML	A-6, A-4	0-10	90-100	85-100	85-95	70-80	25-40	5-15
0-6	L	CL-ML, ML	A-4	0-10	90-100	85-95	80-90	60-75	20-30	NP-10
6-30	CL, L	CL, CL-ML	A-4, A-6	0-10	90-100	85-100	80-95	60-80	25-40	5-15
30-60	CL, L	CL, CL-ML	A-4, A-6	0-10	90-100	85-100	80-95	60-80	25-40	5-15

DEPTH	CLAY	MOIST BULK	PERMEA-	AVAILABLE	SOIL	SALINITY	SHRINK-	EROSION	WIND	ORGANIC	CORROSIVITY	
0-6	27-35	-	0.6-2.0	0.14-0.18	7.4-8.4	<2	MODERATE	.37	5	4L	.5-2	HIGH / LOW
0-6	20-27	-	0.6-2.0	0.16-0.20	7.4-8.4	<2	LOW	.43	5	4L	.5-2	
6-30	25-35	-	0.2-0.6	0.14-0.18	7.4-8.4	<2	MODERATE	.37				
30-60	20-35	-	0.06-0.2	0.14-0.18	7.4-9.0	<2	MODERATE	.37				

FLOODING			HIGH WATER TABLE			CEMENTED PAN		BEDROCK		SUBSIDENCE		HYD	POTENT'L
FREQUENCY	DURATION	MONTHS	DEPTH (FT)	KIND	MONTHS	DEPTH (IN)	HARDNESS	DEPTH (IN)	HARDNESS	INIT. (IN)	TOTAL (IN)	GRP	FROST ACTION
NONE			>6.0			-		>60		-		B	MODERATE

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY	WHEAT, SPRING (BU)		OATS (BU)		BARLEY (BU)		ALFALFA HAY (TONS)		GRASS-LEGUME HAY (TONS)		GRASS HAY (TONS)			
		NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
2-8%	4E	26		46		38		1.4		1.2		0.9			
8-15%	4E	24		42		32		1.2		1.1		0.7			
15-35%	6E														
35+%	7E														

Appendix B. Soil Performance Data Questionnaire.

Date July 23, 1984

PART I. Site Manager Interview

Site location and manger

State . . . . . Montana

County. . . . . Chouteau

Legal Description . . . . . R 21 T 12 Sec. 5 Qtr. Sec. NE

Nearest Town . . . . . Geraldine, MT.

Site manager . . . . . Roger VanVoast

Phone 406-737-4456

Date of interview . . . . . July 23, 1984

Climate for yield reported here
(1= above av., 2 = av., (3) = below av.)

Growing season precipitation . . . . . 3.3" rainfall _____ temp.
(from first spring growth to 10 days after heading)

Growing degree days (if available) . . . 120

Last spring frost . . . . . May 6, 1984

Culture

Tillage 4, 4, 4, 4
(1=fall plow, 2=spring plow, 3=no-till 4=chisel till, 5=disk till, 6=chisel & disk)

Residue cover . . . . . < 15 %

Previous crop . . . . . fallow 1 year previous
barley 2 years previous
fallow 3 years previous

(1=alfalfa, 2=alfalfa-grass, 4=small grain, 5=fallow, 6=_____ other)

Planting date . . . . . 20 day 9 month 83 year

Harvest date . . . . . 25 day 7 month 84 year

Seed variety . . . . . Vond

Fertility (information from soil test reports)

Soil sampling date . . . . . 22 day 8 month 81 year

Area sampled . . . . . adjacent fields
(1=entire field, 2=wheat field sampling site)

Name of soil test lab . . . . . Montana Testing Lab

Fertilizer recom/acre for . . . . . 60 bu. wheat

Amount of N, P_2O_5, K_2O (lbs.) . . . . . 80 N 35 P_2O_5 0 K_2O

Soil test results

pH 7.7

	Method	Results	Interpretive Rating (1=low, 2=med., 3=high)
N		15 ppm	
P		41 ppm	
S		100 ppm	
K		275 m.e.	
Organic Matter		1.5 %	(0-6" depth)

Fertilization

	Date Applied	Formulation (%)			Amount/acre	
Basic application:						
Bagged or bulk	9-83	11	52	0	60	lb
Nitrogen	9-83	50-0-0-20 (broadcast)			50	lb
Anhydrous, aqueous or (dry)						lb
Planter (row)						lb

Fertilizer placement . . . . . 11-52-0 banded, 50-0-0-20 broadcast

Other amendments added (e.g. sludge) . . . . .

Leaf analysis (if available) . . .

Weed control data

Date: 5-3-84 Field ID: site #2 Plot ID: all plots

Crop: Winter wheat Scout: Roger VanVoast

Growth stage of weeds leaf stage — small amount of Tansy mustard

Herbicide application date(s) 5-3-84

Herbicide(s) applied . . . . . 8 oz. 2,4D ; 1 oz. Banvel with

Amount applied . . . . . 6 lb Ester

Unusual weather, site, or management

(factors that may have caused yield data to be far above or below long-term averages, e.g. hail) dry growing season although this part of Chouteau Co. received more precipitation than most other areas

Contributor(s) or Correspondent

Data Source

Individual(s)
Institution(s)
Documentary source . . . Roger Vanvoast (landowner), SCS staff, author visited site 3 times

Plot location diagram attached

see Figure 3

Part II. Soil Scientist's Field Observations

Field no. Site 2 Plot no. Bearpaw

These observations and soil samples apply to small plots, usually 8 feet long and 4 wheat rows in width, and not to entire fields of mapping units.

Soil identified at sampling site .. Bearpaw
(series or phase)

Soil identified by soil scientist . Bearpaw

Most recent soil map (title the map) never mapped

	B1	B2	B3	B4	B5
Elevation					
Slope (%)	1	2	2	3	5
Kind . . . . . (1=convex, 2=plane, 3=concave)	1	1	3	1	1
Length of slope (ft.) to nearest micro-topog. divide	200	200	150	150	100
Aspect (0-360°; 90° = East)	S	S	S	S	—
Drainage class . . . . . (Soil Survey Manual)	well				
Surface drainage . . . . . (1=run-on exceeds run-off, 2=neutral 3=run-off exceeds run-on, 4=cannot be evaluated)	4	4	1	2	3
Depth to $CaCO_3$; effervescence w/Hcl (cm)	38	37	42	38	43
Depth to root restricting layer (cm) . . (est. depth at which roots are restricted to ½ or "normal" abundance)	deep				
Depth to water restricting layer (cm) . (est. depth at which hydraulic conductivity is less than 0.5 cm/hr)	deep				

Erosion Estimate
(1=none to slight, 2=moderate, 3=severe)

Erosion class 1
(Soil Survey Manual)

Projected erosion due to . . . . . Slight (<5 tons/acre/year)
current practices

Brief soil profile description: Date _____

Report observations to a depth of 150 cm if possible using soil survey manual terminology.

Horizon	Depth	Texture class	Texture clay	Rock frag. vol.+	Reaction eff.	Reaction pH	Soil water state*
	(cm)		(est.%)	(est.%)			
Ap	0-15	clay loam		<5%	0		2.8
Bt	15-40	clay loam to clay		"	0		3
Bk1	40-90	"		"	+ strong		3
Bk2	90-135				+		
By	135-150	clay loam		"	+		3

+Size and type of rock fragments.
*Report water content as 1, 2, 3, or 4 as follows:

(dry)1 2 3 4(wet)
....
wilting point (15 bar) field capacity (1/3 bar)

Weed count

Weed species	Growth stage	Density	
Tansy mustard	1-leaf 0-6"	few prior to herbicide trt.	(dm^2, m^2)
			(dm^2, m^2)
			(dm^2, m^2)
			(dm^2, m^2)
			(dm^2, m^2)

Signature of sampler _____ Date _____

Part III. Wheat Yield Measurement

Average distance between rows ..... 14 inches
(measure distance between 6 wheat rows and divide by 5. The measurement extends one row on each side of 4 rows harvested)

Harvest four, 8 foot rows and record results below:

	Row 1	Row 2	Row 3	Row 4	Total	Average
Plant height	NOT RECORDED					
Plants/8 ft. row (Ave) - 4 rows	Plot 1 608	Plot 2 686	Plot 3 700	Plot 4 666	Plot 5 718	676

Grain yield (net weight) . Table 2. .....

Grain moisture . Estimated ..... ~13 %

Protein . . . . APPENDIX E ..... %

Test weight . . APPENDIX E ..... lb/bu

Signature(s) of person(s): Michael H. Lawson

measuring yield . . . . . Date

measuring test weight & moisture Date

Appendix C.

Table 19. Management Questionnaire Summary.

Site #	Name/ Legal Descr.	Crops & Variety	Fertilizer Amnt. & Grade (lb./A)		Herbicide	Cropping System	Tillage
1	Don Gray SW¼ Sec 3 T24N R5E	winter wheat (Rocky)	41 55	11-52-0 anhy. NH4	12 oz. MCP 2 oz. Banvel	fallow w. wheat fallow	chisel (2) double shot chisel
2	Roger VanVoast NE¼ Sec 5 T21NR12E	winter wheat (Vond)	60 50	11-52-0 50-0-0-20	8 oz. 2,4D 1 oz. Banvel	fallow barley fallow wheat	chisel till (4)
3	Gary Weldele NE¼ Sec 28 T24N R5E	winter wheat (Rocky)	50	11-52-0	2/3 pt. 2,4D	fallow w. wheat fallow	duckfoot & harrow (4)
4	Mike O'Hara SW¼ Sec 24 T26NR7E	winter wheat (Rocky)	70 46 115	11-52-0 anhy. NH4 urea	6 lbs. LV 8 oz. 2,4D 2 oz. Banvel	fallow w. wheat fallow	tandem disk duckfoot (3)

Site #	Growing Season Precipitation (inches)	Fertilizer Placement	Row Spacing (inches)	Planting Date	Harvest Date	Growing Season Conditions
1	2.5	banded	12	9/18/83	7/29/84	extremely dry
2	3.3	w/seed broadcast dry	14	9/20/83	7/27/84	dry
3	2.3	banded topdressed N	10	9/19/83	7/25/84	extremely dry 2 showers (hard)
4	2.5	w/seed topdressed N	10	9/18/83	7/27/84	extremely dry

Appendix D.

Table 20. Slope Characteristics of Research Plots.

Soil Series	Plot	Gradient	Aspect	Shape
		%		
Ethridge	1	1	neutral	neutral
	2	1	neutral	neutral
	3	1	neutral	neutral
	4	1	neutral	neutral
	5	1	neutral	neutral
Lonna	1	1	neutral	neutral
	2	1	neutral	neutral
	3	1	neutral	neutral
	4	1	neutral	neutral
	5	1	neutral	neutral
Bearpaw	1	1	S	convex
	2	2	S	convex
	3	2	S	concave
	4	3	S	convex
	5	5	neutral	convex
Vida	1	2	S	concave
	2	2	S	concave
	3	7	S	convex
	4	3	S	concave
	5	2	S	concave
Zahill	1	3	S	convex
	2	3	S	convex
	3	8	S	convex
	4	3	SW	convex
	5	2	N	convex
Scobey	1	1	neutral	neutral
	2	1	neutral	neutral
	3	1	neutral	neutral
	4	1	neutral	neutral
	5	1	neutral	neutral
Kevin	1	1	neutral	neutral
	2	1	neutral	neutral
	3	1	neutral	neutral
	4	1	neutral	neutral
	5	1	neutral	neutral

Soil Series	Plot	Gradient	Aspect	Shape
		%		
Hillon	1	3	N	convex
	2	3	N	convex
	3	3	N	convex
	4	3	N	convex
	5	3	N	convex
Telstad	1	1	N	concave
	2	2	SW	concave
	3	1	NE	neutral
	4	2	N	concave
	5	1	N	neutral
Joplin	1	2	SE	concave
	2	1	N	concave
	3	3	NE	convex
	4	2	NE	neutral
	5	2	NE	neutral
Hillon	1	3	S	convex
	2	2	N	convex
	3	2	SW	convex
	3	2	SW	convex
	4	2	NW	convex
	5	2	SW	convex

APPENDIX E.

Table 21. Yield, Test Weight, Percent Protein and Plant Density.

Soil series	Plot	Yield	Test Weight	Protein	Plant Density
		Mg/ha	lb/bu	%	1000 plants/ha
Ethridge	1	2.84	64.0	8.6	1336
	2	3.07	65.1	12.2	1390
	3	2.93	64.2	10.4	1215
	4	2.64	64.5	9.1	1396
	5	2.76	65.4	10.7	1302
Lonna	1	2.35	64.0	11.1	1322
	2	2.21	66.8	9.8	1318
	3	2.58	62.9	11.2	1128
	4	2.64	62.1	10.0	1336
	5	2.65	62.2	12.3	1181
Bearpaw	1	4.43	64.9	11.0	608
	2	3.95	64.7	10.4	686
	3	4.16	65.0	10.0	700
	4	4.10	65.7	10.7	666
	5	3.62	65.2	12.3	718
Vida	1	3.81	66.4	9.3	648
	2	4.60	64.1	9.1	640
	3	64.1	65.4	10.7	677
	4	3.37	64.4	11.3	562
	5	4.71	65.0	9.4	677
Zahill	1	1.88	66.4	13.4	550
	2	2.95	65.7	10.6	588
	3	2.96	64.0	13.3	746
	4	1.98	64.0	13.3	568
	5	1.94	65.2	14.0	602
Scobey	1	2.17	64.8	13.2	1363
	2	3.02	64.8	14.2	1419
	3	2.97	66.0	12.9	1548
	4	2.27	64.4	13.5	1145
	5	2.80	64.6	13.8	1298
Kevin	1	2.33	65.6	10.7	1222
	2	2.27	65.2	13.2	1290
	3	2.02	64.8	13.0	1133
	4	2.46	64.8	13.1	1004
	5	2.24	65.2	12.9	1250

Soil series	Plot	Yield	Test Weight	Protein	Plant Density
		Mg/ha	lb/bu	%	1000 plants/ha
Hillon	1	1.86	64.6	12.4	1161
	2	1.80	65.4	11.2	1000
	3	1.93	63.8	12.9	1468
	4	1.88	65.4	12.9	1306
	5	2.13	65.7	10.8	1000
Telstad	1	2.83	64.8	10.5	1282
	2	2.71	63.6	14.3	1500
	3	2.58	64.0	12.9	952
	4	2.10	62.4	12.3	911
	5	2.23	63.2	13.0	1177
Joplin	1	2.48	64.8	10.5	1339
	2	2.41	64.4	11.5	940
	3	2.15	64.0	9.5	1153
	4	2.23	64.4	11.6	1177
	5	2.73	64.8	11.3	1065
Hillon	1	2.39	62.8	12.9	948
	2	2.37	65.2	14.0	1036
	3	2.51	63.6	14.7	1089
	4	1.66	64.8	13.9	1226
	5	1.90	65.2	12.0	1065

Appendix F.

Table 22. Means, Standard Deviations, Ranges, Coefficients of Variation, and Significant Differences of Soil Chemical and Morphological Properties for Ethridge and Lonna.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
E	7.88	0.08	7.8 - 8.0	1.0	**
L	6.46	0.05	8.4 - 8.5	0.6	
pH, 15-30 cm					
E	8.30	0.10	8.2 - 8.4	1.2	*
L	8.54	0.21	8.2 - 8.7	2.5	
pH, 30-60 cm					
E	8.54	0.15	8.4 - 8.7	1.8	
L	8.40	0.32	8.1 - 8.8	3.8	
pH, 60-120 cm					
E	8.12	0.15	8.4 - 8.7	1.9	
L	8.06	0.32	8.1 - 8.8	4.0	
OM, 0-15 cm (%)					
E	1.98	0.35	1.74 - 2.60	17.7	
L	1.70	0.80	1.60 - 1.81	47.1	
OM, 15-30 cm					
E	1.46	0.25	1.14 - 1.74	17.1	
L	1.35	0.22	1.08 - 1.60	16.3	
OM, 30-60 cm					
E	1.27	0.12	1.14 - 1.47	9.5	**
L	0.88	0.13	0.67 - 1.02	14.6	
OM, 60-120 cm					
E	0.70	0.19	0.40 - 0.90	27.1	
L	0.73	0.10	0.67 - 0.90	13.7	
P, 0-15 cm (mg/kg)					
E	17.9	1.5	16.7 - 20.5	8.4	**
L	6.0	1.7	3.4 - 7.4	28.8	
P, 15-30 cm					
E	9.5	13.5	2.2 - 33.5	14.3	**
L	1.2	0.8	0.3 - 1.8	68.4	
P, 30-60 cm					
E	2.9	2.2	0.7 - 5.8	75.9	
L	3.1	2.4	0.3 - 6.6	77.7	
P, 60-120 cm					
E	5.7	1.2	3.7 - 6.8	21.1	
L	4.3	2.6	1.8 - 8.1	60.5	

K, 0-15 cm (mg/kg)					
E	597.	43.4	541.8- 655.8	7.3	**
L	287.	50.1	235.6- 360.2	17.5	
K, 15-30cm					
E	245.	73.3	165.2- 325.8	30.0	**
L	145.	16.2	124.6- 168.4	11.2	
K, 30-60 cm					
E	189.	24.2	154.0- 215.0	12.9	
L	182	15.2	159.0- 201.0	8.4	
K, 60-120 cm					
E	175.	14.1	161.0- 198.0	8.1	
L	183.	16.9	162.0- 208.0	9.2	
N, 0-15 cm (mg/kg)					
E	1.6	2.8	0.1 - 6.5	177.6	
L	0.7	0.9	0.1 - 2.2	127.1	
N, 15-30 cm					
E	3.5	4.4	0.8 - 11.3	126.0	
L	1.7	2.4	0.4 - 6.0	144.0	
N, 30-60 cm					
E	0.7	0.9	0.1 - 2.2	124.3	
L	0.2	0.3	0.0 - 0.8	133.3	
N, 60-120 cm					
E	0.5	1.0	0.0 - 2.3	204.0	
L	0.1	0.1	0.0 - 0.3	216.6	
EC, 0-15 cm (dSM/cm)					
E	0.3	0.1	0.28 - 0.40	14.7	**
L	0.5	0.7	0.45 - 0.62	137.7	
EC, 15-30 cm					
E	0.4	0.1	0.29 - 0.50	19.5	
L	0.9	1.0	0.42 - 2.62	103.3	
EC, 30-60 cm					
E	0.6	0.0	0.54 - 0.63	6.8	
L	2.9	2.0	0.72 - 5.41	70.6	
EC, 60-120 cm					
E	6.8	0.8	5.70 - 7.90	12.1	
L	8.0	0.4	7.48 - 8.53	4.8	

Depth to CaCO3 (cm)					
E	30.0	3.1	25.0 - 32.5	10.3	**
L	23.0	2.1	20.0 - 25.0	9.1	
AWHC, 0-120 cm (cm)					
E	23.3	0.6	22.5 - 24.0	2.5	**
L	18.0	0.4	17.3 - 18.3	2.2	
Water Use, 0-120 cm (cm)					
E	30.8	1.4	28.3 - 32.0	4.6	**
L	24.8	1.4	22.5 - 25.8	5.5	
Clay, 0-15 cm (%)					
E	31.2	1.1	30.0 - 32.0	3.5	**
L	35.0	1.4	33.0 - 36.0	4.0	
Clay, 15-30 cm (%)					
E	38.0	2.1	35.0 - 41.0	5.5	**
L	45.6	2.5	42.0 - 48.0	5.5	

*, ** = 0.05 and 0.01 significance difference levels, respectively
N = sample size of 5
E =
L =
X = mean
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 23. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Bearpaw and Vida.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
B	8.14	0.59	7.5 - 8.7	7.3	
V	8.40	0.12	8.3 - 8.6	1.4	
pH, 15-30 cm					
B	8.16	0.52	7.6 - 8.8	6.9	*
V	8.66	0.19	8.4 - 8.8	2.3	
pH, 30-60 cm					
B	8.44	0.11	8.3 - 8.6	1.3	
V	8.58	0.04	8.5 - 8.6	0.5	
pH, 60-120 cm					
B	8.72	0.20	8.5 - 8.9	2.3	*
V	8.40	0.32	8.0 - 8.8	3.8	
OM, 0-15 cm (%)					
B	2.17	0.13	2.08 - 2.35	6.0	
V	2.27	0.20	2.0 - 2.5	8.9	
OM, 15-30 cm					
B	1.24	0.25	0.96 - 1.60	20.6	**
V	1.84	0.10	1.74 - 1.96	5.4	
OM, 30-60 cm					
B	1.36	0.10	1.21 - 1.47	7.4	**
V	1.24	0.05	1.14 - 1.27	4.0	
OM, 60-120 cm					
B	0.61	0.16	0.35 - 0.73	26.2	
V	0.66	0.37	0.20 - 1.14	56.1	
P, 0-15 cm (mg/kg)					
B	20.8	3.7	16.0 - 24.4	17.6	
V	18.4	3.2	16.0 - 23.2	17.3	
P, 15-30 cm					
B	4.9	2.1	1.8 - 7.0	43.0	
V	3.7	2.5	1.8 - 7.6	68.3	
P, 30-60 cm					
B	7.1	10.8	1.2 - 26.4	152.8	
V	2.6	1.6	1.2 - 5.0	61.3	
P, 60-120 cm					
B	9.7	9.6	3.0 - 26.4	99.0	
V	5.8	4.2	2.0 - 12.8	72.1	

K, 0-15 cm (mg/kg)					
B	365.	65.6	288.- 441.	17.9	
V	339.	45.9	289.- 391.	13.5	
K, 15-30cm					
B	278.	63.6	216.- 378.	22.9	**
V	91.	44.5	27.- 146.	49.1	
K, 30-60 cm					
B	273.	42.1	233.- 337.	15.4	**
V	160.	38.5	108.- 213.	24.1	
K, 60-120 cm					
B	175.	23.9	140.- 207.	13.6	
V	209.	92.3	115.- 337.	44.0	
N, 0-15 cm (mg/kg)					
B	1.3	1.2	0.4 - 3.4	91.0	
V	0.7	0.3	0.3 - 1.2	48.5	
N, 15-30 cm					
B	1.2	0.5	0.4 - 1.7	42.4	
V	1.3	0.7	0.8 - 2.3	0.5	
N, 30-60 cm					
B	0.3	0.1	0.2 - 0.5	40.0	*
V	0.3	0.2	0.0 - 0.5	69.2	
N, 60-120 cm					
B	0.5	1.1	0.0 - 2.5	203.7	
V	0.0	0.0	0.0 - 0.0	0.0	
EC, 0-15 cm (dSM/cm)					
B	0.2	0.1	0.18 - 0.30	22.7	
V	0.3	0.1	0.20 - 0.33	18.5	
EC, 15-30 cm					
B	0.2	0.1	0.10 - 0.35	55.6	**
V	0.3	0.1	0.30 - 0.41	17.7	
EC, 30-60 cm					
B	0.5	0.1	0.49 - 0.64	11.1	
V	0.5	0.0	0.46 - 0.53	8.0	
EC, 60-120 cm					
B	1.8	1.7	0.60 - 4.20	90.8	
V	2.9	2.7	0.64 - 7.24	94.3	

Depth to CaCO3 (cm)					
B	40.5	2.8	85.0 - 92.5	6.8	**
V	20.5	2.1	17.5 - 22.5	10.2	
AWHC, 0-120 cm (cm)					
B	24.4	1.7	23.0 - 26.5	7.0	**
V	20.2	1.5	18.5 - 21.8	7.4	
Water Use, 0-120 cm (cm)					
B	28.7	2.1	26.0 - 31.3	7.2	**
V	23.0	3.4	18.8 - 26.8	14.6	
Clay, 0-15 cm (%)					
B	25.6	2.0	23.0 - 27.0	7.6	*
V	22.4	3.3	20.0 - 28.0	14.7	
Clay, 15-30 cm (%)					
B	35.4	1.5	34.0 - 37.0	4.3	**
V	27.6	1.5	26.0 - 29.0	5.5	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
B = Bearpaw
V = Vida
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = $NaHCO_3$ phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 24. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Bearpaw and Zahill.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
B	8.14	0.59	7.5 - 8.7	7.3	
Z	8.38	0.04	8.3 - 8.4	0.5	
pH, 15-30 cm					
B	8.16	0.52	7.6 - 8.8	6.9	
Z	8.56	0.09	8.5 - 8.7	1.1	
pH, 30-60 cm					
B	8.44	0.11	8.3 - 8.6	1.3	
Z	8.44	0.26	8.0 - 8.6	3.1	
pH, 60-120 cm					
B	8.72	0.20	8.5 - 8.9	2.3	**
Z	7.98	0.11	7.9 - 8.1	1.4	
OM, 0-15 cm (%)					
B	2.17	0.13	2.08 - 2.35	6.0	
Z	2.03	0.33	1.44 - 2.27	16.3	
OM, 15-30 cm					
B	1.24	0.25	0.96 - 1.60	20.6	
Z	1.18	0.30	0.79 - 1.60	25.4	
OM, 30-60 cm					
B	1.36	0.10	1.21 - 1.47	7.4	
Z	0.80	0.18	0.62 - 1.08	22.5	
OM, 60-120 cm					
B	0.61	0.16	0.35 - 0.73	26.2	**
Z	0.51	0.37	0.20 - 1.14	72.6	
P, 0-15 cm (mg/kg)					
B	20.8	3.7	16.0 - 24.4	17.6	**
Z	11.2	2.4	8.6 - 14.4	21.0	
P, 15-30 cm					
B	4.9	2.1	1.8 - 7.0	43.0	
Z	3.2	0.1	2.2 - 4.4	3.1	
P, 30-60 cm					
B	7.1	10.8	1.2 - 26.4	152.8	
Z	2.3	0.6	1.4 - 2.9	27.9	
P, 60-120 cm					
B	9.7	9.6	3.0 - 26.4	99.0	
Z	2.9	1.1	1.2 - 4.1	39.0	

K, 0-15 cm (mg/kg)					
B	365.	65.6	288.- 441.	17.9	*
Z	270.	38.2	223.- 305.	14.1	
K, 15-30cm					
B	278.	63.6	216.- 378.	22.9	**
Z	74.	31.3	36.- 109.	42.5	
K, 30-60 cm					
B	273.	42.1	233.- 337.	15.4	**
Z	175.	35.2	130.- 218.	20.2	
K, 60-120 cm					
B	175.	23.9	140.- 207.	13.6	
Z	167.	31.8	122.- 196.	19.0	
N, 0-15 cm (mg/kg)					
B	1.3	1.2	0.4 - 3.4	91.0	
Z	0.8	0.3	0.5 - 1.2	35.4	
N, 15-30 cm					
B	1.2	0.5	0.4 - 1.7	42.4	
Z	1.9	1.0	0.9 - 3.2	53.2	
N, 30-60 cm					
B	0.3	0.1	0.2 - 0.5	40.0	*
Z	0.5	0.1	0.4 - 0.5	10.9	
N, 60-120 cm					
B	0.5	1.1	0.0 - 2.5	203.7	
Z	0.2	0.2	0.0 - 0.4	100.	
EC, 0-15 cm (dSM/cm)					
B	0.2	0.1	0.18 - 0.30	22.7	**
Z	0.4	0.1	0.32 - 0.43	13.2	
EC, 15-30 cm					
B	0.2	0.1	0.10 - 0.35	55.6	
Z	1.0	1.5	0.36 - 3.72	144.2	
EC, 30-60 cm					
B	0.5	0.1	0.49 - 0.64	11.1	
Z	1.4	1.8	0.44 - 4.5	128.5	
EC, 60-120 cm					
B	1.8	1.7	0.60 - 4.2	90.8	**
Z	5.5	2.0	2.59 - 7.39	36.4	

Depth to CaCO3 (cm)					
B	40.5	2.8	85.0 - 92.5	6.8	**
Z	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
B	24.4	1.7	23.0 - 26.5	7.0	
Z	23.2	0.5	23.0 - 24.0	1.9	
Water Use, 0-120 cm (cm)					
B	28.7	2.1	26.0 - 31.3	7.2	
Z	26.4	1.9	23.8 - 28.8	7.0	
Clay, 0-15 cm (%)					
B	25.6	2.0	23.0 - 27.0	7.6	**
Z	20.8	1.6	19.0 - 23.0	7.9	
Clay, 15-30 cm (%)					
B	35.4	1.5	34.0 - 37.0	4.3	*
Z	33.8	1.1	33.0 - 35.0	3.2	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
B = Bearpaw
Z = Zahill
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 25. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Vida and Zahill.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
V	8.40	0.12	8.3 - 8.6	1.4	
Z	8.38	0.04	8.3 - 8.4	0.5	
pH, 15-30 cm					
V	8.66	0.19	8.4 - 8.8	2.2	
Z	8.56	0.09	8.5 - 8.7	1.1	
pH, 30-60 cm					
V	8.58	0.04	8.5 - 8.6	0.0	*
Z	8.44	0.26	8.0 - 8.6	3.1	
pH, 60-120 cm					
V	8.40	0.32	8.0 - 8.8	3.8	*
Z	7.98	0.11	7.9 - 8.1	1.4	
OM, 0-15 cm (%)					
V	2.27	0.20	2.00 - 2.5	8.8	
Z	2.03	0.33	1.44 - 2.27	16.3	
OM, 15-30 cm					
V	1.84	0.10	1.74 - 1.96	5.4	**
Z	1.18	0.30	0.79 - 1.60	25.4	
OM, 30-60 cm					
V	1.24	0.05	1.14 - 1.27	4.0	*
Z	0.80	0.18	0.62 - 1.08	22.5	
OM, 60-120 cm					
V	0.66	0.37	0.20 - 1.14	56.1	
Z	0.51	0.37	0.20 - 1.14	72.6	
P, 0-15 cm (mg/kg)					
V	18.4	3.2	16.0 - 23.2	17.3	**
Z	11.2	2.4	8.6 - 14.4	21.0	
P, 15-30 cm					
V	3.7	2.5	1.8 - 7.6	68.3	
Z	3.2	0.1	2.2 - 4.4	3.1	
P, 30-60 cm					
V	2.6	1.6	1.2 - 5.0	61.3	
Z	2.3	0.6	1.4 - 2.9	27.9	
P, 60-120 cm					
V	5.8	4.2	2.0 - 12.8	72.1	
Z	2.9	1.1	1.2 - 4.1	39.0	

K, 0-15 cm (mg/kg)					
V	339.	45.9	289.- 391.	13.5	*
Z	270.	38.2	223.- 305.	14.1	
K, 15-30cm					
V	91.	44.5	27.- 146.	49.1	
Z	74.	31.3	36.- 109.	42.5	
K, 30-60 cm					
V	160	38.5	108.- 213.	24.1	**
Z	175.	35.2	130.- 218.	20.2	
K, 60-120 cm					
V	210.	92.3	115.- 337.	43.9	
Z	167.	31.8	122.- 196.	19.0	
N, 0-15 cm (mg/kg)					
V	0.7	0.3	0.3 - 1.2	48.5	
Z	0.8	0.3	0.5 - 1.2	35.4	
N, 15-30 cm					
V	1.3	0.7	0.8 - 2.3	50.0	
Z	1.9	1.0	0.9 - 3.2	53.2	
N, 30-60 cm					
V	0.3	0.2	0.0 - 0.5	69.2	*
Z	0.5	0.1	0.4 - 0.5	10.9	
N, 60-120 cm					
V	0.0	0.0	0.0 - 0.0	0.0	*
Z	0.2	0.2	0.0 - 0.4	100.	
EC, 0-15 cm (dSM/cm)					
V	0.3	0.1	0.20 - 0.33	18.5	**
Z	0.4	0.1	0.32 - 0.43	13.2	
EC, 15-30 cm					
V	0.3	0.1	0.30 - 0.41	17.7	
Z	1.0	1.5	0.36 - 3.72	144.2	
EC, 30-60 cm					
V	0.5	0.0	0.46 - 0.53	8.0	
Z	1.4	1.8	0.44 - 4.50	128.5	
EC, 60-120 cm					
V	2.9	2.7	0.64 - 7.24	95.1	
Z	5.5	2.0	2.59 - 7.39	36.4	

Depth to CaCO3 (cm)					
V	20.5	2.1	17.5 - 22.5	10.2	**
Z	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
V	20.0	1.5	18.5 - 21.8	7.5	**
Z	23.2	0.5	23.0 - 24.0	1.9	
Water Use, 0-120 cm (cm)					
V	23.0	3.4	18.8 - 26.8	14.6	*
Z	26.4	1.9	23.8 - 28.8	7.0	
Clay, 0-15 cm (%)					
V	22.4	3.3	20.0 - 28.0	14.7	
Z	20.8	1.6	19.0 - 23.0	7.9	
Clay, 15-30 cm (%)					
V	27.6	1.5	26.0 - 29.0	5.5	**
Z	33.8	1.1	33.0 - 35.0	3.2	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
V = Vida
Z = Zahill
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 26. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Scobey and Kevin.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
S	6.92	0.30	6.6 - 7.4	4.3	
K	6.88	0.27	6.6 - 7.3	3.9	
pH, 15-30 cm					
S	8.48	0.13	8.4 - 8.7	1.5	
K	8.44	0.23	8.1 - 8.7	2.8	
pH, 30-60 cm					
S	8.36	0.09	8.2 - 8.4	1.1	
K	8.46	0.31	8.0 - 8.7	3.7	
pH, 60-120 cm					
S	8.60	0.29	8.3 - 9.0	3.4	**
K	8.00	0.07	7.4 - 8.1	0.9	
OM, 0-15 cm (%)					
S	2.06	0.14	1.88 - 2.27	6.8	
K	2.13	0.10	1.96 - 2.19	4.7	
OM, 15-30 cm					
S	1.74	0.41	1.33 - 2.43	23.6	
K	1.75	0.06	1.67 - 1.81	3.4	
OM, 30-60 cm					
S	1.69	0.28	1.47 - 2.03	0.2	
K	1.32	0.60	0.45 - 2.02	45.5	
OM, 60-120 cm					
S	0.04	0.13	0.20 - 0.51	25.0	
K	0.53	0.12	0.40 - 0.67	22.6	
P, 0-15 cm (mg/kg)					
S	20.0	1.3	19.0 - 22.0	6.3	
K	19.0	7.5	6.3 - 25.9	39.3	
P, 15-30 cm					
S	2.2	2.2	0.7 - 6.6	100.5	
K	4.3	4.8	1.4 - 12.8	110.4	
P, 30-60 cm					
S	6.4	2.9	3.7 - 9.8	44.7	
K	5.5	4.0	1.4 - 12.1	72.3	
P, 60-120 cm					
S	4.4	1.7	2.9 - 6.6	39.5	
K	5.0	1.9	2.2 - 7.3	38.0	

K, 0-15 cm (mg/kg)					
S	482.	27.6	460.- 530.	5.7	**
K	591.	48.9	520.- 641.	8.3	
K, 15-30cm					
S	395.	65.9	322.- 485.	16.7	
K	341.	113.6	232.- 530.	33.3	
K, 30-60 cm					
S	288.	39.2	242.- 332.	13.6	
K	300.	65.6	255.- 413.	21.9	
K, 60-120 cm					
S	190.	20.2	173.- 225.	10.6	
K	189.	28.3	152.- 226.	15.0	
N, 0-15 cm (mg/kg)					
S	4.4	6.6	1.1 - 16.2	148.4	
K	7.8	10.3	0.8 - 26.0	132.1	
N, 15-30 cm					
S	3.4	1.5	2.2 - 5.8	42.9	
K	4.7	2.1	2.1 - 7.7	45.1	
N, 30-60 cm					
S	1.6	0.4	1.2 - 2.2	27.5	
K	2.2	1.2	0.7 - 3.8	53.2	
N, 60-120 cm					
S	0.8	0.5	0.3 - 1.6	67.5	*
K	3.5	3.0	0.5 - 7.6	84.1	
EC, 0-15 cm (dSM/cm)					
S	0.3	0.1	0.17 - 0.45	42.3	
K	0.4	0.2	0.26 - 0.63	39.5	
EC, 15-30 cm					
S	0.4	0.1	0.38 - 0.52	11.4	
K	0.5	0.1	0.37 - 0.57	17.8	
EC, 30-60 cm					
S	0.6	0.1	0.54 - 0.69	11.3	
K	1.9	2.8	0.51 - 6.85	144.5	
EC, 60-120 cm					
S	2.6	1.2	1.04 - 3.94	47.1	**
K	7.1	1.4	5.02 - 8.59	19.9	

Depth to CaCO3 (cm)					
S	36.0	2.2	32.5 - 37.5	6.2	**
K	21.5	1.4	20.0 - 22.5	6.4	
AWHC, 0-120 cm (cm)					
S	21.0	0.7	20.0 - 21.8	3.5	**
K	15.8	1.0	14.0 - 16.3	6.2	
Water Use, 0-120 cm (cm)					
S	28.3	1.5	26.3 - 29.8	5.3	**
K	19.6	4.3	13.8 - 25.0	21.7	
Clay, 0-15 cm (%)					
S	26.0	1.4	24.0 - 27.0	5.4	
K	25.8	1.6	24.0 - 28.0	6.4	
Clay, 15-30 cm (%)					
S	38.0	0.0	38.0 - 38.0	0.0	*
K	29.4	1.5	28.0 - 32.0	5.2	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
S = Scobey
K = Kevin
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 27. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Scobey and Hillon.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
S	6.92	0.30	6.6 - 7.4	4.3	**
H	8.34	0.89	8.7 - 8.4	10.7	
pH, 15-30 cm					
S	8.48	0.13	8.4 - 8.7	1.5	
H	8.56	0.89	8.5 - 8.7	10.4	
pH, 30-60 cm					
S	8.36	0.09	8.2 - 8.4	1.1	
H	8.54	0.22	8.2 - 8.8	2.6	
pH, 60-120 cm					
S	8.60	0.29	8.3 - 9.0	3.4	
H	8.18	0.48	7.8 - 8.8	5.9	
OM, 0-15 cm (%)					
S	2.06	0.14	1.88 - 2.27	6.8	*
H	1.79	0.11	1.67 - 1.96	6.1	
OM, 15-30 cm					
S	1.74	0.41	1.33 - 2.43	23.6	*
H	1.22	0.27	0.90 - 1.53	22.1	
OM, 30-60 cm					
S	1.69	0.28	1.47 - 2.03	16.6	**
H	0.57	0.22	0.25 - 0.79	38.6	
OM, 60-120 cm					
S	0.04	0.13	0.20 - 0.51	325.0	*
H	0.19	0.10	0.10 - 0.35	52.6	
P, 0-15 cm (mg/kg)					
S	20.0	1.3	19.0 - 22.0	6.3	*
H	14.0	3.7	10.1 - 18.0	26.3	
P, 15-30 cm					
S	2.2	2.2	0.7 - 6.6	100.5	*
H	5.3	2.5	2.9 - 9.3	47.5	
P, 30-60 cm					
S	6.4	2.9	3.7 - 9.8	44.7	*
H	3.9	0.4	3.3 - 4.4	11.0	
P, 60-120 cm					
S	4.4	1.7	2.9 - 6.6	39.5	
H	3.8	1.8	2.2 - 6.6	47.9	

K, 0-15 cm (mg/kg)					
S	482.	27.6	460.- 530.	5.7	**
H	342.	54.9	290.- 414.	16.0	
K, 15-30cm					
S	395.	65.9	322.- 485.	16.7	**
H	165.	72.8	94.- 281.	44.1	
K, 30-60 cm					
S	288.	39.2	242.- 332.	13.6	*
H	219.	47.6	163.- 283.	21.8	
K, 60-120 cm					
S	190.	20.2	173.- 225.	10.6	**
H	139.	20.6	117.- 168.	14.9	
N, 0-15 cm (mg/kg)					
S	4.4	6.6	1.1 - 16.2	148.4	
H	1.1	0.7	0.5 - 2.1	60.0	
N, 15-30 cm					
S	3.4	1.5	2.2 - 5.8	42.9	*
H	1.2	1.6	0.2 - 3.9	129.2	
N, 30-60 cm					
S	1.6	0.4	1.2 - 2.2	27.5	*
H	0.2	0.3	0.0 - 0.6	138.9	
N, 60-120 cm					
S	0.8	0.5	0.3 - 1.6	67.5	
H	0.4	1.0	0.0 - 2.2	222.7	
EC, 0-15 cm (dSM/cm)					
S	0.3	0.1	0.17 - 0.45	42.3	
H	0.4	0.1	0.11 - 0.45	40.0	
EC, 15-30 cm					
S	0.4	0.1	0.38 - 0.52	11.4	*
H	0.4	0.2	0.36 - 0.41	60.5	
EC, 30-60 cm					
S	0.6	0.1	0.54 - 0.69	11.3	
H	0.6	0.4	0.37 - 1.40	67.2	
EC, 60-120 cm					
S	2.6	1.2	1.04 - 3.94	47.1	
H	3.8	3.1	0.44 - 6.67	81.2	

Depth to CaCO3 (cm)					
S	36.0	2.2	32.5 - 37.5	6.2	**
H	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
S	21.0	0.7	20.0 - 21.8	3.5	**
H	11.3	1.5	9.0 - 13.0	13.8	
Water Use, 0-120 cm (cm)					
S	28.3	1.5	26.3 - 29.8	5.3	**
H	15.4	1.1	13.5 - 16.5	7.3	
Clay, 0-15 cm (%)					
S	26.0	1.4	24.0 - 27.0	5.4	**
H	21.6	1.3	20.0 - 23.0	6.2	
Clay, 15-30 cm (%)					
S	38.0	0.0	38.0 - 38.0	0.0	**
H	25.4	2.7	22.0 - 29.0	10.6	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
S = Scobey
K = Kevin
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 28. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Kevin and Hillon.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
K	6.88	0.27	6.6 - 7.3	14.5	**
H	8.34	0.89	8.2 - 8.4	10.7	
pH, 15-30 cm					
K	8.44	0.23	8.1 - 8.7	2.7	
H	8.56	0.89	8.5 - 8.7	10.4	
pH, 30-60 cm					
K	8.46	0.31	8.0 - 8.7	3.7	
H	8.54	0.22	8.2 - 8.8	2.6	
pH, 60-120 cm					
K	8.00	0.07	7.9 - 8.1	0.9	
H	8.18	0.48	7.8 - 8.8	5.9	
OM, 0-15 cm (%)					
K	2.13	0.10	1.96 - 2.19	4.7	**
H	1.79	0.11	1.67 - 1.96	6.1	
OM, 15-30 cm					
K	1.75	0.06	1.67 - 1.81	3.4	**
H	1.22	0.27	0.90 - 1.53	22.1	
OM, 30-60 cm					
K	1.32	0.60	0.45 - 2.02	45.5	*
H	0.57	0.22	0.25 - 0.79	38.6	
OM, 60-120 cm					
K	0.53	0.12	0.40 - 0.67	22.6	**
H	0.19	0.10	0.10 - 0.35	52.6	
P, 0-15 cm (mg/kg)					
K	19.0	7.5	6.3 - 25.9	39.3	
H	14.0	3.7	10.1 - 18.0	26.3	
P, 15-30 cm					
K	4.3	4.8	1.4 - 12.8	110.4	
H	5.3	2.5	2.9 - 9.3	47.5	
P, 30-60 cm					
K	5.5	4.0	1.4 - 12.1	72.3	
H	3.9	0.4	3.3 - 4.4	11.0	
P, 60-120 cm					
K	5.0	1.9	2.2 - 7.3	38.0	
H	3.8	1.8	2.2 - 6.6	47.9	

K, 0-15 cm (mg/kg)					
K	591.	48.9	520.- 641.	8.3	**
H	342.	54.9	290.- 414.	16.0	
K, 15-30cm					
K	341.	113.6	232.- 530.	33.3	*
H	165.	72.8	94.- 281.	44.1	
K, 30-60 cm					
K	300.	65.6	253.- 413.	21.9	*
H	219.	47.6	163.- 283.	21.8	
K, 60-120 cm					
K	189.	28.3	152.- 226.	15.0	**
H	139.	20.6	117.- 168.	14.9	
N, 0-15 cm (mg/kg)					
K	7.8	10.3	0.8 - 26.0	132.1	
H	1.1	0.7	0.5 - 2.1	60.0	
N, 15-30 cm					
K	4.7	2.1	2.1 - 7.7	45.1	*
H	1.2	1.6	0.2 - 3.9	129.2	
N, 30-60 cm					
K	2.2	1.2	0.7 - 3.8	53.2	**
H	0.2	0.3	0.0 - 0.6	138.9	
N, 60-120 cm					
K	3.5	3.0	0.5 - 7.6	84.1	*
H	0.4	1.0	0.0 - 2.2	222.7	
EC, 0-15 cm (dSM/cm)					
K	0.4	0.2	0.26 - 0.63	39.5	
H	0.4	0.1	0.11 - 0.45	40.0	
EC, 15-30 cm					
K	0.5	0.1	0.37 - 0.57	17.8	*
H	0.4	0.2	0.36 - 0.41	60.5	
EC, 30-60 cm					
K	1.9	2.8	0.51 - 6.85	144.5	
H	0.6	0.4	0.37 - 1.40	67.2	
EC, 60-120 cm					
K	7.1	1.4	5.02 - 8.59	19.9	*
H	3.8	3.1	0.44 - 6.67	81.2	

Depth to CaCO3 (cm)					
K	73.5	3.8	70.0 - 80.0	5.2	**
H	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
K	15.8	1.0	14.0 - 16.3	6.2	**
H	11.3	1.5	9.0 - 13.0	13.7	
Water Use, 0-120 cm (cm)					
K	19.6	4.3	13.8 - 25.0	21.7	*
H	15.4	1.1	13.5 - 16.5	7.3	
Clay, 0-15 cm (%)					
K	25.8	1.6	24.0 - 28.0	6.4	**
H	21.6	1.3	20.0 - 23.0	6.2	
Clay, 15-30 cm (%)					
K	29.4	1.5	28.0 - 32.0	5.2	*
H	25.4	2.7	22.0 - 29.0	10.6	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
K = Kevin
H = Hillon
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 29. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Telstad and Joplin.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
T	7.84	0.36	7.5 - 8.4	4.6	*
J	8.28	0.16	8.0 - 8.4	1.9	
pH, 15-30 cm					
T	7.94	0.25	7.7 - 8.3	3.2	**
J	8.50	0.00	8.5 - 8.5	0.0	
pH, 30-60 cm					
T	8.18	0.16	7.9 - 8.3	2.0	**
J	8.64	0.05	8.6 - 8.7	0.6	
pH, 60-120 cm					
T	8.9	0.00	8.9 - 8.9	0.0	*
J	8.4	0.45	7.9 - 9.0	5.4	
OM, 0-15 cm (%)					
T	1.47	0.20	1.27 - 1.74	13.7	
J	1.61	0.11	1.53 - 1.81	6.8	
OM, 15-30 cm					
T	0.86	0.24	0.62 - 1.21	27.9	**
J	1.49	0.16	1.27 - 1.67	10.7	
OM, 30-60 cm					
T	0.86	0.37	0.56 - 1.40	43.0	
J	0.95	0.08	0.84 - 1.02	8.4	
OM, 60-120 cm					
T	0.60	0.16	0.40 - 0.79	26.7	
J	0.43	0.12	0.30 - 0.56	27.9	
P, 0-15 cm (mg/kg)					
T	29.0	3.3	24.8 - 33.6	11.4	**
J	22.9	2.5	19.7 - 25.5	11.1	
P, 15-30 cm					
T	12.8	3.7	8.0 - 16.8	29.2	*
J	6.6	3.8	2.9 - 11.0	57.1	
P, 30-60 cm					
T	7.3	2.6	3.4 - 10.2	35.3	*
J	3.2	2.0	1.5 - 6.6	61.2	
P, 60-120 cm					
T	6.7	2.0	3.4 - 8.1	29.2	
J	3.8	3.5	1.0 - 9.4	90.5	

K, 0-15 cm (mg/kg)					
T	358.	76.0	279.- 449.	21.2	
J	295.	18.8	280.- 326.	6.4	
K, 15-30cm					
T	232.	41.7	184.- 277.	18.0	**
J	106.	13.8	88.- 126.	13.0	
K, 30-60 cm					
T	234.	70.2	114.- 285.	30.0	*
J	152.	59.8	99.- 253.	39.3	
K, 60-120 cm					
T	224.	113.0	101.- 394.	50.4	
J	190.	52.8	131.- 268.	27.8	
N, 0-15 cm (mg/kg)					
T	0.4	0.2	0.1 - 0.7	54.6	
J	0.6	0.3	0.2 - 1.0	57.1	
N, 15-30 cm					
T	0.5	0.3	0.2 - 0.9	56.3	
J	0.5	0.3	0.1- 0.7	56.5	
N, 30-60 cm					
T	0.2	0.3	0.0 - 0.6	120.8	
J	0.6	1.1	0.0 - 2.5	178.3	
N, 60-120 cm					
T	0.4	0.3	0.0 - 0.7	65.8	
J	0.1	0.2	0.0 - 0.4	121.4	
EC, 0-15 cm (dSM/cm)					
T	0.2	0.1	0.18 - 0.32	20.8	*
J	0.3	0.0	0.29 - 0.33	6.7	
EC, 15-30 cm					
T	0.2	0.1	0.14 - 0.30	31.6	*
J	0.4	0.0	0.37 - 0.43	5.0	
EC, 30-60 cm					
T	0.4	0.1	0.21 - 0.48	28.2	
J	0.5	0.0	0.43 - 0.53	8.7	
EC, 60-120 cm					
T	0.5	0.1	0.44 - 0.61	11.5	*
J	3.7	3.3	0.61 - 7.36	89.5	

Depth to CaCO3 (cm)					
T	40.5	3.3	37.5 - 45.0	8.0	**
J	20.5	2.1	17.5 - 22.5	10.2	
AWHC, 0-120 cm (cm)					
T	12.5	0.7	11.8 - 13.5	5.8	
J	12.0	1.6	10.3 - 14.5	12.9	
Water Use, 0-120 cm (cm)					
T	15.5	1.3	14.3 - 17.3	8.2	*
J	13.3	1.5	11.5 - 15.0	11.1	
Clay, 0-15 cm (%)					
T	15.8	1.1	15.0 - 17.0	7.0	
J	15.2	2.1	13.0 - 17.0	13.5	
Clay, 15-30 cm (%)					
T	18.6	1.8	16.0 - 21.0	9.8	
J	18.2	1.6	17.0 - 20.0	9.0	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
T = Telstad
J = Joplin
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 30. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Telstad and Hillon.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
T	7.84	0.36	7.5 - 8.4	4.6	**
H	8.46	0.05	8.4 - 8.5	0.6	
pH, 15-30 cm					
T	7.94	0.25	7.7 - 8.3	3.2	**
H	8.60	0.07	8.5 - 8.7	0.8	
pH, 30-60 cm					
T	8.18	0.16	7.9 - 8.3	2.0	**
H	8.84	0.09	8.8 - 9.0	1.0	
pH, 60-120 cm					
T	8.9	0.00	8.9 - 8.9	0.0	**
H	8.3	0.46	8.0 - 9.1	5.5	
OM, 0-15 cm (%)					
T	1.47	0.20	1.27 - 1.74	13.7	**
H	1.81	0.14	1.67 - 2.03	7.7	
OM, 15-30 cm					
T	0.86	0.24	0.62 - 1.21	27.9	*
H	1.32	0.31	0.96 - 1.74	23.5	
OM, 30-60 cm					
T	0.86	0.37	0.56 - 1.40	43.0	
H	0.81	0.28	0.51 - 1.21	34.6	
OM, 60-120 cm					
T	0.60	0.16	0.40 - 0.79	26.7	
H	0.47	0.24	0.35 - 0.90	51.1	
P, 0-15 cm (mg/kg)					
T	29.0	3.30	24.8 - 33.6	11.4	**
H	13.2	5.59	8.0 - 22.6	42.4	
P, 15-30 cm					
T	12.8	3.7	8.0 - 16.8	29.2	**
H	3.4	2.7	1.0 - 6.6	63.2	
P, 30-60 cm					
T	7.3	2.6	3.4 - 10.2	35.3	**
H	2.1	1.0	0.3 - 2.9	49.5	
P, 60-120 cm					
T	6.7	2.0	3.4 - 8.1	29.2	**
H	2.0	1.7	0.3 - 4.2	86.4	

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
K, 0-15 cm (mg/kg)					
T	358.	76.0	279.- 449.	21.2	**
H	211.	42.2	170.- 279.	20.0	
K, 15-30cm					
T	232.	41.7	184.- 277.	18.0	**
H	90.	37.	65.- 150.	41.1	
K, 30-60 cm					
T	234.	70.2	114.- 285.	30.0	**
H	113.	19.3	98.- 140.	17.1	
K, 60-120 cm					
T	224.	113.0	101.- 394.	50.4	
H	144.	18.2	119.- 161.	12.6	
N, 0-15 cm (mg/kg)					
T	0.4	0.2	0.1 - 0.7	54.5	
H	1.6	1.5	0.6 - 4.2	95.5	
N, 15-30 cm					
T	0.5	0.3	0.2 - 0.9	56.3	*
H	1.2	0.6	0.4 - 1.9	47.4	
N, 30-60 cm					
T	0.2	0.3	0.0 - 0.6	120.8	
H	0.7	0.6	0.2 - 1.6	89.7	
N, 60-120 cm					
T	0.4	0.3	0.0 - 0.7	65.8	
H	1.5	1.7	0.0 - 3.4	113.0	
EC, 0-15 cm (dSM/cm)					
T	0.2	0.1	0.18 - 0.32	20.8	**
H	0.4	0.0	0.38 - 0.45	9.8	
EC, 15-30 cm					
T	0.2	0.1	0.14 - 0.30	31.6	**
H	0.4	0.0	0.36 - 0.40	5.3	
EC, 30-60 cm					
T	0.4	0.1	0.21 - 0.48	28.2	
H	0.5	0.1	0.41 -10.55	13.0	
EC, 60-120 cm					
T	0.5	0.1	0.44 - 0.61	11.5	**
H	4.2	1.8	1.42 - 5.71	43.5	

Depth to CaCO3 (cm)					
T	40.5	3.3	37.5 - 45.0	8.0	**
H	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
T	12.5	0.7	11.8 - 13.5	5.8	**
H	10.3	0.5	9.8 - 11.0	4.6	
Water Use, 0-120 cm (cm)					
T	15.5	1.3	14.3 - 17.3	8.2	*
H	12.8	2.0	10.5 - 15.8	15.7	
Clay, 0-15 cm (%)					
T	15.8	1.1	15.0 - 17.0	7.0	**
H	19.4	1.5	18.0 - 21.0	7.9	
Clay, 15-30 cm (%)					
T	18.6	1.8	16.0 - 21.0	9.8	**
H	23.4	2.0	21.0 - 26.0	8.3	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
T = Telstad
H = Hillon
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Table 31. Means, Standard Deviations, Ranges, Coefficients of Variations, and Significant Differences of Soil Chemical and Morphological Properties for Joplin and Hillon.

Property, depth	Mean	SD	Range	CV (%)	Sig. Level
pH, 0-15 cm (2:1)					
J	8.28	0.16	8.0 - 8.4	1.9	*
H	8.34	0.89	8.2 - 8.4	10.7	
pH, 15-30 cm					
J	8.50	0.00	8.5 - 8.5	0.0	**
H	8.56	0.89	8.5 - 8.7	10.4	
pH, 30-60 cm					
J	8.64	0.05	8.6 - 8.7	0.6	**
H	8.54	0.22	8.2 - 8.8	2.6	
pH, 60-120 cm					
J	8.40	0.45	7.9 - 9.0	5.4	
H	8.18	0.48	7.8 - 8.8	5.9	
OM, 0-15 cm (%)					
J	1.61	0.11	1.53 - 1.81	6.8	*
H	1.79	0.11	1.67 - 1.96	6.1	
OM, 15-30 cm					
J	1.49	0.16	1.27 - 1.67	10.7	
H	1.22	0.27	0.90 - 1.53	22.1	
OM, 30-60 cm					
J	0.95	0.08	0.84 - 1.02	8.4	
H	0.57	0.22	0.25 - 0.79	38.6	
OM, 60-120 cm					
J	0.43	0.12	0.30 - 0.56	27.9	
H	0.19	0.10	0.10 - 0.35	52.6	
P, 0-15 cm (mg/kg)					
J	22.9	2.54	19.7 - 25.5	11.1	**
H	14.0	3.7	10.1 - 18.0	26.3	
P, 15-30 cm					
J	6.6	3.8	2.9 - 11.0	57.1	
H	5.3	2.5	2.9 - 9.3	47.5	
P, 30-60 cm					
J	3.2	1.0	1.5 - 6.6	61.2	
H	3.9	0.4	3.3 - 4.4	11.0	
P, 60-120 cm					
J	3.8	3.4	1.0 - 9.4	90.5	
H	3.8	1.8	2.2 - 6.6	47.9	

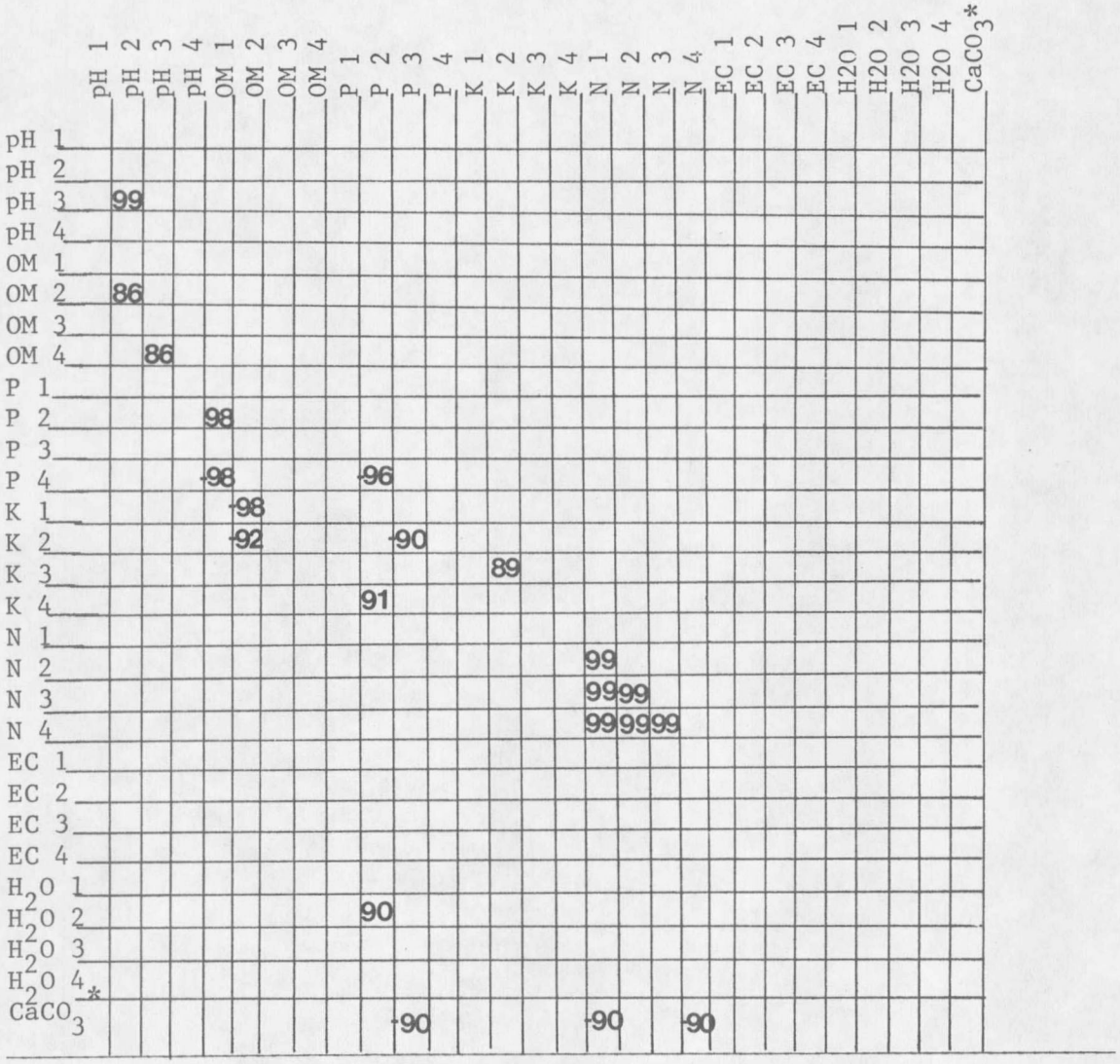
K, 0-15 cm (mg/kg)					
J	295.	18.8	280.- 326.	6.4	**
H	342.	54.9	290.- 414.	16.0	
K, 15-30cm					
J	106.	13.8	88.- 126.	13.0	
H	165.	72.8	94.- 281.	44.1	
K, 30-60 cm					
J	152.	59.8	99.- 253.	39.3	
H	219.	47.6	163.- 283.	21.8	
K, 60-120 cm					
J	190.	52.8	131.- 268.	27.8	
H	139.	20.6	117.- 168.	14.9	
N, 0-15 cm (mg/kg)					
J	0.6	0.3	0.2 - 1.0	57.1	
H	1.1	0.7	0.5 - 2.1	60.0	
N, 15-30 cm					
J	0.5	0.3	0.1 - 0.7	56.5	*
H	1.2	1.6	0.2 - 3.9	129.2	
N, 30-60 cm					
J	0.6	1.1	0.0 - 2.5	178.3	
H	0.2	0.3	0.0 - 0.6	138.9	
N, 60-120 cm					
J	0.1	0.2	0.0 - 0.4	121.4	**
H	0.4	1.0	0.0 - 2.2	222.7	
EC, 0-15 cm (dSM/cm)					
J	0.3	0.0	0.29 - 0.33	6.7	
H	0.4	0.1	0.11 - 0.45	40.0	
EC, 15-30 cm					
J	0.4	0.0	0.37 - 0.43	5.0	
H	0.4	0.2	0.36 - 0.41	60.5	
EC, 30-60 cm					
J	0.5	0.0	0.43 - 0.53	8.7	
H	0.6	0.4	0.37 - 1.40	67.2	
EC, 60-120 cm					
J	3.7	3.3	0.61 - 7.36	89.5	
H	3.8	3.1	0.44 - 6.67	81.2	

Depth to CaCO3 (cm)					
J	20.5	2.1	17.5 - 22.5	10.2	**
H	0.0	0.0	0.0 - 0.0	0.0	
AWHC, 0-120 cm (cm)					
J	12.0	1.6	10.3 - 14.5	12.9	*
H	11.3	1.5	9.0 - 13.0	13.7	
Water Use, 0-120 cm (cm)					
J	13.3	1.5	11.5 - 15.0	11.1	
H	15.4	1.1	13.5 - 16.5	7.3	
Clay, 0-15 cm (%)					
J	15.2	2.0	13.0 - 17.0	13.5	**
H	21.6	1.3	20.0 - 23.0	6.2	
Clay, 15-30 cm (%)					
J	18.2	1.6	17.0 - 20.0	9.0	**
H	25.4	2.7	22.0 - 29.0	10.6	

*, ** = 0.05 and 0.01 significantly different levels, respectively
N = sample size of 5
J = Joplin
H = Hillon
SD = standard deviation
Range = minimum and maximum values
CV = coefficient of variation
OM = organic matter content
P = NaHCO3 phosphorus
K = exchangeable potassium
N = nitrate-nitrogen
EC = electrical conductivity
AWHC = available water holding capacity

Appendix G.

Figure 7. Correlation Coefficients (x 100) for Soil Chemical and Morphological Properties. Matrix Only Includes Correlations Significant at the 5% Level.



*Depth to $CaCO_3$

1, 2, 3, 4 = depth increments 0-15, 15-30, 30-60 and 60-120 cm respectively

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