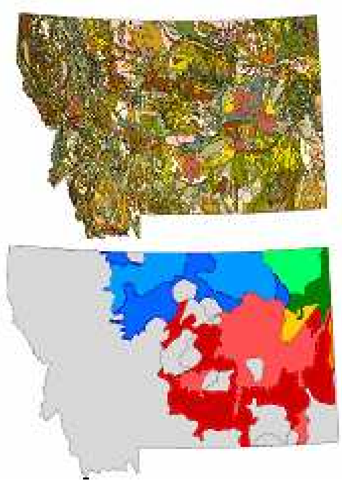
Soil Inventarisation and Land Evaluation Group

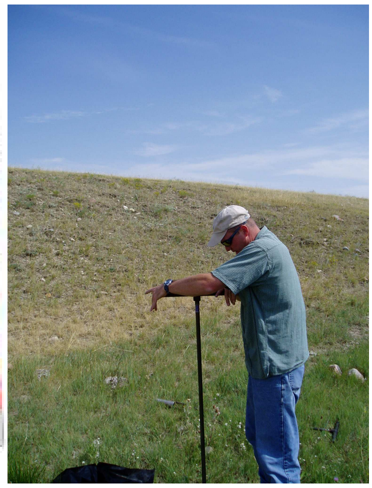
Thesis Soil Inventarisation and Land Evaluation

Multiscale analysis and quantification of soil variability for eastern Montana (USA)

E. Vermue

August 2006





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Multiscale analysis and quantification of soil variability for eastern Montana (USA)

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Supervisor:

Dr. Ir. J.J. Stoorvogel

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Preface

This thesis is submitted in partial fulfillment of the requirements for the master's degree in Soil Science. The study was carried out between May 2005 and June 2006 at Wageningen University, the Netherlands, and Montana State University, USA within the framework of the CASGMS project.

The goal of this study to analyze and quantify the effect of soil variability proved to be a challenge. It provided me with more insight on the analysis of variance and how to handle multiscale soil data. Before starting of with the problem definition for this study I would like to thank several persons who helped me and provided new insights.

First of all John Antle and Susan Capalbo, who made my stay in the United States of America even more pleasant. Kitty Sue Squires for helping me out with so many practical things, which you come across when you go to another university. David Brown and Kevin Dalton for letting me borrow their equipment and for their help with the soil sample analyses. For the statistical part of this thesis, especially the analysis of variance, I would like to thank Gerard Heuvelink.

During the fieldwork campaign the extension agents from Montana State University located in the different counties helped me out with doing the fieldwork and by providing a list of farmers who might be willing to help. Therefore I would like to thank Mike Schuldt, Mark Manoukian, Dan Clark, Stephen Hutton, Judee Wargo and all the farmers who made it possible for me to execute my fieldwork.

Last but not least I would like to thank my supervisor, Jetse Stoorvogel, who introduced the problem to me and who helped me to keep focused on the general picture. Thanks Jetse for the supervision, ideas and comments.

Esther Vermue
Wageningen, The Netherlands
August 2006

Abstract

Environmental sciences require the quantification of soil variability. The quantification of soil variability enables us to accompany our results with confidence limits. Reporting results and the corresponding confidence intervals enhances the use of soil data and derived information. The need for the quantification of soil variability as expressed above is especially true for the analysis and modeling of multiscale processes. The use of soil data across multiscales makes it difficult to assess the influence and effect of variability. The quantification of soil spatial variability will therefore lead to a better understanding of the derived results and to estimate the value of the derived results.

In this study the soil variability for three different soil maps is analyzed and quantified by comparing the means and variances derived for two soil parameters. The three soil maps have different scales, respectively going from a national, state to county scale. It is expected that the large scale soil map explains a large part of the variability for the national soil map, compared to the smaller scale maps.

The study area comprises the eastern part of Montana including the Great Plains. For this area three soil maps, respectively from small to large scale, the MLRA, STATSGO and SSURGO soil maps, were available. The databases accompanying the soil maps were analyzed and a field campaign was executed in the north central part of the study area. The field campaign provided data, which were used to analyze the small scale SSURGO soil map. Furthermore, insight was gained on the agricultural production system in Montana.

For all the soil maps and field data the means and variances were of the same dimension, but the comparisons indicated that there are considerable differences between the means for the soil maps. Besides the two different soil parameters showed a different pattern. Highest amounts of variability were found for the soil parameter: organic matter. The pH showed a more homogenous pattern, which resulted in smaller coefficients of variance. It proved to be possible to quantify the amount of variance which is explained by the SSURGO soil map for the MLRA and STATSGO soil maps.

Depending on the soil parameter, down-scaling can lead to a considerable improvement by taking more of the variance into account. Scaling down one map scale proved for the soil parameters organic matter and pH to achieve the largest improvements. Down-scaling to the largest map scale available resulted in only a small improvement.

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Chapter 1 Introduction

Problem definition

Environmental research, including e.g. modeling of ecological and agricultural systems, precision agriculture and the assessment of environmental problems, requires detailed quantitative information on the spatial distribution of soil properties in the landscape. Knowledge on the variability of these properties can strongly influence the reliability of the derived results and maybe even more important, it provides information on the variability of these results (Pennock & De Jong, 1990; Burrough, 1993; Lin et al., 2005). In order to assign soil mapping units and modeling scenarios with confidence limits to provide soil data users with reliable information, it is necessary to quantify soil spatial variability.
Soil data are described and provided at different scales, for example the national, regional and local scale. For each scale the dominant soils, their properties and the variability among these properties are described. Comparing a small scale soil map with a large scale one leads to the conclusion that a lot of the variability is lost for the small scale soil map, this in order to keep the amount of data manageable and applicable. Nevertheless, soil variability increases with increasing sample area (Burrough, 1993; Seyfried, 1998). The use of these small scale map data in ecological and agricultural modeling results in neglecting possibly relevant variability.
In the last decades soil spatial variability has been mainly studied at a single scale. However, soil data are used for various scales, depending on the objective. For example, the modeling of multiscale processes requires the quantification of soil variability at multiple scales. The need to quantify soil spatial variability and to examine the effect of it across multiple scales is a problem encountered by many soil scientists (Lin et al., 2005). Quantification will help to allocate and estimate the errors due to spatial variability and model results can be accompanied by confidence intervals (Burrough, 1993). Quantification of soil spatial variability will therefore enhance the use and applicability of soil data (Lin et al., 2005).

This study focuses on the analysis and quantification of soil variability at three different map scales. For the United States of America different soil maps are available of which the Major Land Resource Area (MLRA, national scale), the State Soil Geographic (STATSGO, state scale) and the Soil Survey Geographic (SSURGO, county scale) soil maps are used for this study. SSURGO and STATSGO are two soil databases that provide soil data in the shape of map units and map unit components. MLRA's are geographically associated land resource units delineated by the Natural Resources Conservation Service (NRCS) and characterized by a particular pattern that combines soils, water, climate, vegetation, land use and type of farming (USDA- Soil Conservation Services (SCS), 1981)[1]. Soil data for the MLRA's are derived from generalizing data from the STATSGO database. Each MLRA in this study, is further subdivided in two areas, respectively a high precipitation and low precipitation area; the sub-MLRA's.
In order to examine and quantify the effect of soil variability this study focuses on the comparison of the mean (μ) and the variance (σ^2) of a few soil parameters derived from the SSURGO and STATSGO databases, sub-MLRA's and the analysis of soil samples obtained during the field campaign. The means and variances from the different soil maps and soil samples will be compared for a part of the state of Montana. It is expected that the mean μ for the analyzed soil parameters will be almost the same for the different scales as the maps

[1] There are 204 MLRA's in the United States, ranging in size from less than 500,000 acres to more than 60 million acres.

represent the same area. It is furthermore expected that the next larger scale soil map can explain a considerable part of the variability of the smaller scale. In fact this should be the case for the MLRA scale as the data are derived from the STATSGO soil map. For the sub-MLRA's representative profiles derived from the STATSGO database are used. The use of one representative profile per sub-MLRA leads to the assumption that the variance is equal to zero. For the STATSGO and SSURGO databases it is clear that $\sigma^2 \neq 0$ as there are several map units within a sub-MLRA and these map units again contain a number of components. The analysis and quantification of variance for the different map scales will help to validate and understand results derived these databases. Furthermore, the quantification of variance for a single scale makes it also possible to explain part of the variance for a smaller map scale e.g. the SSURGO soil map can explain part of the variance of the STATSGO and MLRA soil maps.
The main objective of this study is:

To analyze and possibly quantify the effect of soil variability for a set of soil parameters for multiple scales for the east part of the state of Montana (USA).

To attain the objective the following research questions need to be answered:

- Is it possible to explain part of the soil variability for a map scale based on the database of the next larger map scale?
- Does the present STATSGO soil map describe the variation in soil variability for the (sub-) MLRA's? And how much of the variance is explained by the STATSGO database for the MLRA map scale?
- Does the present SSURGO soil map describe the variation in soil variability for the STATSGO soil map? And how much of the variance is explained by the SSURGO database for the STATSGO map scale?
- Does the SSURGO soil map describe the variation in soil variability for the MLRA's? And how much of the variance is explained by the SSURGO database for the MLRA map scale?
- Do the field data from the field campaign correspond with the data from the SSURGO database?
- Which database would be recommended for the use of ecological and agricultural modeling?

This pilot study started with the choice for a sub-MLRA for which different field samples were analyzed. The samples were compared with the same parameters derived after the analysis of the different databases. A short fieldwork campaign provided data to verify the data from the local scale database.

Background

Soils form as the result of five soil forming factors, i.e. topography, climate, biota and organisms, parent material, and time (Jenny, 1941). The intensity and the interactions of/and between these factors result in spatial and temporal variation. Part of this variation is systematic and can to a certain extent be predicted based on the soil-landscape relation (landforms and geomorphic elements) (Hartung et al, 1991). Another part of the variability is indicated as stochastic i.e. random and can (partly) be due to the sampling method. The stochastic variability can be subdivided in spatially dependent and spatially independent variability. The spatially dependent variability indicates that samples closer to one another are more similar than samples at a larger distance (Wilding & Drees, 1983; Pennock & De Jong, 1990; Arnold & Wilding, 1991). Spatially independent variability is purely random.

Soil surveys are performed to indicate and delineate discrete units that contain less variability than the soil population as a whole. However, despite the idea of discrete entities for continuous variables, soil mapping units nearly always contain unidentified parts, associations or miscellaneous areas that often remain unmentioned (Nordt et al., 1991; Lin et al., 2005). Besides, the largest variability is often found within a few meters, thus within a soil type. Therefore soil observations done to measure the soil properties of a map unit do not represent the average value, but a part of the soil variability of the mapping unit. With an increasing number of observations, the value for a soil property approaches the true mean of the map unit (Burrough, 1993). Therefore, the utility and reliability of the classification system depends upon the precision of the delineation, the additional information and the number of observations (Wilding & Drees, 1983).

This study on spatial variability is performed within the context of the Consortium for Agricultural Soil Mitigation of Greenhouse Gasses (CASMGS) project, which focuses on the terrestrial sequestration of carbon dioxide by changes in management practices on agricultural land (Website CASMGS [1]). The sequestration of organic carbon is calculated by an agro-ecosystem model, the Century model (Metherell et al., 1993), which calculates nutrient dynamics over time scales of centuries to millennia for several types of management practices (Website Natural Resource Ecology Laboratory [2]). These calculations are based on a representative profile for each sub-MLRA. This study will provide the necessary information to judge whether this assumption is valid or if better results will be obtained by incorporating more variance. Furthermore, the analysis of different soil parameters serves as a mean to compare the different soil maps to indicate whether or not it is desirable to incorporate a certain amount of variance to derive a spatially more explicit pattern of the heterogeneity or to use the mean. It is expected that all three soil maps represent the general pattern relatively well. The performance of the soil map for a desired goal will therefore depend on the incorporation of a certain amount of variance.

Reading guide

The report starts with the background and the introduction of the problem. Chapter 2 provides information on the location, the geological situation and other relevant geophysical factors. In Chapter 3 the materials and methods are described. Chapter 4 discusses the results. The discussion is presented in Chapter 5, followed by the conclusions and recommendations in Chapter 6.

Chapter 2 Area description

This chapter deals with environmental factors like, geology and topography, climate and land use in Montana. Maps are presented to illustrate the location, the geology and the distribution of precipitation. Soils and land use are described per MLRA. For each MLRA also some climate facts are quoted.

2.1 Location

The state of Montana is located between longitudes 104° 2’W and 116° 2’W and latitudes 44° 26’N to 49° N and covers an area of 380,837 km^2 (Website Encarta Encyclopedia [3]) of which 237,000 km^2 comprises agricultural land. Montana can be divided in three main topographical units (Figure 2.1). The western one third of the state comprises the large mountain ranges and broad valleys of the Rocky Mountains. The Great Plains make up the other two thirds of the state. The western one third consists of the plains surrounding isolated mountain ranges, while the eastern one third lacks these isolated mountain ranges. Besides these topographical divisions, the state is also divided in administrative units, the counties (Figure 2.1).

2.2 Geology

Montana has a long and complicated geologic history. Two of the main landscaping processes comprise the formation of the Rocky Mountains and the glaciations during the Pleistocene. For a general description of the geology of Montana, see Appendix A. In this section only the geological events and deposits relevant for the study area are described.

The study area is part of the Great Plains of America, for the geological map, see Appendix A. The Great Plains form a distinct geomorphologic unit extending from Canada to as far south as the Pecos and Rio Grande River in Texas, USA (Thornbury, 1965). The unit is characterized by a gently rolling landscape, which is generally sloping towards the east. The Plains are bordered in the west by the Rocky Mountains and in the east by the Wyoming basin. The Great Plains form, in fact, a large geosynclinal with several smaller units, the local uplifts and basins (Thornbury, 1965; Wayne et al, 1991) of which the glaciated and nonglaciated Missouri Plateau are located in Montana.

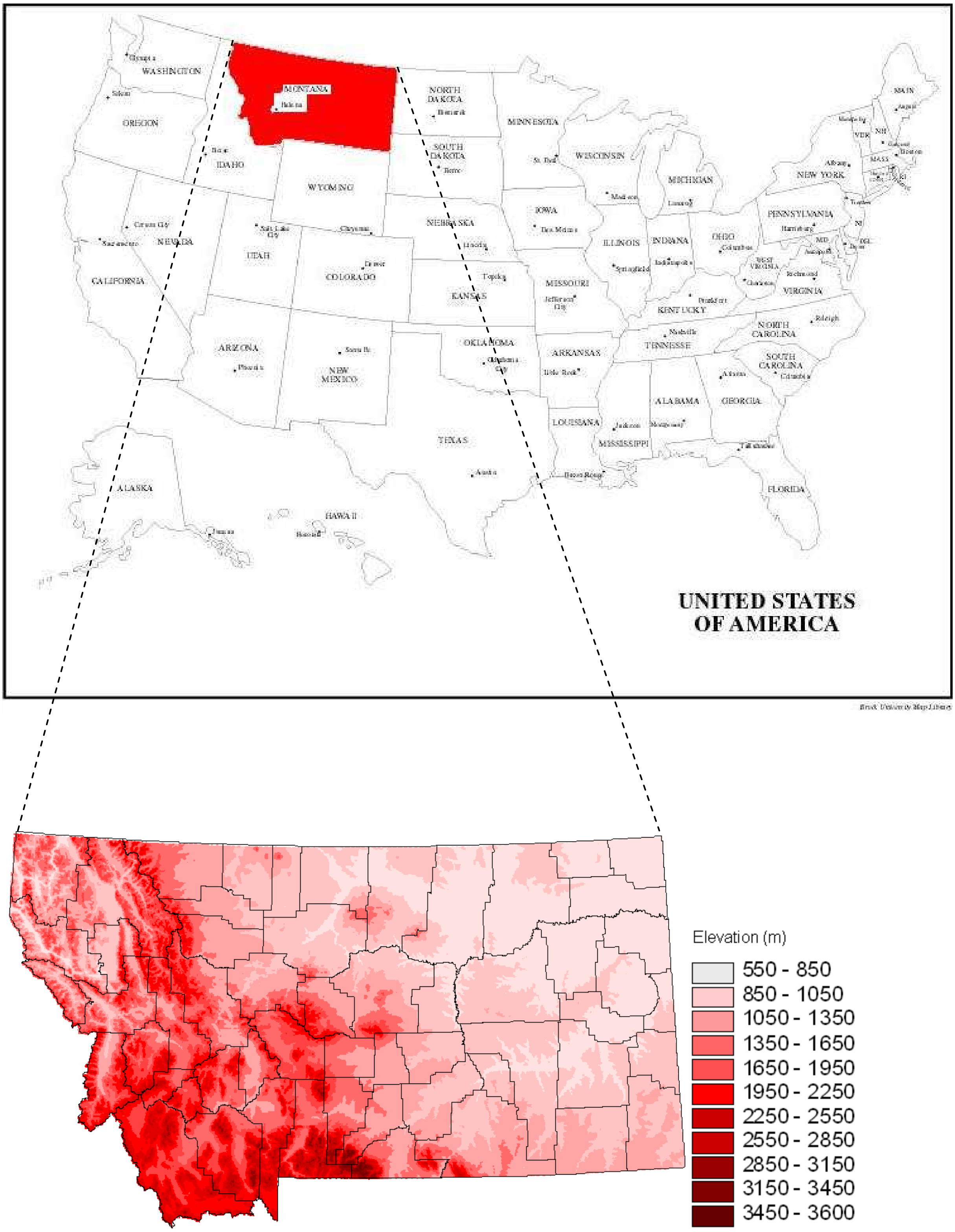

Figure 2.1 Location of the state of Montana in the United States of America and the different counties of Montana at the elevation map (Map USA: Website Brock University [4]).

The Great Plains are underlain by marine Cretaceous rocks. A sequence of erosional periods and renewed uplifts followed the Cretaceous during which, the Rocky Mountains were eroded to a peneplain. The sediments formed the piedmont that is now the Great Plains. The present Montana landscape is from Pliocene age or younger. Erosion prevailed during the Pliocene and the main rivers dissected the piedmont (Thornbury, 1965; Wayne et al, 1991). The northern part of the Great Plains, the boundary is roughly formed by the Missouri river, was glaciated by a complex pattern of mountain glaciers, originating from what is now Glacier National Park, and continental glaciers, which had their origin in Canada (Thornbury, 1965). A thick layer of glacial debris was left on the northern Great Plains. South of the glaciated area, glacial lakes occurred, as did glacial outwash terraces and dunes derived from glacial outwash. In this southern part a sequence of erosional and depositional events prevailed, which resulted in the formation of five distinct terrace levels in each valley (Wayne et al., 1991). Since the ice ages, the landscape has been little modified (Lemke et al., 1965).

2.3 Climate

The continental divide, which runs through the Rocky Mountains, forms roughly the boundary for the different climates in Montana. The differences in climate are caused by changes in topography. The mountainous western part experiences a north Pacific coast type of climate with mild winters, evenly distributed precipitation throughout the year, cool summers and a shorter growing season than the more continental eastern climate of the Great Plains were hot summers and cool winters prevail. Precipitation distribution depends also mainly on topography as is illustrated in Figure 2.2.

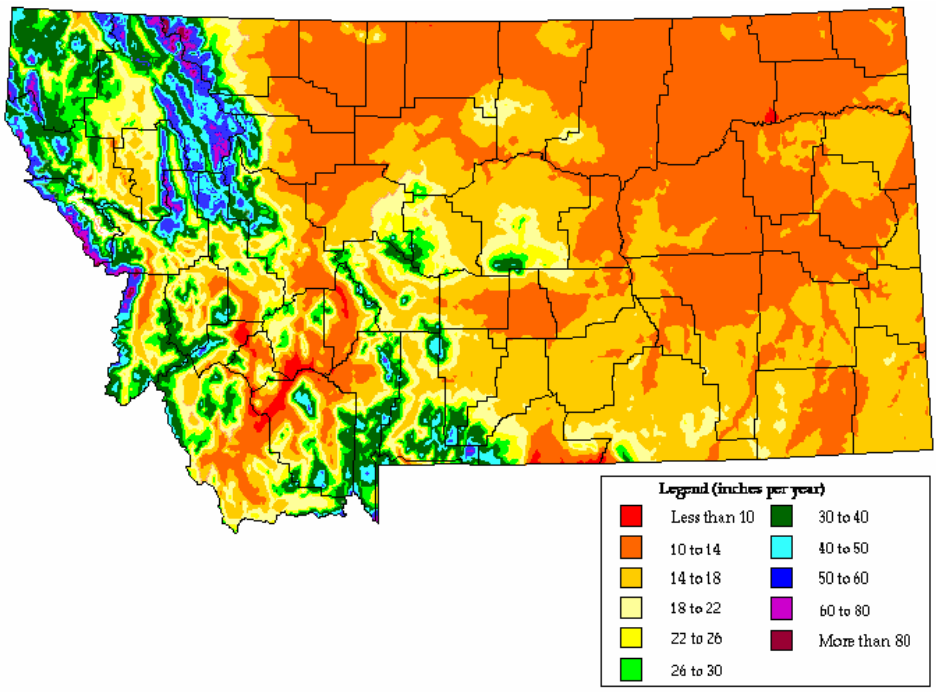

Figure 2.2 Average annual precipitation for Montana (1961 – 1990) in inches per year. One inch = 25.4 mm (After the figure from Website Western Regional Climate Center [5]).

The Rocky Mountains in the west and the isolated mountain ranges in the central part of the state receive the highest amounts of precipitation. Some parts receive up to 2000 mm per year. The northern and eastern parts of the Great Plains in Montana are the driest and receive less than 254 mm per year (Website Western Regional Climate Center [5]). Further details on climatic conditions are given for specific regions in the following section.

2.4 MLRA's

The occurrence of different soil types and land management practices is easiest described according to the different MLRA's. In Figure 2.3 the MLRA's for the state of Montana are presented. As not all the MLRA's for Montana are analyzed in this study, only the relevant ones are described in the section below. These MLRA's comprise the major agricultural areas of which nearly all the land is cropped or used for grazing cattle. Montana has a large portion of agricultural land. Agriculture forms the state most important economic activity. The larger part of the 237,000 km^2 of agricultural land is pasture/ rangeland, which comprises 64.8% of the area. The most important agricultural crop is spring wheat, which is in fact the main crop for the Great Plains and makes up for 30.1% of all the agricultural land (Website Montana Department of Agriculture [6]). Other crops are barley and oat. Wheat is dry farmed and often cropped in a two-year system. Because of the lack of moisture the land is left fallow for a year to gain moisture for the next growing season. Only along the major rivers the lands are irrigated. In the section below the climate conditions, the soils and the land use are described for each of the MLRA's separately (USDA, 1981).

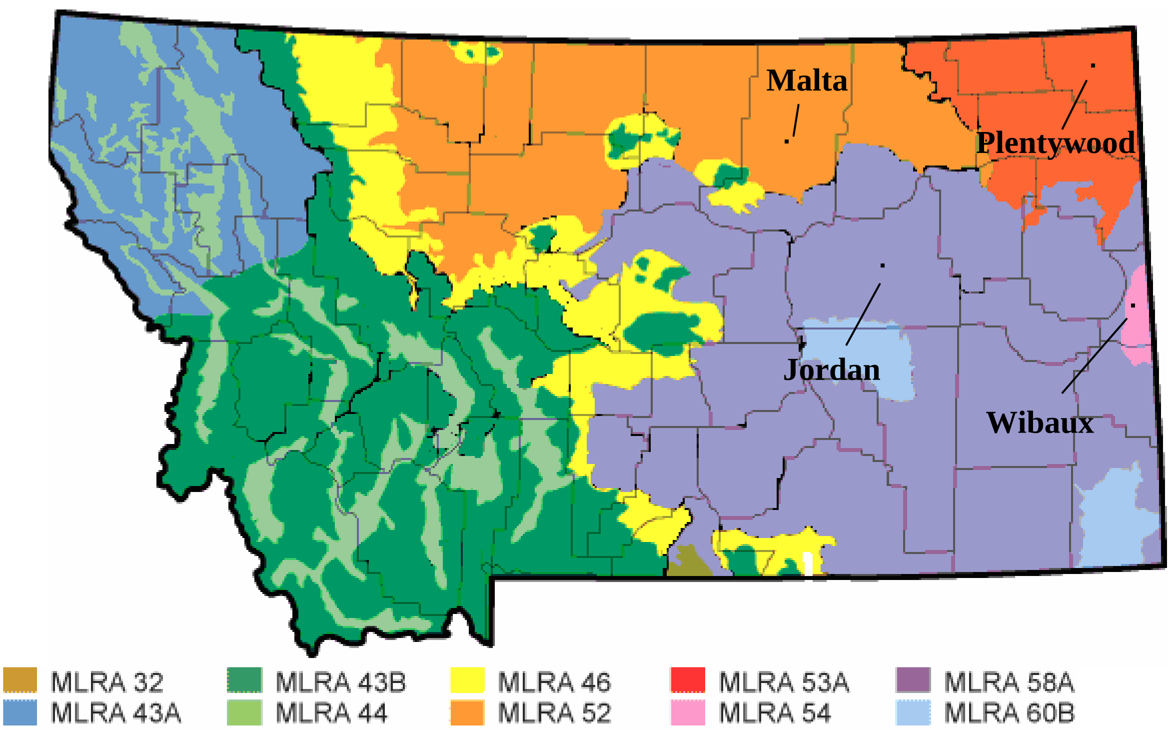

Figure 2.3 Major Land Resource Areas in the state of Montana (Website NRCS [7]).

2.4.1 MLRA 52 Brown Glaciated Plain

Land use

In the western part of MLRA 52 the main crop is wheat (dry farmed). The rangelands for cattle are mainly found in the eastern part of the area. A small band of irrigated lands with crops like sugar beets, corn silage and feed grains is found along the major rivers.

Climate

Figure 2.4 presents the average monthly precipitation and temperature for the city of Malta. The largest amounts of precipitation occur at the end of spring/ early summer, when the monthly total can reach up to 60 mm. During winter, precipitation is limited. The temperature curve shows a minimum of almost –10˚C for the month of January to a maximum of just above 20˚C in the months of July and August.

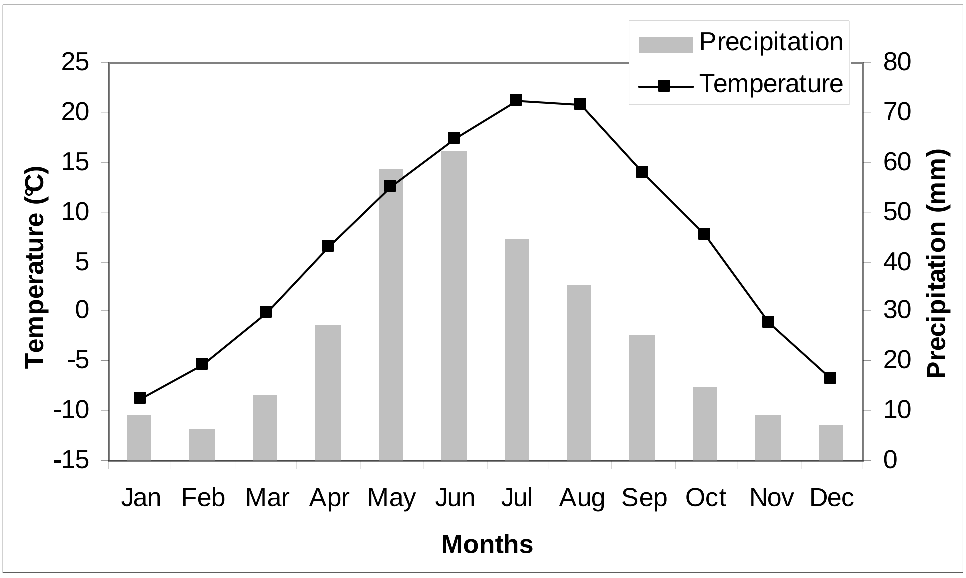

Figure 2.4 Average monthly temperature and precipitation (derived from the years: 1959-2004) for the city of Malta located in MLRA 52.

Soils

The dominant soil types are Borolls, Orthents, Argids and Fluvents. These medium to fine textured soils are well drained and have a frigid temperature regime. Argiborolls and Torrifluvents occur on glacial till plains with a topography ranging from nearly level to strongly rolling. Torriorthents are dominant on the shale uplands, lacustrine terraces, fans and foot slopes. Natrargids occur near the stream at low lying terraces and the lower part of alluvial fans.

2.4.2 MLRA 53A Northern Dark Brown Glaciated Plains

Land use

More than half of the land is dry farmed cropland, mainly cropped with spring wheat. Sloping soils are vegetated with the naturally occurring grasses and shrubs.

Climate

The monthly precipitation for MLRA 53A is highest in the month of June, reaching up to more than 70 mm, as is indicated by Figure 2.5. The average monthly temperature varies from –11˚C for January to a maximum average of again just above 20˚C for the month of July.

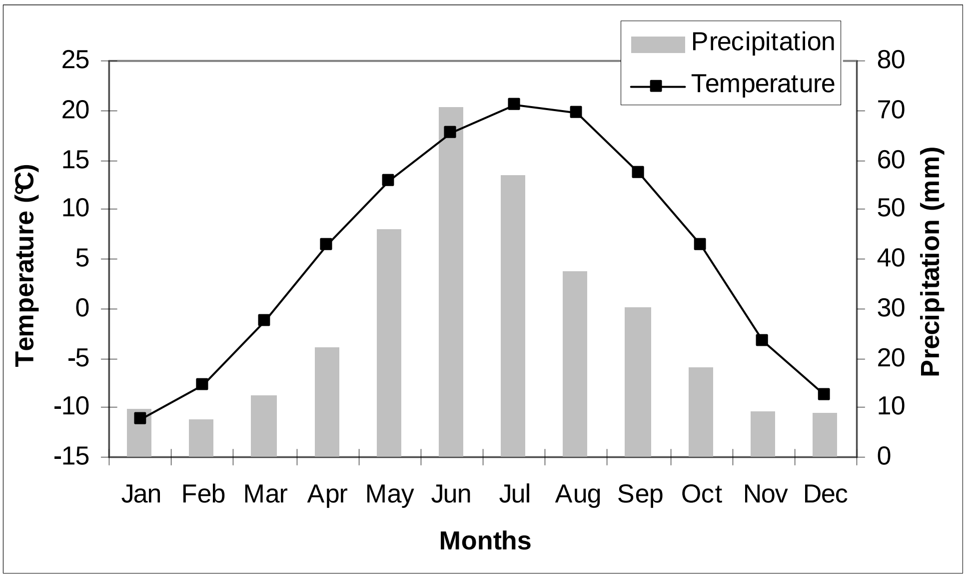

Figure 2.5 Average monthly temperature and precipitation (derived from the years: 1950-2004) for the city of Plentywood located in MLRA 53A.

Soils

Borolls form the dominant soil order type for MLRA 53A. The Borolls are well drained, have a medium texture, a frigid temperature regime and a mixed mineralogy. At the till plains, Agriborolls mainly occur, while at the alluvial fans and terraces Haploborolls are more dominant.

2.4.3 MLRA 54 Rolling Soft Shale Plain

Land use

In this MLRA most often agriculture is combined with cattle breeding. About sixty percent of the area is used for grazing cattle on native grasses and shrubs. Soils with little topography are used for dry farming wheat. Also in this area the lands along the major rivers are irrigated for cultivating cash crops.

Climate

Figure 2.6 shows the average monthly temperature and precipitation for MLRA 54. The precipitation distribution in time is similar to the previous two MLRA's. The highest amounts of precipitation occur in spring and early summer. During the winter months, monthly amounts remain below 10 mm. Winter temperatures are below zero for the months of November till March. In summer the average monthly temperature is around 20˚C.

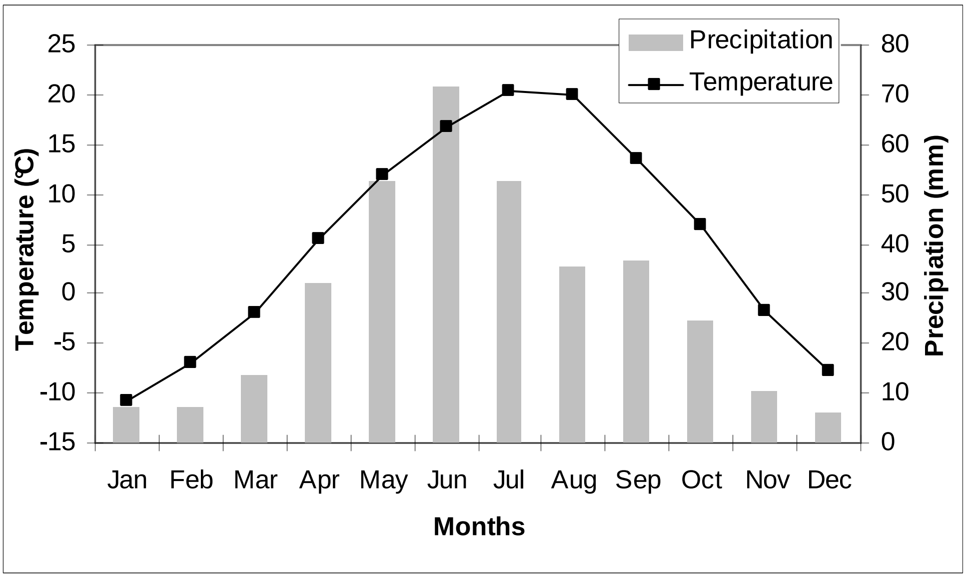

Figure 2.6 Average monthly temperature and precipitation (derived from the years: 1948-2004) for the city of Wibaux located in MLRA 54.

Soils

The Borolls are deep, well to moderately well drained and have a clayey to loamy texture. The temperature regime is frigid. The level to rolling uplands are dominated by the Haploborolls and Argiborolls, while at the slopes of the uplands Ustorthents and Ustipsamments occur. Ustochrepts and Ustorthents are present at alluvial fans, terraces and foot slopes.

2.4.4 MLRA 58A Northern Rolling High Plains

Land use

The main part of the land consists of native grasses and shrubs that are grazed by cattle and sheep. The remaining part of the land is cropped with wheat and along the main rivers some cash crops are cultivated.

Climate

Figure 2.7 indicates that the amount of precipitation in spring to early summer is less for MLRA 58A than for the other three MLRA's. The maximum average during the month of June is about 65 mm compared to 70 mm for the other MLRA's. Winter temperatures are about the same as the ones previously mentioned for the other MLRA's. Summer temperatures are however slightly higher, reaching up to 22 to 23˚C.

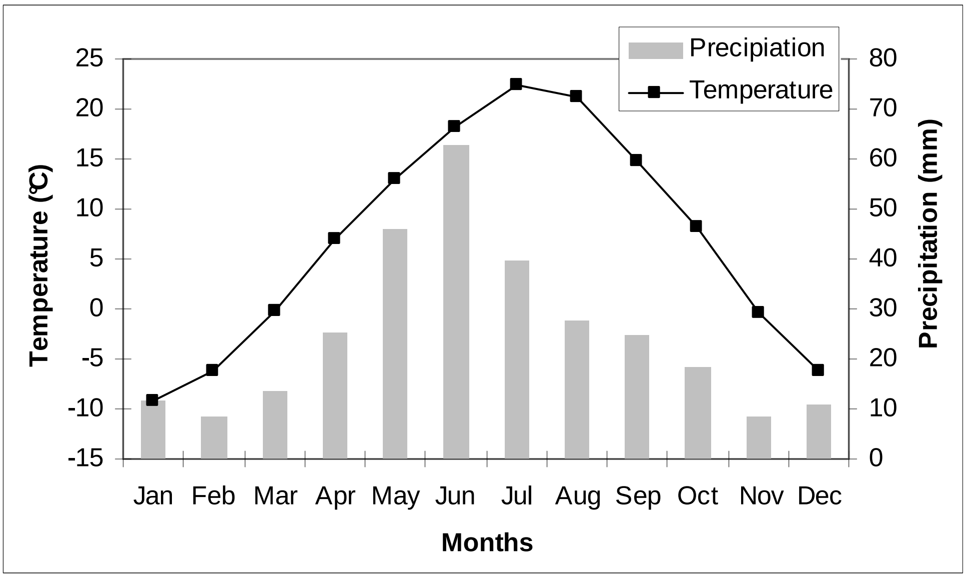

Figure 2.7 Average monthly temperature and precipitation (derived from the years: 1905-2004) for the city of Jordan located in MLRA 58A.

Soils

Orthents, Orthids, Argids, Borolls and Fluvents, all occur in MLRA 58A. These soils are medium to fine textured and mainly well drained with most often a frigid temperature regime. Torriorthents, Camborthids, Calciorthids, Haplargids, Natrargids and Agriborolls occur at the sedimentary uplands, alluvial fans, terraces and foot slopes. The flood plains and lowest elevated terraces are dominated by Torrifluvents.

Chapter 3 Materials and Methods

This chapter describes the materials and methods used during this study. The first paragraph describes the different databases and other electronic data sources. Furthermore the materials used during the field campaign are mentioned. The paragraph on methods explains the procedures for the analysis of the datasets. Moreover, laboratory procedures and fieldwork methods are described.

3.1 Materials

3.1.1 Soil databases

Three soil maps at different scale levels are selected. The MLRA map is chosen as this map is used within the CASGMS project for model simulations. The data on the soil parameters for the MLRA's were derived from the STATSGO database. The SSURGO database is the most detailed database available for nearly the whole state of Montana and was consequently also selected. In the following paragraphs the details of these soil maps are discussed.

MLRA

The United States of America are divided in different land resource units (LRU's) (Website NRCS [7]). Land resource units consist of geographically associated Major Land Resource Areas (MLRA's). These areas represent similar conditions for land use, elevation, climate, water, soils and potential natural vegetation as described in Chapter 1 (USDA, 1981). The four MLRA's used within the CASGMS project are described in Chapter 2.

STATSGO

The soils for the state of Montana are selected from the State Soil Geographic database (STATSGO), developed by the United States Department of Agriculture's (USDA) National Resources Conservation Service (NRCS), (STATSGO Data Base User Information, 1995). The data have a mapping scale of 1:250,000 (with the exception of Alaska, which is mapped at a scale of 1:1,000,000). The STATSGO soil maps are derived by aggregating data from more detailed soil surveys (SSURGO). If not available, Land Remote Sensing Satellite (LANDSAT) images and data on geology, topography, vegetation and climate were used to compile the soil maps. The maps are projected in the Albers equal area projection and have as horizontal datum reference system the North American Datum of 1927.

The STATSGO database for Montana contains 693 identified mapping units and 4266 delineated areas. The database structure is presented in Figure 3.1. A map unit can consist of a maximum of 21 components. The components are part of a soil series and represent the different soils present in a map unit. For each component different properties are described and analyzed, these include characteristics like, soil surface texture and slope of the soil. The components are made up of one or more layers with a maximum of six. For each soil layer 28 different layer properties have been determined, these include among other things: organic matter percentage, pH and texture.

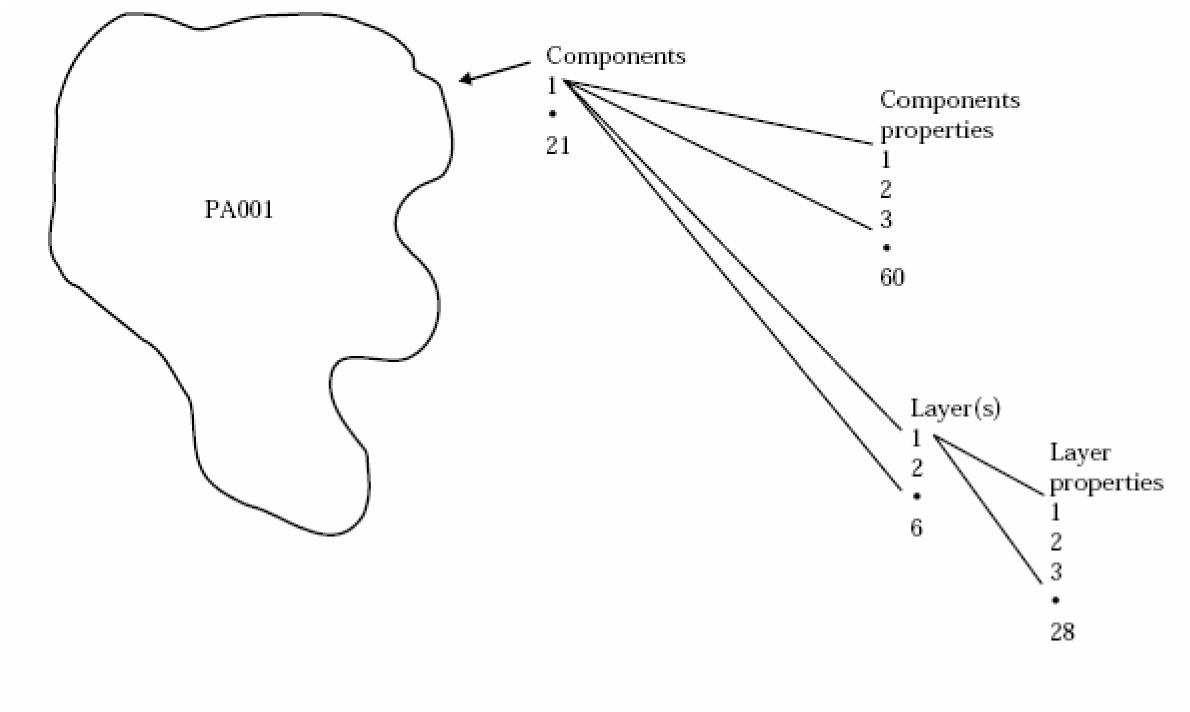

Figure 3.1 Map unit PA001 and the associated components and layers (STATSGO Data User Information, 1995).

SSURGO

The SSURGO database, also developed by the NRCS, is provided through the NASIS Soil Information System, Version 5.2 (Website NASIS [8]). The data are provided per state county (see Figure 2.1). The SSURGO soil maps are generated from field mapping methods based on the international standards (Website NRCS [7]). The SSURGO database is still under development and does not cover the entire state of Montana yet. In this study all the SSURGO county databases located in one of the MLRA's described in Chapter 2 are used. A list of the counties and their last updates are recorded in Appendix B (Website Montana Soil Data Download [9]). The SSURGO data cover a map scale that ranges from 1:12,000 to 1:63,360. This map scale is mainly used by landowners, townships and counties (SSURGO Data Base User Information, 1995). Maps are projected in an UTM projection with meter coordinate values. As horizontal datum reference system the North American Datum of 1983 was used. The SSURGO database has a similar structure as the above described STATSGO database. A SSURGO map unit consists of 1 to 3 components, which are subdivided in soil horizons (maximum of six). This in contrast to the STATSGO database were the components were subdivided in layers. The soil data elements analyzed for the SSURGO database are similar to the ones for the STATSGO database. These soil data elements include both the layer and component properties.

3.1.2 Digital Elevation model (DEM)

In this study the Montana one kilometer digital elevation model (DEM) is used, as was published by the Montana State Library in 1992. This elevation model was derived from the EROS Data Center 30-second Digital Elevation Model of North America. The DEM is bounded by the following coordinates (Table 3.1):

Table 3.1 Bounding coordinates of the DEM of Montana

Direction	Bounding coordinate
West	-115.745300
East	-102.968697
North	50.129799
South	43.852100

The horizontal accuracy is around 2000 meters, the vertical positional accuracy around 650 meters.

3.1.3 Maps

The digital geological map is derived from the geological map from the United States Geologic Survey and the Montana Bureau of Mines and Geology, and was published in 1955. In this map the different formations, the corresponding surface area, the associated rock type, the era, system and lithology are recorded. Unfortunately this map lacks a good representation of the extent of the glacial sediments. Furthermore, a road map published in 1993 by the Montana State Library was used. Other maps used that were also published by the Montana State Library are hydrographic maps indicating the river basins (published in 1994), streams and lakes (published in 1990, 1993, and 1994) at different scales. For the analysis in Chapter 4 also a land use map is used.

3.1.4 GIS platform

As an integrative tool for the different data and maps, a GIS package, Arcview, version 3.3 developed by the Environmental Systems Research Institute (ESRI), was used. This GIS platform provides the possibilities to overlay different maps and to combine and calculate data from different sources.

3.1.5 Fieldwork equipment

Soil samples were collected using a standard hand auger or a so-called riverside auger (closed sides) (Website Eijkelkamp [10]) of 1.20 m (4 ft) length. Occasionally a similar type of soil auger with a length of 1.52 m (5 ft) or 1.83 m (6 ft) was used. Samples were collected in paper bags that were plasticized at the inside. Sample locations were noted, using the Global Positioning System. A Silva Multi-Navigator GPS was used to locate the different sampling points.

3.2 Methods

This paragraph describes how the goals formulated in Chapter 1 will be derived. Each of the databases is analyzed according to the same procedure.

3.2.1 Data base analysis

A schematic overview of the database analysis is presented in Figure 3.2. It presents the different soil maps used in this study and what will be calculated for these soil maps. The three different soil maps are ordered from the smallest scale (MLRA) at the top to the largest scale (SSURGO) at the bottom of the figure. The horizontal arrows indicate the calculation of a weighted mean (μ) and variance (σ) for the units of each of the three maps. Moreover, the means and variances for these maps will also be calculated based on the soil map from the underlying larger scale. For example the mean and variance for a MLRA will be calculated from the STATSGO map units that are located within this MLRA. The same procedure is followed for the STATSGO soil map units for which the mean and variance will be calculated based on the SSURGO database. These steps are indicated by the vertical arrows. Furthermore, the means and variances for the different MLRA's are also calculated from the SSURGO database. It is therefore possible to make a comparison for all three different soil maps i.e. MLRA, MLRA (STATSGO) and MLRA (SSURGO) at the same scale. The field samples do not form a separate soil map, but are used to compare with the large scale SSURGO soil map.

In the following sections first the calculation of the mean is described followed by the calculation of variance. The last part of this paragraph focuses on the procedure that is followed to compare the different soil maps.

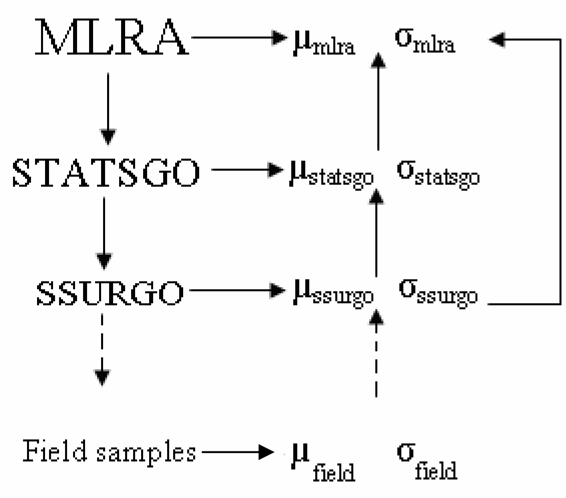

Figure 3.2 Schematic presentation of the comparison of the different soil maps.

Mean

The hierarchical order of the databases is presented in Figure 3.1, from there it follows that one starts at the lowest level i.e. that of the layer properties, with the calculations. The layers are part of a representative soil profile identified for each component. The components again, form a map unit as is shown in Figure 3.3. For some of the layer properties only the high and low mean values are defined. In these cases it was necessary to calculate the mean for the involved layer property first according to Equation 3.1.

$$x_i = \frac{(SL_H + SL_L)}{2} \qquad \text{Eq. 3.1.}$$

x_i	=	mean for layer property
SL_H	=	high mean for layer property
SL_L	=	low mean for layer property

For the STATSGO database the layer thickness is recorded in inches, these values are converted to cm by multiplying with 2.54. To calculate a weighted mean representing the topsoil, the mean layer property (SL_M) is multiplied with the layer thickness. In the next step of the analysis all the layers to a depth of 30 cm are selected. This, because the samples from the field campaign are taken from the first foot (≈ 30 cm) of the sampling location. It is therefore necessary, in order to compare the field samples with the databases to select only the relevant (part of the) layers. Layers consisting of unweathered or weathered bedrock were left out of the analysis as these have no available soil property data.

To derive the soil property mean for a component, the multiplications are summed up for all selected layers within one component. The sum is then divided by the total thickness of these layers (not all components extend to a depth of 30 cm). Thus the soil property mean for the topsoil of a component is derived according to the general equation for calculating the mean, Equation 3.2., where d_{tot} represents the depth of the summed up layers.

$$\mu = \frac{1}{d_{tot}} \sum_{i=1}^{n} x_i d_i \qquad \text{Eq. 3.2}$$

Where:

μ	=	soil property mean for component
d_i	=	thickness of layer *i*
d_{tot}	=	total depth of selected layers
x_i	=	soil layer mean for layer *i*
n	=	number of layers

The calculation of a weighted mean for a map unit holds that in case of associations i.e. several components within a map unit, the relative portion of these associations within the map unit is taken into account. Data on the ratio of components within a map unit are provided in the databases as absolute surface areas or as percentages of a map unit. In both cases the weighted mean for a map unit can be calculated as in Equation 3.3. In case of a map unit association as presented in Figure 3.3, with three map unit components, the mean is calculated by summing up for all components the multiplication of the surface area with the components' soil property mean. The sum is divided by the total surface area of the map unit, Equation 3.3.

$$\mu = \frac{\sum_{j=1}^{N} \left(x_j * a_j \right)}{\sum_{j=1}^{N} a_j} \qquad \text{Eq. 3.3}$$

Where:

a_j	=	surface area or percentage of component *j*
x_j	=	mean for component *j*
μ	=	map unit mean
N	=	number of components

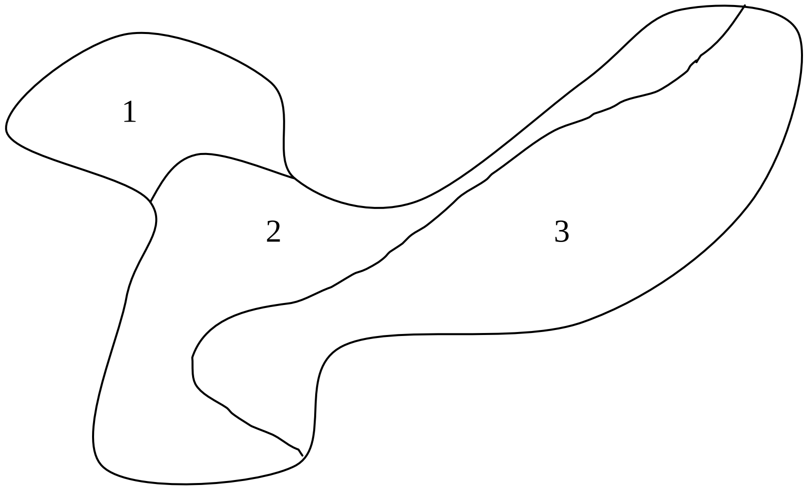

Figure 3.3 Map unit association consisting of three components.

By calculating the weighted mean also a correction is made for map units with unidentified areas. It is then assumed that the remaining surface area is proportionally represented by the map units' components. Thus for example a map unit with two components representing the map unit surface area for 60 and 30% will represent the surface area in the database analysis for respectively 67 and 33%.

Variance

The standard deviation (σ) is calculated according to Equation 3.4, the variance (σ^2) is the square of the standard deviation.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \mu\right)^2} \qquad \text{Eq. 3.4}$$

Where:

σ	=	standard deviation
N	=	number of samples
x_i	=	soil property for sample i
μ	=	soil property mean

The calculation of the variance requires the individual soil property sample values. However, in both databases, the individual sample properties are not recorded, only a high, a low and an intermediate mean. This makes the calculation of the variance according to Equation 3.4. impossible. Furthermore, most of the map units consist of more than one component, as is shown in Figure 3.3, and summing up the variance for all map unit components would result in a biased map unit variance instead of the total map unit variance.

To calculate the variance among the different components of a map unit Equation 3.5 is used. The derivation of this equation can be found in Appendix C. This equation calculates the variance for two different databases i.e. two components/ map units are considered as two databases.

$$\frac{(M+N)\left(M\sigma_1^{\,2} + N\sigma_2^{\,2}\right) + MN\left(\mu_1 - \mu_2\right)^2}{(M+N)^2} \qquad \text{Eq. 3.5}$$

Where:

M	=	surface area component 1
N	=	surface area component 2
σ_1	=	standard deviation component 1
σ_2	=	standard deviation component 2
μ_1	=	mean component 1
μ_2	=	mean component 2

The mean, surface area and the standard deviation are required for the calculation of the total variance of a map unit. The surface area is recorded in the databases and the mean is calculated as described above. For the standard deviation the previously mentioned high and low value for a layer property are used. These high and low values are assumed to be the mean high and the mean low values for the soil property, as the number of samples is unclear and not recorded in the database. From this assumption follows that an estimate of the standard deviation can be made, see Figure 3.4.

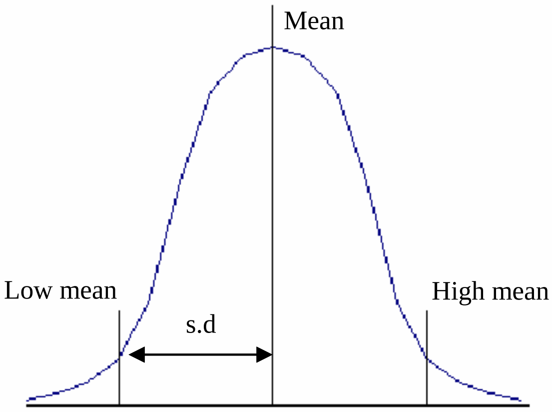

Figure 3.4 Estimate of the standard deviation based on the high and low means for a soil parameter.

The standard deviation can than be calculated as:

$$\sigma = \left(SP_H - SP_L\right) * \frac{1}{2} \qquad \text{Eq. 3.6}$$

Where:

σ	=	Standard deviation
SP_H	=	High mean soil property
SP_L	=	Low mean soil property

When the standard deviation for each soil layer is calculated, a similar procedure as for the calculation of the mean follows. The soil layer standard deviation is multiplied with the soil layer thickness and the layers to a depth of 30 cm are summed up. The multiplications are then divided by the total depth, which results in the derivation of the standard deviation for a component. The variance for a map unit is calculated iteratively. In the first part of the calculation the first two components from a single map unit serve as the different databases *M* and *N*. The variance based on the input variables of these two components is calculated. In case of a third map unit component, the calculated variance ($\sigma_{(M+N)}$), the sum of the surface areas of the components M and N and the new calculated mean for components M and N together serve as input variables for one database. The third map unit component is the other input database O. This procedure is repeated for all map unit components, thus in the end one total variance is calculated for the entire map unit.

Two map overlay

The calculation of the mean and variance as described above, results in the derivation of the means and variances as indicated by the horizontal arrows in Figure 3.2. To derive the means and variances indicated by the vertical arrows, the analysis is taken a step further. First, the individual SSURGO county maps are converted to the right projection (Montana State Plane, NAD 1983) if necessary (Powder River Area, Carter county) and are then merged to become one mapping theme; the SSURGO soil map for the Great Plains of Montana. The STATSGO mapping theme is converted to the desired datum of 1983. For the STATSGO and SSURGO databases the calculated means and variances are exported to ARCVIEW and are joined with the corresponding maps' attribute tables. In the Montana ARCVIEW project the MLRA's, used within the CASGMS project and the map units of the two databases are present as mapping themes. An overlay, which calculates the surface area of a STATSGO/SSURGO map unit per MLRA or the surface area of a SSURGO map unit per STATSGO map unit, is made. The map units located in a MLRA or STATSGO map unit are then selected and the associated table is exported to Microsoft Excel. Again a weighted mean is calculated for each MLRA or STATSGO map unit, like was done before for a map unit based on the components, according to Equation 3.2. The mean multiplied with the associated area is summed up for all areas and is then divided by the total area of the MLRA or STATSGO map unit. For the subMLRA's the same procedure is followed. The variance for a MLRA or STATSGO map unit is calculated according to Equation 3.5, thus the different STATSGO/SSURGO map units are considered as separate databases.

Coefficient of variance

For the analysis of the means and variances, the coefficient of variance is used, see Equation 3.6. This coefficient of variance (*CV*) or also called the relative standard deviation is a standardized measure that indicates to which degree a set of data points varies. It is used to compare the dispersions of separate datasets, thus with different means and standard deviations. For this study it makes it possible to compare the variation for the different maps.

$$CV = \frac{\sigma}{\mu} * 100 \qquad \text{Eq. 3.6}$$

Multiscale variance

The calculated variances give an indication of the amount of variance for a single scale. It is also possible to calculate that part of the variance, which is explained by a particular soil map assuming that the next larger scale soil map represents the actual variation. For this study this implicates which fraction of the variation in the SSURGO map is explained by the STATSGO and MLRA maps. If this fraction is high, the smaller scale soil map provides almost the same information. It is assumed that the SSURGO database represents the actual and current field situation, the variance derived from this database is therefore assumed to be the total variance present. Although the SSURGO soil map is already a simplification of reality, in this study it is the closest approximation to the actual field situation. Assuming this, the explained variance for the STATSGO and MLRA soil maps can be calculated by performing an analysis of variance (ANOVA) (Davis, 1986). First, the total variance is calculated for the entire SSURGO soil database, according to equation 15 in Appendix C. The total sum of squares is derived by multiplying the total SSURGO variance with the total surface area of the SSURGO database. The total sum of squares (SSQ_{total}) consists of the sum of squares of variance within (SSQ_{within}) the map units and the sum of squares of variance between the map units ($SSQ_{between}$), see equation 3.7. SSQ_{within} for a MLRA/STATSGO map unit is thus in fact the variance between the SSURGO map units located in this MLRA/STATSGO map unit.

$$SSQ_{total} = SSQ_{within} + SSQ_{between} \qquad \text{Eq. 3.7}$$

During the following step the variance within the map units, as this is the part of the variance that can be explained by upscaling from SSURGO to STATSGO or MLRA, is calculated. Again this is done following equation 15 in Appendix C, which is calculated for each STATSGO map unit or MLRA. The sum of squares within is derived by multiplying the variance within with the surface area of the map unit/ MLRA and a summation over all map units. The explained SSURGO variance by the MLRA or STATSGO map is than calculated according to equation 3.8.

$$\sigma^2_{explained} = \frac{SSQ_{within}}{SSQ_{total}} * 100\% \qquad \text{Eq. 3.8}$$

When SSQ_{within} is known, also $SSQ_{between}$ is known following equation 3.9.

$$SSQ_{within} = SSQ_{total} - SSQ_{between} \qquad \text{Eq. 3.9}$$

3.2.2 Fieldwork

Soils were selected on the basis of their relative importance (size) and the intersection (access) by a road for accessibility of the area. Field sites were chosen based on the fact that the highest amounts of variability are likely to occur e.g. along streams and as a result of elevation differences. Specific augering locations were chosen based on vegetation differences and landscape properties. At each location, if possible, the samples were taken along two crossing transects or in a zigzag pattern. By doing so, the variance related to different directions was covered. Samples were collected from the topsoil e.g. the first foot (≈ 30 cm) of the soil as the highest amounts of organic matter were expected there. Besides collecting a soil sample, soil depth was estimated. A mixed soil sample was collected in plasticized paper bags, which were closed and transported to the laboratory. The samples were dried in an oven at 40°C for one and a half days ("air-dry"). Very wet samples were spread on a plate and left to dry in the oven, less wet samples were dried in the paper bags. After drying, the samples were sieved on a 2 mm standard sieve.

3.2.3 Laboratory analyses

The laboratory analyses were performed by the Soil, Plant and Water Analytical Laboratory from the Department of Land Resources and Environmental Sciences at Montana State University. For the organic matter analysis, from 20% of the samples a duplicate was taken to analyze and check for analytical errors. For the pH analysis no duplicates were analyzed as this analysis is more accurate and reliable. The organic matter analysis is a colorimetric method according to the Walkley-Black method, which uses potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4) as reagents. Further details on the organic matter determination can be found in the following references: Sims, J.R. & V.A. Haby, 1970 and Page, A.L. et al., 1982. The determination of the pH is done according to the 1:1 pH procedure, this means that the suspension has a proportion of 1:1 for soil and water, see also USDA, 1954; Page et al., 1982; Clesceri et al., 1989. The procedures are briefly described in the Appendix D.

3.2.4 Field sample analysis

The field samples are used for a comparison with the corresponding SSURGO map units. First of all the organic matter duplicates from the laboratory analyses (see section 3.2.3.) are compared and the mean value for the corresponding sample is calculated (Equation 3.2.). The recorded locations (GPS) of the field samples are marked and mapped in an ARCVIEW theme in the same coordinate system as the other soil maps are mapped. By overlaying the SSURGO and the field sample map, the corresponding SSURGO map units can be selected. The means and variances calculated as described above can be compared.

Chapter 4 Results

This chapter presents the results derived from the different analyses of the databases and field data. The analyses are performed for the parameters: organic matter percentage and pH. Besides the relevance of the organic matter percentage for several soil carbon sequestration projects, these parameters were chosen arbitrarily. In this chapter first the means and variances calculated for the present soil maps are presented followed by the multiple scale comparison of these means and variances. For the comparison of the surface areas of each soil map see Appendix E.

4.1 Soil maps

This section presents the results for the database analyses for the present soil maps, like represented by the horizontal arrows in Figure 3.2. First the results for the organic matter percentages for the three different soil maps are presented, followed by the coefficients of variance for the OM percentages. In the second section the results for the pH and the coefficients of variance for the pH are presented. The field observations do not form a separate soil map, but are presented in the last paragraph of this section.
In each of the four figures below the MLRA map is presented according to the subMLRA's as described in Chapter 2. MLRA 58A has, besides the two subMLRA's, an extra subdivision of a forested area. The surface area of these forested areas is however very limited, therefore these areas hardly influence the data and are left out of the analysis. The present STATSGO soil map is presented in Appendix F, followed by the table with the OM percentages and pH values for each map unit of the STATSGO soil map. The SSURGO soil map does not cover the entire MLRA map as presented in Appendix B, therefore only the agricultural areas, the part covering the MLRA's is taken into account.

4.1.1 Organic matter

The organic matter percentages for the three soil maps; MLRA, STATSGO and SSURGO are presented in Figure 4.1. In Figure 4.2 the corresponding coefficients of variance for the OM percentages are presented. All soil maps present a similar spatial pattern despite the difference in scale. Percentages vary from 0.0 to 42.1%, with on average a range from 0.0 to 6% for the state of Montana (The OM percentage of 42.1% is an extreme and only representative for one map unit). The highest OM means are found in the Rocky Mountains and the isolated mountain ranges in the western Great Plains (1.5-6%) as can be seen from the STATSGO soil map. The organic matter percentages decrease from the mountains towards the eastern Great Plains. For the northern part of the Great Plains (MLRA's 52 and 53A) the percentages vary from 0-2%. Towards the southeast percentages decrease further to values varying from 0-1.25%.
The presence of forest and woodland, see Appendix G for land use, in combination with the higher amounts of precipitation (see Chapter 2), result in higher organic matter production for the mountainous areas, compared to other parts of the state. The intermediate OM percentages occurring in the north central part of Montana correspond with the presence of croplands or croplands with grazing lands. The southeast part of Montana, where the lowest organic matter percentages occur, is mainly used as sub-humid grassland and semi-arid grazing land. It was expected that higher OM percentages would be found for the grasslands, a possible

explanation for this situation can be that the input of organic matter for the croplands is in fact higher than for the grasslands. The crop residue is left at the fields after harvest; furthermore the croplands are hardly ploughed, because this results in a loss of moisture. Compared to the grasslands that have a continuous cover of grass and are extensively grazed, the netto input of organic materials might be higher for the croplands and as there is probably more moisture available, turnover processes might be enhanced as well.

The coefficients of variance for the mean OM percentages are presented in Figure 4.2. The three different soil maps all indicate different amounts of variance. For the MLRA soil map all map units have zero variance as the means are derived from the STATSGO soil map and thus no variance could be calculated. For the STATSGO soil map CV's vary from 29.5 to 403.1 %, with on average a range from 40 to 75 %. Based on the pattern for the OM coefficients of variance, the state of Montana can be subdivided in two areas, although differences are small. The first area consists of the mountainous parts of the state i.e. the Rocky Mountains in the west and south and the isolated mountain ranges in the middle part of the state, which have variances that are higher (on average varying from 60 to 100%), than the variances for the Great Plains, where coefficients of variance range from 35 to 55%. For the SSURGO soil map a similar pattern is found i.e. higher CV's are found in the northern central part of the Great Plains, while CV's decrease towards the southeast. Compared to the STATSGO soil map CV's are lower for the SSURGO soil map, on average from 30-50%.
The higher coefficients of variance in the mountainous parts of the state are explained by the larger differences in geology and topography and thus in climate, vegetation, erosion, soil development etc. As there is more variation in the conditions, the organic matter percentages for the different map units tend to vary more as well. This effect is probably already partly diminished as there are a lot of mapping units identified in the mountainous part of Montana, see Appendix F, which already implies a high amount of variation in the soil forming factors. This results in the differentiation of the soils and consequently also more variation within a map unit. The Great Plains have a quite homogeneous pattern for the CV's with the exception of the isolated mountain ranges (see also Figure 2.1) and some map units in the east central part, which have higher CV's. These small differences might be related to the different land use types, like can be illustrated by MLRA 58A, which shows less variation, and MLRA 52 (croplands). The croplands undergo more management practices and therefore more variance is present compared to the extensive grasslands that hardly undergo any active type of management (pers. comm. farmers Montana). The east part of the state (MLRA's 53A and 54) shows more differences in the coefficients of variance for the different map units. The range of organic matter percentages for this area is wider than for MLRA's 52 and 58A, therefore the amount of variance compared to these MLRA's is as a consequence larger.

4.1.2 PH

In Figure 4.3 the mean pH for the three soil maps is presented. All soil maps present a fairly similar homogenous spatial pH pattern for the Great Plains of around 7-8. The mountainous areas, as presented by the STATSGO soil map, have pH values generally below pH 7. For the Great Plains again a subdivision between the northern part and the southeast can be made. For the southeast relatively more areas with pH's varying from 7.5 to 8 are found. For the north-central Great Plains pH values of 7.5-7.75 prevail. These areas are separated by an area with lower pH values of 6.5-7.5. The observed pattern shows the inverse pattern of the precipitation distribution, see Figure 2.2 and Chapter 2. The amount of precipitation is higher in the west part of the state, the mountains, where consequently pH is lower. The pH values for the other two thirds of the state show a pattern where pH values are higher in the southeast/ south-central part (MLRA 58A) than up north (MLRA's 52 and 53A). For the

MLRA's 52 and 53A pH values are more or less similar and vary from 7.1 to 7.6. For MLRA 58A the map units have higher pH values of 7.6 to 8.4. The pattern might be correlated to the landuse in these areas. The croplands lie fallow for one year to gain moisture and grow a crop in the following year. The grasslands are continuously vegetated and do not gain/store extra moisture. This might result over time spans of several decades or more in differences in evapotranspiration and consequently in pH.

For the MLRA soil map the coefficients of variance are zero. The coefficients of variance for the STATGO soil map range from 4.7 to 93.5% with on average a range from 8 to 13%. The coefficients of variances for the pH follow the geographic pattern as well. The standardized variances are higher for the Rocky Mountains (ranging from 14 to 20%), but the large, flat valleys in the mountains show again less variation. The agricultural areas show smaller coefficients of variance i.e. 6.5 to 11%, the exception is made by the area located in central Montana, which has CV's in the order of 15-20%. As with the OM coefficients of variance, also the pH CV's for the SSURGO soil map are smaller compared to the STATSGO ones. For this soil map the coefficients of variance vary from 0.38 to 48.24%. The difference with the STATSGO soil map is illustrated by the smaller area covered by pH values of 10-13% and a larger area with coefficients of variance ranging from 6.5-10%. The Rocky mountain valleys are very pronounced in Figure 4.3. The valleys are relatively flat compared to the surrounding mountain ridges, which explains the differences in the coefficients of variance. Level areas are more often uniform for soil characteristics than areas with large differences in topography. When Figure 4.3 and Figure 4.4 are compared it is seen that the areas with the highest pH values have the smallest coefficients of variance.
Compared to the coefficients of variance for the OM percentages (29.5-75%) the ones for the pH (8-13%) are considerably smaller, but for both the CV for OM and pH yields that the amount of variance is determined by the presence of topographic differences and consequently climatic differences. The OM percentages are further determined by management practices.

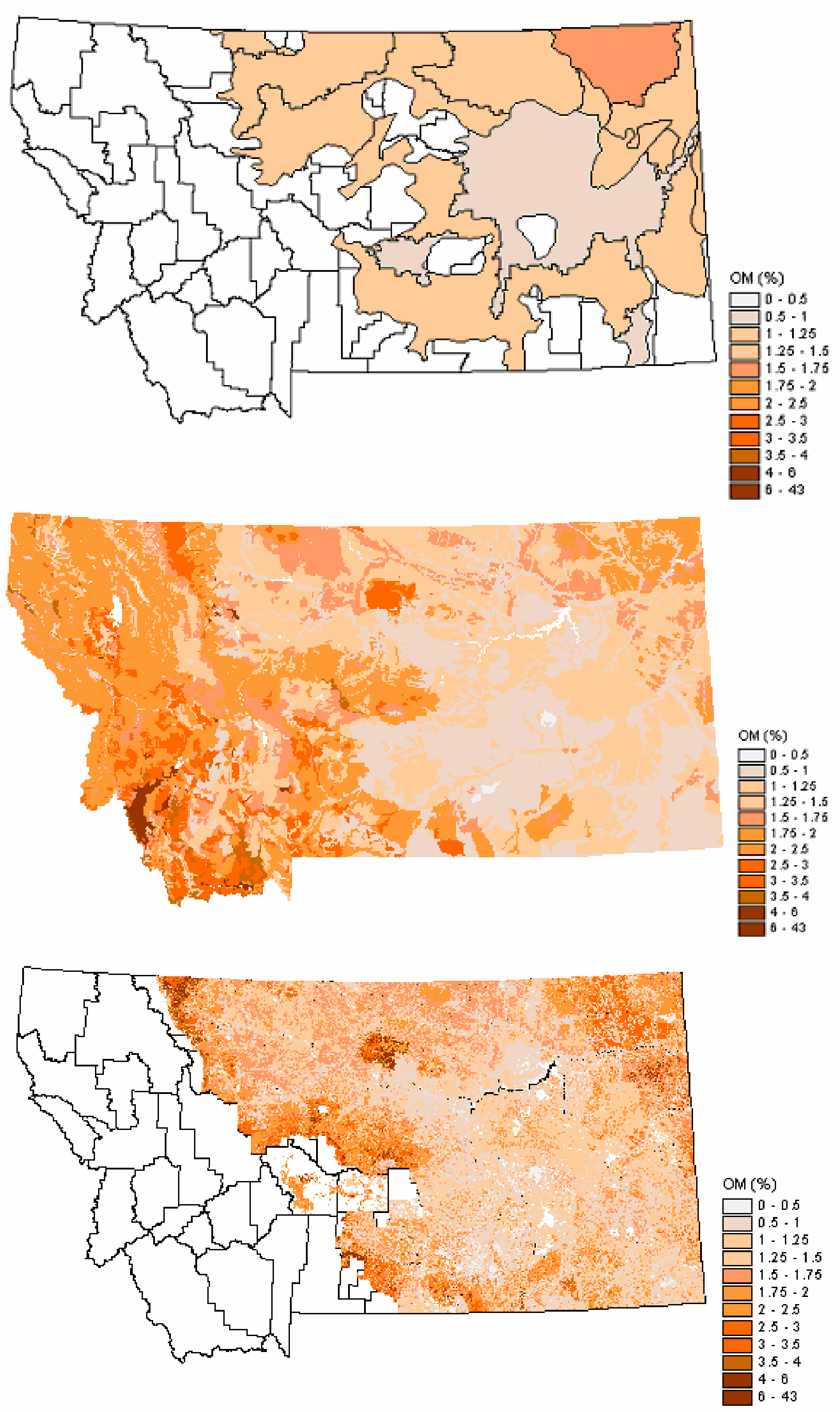

Figure 4.1 OM percentages for the three soil maps. From top to bottom respectively the MLRA, STATSGO and SSURGO soil map.

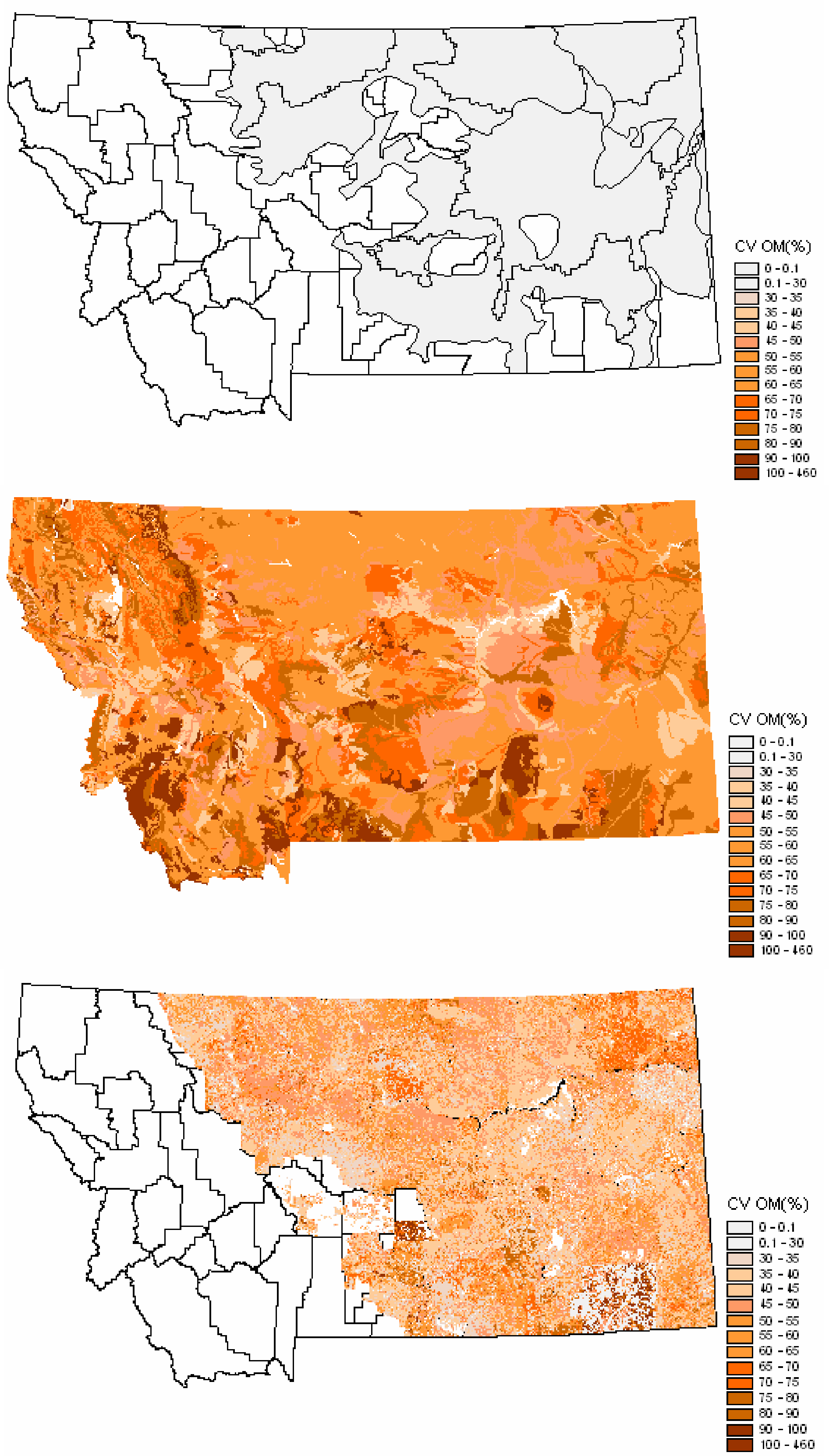

Figure 4.2 Coefficients of variance for the OM percentages for the three soil maps.

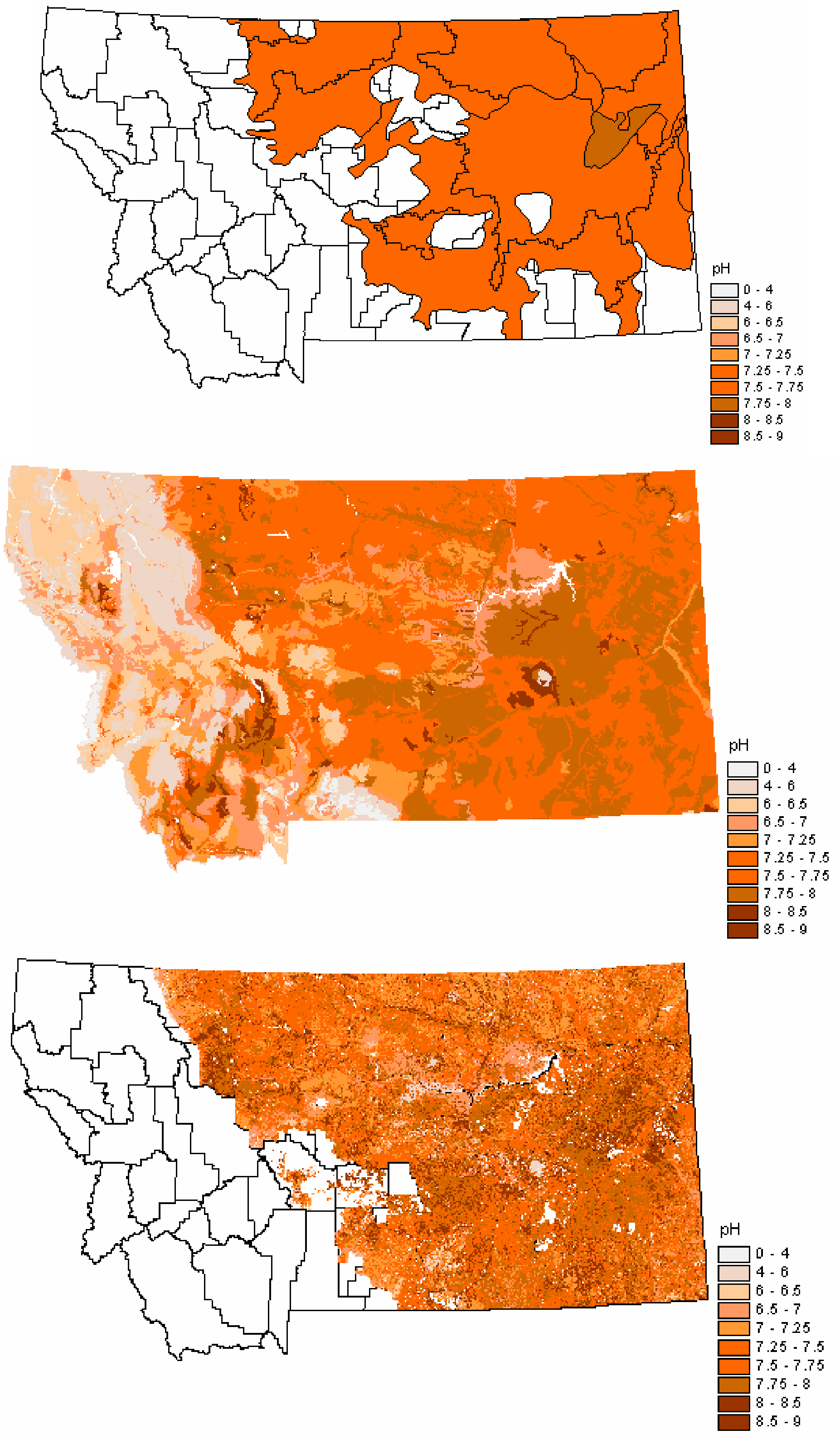

Figure 4.3 Mean pH for the three soil maps. From top to bottom respectively the MLRA, STATSGO and SSURGO soil map.

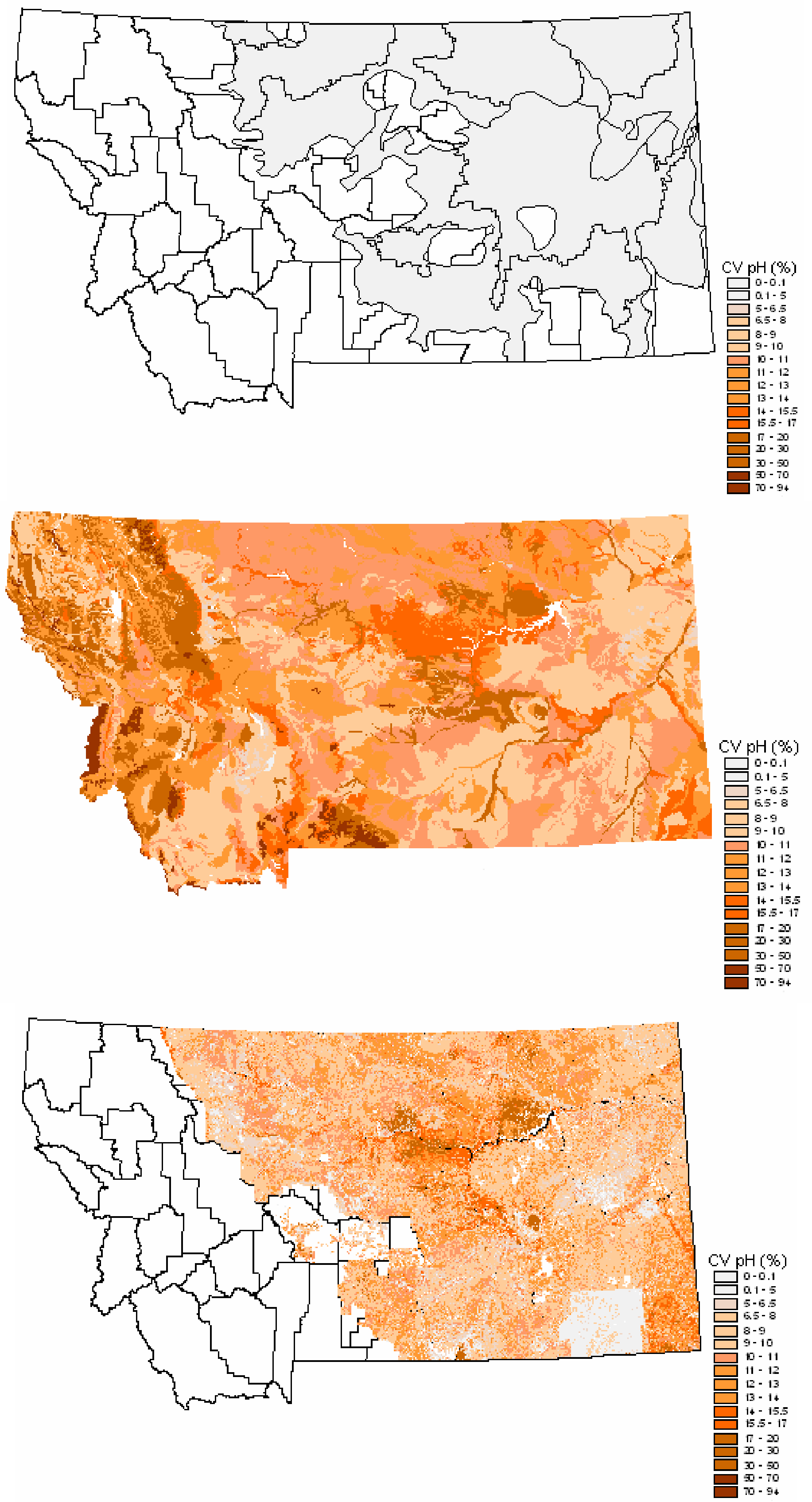

Figure 4.4 Coefficients of variance for the pH.

4.1.4 Field data

MLRA 52 (Brown Glaciated Plains) was chosen as sampling area, because of its status as main agricultural area for Montana's wheat production. For the field data analysis 108 samples were taken at various locations in MLRA 52, see Figure 4.5 for the location and sampling ID. In Appendix H the state county map is presented with the corresponding county names. As described in Chapter 3, sampling sites were chosen randomly, while taking into account the expected variability for the soil parameters based on landscape variation. However, the selection of the sampling locations also depended on the cooperation of the extension agents and the farmers and their permission to take samples on their fields. During the field campaign it was observed that nearly the whole sample area consists of glacial sediments, probably deposited after the last glacial episode (Wisconsin glaciation). From each location three to fourteen samples were taken from the upper 30 cm of the soil profile. If possible, different fields with different crop rotations were sampled in order to obtain most variability, meaning that samples were taken from harvested wheat fields, fields that were fallow for this season and grasslands. Most often these three different land use types were not sampled at the same location as most farmers are specialized in only one agricultural production system._In the following sections the general pattern for the two parameters is presented, as well as the correlation of the parameters with the corresponding land use. In the last paragraph of this section the duplicates for the organic matter laboratory analyses are discussed.

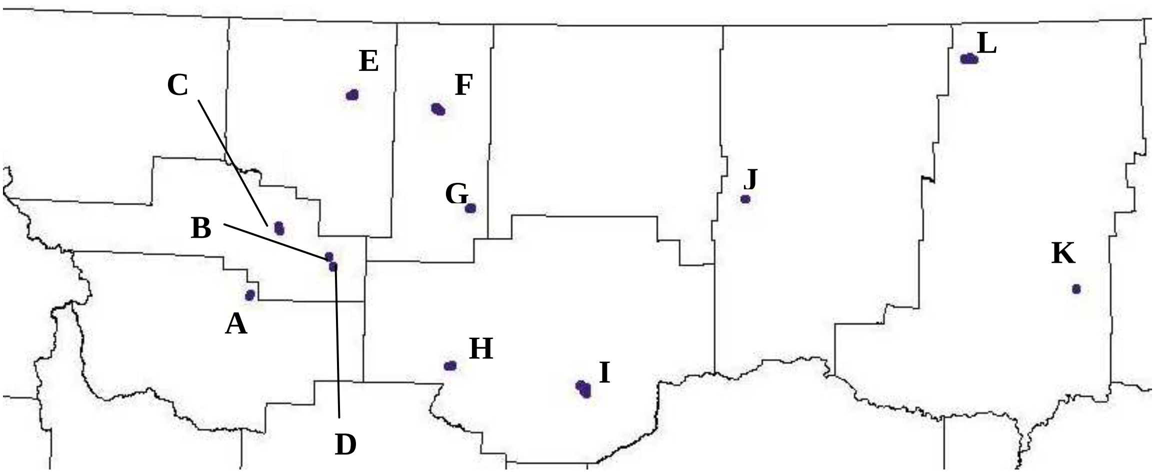

Figure 4.5 The sampling locations and their identification numbers in the north-central part of Montana.

Organic matter

The results of the field sample laboratory analysis for the individual soil samples are presented in Appendix I. Table 4.1 presents the average values for each sampling location. The average organic matter percentage varies for the different locations from 1.44% (Location G) to 5.73% (Location J), with a general organic matter percentage of around 1.9%. The counties in the east have higher organic matter percentages (2.29-5.73%), while Toole, Liberty and Chouteau counties show lower percentages ranging from 1.44 to 1.95%. Teton and Pondera county show again values in the range of the organic matter percentages for the eastern counties, with one exception for sampling location D. It should however be noted that there are only 111 soil samples analyzed. This number of soil samples is too small to deduce a systematic geographic pattern for these soil parameters.

The organic matter percentage for location J in Blaine county shows a higher trend, with an outlier of 18.63%, see Appendix I. This is according to the field observations for samples 3 and 5 till 7. The variation for this location is also higher, respectively a CV of 86.74% than for the other locations, where the coefficients of variance vary from 15.58 to 61.11%. Thus the organic matter percentages for this location cover a wide range.

Table 4.1 OM and pH data for the field samples.

Location			**OM**			**pH**		
County	*Location ID*	*# samples*	*μ*	*σ*	*CV*	*μ*	*σ*	*CV*
Teton	A	8	2.52	1.03	40.87	8.1	0.18	2.24
Pondera	B	3	2.31	0.36	15.58	8.2	0.12	1.47
	C	9	2.09	0.95	45.45	8.0	0.28	3.49
	D	7	1.51	0.28	18.54	8.1	0.06	0.74
Toole	E	14	1.82	0.60	32.97	8.1	0.45	5.56
Liberty	F	11	1.92	0.36	18.75	8.2	0.12	1.46
	G	9	1.44	0.66	45.83	8.2	0.17	2.08
Chouteau	H	6	1.52	0.59	38.82	7.8	0.67	8.57
	I	10	1.95	0.59	30.26	7.8	0.84	10.76
Blaine	J	10	5.73	4.97	86.74	7.3	0.93	12.77
Phillips	K	10	2.29	0.73	31.88	7.5	0.50	6.71
	L	11	2.52	1.54	61.11	7.8	0.63	8.07

PH

The pH for the different locations varies from 7.3 (Location J) to 8.2 (Location F, G and B), with an average of 7.9. The range of the pH is relatively narrow and for all sampling locations the pH is higher than 7, indicating slightly to moderately alkaline soils. During the field campaign it was observed that at several locations white salts had precipitated in the subsoil, which might indicate the presence of calcium carbonate in the soil, which again supports the analysis that most soils have pH values higher than 7. For as far as a geographic pattern can be deduced from the field samples, the trend for the pH is that the lower pH values from around 7.5 are located in the eastern part of MLRA 52, thus the counties of Chouteau, Blaine and Phillips. The pH values around 8.1 are all located in the western part, thus the counties Teton, Pondera, Toole and Liberty.

The coefficients of variance range from 0.74 (Location D) to 12.77% (Location J). Again the sample location in Blaine county has the highest coefficient of variance, but this time in combination with the lowest pH value compared to the other sampling locations. The coefficients of variance for the pH are generally ten times as small as the ones for the organic matter percentages. The variation for the pH is thus considerably less between the different samples for one sampling location compared to the organic matter samples.

Land use

The field soil samples have also been divided according to land use. For all field samples the land use is recorded and the samples are divided in two groups with respectively land use types: cropland (wheat) and grassland (extensive grazing), Figure 4.6.

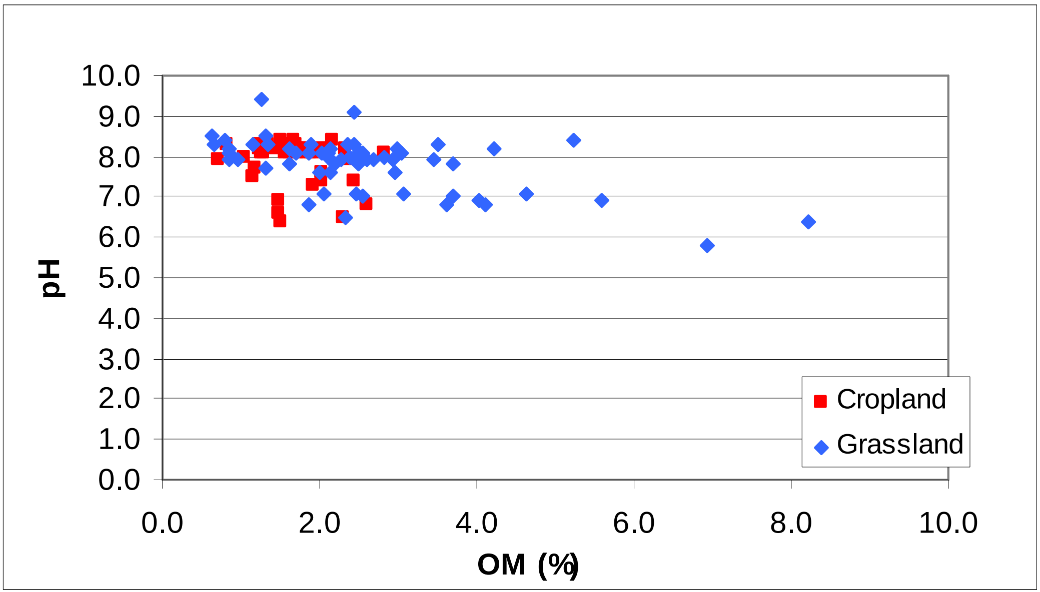

Figure 4.6 Mean OM and pH for the field samples according to land use type: grassland and cropland. One outlier (18.6; 8.5) is not represented in the figure above.

The fields that were fallow for this season are considered as croplands. 61 Samples were obtained from grasslands, for the croplands 47 samples are used. The pH ranges from 5.8 to 9.4 for the grasslands, while for cropland the range is limited to 6.4-8.4. Although the pH range for the croplands is smaller, the two ranges overlap and do not discriminate the presence of grass- or croplands. The same yields for the OM percentages, where the range of the grassland samples varies from 0.6-18.6% and for cropland from 0.7-2.8%. The ranges overlap, thus also for the OM percentage one can not discriminate based on the type of land use. It is however likely that high OM percentages (> 3.5%) correspond to grasslands as there is much more variation for both the organic matter of grassland samples compared to the cropland samples.

Duplicates

For the organic matter analysis some duplicates of the field samples have been analysed to check for analytical errors, see Table 4.2. The differences between the duplicates are small, only for the samples: A nr.3, F nr.9 and G nr.9 differences are larger than 0.2 %. For most of the samples the difference is less than 0.1%. The means of the duplicates are used for the analyses and comparisons with the soil maps in the following sections.

Table 4.2 Duplicates of the organic matter percentages for the field samples.

ID	Sample 1	Sample 2	Mean	Difference
A - nr. 3	4.19	4.25	4.22	0.25
A - nr. 8	2.52	2.43	2.48	-0.03
B - nr. 1	2.51	2.47	2.49	0.02
C - nr. 5	2.96	3.1	3.03	0.05
D - nr. 2	1.06	1.04	1.05	0
D - nr. 7	1.75	1.69	1.72	0
E - nr. 5	2.36	2.49	2.43	0.01
E - nr. 10	1.57	1.48	1.52	0
F - nr. 5	1.95	1.95	1.95	-0.02
F - nr.9	2.44	2.46	2.45	-0.28
G - nr. 4	1.76	1.76	1.76	0
G - nr. 9	0.8	0.79	0.8	-0.41
H - nr. 5	1.73	1.71	1.72	-0.03
I - nr. 4	1.5	1.45	1.48	0.02
I - nr. 9	1.27	1.27	1.27	0.06
J - nr. 5	8.34	8.09	8.21	-0.14
J - nr. 10	2.55	2.58	2.56	0.04
K - nr. 3	2.12	2.53	2.32	-0.06
K - nr. 8	2.93	2.96	2.95	0.09
L - nr. 4	3.56	3.84	3.7	-0.13
L - nr. 9	1.32	1.32	1.32	0.09

4.2 Multiscale comparison

4.2.1 MLRA – STATSGO

In Figure 4.7, Figure 4.8 and Appendix J, Tables 1 and 2, the mean (μ), the standard deviation (σ) and the coefficient of variance (CV) for the soil parameters organic matter and pH, which were calculated for the intersection of the MLRA map with the STATSGO soil map, are presented.

Organic Matter

The means calculated from the STATSGO database for the MLRA's are the ones used for the MLRA's. In Figure 4.7 the means and the corresponding standard deviations for the MLRA's and subMLRA's are presented.

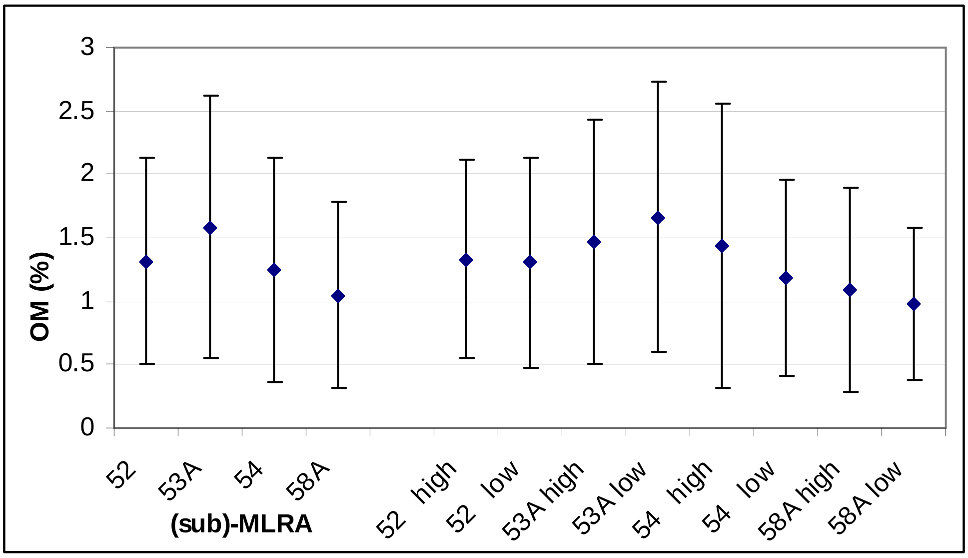

Figure 4.7 Comparison STATSGO – MLRA; OM percentages and the standard deviations for the (sub-)MLRA's.

The average OM percentages vary from 0.98 for subMLRA 58A Low to 1.66% for subMLRA 53A Low. The lowest OM percentages are located in the south-central and south-east part of Montana. The mean highest percentages can be found in the north-east area, near the border, like was also described in section 4.1. All standard deviations have the same dimension and vary from 0.6 for subMLRA 58A Low to 1.12 for subMLRA 54 High. The standard deviations are relatively high compared to the mean OM percentages. Within the MLRA's a wide range of OM percentages can thus be found, that differ from the mean values with more than 50% as can also be seen from the CV's in Table 1 in Appendix J.

PH

The pH values vary from 7.4 for subMLRA 52 High to 7.8 for subMLRA 54 Low. The range of the mean pH is very narrow compared to the OM percentages. This narrow range is also reflected for the pH's coefficient of variance, which varies from 9.7 (subMLRA 54 Low) to 13.4% (subMLRA 52 High). Thus within the MLRA's the variation of the pH is considerably less compared to the variation of the OM percentages. The differences between the pH values of the different MLRA's are only small. Within the MLRA's all the samples are classified as slightly to moderately alkaline soils.

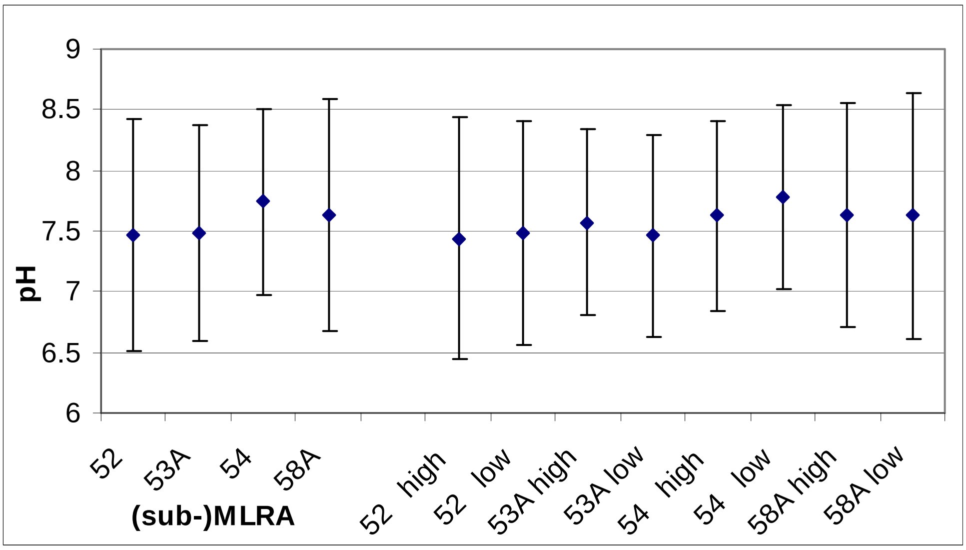

Figure 4.8 Mean pH and the standard deviations for the (sub-)MLRA's.

4.2.2 MLRA - SSURGO

The MLRA's are in this section compared with the means and variances derived from the SSURGO soil map. In fact this is also the comparison of the STATSGO and SSURGO soil map at MLRA scale. Thus the STATSGO delineated areas located within a MLRA are compared with the SSURGO delineated areas located within the same MLRA. Only for the STATSGO- SSURGO comparison it is also possible to compare the variances of the two databases, this is discussed section 4.2.3.

Organic matter

Figure 4.9 presents the OM percentages for the SSURGO soil map compared with the OM percentages for the MLRA's, see also Appendix K. Organic matter percentages vary for the SSURGO database from 1.1 (MLRA 58A Low) to 1.9 % (MLRA 53A Low) with the coefficients of variance ranging from 59.6 (MLRA 52 High) to 72.0% (MLRA 58A High).

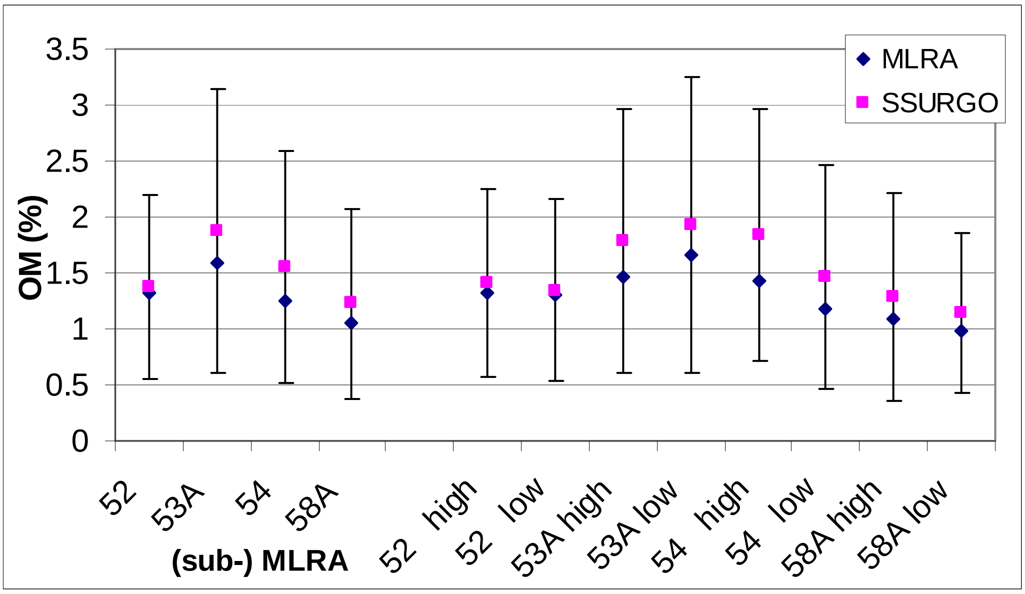

Figure 4.9 OM percentages for the SSURGO and MLRA soil maps. For the SSURGO soil maps also the standard deviations are presented as error bars.

For both soil maps the same trend for the OM percentages is observed, however SSURGO mean OM percentages are consistently higher then the MLRA means, this difference is about 0.2%, see Appendix K. For MLRA 52 differences between the two soil maps are small (0.06%), while for MLRA 53A and MLRA 54 differences are on average 0.3%. For these last two MLRA's OM percentages are higher than for the other MLRA's, also larger differences between the mean OM percentage of the corresponding subMLRA's are observed. Higher OM percentages seem to correspond with larger differences between the two soil maps.

All the MLRA OM percentages fall easily within the range of the SSURGO standard deviations. But from the standard deviations for the SSURGO database it can be seen that there is a considerable amount of variance within a MLRA for the OM percentage. While the mean OM percentages vary from 1 to 2%, the coefficients of variance vary from nearly 60 to almost 75%, thus from OM percentages of below 0.5 to 3.3%. MLRA's with higher OM percentages contain more variance within the MLRA, which can be observed from MLRA 53A and 54.

PH

Figure 4.10 presents the results for the comparison of the MLRA map and the SSURGO soil map. The pH values vary from 7.4 (MLRA 53A Low) to 7.7 (MLRA 58A Low) for the SSURGO database, with the coefficients of variance ranging from 10.4 (MLRA 53A High) to 17.9% (MLRA 54 low). In this case the difference between the two soil maps is not as obvious as for the OM percentages, all MLRA pH means fall easily within the SSURGO standard deviation range, indicating that the SSURGO database at least covers the variance between the MLRA mean pH and the SSURGO mean pH. The difference between the SSURGO pH mean and the MLRA pH mean is on average 0.05%, see Appendix K. The coefficients of variance have for all MLRA's except MLRA 54 more or less the same size. For MLRA 54 the range is broader and due to subMLRA 54 Low. Only for MLRA 52 can be said that for the SSURGO database higher pH values are found. For the other MLRA's differences differ among subMLRA's or the MLRA map gives slightly higher means. The coefficients of variance for the SSURGO database indicate that there is quite some variation, for most MLRA's almost up to one pH unit that is not taken into account for the MLRA map.

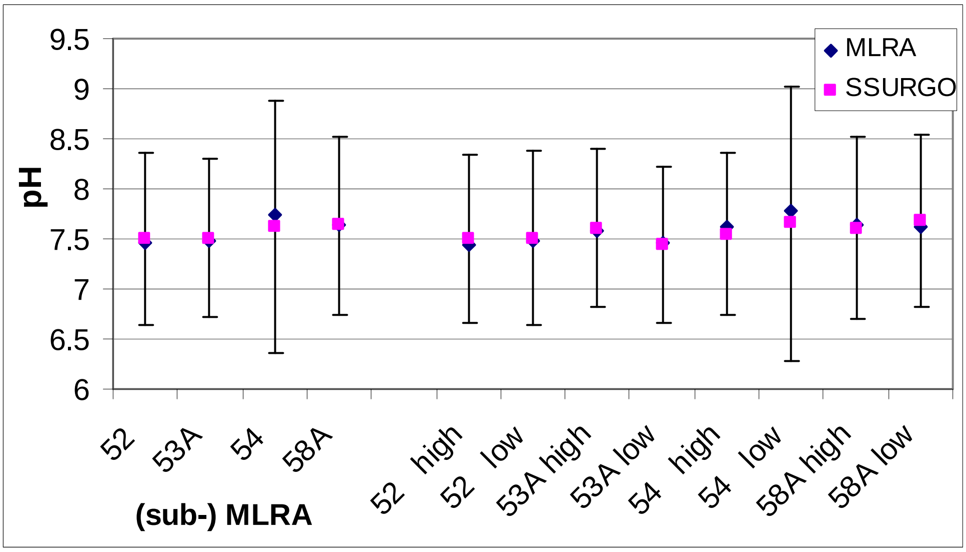

Figure 4.10 PH for the SSURGO and MLRA soil maps. For the SSURGO soil maps also the standard deviations are presented as error bars.

4.2.3 STATSGO – SSURGO

Besides comparing the STATSGO and SSURGO databases with the MLRA map, as will be described in the first section of this paragraph, the means and variances of the STATSGO database can also be compared with the means and variances from the SSURGO database for the same STATSGO map units. The SSURGO and STATSGO databases are the two most detailed soil maps used in this study and are therefore compared for two different points of view, i.e. the producer perspective and the and the user perspective as is described in section 4.2.3.2 and 4.2.3.3.

4.2.3.1 Comparison STATSGO – SSURGO at MLRA scale

The mean OM percentages and pH's are already discussed in the section 4.2.2, therefore only the comparison of the coefficients of variance is covered in this section.

Organic matter

The CV's for both database are in the same order of magnitude, ranging from 58 to 78%, see Appendix L. The comparison of the OM coefficients of variance for the two different databases in Figure 4.11 shows that for MLRA's 52 and 54 the CV's are larger for the STATSGO database (This is not the case for subMLRA 54 Low and 52 High). For MLRA 53A yields that the coefficient of variance is larger for the SSURGO database. MLRA 58A is located very close to the 1:1 trend line i.e. the differences between the databases are minimal. Remarkably is the fact that the subMLRA's of MLRA 58A and MLRA 54 are located very far apart. The subMLRA's with higher precipitation have higher variances for the STATSGO database compared to the other subMLRA's. The MLRA's were the croplands are located i.e. MLRA 52 and 53A show less difference in variance among the corresponding subMLRA's.

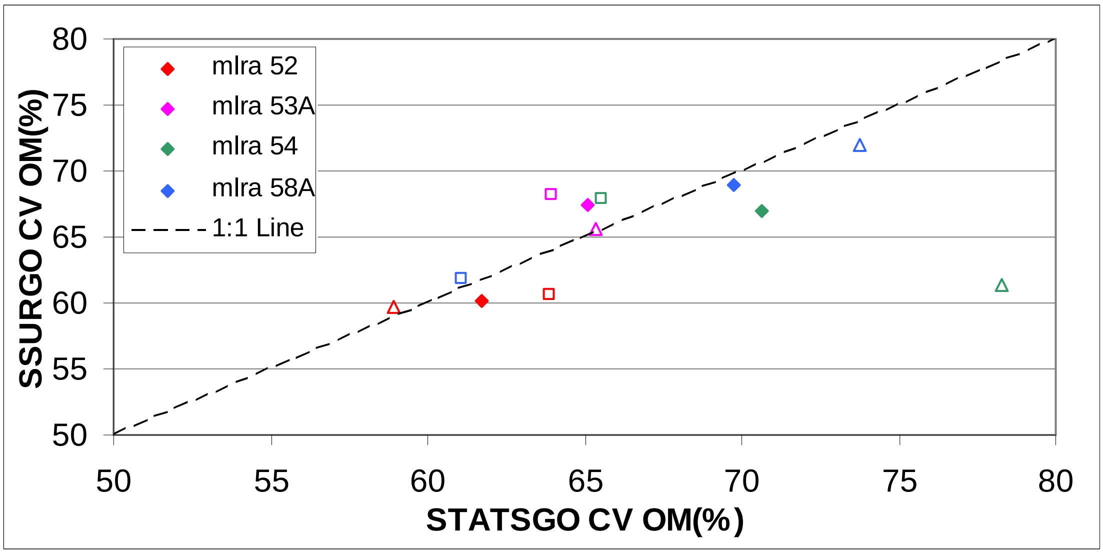

Figure 4.11 Coefficients of variance for the OM percentages plotted for both STATSGO and SSURGO databases at MLRA scale. The triangles correspond with the subMLRA's High, the squares with the subMLRA's Low of the corresponding colour.

PH

The coefficients of variance for the pH are presented in Figure 4.12 and vary on average around 12% for both databases. The coefficients of variance are located around and mainly below the 1:1 trendline, except for MLRA 54. The CV's are smallest for MLRA 53A (10-12%). The highest CV's for this MLRA are found for the total MLRA, followed by subMLRA Low and High. MLRA 52 shows a similar trend for slightly higher coefficients of variance. Only the highest CV (STATSGO) is found for subMLRA High. The coefficients of variance for MLRA 58A vary from 11 to 13.3 %. The data points for subMLRA High is located just below the 1:1 trendline, while the datapoint for subMLRA Low is located relatively far below the trendline. For MLRA 54 high pH CV's were calculated for the SSURGO database, especially for subMLRA Low, and consequently for the total MLRA. SubMLRA High has again more or less the same CV's for both databases.

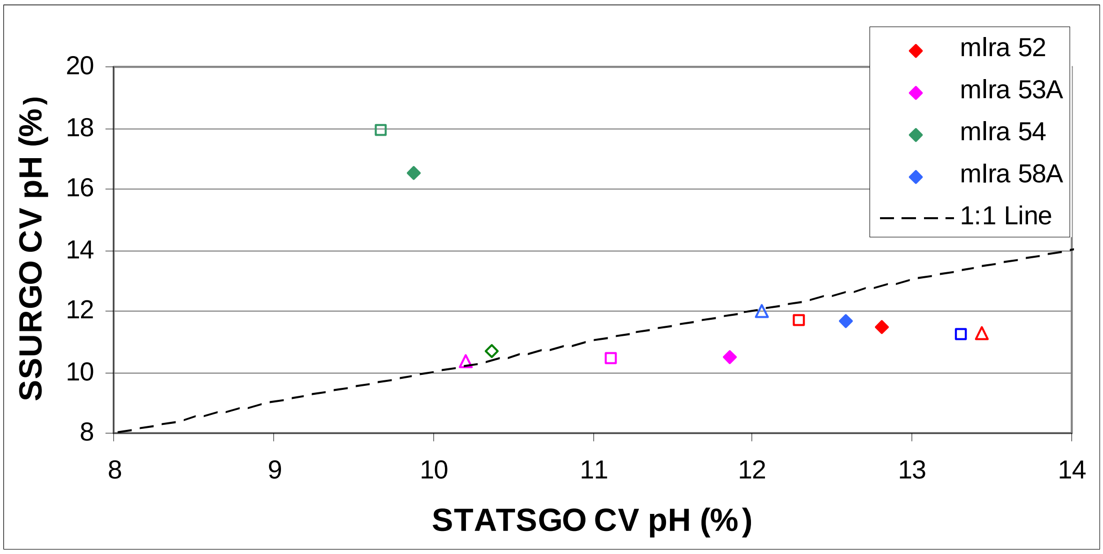

Figure 4.12 Coefficients of variance for the pH plotted for both STATSGO and SSURGO databases at MLRA scale. The triangles correspond with the subMLRA's High, the squares with the subMLRA's Low of the corresponding colour.

On average it seems that for both OM and pH the CV's of the STATSGO database are slightly higher compared to the SSURGO database. Which is unexpected as one would think that the SSURGO database covers more of the variability, because of the small scale. The differences between the CV's for both databases are however minimal, with the exception of MLRA 54.

4.2.3.2 Producer point of view

This point of view is, in fact, used continuously throughout this study. When for example a soil survey specialist performs a soil survey, he/she will assign areas that are similar the same map unit ID. Thus in case of the STATSGO soil map, two areas at different locations can have the same map unit ID and have therefore the same soil parameter characteristics. When overlaying the STATSGO soil map with the SSURGO soil map, a STATSGO map unit often can be subdivided in one or more SSURGO delineated areas. From a producer point of view it is than expected that summing up the means of the SSURGO map units relative to their STATSGO map units' surface area will result in a mean for the STATSGO map unit. The two databases are compared for 408 different map units from the STATSGO database. These map units are all covered by SSURGO delineated areas from which the new weighted means and variances were calculated for the STATSGO map units. An overview of all the means and variances of both databases for the STATSGO map units are found in Appendix L, Tables 2 and 3.

Organic matter

The means for the STATSGO map units are plotted in Figure 4.13; the STATSGO means are on the X-axis, while the SSURGO means are plotted on the Y-axis.

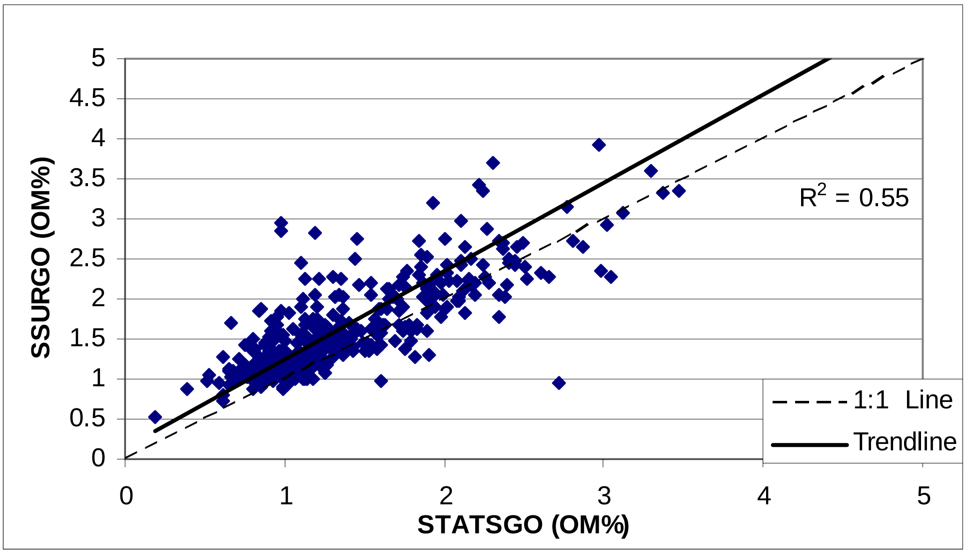

Figure 4.13 Mean organic matter percentage for both the STATSGO and SSURGO databases. Five outliers are not presented in the figure above, namely: (8.03; 14.71), (5.09; 3.75), (1.88; 8.56), (1.19; 6.37) and (1.48; 5.95).

The OM mean percentages are concentrated for both databases between 0 and 3 %, which is according to the observations in sections 4.1.2 and 4.1.3. For the SSURGO database the percentages range from 0.53 to 14.71% and for the STATSGO database from 0.18 to 8.03%. The cluster of datapoints is for the larger part located above the linear 1:1 line, which is also indicated by the trendline. The trendline is on average located about 0.2 OM% above the 1:1 line, which corresponds with the observations in section 4.2.2. It indicates that for most map units the SSURGO database gives a higher mean organic matter percentage than the STATSGO database, although the trendline does not represent all observations very well. In conclusion it can be said that on average the OM percentages vary from 0 to 3 % for the larger part of the map units. Furthermore, the SSURGO database assigns the STATSGO map units higher mean organic matter percentages.

The coefficients of variance for the organic matter percentages are presented in Figure 4.14 for both the STATSGO and SSURGO databases.

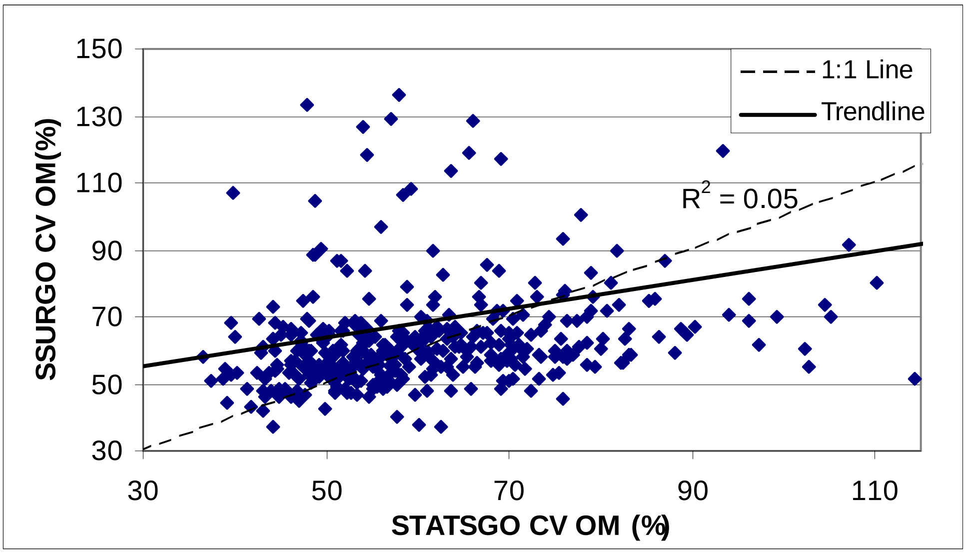

Figure 4.14 The coefficients of variance for the organic matter percentages for both the STATSGO and SSURGO databases. Outliers not represented in this figure are: (228.53; 72.99), (203.09; 173.61), (238.21; 279.75), (40.69; 382.85), (63.30; 365.13), (66.58; 289.84), (60.05; 271.84), (70.12; 269.13), (68.88; 250.94), (56.50; 231.96), (52.36; 317.50), (40.66; 191.80), (71.41; 172.39), (51.60; 153.49) and (29.50; 45.88).

The coefficients of variance in Figure 4.14 show a spread for both databases from 29% to 383%. The majority of the datapoints are clustered in the range from 40 to 95%. The cluster of points is centered around the 1:1 trendline indicating that the coefficients of variance for both databases are of the same size. Presenting the figure at this scale implies that within the cluster of datapoints, the CV's for the two databases can still differ with on average 20%. This is also seen in Figure 4.13. For a STATSGO OM percentage of 2%, the SSURGO soil map gives OM percentages varying from 1.8 to 3.2%. The amount of variance is thus considerable i.e. for most map units in the range of 40 to 100%. The trendline and the R squared indicate that the trend is very poor, due to the high amount of outliers for both the STATSGO and SSURGO databases.

PH

Figure 4.15 plots the STATSGO and SSURGO means for the pH. The mean pH for the SSURGO database varies from 5.22 to 8.23. For the STATSGO database the pH values range from 4.71 to 8.39. The largest number of datapoints is clustered between pH 7 and 8.4 around the 1:1 line. Outliers below pH 7.6 are mostly located above the 1:1 Line, thus the SSURGO means are larger than the ones calculated from the STATSGO database for the same map unit. On the contrary outliers above pH 7 are mainly located below the trendline. This trend is also indicated by the trendline, although the match is not very good (55%). Thus in case of a relatively low pH, in this context below pH 7.6, the SSURGO database gives higher pH means. In case of pH values above 7.6 the STATSGO database presents the higher pH means. However, there are no outliers for pH>8.3, thus the presence of a trend in only a presumption and can not be confirmed by higher pH values.

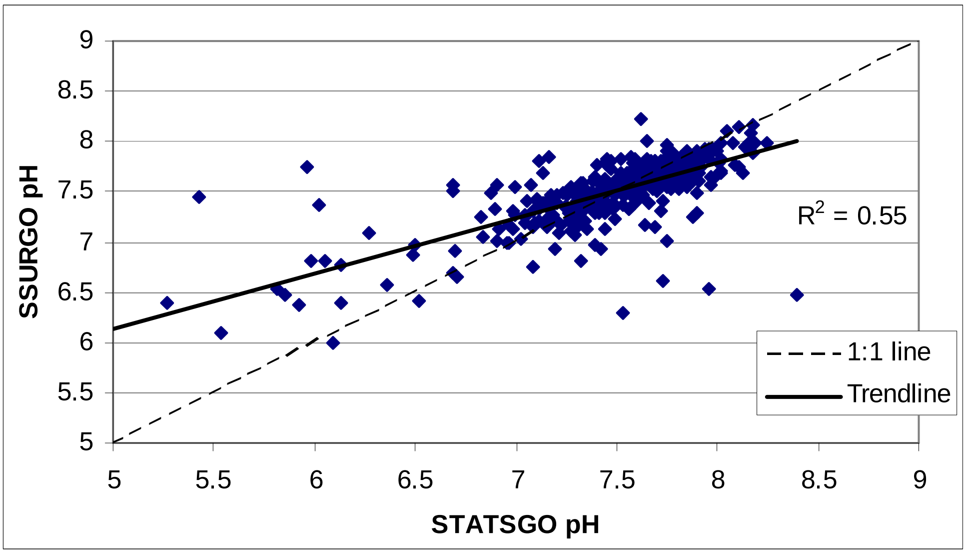

Figure 4.15 Mean pH for the comparison of the STATSGO and SSURGO databases.

The coefficients of variance for the pH show a clustering of datapoints for the range of 5 to 18%. Again this cluster is concentrated around the 1:1 trendline. No general trend is observed, which is also indicated by the poor fit (7%). The outliers are located both underneath the trendline, 20 to 65% (STATSGO axis) and above, 20 to 35% (SSURGO axis). In contrast to the CV OM the range for the outliers for the SSURGO axis is relatively narrow, ranging from 5 to just above 30%.

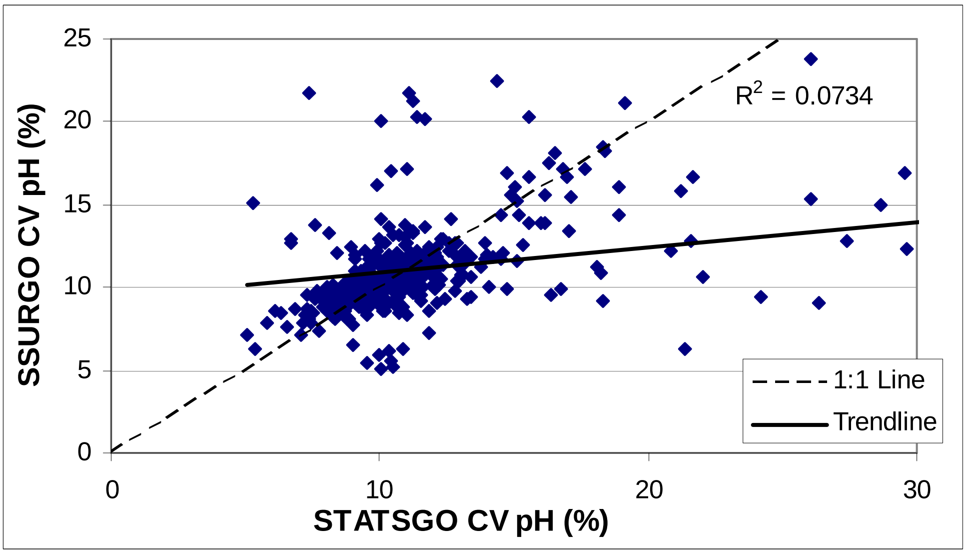

Figure 4.16 The coefficients of variance for the pH for both the STATSGO and SSURGO databases. Outliers are located at: (7.71; 32.83), (10.99; 29.20), (26.56; 30.49), (35.46; 12.24), (32.91; 9.90), (32.80; 9.26) and (31.41; 7.99).

The comparison of the STATSGO and SSURGO soil maps from the producer perspective indicates that there are differences in the mean for OM and pH. These are in the same order of size, but can differ considerably e.g. with several percent for the OM mean. The number of outliers is relatively small compared to the total number of 408.

4.3.2.3 User point of view

The user perspective states that when for example a farmer takes the STATSGO soil map, he expects to find soils with the mean OM percentages and pH as indicated for that particular map unit. In this section, it is checked whether or not the STATSGO soil map can be used at this small scale. Three randomly selected STATSGO delineated areas are presented: MT010 is presented below and the other two, respectively MT162 and MT652 are presented in Appendix L. Table 4.3 presents the corresponding SSURGO delineated areas located within STATSGO delineated area MT001 and their means and variances. STATSGO delineated area MT010 includes 9 SSURGO delineated areas, delineated areas MT162 and MT652 respectively 61 and 90.

Table 4.3 Means and variances for SSURGO delineated areas within STATSGO map unit MT010. SSURGO map units that fall outside the range of variance of the STATSGO map unit are indicated in bold italic.

		μ_{om}	Perc. (%)[1]	σ^2_{om}	μ_{pH}	Perc. (%)	σ^2_{pH}
MT010	STATSGO	2.803		3.719	6.703		0.652
	345248	1.276	54.48	0.374	***7.643***	-14.02	0.419
	345256	0.977	65.14	0.228	***7.861***	-17.28	0.298
	345257	0.977	65.14	0.228	***7.861***	-17.28	0.298
	345265	2.889	-3.07	1.673	7.233	-7.91	0.381
	345293	1.083	61.36	0.340	***5.800***	13.47	0.490
	345294	1.083	61.36	0.340	***5.800***	13.47	0.490
	345297	2.868	-2.32	0.931	6.876	-2.58	0.278
	345298	2.750	1.89	0.841	7.033	-4.92	0.154
	345299	2.750	1.89	0.841	7.033	-4.92	0.154

[1)] Percentages are calculated as $((\mu_{om\ statsgo}-\mu_{om\ ssurgo})/\ \mu_{om\ statsgo})*100\%$

In Table 4.3 it is seen that SSURGO OM percentages and pH values regularly differ considerably from the STATSGO mean. For STATSGO delineated area MT010, the SSURGO OM percentages vary on average from 0.98 to 2.89%. For the SSURGO map units 345256 and 345257 this is a deviation of 65% from the STATSGO map unit mean. However, all SSURGO OM means fall within the range of the variance for the STATSGO OM mean. The SSURGO pH means vary from 5.80 to 7.86, which results in a maximum deviation of 17.3% for map units: 345256 and 345257. The ranges of the variances for both OM and the pH are for the SSURGO delineated areas remarkably smaller than the average variance of the STATSGO delineated area. For MT162, Appendix L, the OM percentages differ from 0.5 to 69.31% for the SSURGO database. For the pH, values vary from 7.446 to 9.115. The range of variances for the pH is again relatively small compared to the range of variances for the OM percentages. Still several SSURGO OM means fall outside the range of the STATSGO map unit, for the pH this number is smaller. MT652 presents a similar pattern as the previous two delineated areas. Despite the broad range of variance more SSURGO OM means falls outside range than for the pH. Often SSURGO map units that classify as peat areas are found within the STATSGO delineated area. In conclusion can be said that the OM percentages and pH values of the SSURGO delineated areas often do not fall within the range of variance of the concerning STATSGO map unit. A user of the STATSGO soil map should thus expect a wide range of especially the organic matter percentages. Local variations, like the presence of the extremely high organic matter percentages e.g. peat areas, can be found within a map unit. It seems therefore that the use of the STATSGO soil map is not preferable for large scale purposes, as is also indicated by the NRCS.

4.3 Comparison field data with soil maps

The locations of the field data have been recorded by GPS. Due to some technical problems, a few sampling points did not have the right coordinates. Based on the notes and field observations, the sampling point locations were sometimes corrected. In case of doubt the observations were not used for the comparison with other databases. This had the most consequences for the SSURGO database as the field samples were located in different map units for the same sampling location. STATSGO map units are accordingly large that there were no consequences for this comparison.

4.3.1 Field data - MLRA

The field samples can be divided for the two subMLRA's of MLRA 52. Of the 108 analysed soil samples 23 samples lie within subMLRA 52 High and 75 in subMLRA 52 Low. The other 10 samples, the samples from location J, see Figure 4.5, fall just outside any of the studied MLRA's.

Table 4.4 Comparison of the field samples with the subMLRA's for the two parameters.

	Field samples			MLRA		Field samples			MLRA	
subMLRA	μ_{OM} (%)	σ_{OM}	CV_{OM} (%)	μ_{OM} (%)	σ_{OM}	μ_{pH} (%)	σ_{pH}	CV_{Ph} (%)	μ_{pH}	σ_{pH}
52 high	1.73	0.51	29.62	1.329	0	7.8	0.74	9.48	7.438	0
52 low	2.08	0.92	44.03	1.305	0	8.0	0.44	5.55	7.480	0

Table 4.4 presents the results of the comparison of the field data with the subMLRA's. The means for the field samples are higher than the means for the subMLRA's. The subMLRA means do, however, fall within the standard deviation range of the field samples. The coefficients of variance for the field samples indicate a considerable amount of variance for the OM percentages. The amount of variance is, compared to the CV's of the previously described STATSGO and SSURGO soil maps, still less. For the pH also higher field sample means were obtained compared to the subMLRA's. The mean pH for subMLRA 52 High falls within the range of the standard deviation of the field samples of this subMLRA. The mean pH for subMLRA 52 Low falls outside the standard deviation range. Of course it should be noted that the number of field samples per subMLRA is very small in comparison to the surface area, for subMLRA high and low respectively 9.07E-10 and 2.37E-09 samples per acre. This is of course far too less to derive reliable means and variances.

4.3.2 Field data – STATSGO

In Table 4.5 and Table 4.6 the results for the analysis of the field samples for a STATSGO map unit are presented. It should be noted that the field samples are assigned to a STATSGO map unit, the samples can however still be located in different delineated areas of the map unit.

Organic matter

In Table 4.5 the mean, standard deviation and coefficient of variance as calculated for the field samples located within a map unit of the STATSGO soil map are presented. In the column "percentage" the deviation of the field data from the STATSGO map unit mean is calculated. It can be seen that for the field data the organic matter means are consistently higher than the means of the STATSGO database. On average the deviation is about 85%. The four field samples that fall outside the range of the STATSGO map unit are indicated in bold, italic.

Table 4.5 Comparison of the field organic matter data with organic matter data of the corresponding STATSGO map units.

	Field data				STATSGO			
MUID	Number of field samples	μ_{OM} (%)	σ_{OM}	CV_{OM} (%)	μ_{OM} (%)	σ_{OM}	CV_{OM} (%)	Percentage [1)]
MT035	10	1.95	0.59	30.46	1.42	0.71	50.35	37.32
MT036	10	***5.73***	4.97	86.74	1.42	0.73	51.51	303.52
MT058	10	***2.29***	0.73	31.96	0.93	0.45	48.96	146.24
MT186	15	1.52	0.59	39.06	1.31	0.68	51.68	16.03
MT206	7	2.02	0.83	41.20	1.36	0.67	49.38	48.53
MT223	15	1.76	0.59	33.51	1.17	0.62	52.92	50.43
MT370	7	1.51	0.28	18.70	1.11	0.53	48.05	36.04
MT417	5	***2.32***	0.90	38.63	0.98	0.49	49.98	136.73
MT454	6	2.09	0.31	14.86	1.54	0.80	51.56	35.71
MT526	16	***2.74***	1.29	47.11	1.33	0.77	58.00	106.02
MT564	6	1.74	0.58	33.63	1.51	0.77	51.08	15.23

[1)] $((\mu_{om\ field\ data} - \mu_{om\ STATSGO})/\mu_{om\ STATSGO}) * 100\%$

The coefficients of variance for the STATSGO database are larger than most of the coefficients of variance of the field data, with the exception of map unit MT036, but the CV's of the STATSGO map unit vary within a smaller range than the field data CV's. MT036 is the map unit that corresponds with sampling location J for which, as mentioned before, high OM percentages were recorded. On average the field data of the organic matter percentages are nearly one and a half times as high as the STATSGO data. It should be noted that the number of field samples for each map unit is limited. The number of field samples for the STATSGO database is unknown.

PH

The difference between the mean pH for the field data and the STATSGO data is considerably smaller than for the organic matter percentage as can be seen in Table 4.6. For two map units MT036 and MT058 the STATSGO data gives a higher mean pH, all other STATSGO pH means are smaller than the field data. The field data still fall within the range of the STATSGO map units, except for map unit MT454, indicated in bold italic. The coefficient of variance indicates variances of 10% and often less for the pH field data and a bit more (10-

15%) for the pH STATSGO data. Only the variances for MT036 and MT035 are more or less similar to the variance for these data from the STATSGO database.

Table 4.6 Comparison of the field pH data with the STATSGO map units.

	Field data				STATSGO			
MUID	**Number of field samples**	**μ_{pH}**	**σ_{pH}**	**CV pH**	**μ_{pH}**	**σ_{pH}**	**CV pH**	**Percentage**
MT035	10	7.81	0.84	10.79	7.18	0.86	11.94	8.77
MT036	10	7.28	0.93	12.74	7.34	0.80	10.85	-0.82
MT058	10	7.45	0.50	6.73	7.90	0.99	12.56	-5.70
MT186	15	7.82	0.67	8.57	7.65	0.82	10.72	2.22
MT206	7	8.06	0.33	4.04	7.61	0.77	10.06	5.91
MT223	15	8.19	0.38	4.68	7.83	0.94	11.96	4.60
MT370	7	8.10	0.06	0.71	7.87	0.73	9.28	2.92
MT417	5	8.06	0.11	1.41	7.39	1.13	15.35	9.07
MT454	6	***8.18***	0.12	1.43	7.33	0.81	11.01	11.60
MT526	16	7.86	0.49	6.24	7.53	0.83	10.95	4.38
MT564	6	8.00	0.45	5.65	7.43	0.76	10.29	7.67

In conclusion can be said that the field data for both the OM percentages and pH are in general higher than the STATSGO data. For the OM percentage field data one third of the data fall outside the STATSGO range, for the pH only one of the eleven samples falls out of the range. The offset between the two databases is thus larger for the organic matter percentage. The coefficients of variances are for both soil parameters in general higher for the STATSGO database.

4.3.3 Field data- SSURGO

The field samples are all located in one of the SSURGO map units as well. Because the SSURGO soil map is very detailed this resulted in the sampling of often more than one SSURGO map unit at the same sampling location. And as a consequence a limited number of field samples per SSURGO map unit. For the comparison of the organic matter percentages and pH for the map units, only map units with two or more field samples were used, other map units were left out of the analysis. See Appendix M for the table with the data from the corresponding Figures 4.18 till 4.21, where the results for the comparison of the field data with the SSURGO data are presented.

Organic matter

In Figure 4.17 the mean OM percentages for both databases are presented per SSURGO map unit. All data points are located within the range of 0.7 to 2% for the SSURGO database. The range of the field data is not as narrow, but varies from 0.7 to 5.7%. All datapoints except the one for map unit 344139, see Appendix M, are located above the 1:1 line, indicating that the field data show consistent higher OM percentages in relation to the SSURGO database. A cluster of data is seen for organic matter percentages 0.8 to 1.7% (SSURGO) and 1% to 3.7% for the field data. There is only one true outlier for an organic matter percentage (field data) of 5.7 %. This is due to again the sampling location J in Blaine county. Thus the field data show a clear trend of higher percentages for nearly all samples compared to the SSURGO data. On average this trend is + 1%.

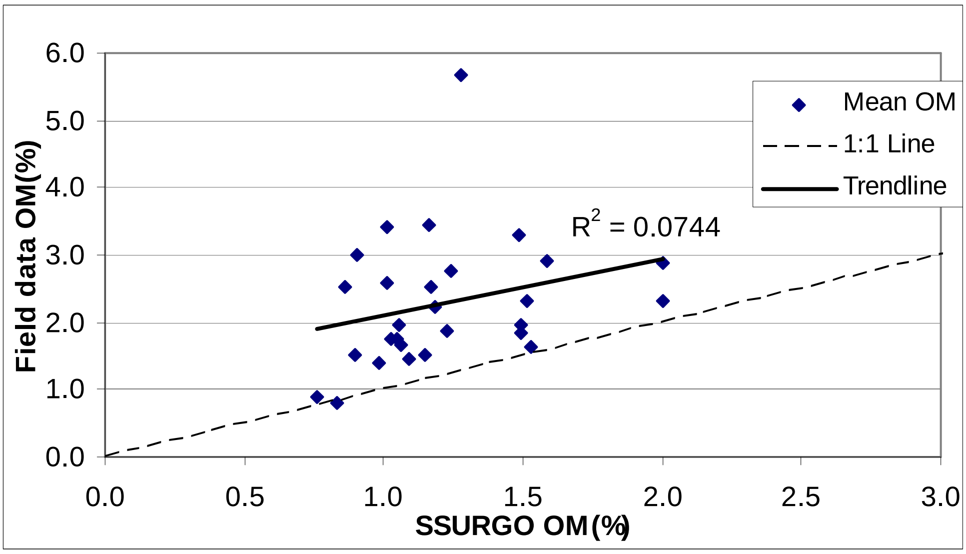

Figure 4.17 Mean organic matter percentages plotted for the SSURGO database and the field samples per SSURGO map unit.

In the Figure 4.18, the coefficients of variance are presented for the organic matter percentages. For the SSURGO database most coefficients of variance are in between 20 and 42%, with some outliers around 15, 60 and 95%. The cluster of the coefficients of variance for the field data has a range varying from 0 to 40%, with outliers extending to 60%, but the data points are located at both sides of the 1:1 line. There are thus no clear indications that one of the two databases contains consistently more variance, therefore no trendline is presented.

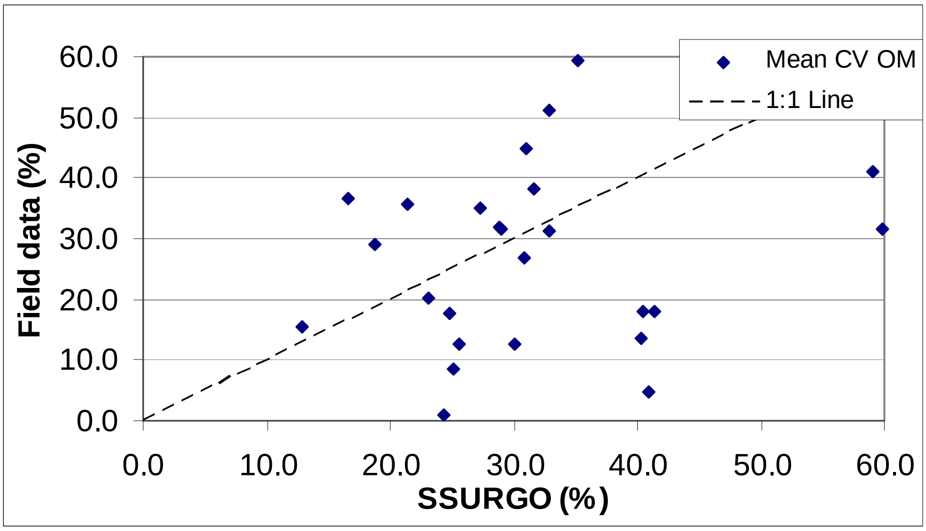

Figure 4.18 Coefficients of variance for the organic matter percentage for the SSURGO database and field data per SSURGO map unit. Outliers are located at: (94.10; 15.68), (94.10; 30.04) and (25.54; 89.40).

PH

Figure 4.19 presents the mean pH for both databases per SSURGO map unit. The mean pH varies from 7.1 to 8.8 for the SSURGO database and from 6.7 to 8.5 for the field data. Thus the range of the pH means has about the same width for both databases. All of the datapoints are located around the 1:1 line, with most of them located above. No true outliers for one of the databases are observed, only one datapoint which had a higher mean pH (8.8; 8.5) for both databases. Thus the field data seem to correspond relatively well with the SSURGO map unit means despite the low number of samples per SSURGO map unit.

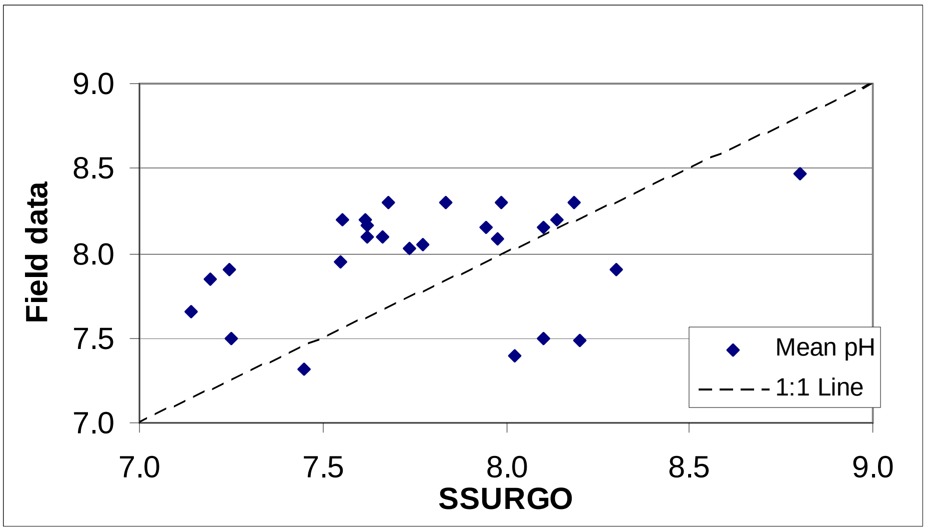

Figure 4.19 The mean pH plotted for the SSURGO database and the field samples per SSURGO map unit.

The coefficients of variance for the pH show far less variability than the ones for the organic matter percentages as was observed for all soil maps. There is no real cluster observed for the datapoints in Figure 4.20. For the SSURGO database the coefficients of variance vary from 0.7 to 10%, for the field data from 0 to almost 18 %. There is no obvious 1:1 relation as indicated by the 1:1 line in Figure 4.20 as compared to the previous figures representing data on the CV pH. Only one data point is located near the 1:1 line. For the comparison for the CV pH of the field data with the SSURGO data there seem to be too little samples available per SSURGO map unit.

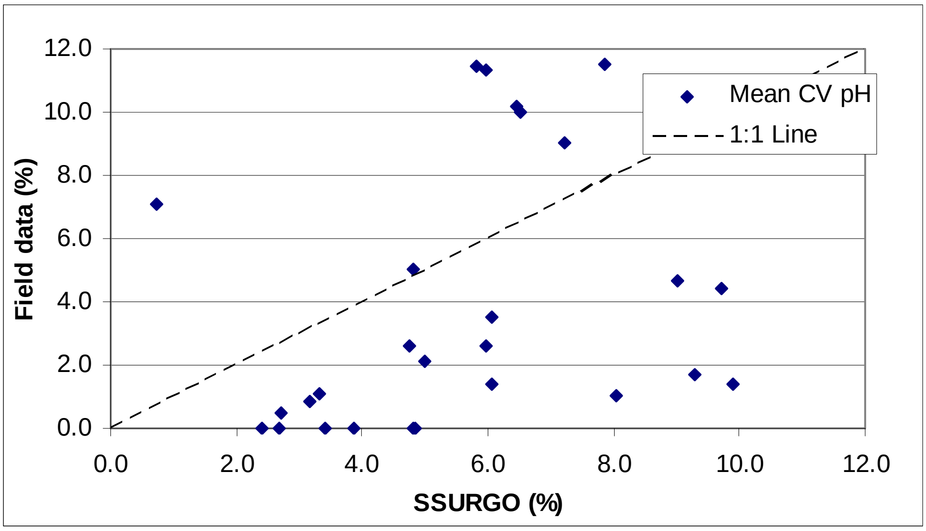

Figure 4.20 Coefficients of variance for the mean pH for the SSURGO database and field data per SSURGO map unit. An outlier is located at (5.50; 17.63).

4.4 Quantification multiscale variance

As described in section 3.2.1 Multiscale variance, it is possible to quantify which part of the variation presented in the SSURGO databases is explained by the MLRA and STATSGO databases[2]. The results for the two parameters for the two soil maps are presented in Table 4.7. The SSURGO soil map is assumed to present the total variance.

Table 4.7 The explained SSURGO variance by the MLRA and STATSGO maps for both soil parameters.

	OM (%)	pH (%)
MLRA	19.51	71.99
STATSGO	84.87	93.06

Organic matter

The MLRA soil map explains 19.5% of the total variance, this indicates that more than three quarters of the variance is found within the MLRA's and can therefore be explained by upscaling from the SSURGO database. The fact that most of the variance is found within a MLRA corresponds with the size of the MLRA's. As these areas cover a large surface, a few of them make up an entire state, it was expected that most of the variance is found within the map unit itself. The STATSGO soil map explains 84.9% of the SSURGO variance, this is considerably higher than for the MLRA map. The STATSGO map units contains a lot of map units and will thus include less variance within a map unit, which results in larger part of the variance being explained by the STATSGO soil map compared to the explained variance by the MLRA map.

PH

The MLRA and STATSGO soil maps explain respectively 72 and 93% of the total SSURGO variance. This indicates that most of the variance is explained by the variance between the map units. Although the MLRA map units are large, they still represent the fairly homogenous pattern for the pH well as can be seen in Figure 4.3. This corresponds with the relation observed for the pH and the precipitation division in Chapter 4. The (sub-)MLRA's are defined, based on differences in precipitation and these differences in precipitation are the primary factor for changes in pH. It seems therefore likely that a lot of the variation will be explained by the variance between the map units.

[2] The surface areas of the STATSGO-SSURGO intersection map and the SSURGO-MLRA intersection map, used for the multiple scale calculation, are not the same as also can be seen in Figure 4.1. About 25% more surface area is taken into account for the STATSGO-SSURGO intersection map.

Chapter 5 Discussion

The two soil parameters that have been analyzed show different behavior when compared for different map scales. In this chapter the general trend and the implications for the use of the different soil maps are discussed.

Organic matter

All the analyses indicate OM percentages for the Great Plains of Montana varying from 0.5-3%. Of more importance for this study is the fact that for all soil databases a considerable amount of variance for the OM percentage was found of several tens of percents.
For the mean OM percentage it was observed that both the SSURGO and field data means were considerably higher than the MLRA/STATSGO means. For the SSURGO data at MLRA scale and the SSURGO data at STATSGO (section Producer point of view) this deviation was on average 0.2%, while for the field data it reached up to about 1%. These deviations are considerable, with respect to the general OM percentages found for the Great Plains: 1-2% for croplands and 1.5-3% for native grasslands (Bowman & Petersen, ?). The choice for a soil map does thus not only determine the amount of variation that will be taken into account, but can also have considerable influence on the initial organic matter percentages used. An average deviation of 0.2% for the OM percentages is high and will affect amongst others soil moisture storage and the availability of nutrients. The field data having higher OM percentages might partly be due to the fact that sampling has occurred on topographical/hydrological differences in the landscape. Therefore the field data may overestimate the map unit OM percentage as less samples were taken in the more homogenous part of the map unit compared to the smaller more variable parts. Differences in OM percentages for the duplicates for the field data were generally small, higher percentages are thus not due to laboratory errors. For the difference in OM percentage between the STATSGO and SSURGO database no obvious reason can be found.

Coefficients of variance for the OM percentage amount, as indicated by the STATSGO, SSURGO and field databases, to several tens of percents often over 50%. There is thus considerable variance present in the field. Also here differences in the amounts of variance between the soil maps where found. The STATSGO soil map indicated slightly higher percentages of variance followed by the SSURGO soil map and the field data. However, these differences did not show a bias for one of the soil maps as for the OM mean. The presence of these large amounts of variance does have consequences for the use of a soil map. The use of the MLRA map for the OM percentages and corresponding variance results in the loss of 80% of the variance and the possible underestimation of the mean OM percentages. From Table 4.7 it can be seen that the use of the STATSGO soil map instead of the MLRA map will result in incorporating most of the variance. Using the SSURGO soil map instead of the STATSGO soil map only results in incorporating 15% more variance. It can thus be concluded that the assumption of the variance within the (sub-) MLRA's being equal to zero, is not valid. Now after the quantification of the explained variance it is seen that in case of the organic matter percentage this assumption might even have substantial consequences depending on the intended goal. In case of ecological and agricultural modeling, the use of more detailed data for a national scale will result in more reliable and more accurate results. The STATSGO soil map serves as a good soil map for the intended purposes identified by the NRCS. But also for this soil map yields that it is advisable to take the variance into account to derive more reliable results. From the section User point of view and the comparison with the field data it can be concluded that for the field scale, the SSURGO soil map is the soil map to use. Also for this soil map CV's where high, thus when going to an even larger scale it is recommended to use the SSURGO soil map with additional field samples.

PH

The mean pH for both the different MLRA's and the different soil maps shows a homogenous pattern and the means differs only slightly. Except for the mountainous parts of Montana nearly all soils are classified as slightly to moderately alkaline soils. Between the different map units only small changes in pH occur. These small changes are also reflected in the amount of variance found i.e. in general below 15%. Table 4.7 presents the same picture: for the pH the profits of incorporating a more detailed soil map will result in including less than 30% (SSURGO- MLRA) of variance. For this soil parameter thus yields that scaling down is not necessary profitable. It is for this soil parameter questionable if the increase of detail is relevant for the user. In case of a farmer, it is more important to know if soils have a pH above 7 than to know if a soil has pH 7.3 or 7.5.

The large difference in spatial pattern and the amount of (explained) variance of the pH and OM percentage indicates that there are large differences according to the soil parameter. Depending on the (soil forming) factors that determine the soil parameter soil maps are able to predict the amount of variance. For the OM percentage the amount of variance is high as there are many factors that determine the amount of organic matter e.g. management practices, vegetation, topography, climate etc. For the pH there are less main determining factors, mainly parent material and climate. The pH variance is therefore more easily incorporated in a soil map by discriminating map units. Thus incorporating a more detailed soil map will not lead for every soil parameter to a similar improved reliability. Thus no uniform conclusion can be drawn on which soil map to use for a certain goal. Depending on the selection of parameters used, a soil map has to be selected that takes for highly variable parameters enough variance into account, while not going in too much detail.

Chapter 6 Conclusions and Recommendations

6.1 General

- The different soil databases showed biased mean OM percentages. PH means were similar for the databases.
- The amount of variance differs for each soil parameter.
- The choice for a soil map depends on the amount of variance of the selected soil parameters and the amount of detail that is needed.

6.1 Soil maps

- The spatial pattern for the OM percentage is similar for all three soil maps.
- The highest OM percentages are found in the Rocky Mountains and isolated mountain ranges of the western Great Plains, with on average a range from 6-15%.
- Lower OM percentages are found for the Great Plains. In the north, percentages range from 0-2%, to the south-east percentages decrease to 0-1.25%.
- The OM percentages are mainly determined by the factors: topography, vegetation, climate and the management practices.
- The amount of variance differs for all three soil maps. The STATSGO and SSURGO soil maps present a similar spatial pattern.
- The spatial pattern can be subdivided in the Rocky Mountains and isolated mountain ranges with variance percentages ranging from 60-100%. For the Great Plains percentages of 35-55% are found, the higher ones located in the north and a decreasing trend towards the south-east
- The MLRA soil map has zero variance, for the STATSGO soil map CV's range on average from 40-75%. For SSURGO the CV's are smaller ranging on average from 30-50%.
- The main factors determining the CV's for the OM percentage are topography, geology and management practices.
- The OM percentage field data varies from 1.4-5.7%, with CV's ranging from 15.6-86.7%.

- All three soil maps show a similar, fairly homogenous spatial pattern for the pH.
- The lowest pH's are found in the Rocky Mountains, where pH's below 7 occur. At the Great Plains the highest pH's are found in the southeast: 7.5-8, while more up north pH's lie in the range of 7.5-7.75.
- Nearly all the soils of the Great Plains are classified as slightly to moderately alkaline soils.
- The main factors determining the pH are climate and consequently also topography and management practices.
- The amount of variance for the pH differs only slightly amongst the soil maps and no clear trend of higher variances for a certain map was observed.
- The spatial pattern can be subdivided in the Rocky Mountains and isolated mountain ranges with variance percentages ranging from 14-20%. For the Great Plains percentages of 6.5-11% are found, except for the central area where percentages of 15-20% are found.

- The MLRA soil map has zero variance, for the STATSGO soil map CV's range on average from 8-13%. For SSURGO the CV's are smaller ranging on average from 6.5-13%.
- The main factors determining the CV's for the pH are topography and climate.
- The field data pH varies from 7.3-8.2, with CV's ranging from 0.7-12.8%.

6.2 Multiscale analysis

- Mean OM percentages for the MLRA/STATSGO soil maps are consistently 0.3% lower than the OM mean percentages for the SSURGO soil map, but fall within the standard deviations of the SSURGO map.
- Mean OM percentages for the MLRA/STATSGO soil maps are about 1% lower than the OM mean percentages of the field data.
- Most means fall within the standard deviation range of the next larger map scale, due to the high amount of variance for the OM percentage.
- Due to the high amount of variance a wide range of OM percentages is present within a map unit as was demonstrated by the field data.
- The MLRA soil map explains less than 20% of the total variance for the OM percentage.The STATSGO soil map explains almost 85% of the total variance.

- The pH means of the MLRA, STATSGO and SSURGO soil map are nearly the same, and fall within the standard deviations of the next larger map scale.
- The amount of variance for the pH is considerably less than for the OM percentage, which is also demonstrated by the strong clustering of the datapoints for the producer point of view.
- The MLRA soil map explains more than 70% of the total variance, the STATSGO soil map even over 90% of the total variance.

6.3 Recommendations

- Other soil parameters need to be analyzed for the different soil maps to see whether or not these means show consistent deviations.
- Further investigation is suggested to find the cause for the large difference in OM mean percentage between the STATSGO and SSURGO/Fielddata databases.
- The representative profiles for the MLRA map need to be accompanied with variance intervals for the soil parameters, in order to be able to value the derived results when using this soil map.
- The two studied soil parameters indicated large differences in amounts of variance and spatial pattern. It is therefore recommended to make a multiscale comparison of other soil parameters to know how much variance is taken into account and where most of the variance is found.
- The multiscale comparison should be done for those areas, for which information of all three soil maps is available. The use of the same surface areas for all soil maps makes the multiscale comparison more accurate.

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Appendices

A General geology description, geological timetable and the geology map for the state of Montana.
B Status SSURGO soil map
C Derivation of total variance for two databases.
D Laboratory procedures
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F STATSGO soil map, STATSGO map unit table for the OM and Ph
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Appendix A Geology of Montana

General geology description

Until the end of the Cretaceous, the larger part of Montana was below sea level. Before the Cretaceous (see Geological timetable below) large amounts of mineral calcite from marine animal shells were deposited at the sea bottom, forming the Madison formation (300 million years). Nowadays, the oil and gas production from this formation forms an important part of Montana's national income. The inland sea continued throughout the Mesozoic Era, but conditions changed and shales and sandstones were deposited. At the end of the Mesozoic Era the formation of the Rocky Mountains was initiated by the breaking up of Pangaea and the formation of the Atlantic Ocean. As a result, the North American plate collided in the west with the Pacific plate. The subduction of the Pacific plate underneath the North American plate resulted in a huge compression of the western margin of the North American plate. The formation and the associated uplift caused the inland sea to retreat (Alt & Hyndman, 2001).

The formation of the Rocky Mountains continued throughout Cenozoic times, although the intensity of the geologic activity varied. Around 50 million years ago the area experienced a renewed period of intense geologic activity. The continued subduction of the oceanic plate was accompanied by volcanic activity. Parts of western and central Montana were covered by volcanic deposits. In this period the Rocky Mountains were reshaped from a peneplain to a dissected mountain range. Faults were (re-)activated and blocks were lifted, while others descended. Most of the remotely situated mountain ranges in the Great Plains date from this period as local igneous intrusions.

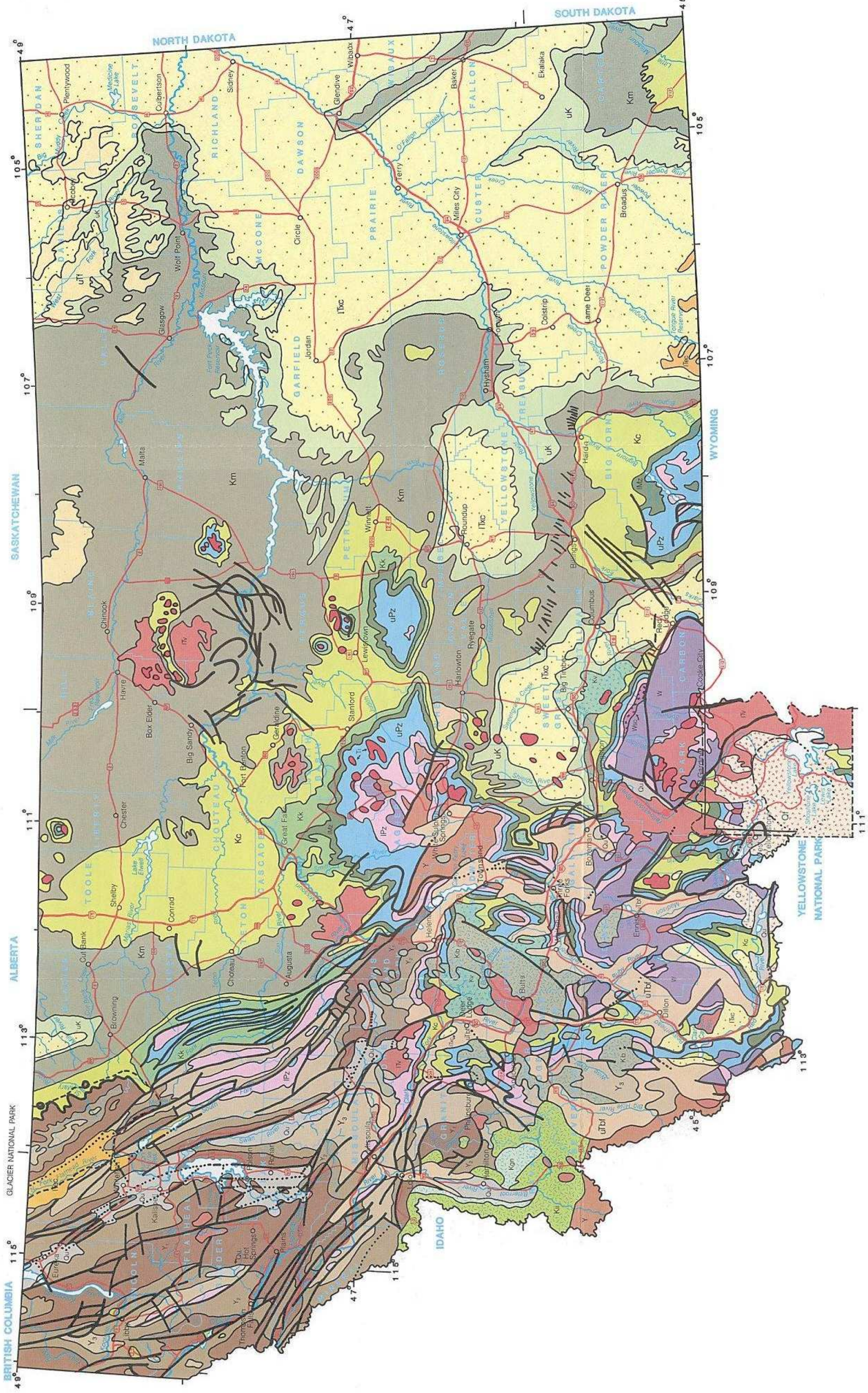
During Middle Miocene, Montana experienced a tropical climate. This tropical climate resulted in the weathering of the sediments and the formation of tropical red soils. Heavy tropical showers and consequently the high discharges formed large valleys (Miocene valleys), which are still recognized in the present day landscape. Early Pliocene indicated a new dry period that lasted until the Pleistocene ice ages. The streams dried up and at the Great Plains, desert streams spread coarse gravels, the Six Mile Creek/ Flaxville Formation.

The Pleistocene is characterized by large climatic fluctuations, e.g. glacials and interglacials. The continental and mountain glaciers covered the northern plains and mountains and deposited till, glacial debris and moraines. In the Holocene Montana experienced wind erosion, in western Montana loss was deposited, but landscape changes were limited.

Geological timetable

Era	Age	Period	Series		Stage
Cenozoic Era	0.01	Quaternary	Holocene		
	1.8		Pleistocene		
		Tertiary	Neogene	Pliocene	
				Miocene	
			Palaeogene	Oligocene	
				Eocene	
	65			Palaeocene	
Mesozoic Era		Cretaceous	Upper		Maastrichtian
					Campanian
					Santonian
					Coniacian
					Turonian
					Cenomanian
	144		Lower		
		Jurassic	Malm		
			Dogger		
	213		Lias		
		Triassic	Keuper		
			Muschelkalk		
	248		Bunter		
Paleozoic Era		Permian	Upper (Zechstein)		
	266		Lower (Rothliegendes)		
		Carboniferous	Upper		Stephanian
					Westphalian
					Namurian
			Lower		Visean
	360				Tournaisian
		Devonian	Upper		Fammenian
					Frasnian
			Middle		Givetian
					Couvinian
			Lower		Emsian
					Siegenian
	408				Gedinnian
	438	Silurian			
	505	Ordovician			
	590	Cambrian			
Precambrian					

Geological map of Montana



GEOLOGICAL MAP of MONTANA and Yellowstone National Park

Scale in miles

30 20 10 0 30 60

Scale in kilometers

30 0 30 60

KEY

Fault, sense of motion not indicated

Contact

CONTINENTAL AND MARINE DEPOSITS

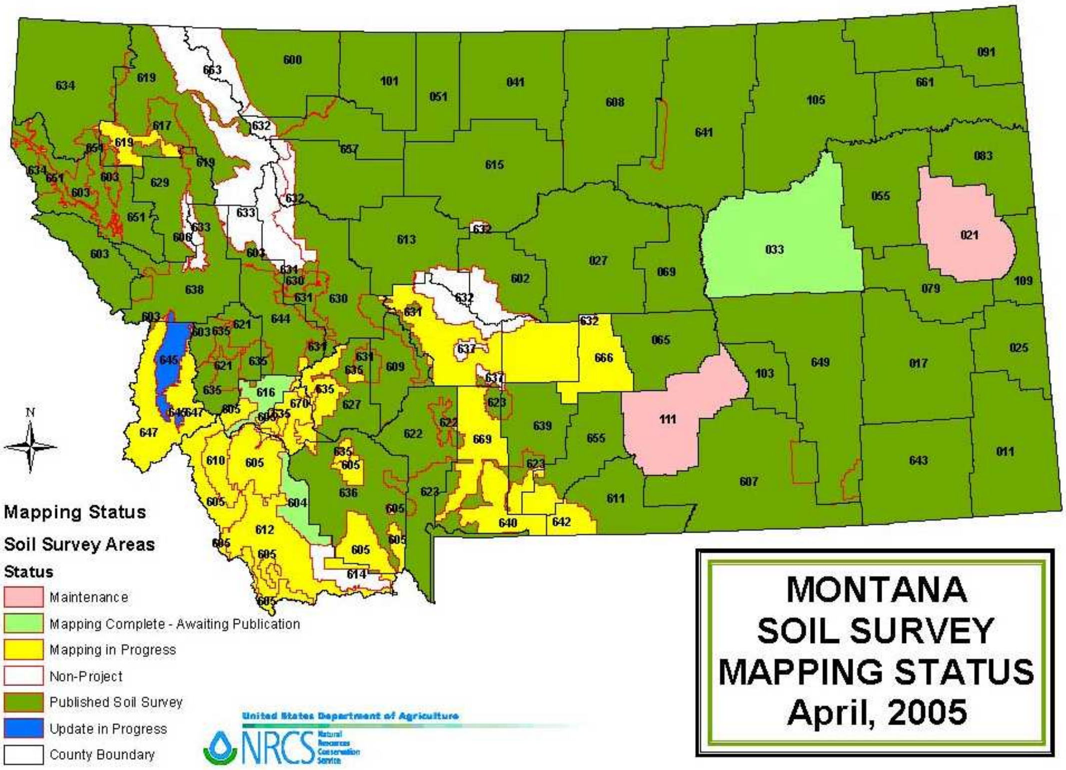
Symbol	Description
Qu	**Quaternary, extensive** Stream, glacial, and lake deposits
uTf	**Tertiary, Flaxville gravel** Gravel and sand with some silt, volcanic ash, and marl
uTbf	**Tertiary, basin fill** Oligocene through Pliocene basin fill composed of a heterogeneous mixture of gravel, sand, silt, and clay deposited by streams and in lakes
lTec	**Eocene, continental deposits** Includes fine to coarse-grained clastic rocks
lTxc	**Paleocene, continental deposits** Including stream-deposited sediments of coal-bearing Fort Union Fm. in the east, Willow Creek Fm. in the north central, and Beaverhead conglomerate in the southwest
uK	**Upper Cretaceous, undifferentiated** Hell Creek sandstone and shale, St. Mary River mudstone, and volcaniclastic Livingston Gp. in southcentral Montana
Km	**Montana Group** Bearpaw shale, Judith River sandstone, siltstone, and shale, Claggett shale, Eagle sandstone, and Telegraph Creek sandy shale. Includes Fox Hills sandstone and Pierre shale in the extreme east
Kc	**Colorado Group** Includes mainly shale of the Niobrara, Belle Fourche, Mowry, and Thermopolis Formations
Kk	**Kootenai Formation** Conglomerate, sandstone, shale, and mudstone
lMz	**Lower Mesozoic** Includes calcareous fossiliferous sandstone, shale, and limestone of the Ellis Group in the central and south central, and the Dinwoody and Thaynes Formations in the southwest as well as the Morrison shale, sandstone, and marl in the west
uPz	**Mississippian, Pennsylvanian, Permian** Includes Madison limestone, Big Snowy dolomite and limestone, and Quadrant sandstone
lPz	**Devonian and Cambrian** Consists of Three Forks shale, Jefferson limestone, Pilgrim and Meagher limestone, Park and Wolsey shale, and Flathead sandstone
Y_3	**Upper Belt-Missoula and Piegan Groups** Chiefly red, maroon, and purple argillites and impure quartzite and limestone
Y_2	**Middle Belt-Wallace, Siyeh, Helena Fms.** Heterogeneous Wallace Fm. including argillite, limestone, sandstone, shale, and quartzite; Siyeh and Helena limestones
Y_1	**Lower Belt-Ravalli and Prichard Fms.** Ravalli Fm. includes siliceous and sandy quartzite, argillite, and shale; Prichard Fm. consists of banded slate with interbedded sandstone
Y	**Undivided Belt Supergroup**

VOLCANIC, PLUTONIC, AND METAMORPHIC ROCKS

Qf	**Quaternary, rhyolitic volcanic rocks** Volcanic rocks, mostly felsic Yellowstone flows and associated pyroclastic deposits
Ti	**Tertiary, intrusives** Mostly granitic to intermediate composition, some alkaline especially in north-central Montana
lTv	**Lower Tertiary, volcanic rocks** Flows and associated pyroclastic deposits; latite, andesite, with some rhyolite and basalt and associated intrusive dikes and necks
Kib	**Younger Cretaceous, granitic rocks** Boulder Batholith and related rocks; predominantly quartz monzonite
Kv	**Cretaceous, volcanic rocks** Mafic to intermediate composition lava flows, ash flows, and other pyroclastic rocks with interbedded sedimentary rocks including Elkhorn Mountains volcanic rocks
Kii	**Older Cretaceous, volcanic rocks** Idaho Batholith and associated masses; monzonite and granodiorite
Kgn	**Border Zone of Idaho Batholith** Metasedimentary rocks of Belt age intruded by granitic rocks
Wsc	**Stillwater Complex** Layered mafic-ultramafic intrusive complex, includes anorthosite; associated with hornfels aureole
W	**Archean, undifferentiated** High-grade metamorphic rocks derived from igneous and sedimentary parent rocks. Lithologies include quartzo-feldspathic gneiss, granulite, amphibolite, quartzite, and marble

Appendix B SSURGO soil map

Status map of the SSURGO soil map



Source: NRCS [7].

Time stamps of the SSURGO soil map counties

Name	Time Stamp
CARTER COUNTY, MONTANA	March 2005
CUSTER COUNTY AREA, MONTANA	May 2005
DAWSON COUNTY, MONTANA	July 2005
FALLON COUNTY, MONTANA	July 2005
FERGUS COUNTY, MONTANA	July 2005
GARFIELD COUNTY, MONTANA	June 2004
HILL COUNTY, MONTANA	June 2004
LIBERTY COUNTY, MONTANA	June 2004
MCCONE COUNTY, MONTANA	July 2005
MUSSELSHELL COUNTY, MONTANA	June 2004
PETROLEUM COUNTY, MONTANA	June 2004
PRAIRIE COUNTY, MONTANA	July 2005
RICHLAND COUNTY, MONTANA	June 2004
SHERIDAN COUNTY, MONTANA	June 2004
TOOLE COUNTY, MONTANA	June 2004
TREASURE COUNTY, MONTANA	March 2005
VALLEY COUNTY, MONTANA	July 2005
WIBAUX COUNTY, MONTANA	June 2004
YELLOWSTONE COUNTY, MONTANA	June 2004
GLACIER COUNTY AREA AND PART OF PONDERA COUNTY, MONTANA	June 2004
JUDITH BASIN AREA, MONTANA	June 2004
BIG HORN COUNTY AREA, MONTANA	June 2004
BLAINE COUNTY AND PART OF PHILLIPS COUNTY AREA, MONTANA	June 2004
CARBON COUNTY AREA, MONTANA	June 2004
CASCADE COUNTY AREA, MONTANA	June 2004
CHOUTEAU COUNTY AREA, MONTANA	June 2004
WHEATLAND COUNTY AREA, MONTANA	Aug 2005
MEAGHER COUNTY AREA, MONTANA	July 2005
SWEETGRASS COUNTY AREA, MONTANA	June 2004
PHILLIPS COUNTY AREA, MONTANA	June 2004
POWDER RIVER AREA, MONTANA	June 2004
ROSEBUD COUNTY AREA AND PART OF BIG HORN COUNTY, MONTANA	June 2004
STILLWATER COUNTY AREA, MONTANA	June 2004

CHOTEAU - CONRAD AREA; PARTS OF TETON AND PONDERA COUNTIES,	June 2004
ROOSEVELT AND DANIELS COUNTIES, MONTANA	Nov. 2004
GOLDEN VALLEY COUNTY, MONTANA	July 2005

Appendix C Derivation of the total variance for two databases

The calculation of the total variance of databases: P_1 and P_2 with respectively M number of observations and mean μ_1 and N number of observations and mean μ_2 starts with the equation for the variance, see Equation 1.

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2 \qquad \text{Eq. 1}$$

Where:

μ	=	mean
N	=	number of samples
x_i	=	value for sample *i*
σ^2	=	variance

The mean, μ, from equation 1 for a database is derived according to Equation 2.

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \text{Eq. 2}$$

The mean for both databases is found by summing the multiplication of the mean for database 1 with the number of samples of database 1 and the multiplication of the mean for database 2 with the number of samples of database 2 and dividing this by the total number of samples, Equation 4.

$$\mu = \frac{\mu_1 N + \mu_2 M}{M + N} \qquad \text{Eq. 3}$$

When Equation 1, 2 and 3 are combined, an equation for the calculation of the total variance for two different databases is derived, see Equation 4.

$$\sigma_{total}{}^2 = \frac{1}{N+M}\sum_{i=1}^{N+M}\left(x_i - \left(\frac{M\mu_1 + N\mu_2}{M+N}\right)\right)^2 \qquad \text{Eq. 4}$$

Equation 4 can be rewritten as Equation 5, in which two almost similar parts can be discriminated, namely part A and B.

$$\Leftrightarrow \underbrace{\frac{1}{N+M}\sum_{i=1}^{M}\left(x_i - \mu_1 + \mu_1 - \left(\frac{M\mu_1 + N\mu_2}{M+N}\right)\right)^2}_{A} + \underbrace{\frac{1}{N+M}\sum_{i=1+M}^{N+M}\left(x_i - \mu_2 + \mu_2 - \left(\frac{M\mu_1 + N\mu_2}{M+N}\right)\right)^2}_{B}$$

Eq. 5.

Parts A and B can be rewritten in an almost similar way, therefore only part A is rewritten according to the abc-formula in the following two equations (Equations 6 and 7):

$$\Rightarrow \frac{1}{N+M}\sum_{i=1}^{M}\left((x_i-\mu_1)^2+\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2+2(x_i-\mu_1)\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)\right)$$

Eq. 6

$$\Leftrightarrow \frac{1}{N+M}\sum_{i=1}^{M}\left(\sigma^2+\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2\right)$$

Eq. 7

The first part of the term between parentheses, $(x_i-\mu_1)^2$, of Equation 6 can be replaced by the variance σ^2 from Equation 1. For the second part of the equation yields that the summation over all values till M for $(x_1-\mu_1)$ will result in 0, as the mean is based on the values in the entire database and should in the end sum up to zero. So this results in the following equation when both part A and B from Equation 5 are again considered:

$$\frac{1}{N+M}\sum_{i=1}^{M}\left[{\sigma_1}^2+\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2\right]+\frac{1}{N+M}\sum_{i=1}^{N}\left({\sigma_2}^2+\left(\mu_2-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2\right)$$

Eq. 8

When summed over the entire database:

$$\Leftrightarrow \frac{1}{N+M}\left\{M{\sigma_1}^2+M\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2+N{\sigma_2}^2+N\left(\mu_2-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2\right\}$$

Eq. 9

The terms $M{\sigma_1}^2$ and $N{\sigma_1}^2$ can now be taken out of the parentheses:

$$\Leftrightarrow \frac{M{\sigma_1}^2+N{\sigma_2}^2}{M+N}+\frac{1}{M+N}\left\{M\left(\mu_1-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2+N\left(\mu_2-\left(\frac{M\mu_1+N\mu_2}{M+N}\right)\right)^2\right\}$$

Eq. 10

Rewriting the terms between braces leads to the following equations (Equations 11, 12, 13 and 14):

$$\Leftrightarrow \frac{M\sigma_1{}^2 + N\sigma_2{}^2}{M+N} + \frac{1}{M+N}\left\{M\left(\frac{(M+N)\mu_1 - M\mu_1 - N\mu_2}{M+N}\right)^2 + N\left(\frac{(M+N)\mu_2 - M\mu_1 - N\mu_2}{M+N}\right)^2\right\}$$

Eq. 11

$$\Leftrightarrow \frac{M\sigma_1{}^2 + N\sigma_2{}^2}{M+N} + \frac{1}{M+N}\left\{\frac{MN^2(\mu_1-\mu_2)^2}{(M+N)^2} + \frac{NM^2(\mu_2-\mu_1)^2}{(M+N)^2}\right\}$$

Eq. 12

$$\Leftrightarrow \frac{M\sigma_1{}^2 + N\sigma_2{}^2}{M+N} + \frac{MN(N+M)(\mu_1-\mu_2)^2}{(M+N)^3}$$

Eq. 13

$$\Leftrightarrow \frac{M\sigma_1{}^2 + N\sigma_2{}^2}{M+N} + \frac{MN(\mu_1-\mu_2)^2}{(M+N)^2}$$

Eq. 14

This leads to the equation for the variance of two different databases:

$$\Leftrightarrow \frac{(M+N)\left(M\sigma_1{}^2 + N\sigma_2{}^2\right) + MN(\mu_1-\mu_2)^2}{(M+N)^2}$$

Eq.15

Appendix D Laboratory procedures

Organic matter determination

References:

1. Sims, J.R. and V.A. Haby. 1970. Simplified colorimetric determination of soil organic matter. Soil Sci. 112 (2):137-141
2. Page, A.L., et al. 1982. Methods of soil analysis. Part 2. 29-3.5.2

Equipment:

Digestion racks with 100-120 ml beakers, filter tubes and racks; Whatman #1 filter paper; balance; bottle tap dispenser; and colorimeter; protective eyewear, clothing and gloves.

Reagents:

1. 1 N Potassium Dichromate ($K_2Cr_2O_7$): Weigh 49.04 g of potassium dichromate into a 1 liter volumetric flask, dissolve and bring to volume with deionized water.
2. Concentrated Sulfuric Acid (H_2SO_4)

Procedure:

Use glass beaker racks. Put tape on rack on which to record sample numbers.

1. Weigh 1 g of soil into each glass beaker.
2. Add 10 ml of 1 N potassium dichromate and swirl.
3. Add 10 ml of concentrated sulfuric acid. Swirl and allow to react 20 minutes (Caution: the beakers get hot!).
4. Add deionized water to bring the volume to 100 ml using bottle top dispenser and allow to cool 20 minutes.
5. Filter through Whatman #1 filter paper. Refilter if cloudy.
6. Analyze on colorimeter, at 600 nm. Set transmittance at 100% with blank. Record to the nearest 0.1%T.

Comments:

1. Be sure to wear protective clothing and gloves.
2. If the % OM in the sample is off the calibrated scale use 0.5-0.1 g of soil.
3. Wash filter papers off under running water before throwing into garbage. Rinse all glassware well before putting in wash area. A 10% sulfuric acid solution can make holes in your clothes.
4. Be sure to wash out hood well and rinse out Potassium Dichromate dispensor.
5. Whatman # 1 filters may leave the sample a little cloudy. This will usually settle out. To avoid interference due to precipitation, make it practice to use only the top portion of the filtered solution. (DO NOT USE last ½ - 1”of the solution in the bottom.)
6. Save all excess used potassium dichromate solution for toxic waste disposal

Soil pH and conductivity

Reference:

1. USDA handbook No.60. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Government Print Office, Washington D.C., p.88.
2. Page, A.L. et al. 1982. Methods for Soil Analysis, Part II, Agronomy No.9: pg 169-173, 199-210.
3. Clesceri, L.S. et al. 1989. Standard methods for the examination of Water and Wastewater, 17^{th} Edition. Pg 2-59 thru 2-61,4-94.

Equipment:
Grey racks, orbital shaker, pH meter (Orion, model 172A), EC meter (Wescan), balance

Reagents:
0.01 N KCl (0.7456 g KCl/L), pH 4, pH 7 and pH 10 buffer solution.

Procedure:

1. Weigh 20 g soil into extraction racks and add 20 ml of deionized water.
2. Same as I 2.
3. Gently mix wetted soil/sample into a slurry.
4. Read the soil conductivity first then place the pH electrode into the slurry. Wait for the pH meter to equilibrate. Resuspend the slurry if the soil becomes too settled.
5. Record values

Appendix E Comparison surface areas soil maps

Figure 1 Major Land Resource Areas and the sub-MLRA's for east Montana (Antle et al., 2004).

The surface areas of the soil maps used for the analyses were compared. The surface area comparison is done for the MLRA scale, which means that for both the STATSGO and SSURGO soil maps the surface area of the map units located within a MLRA are summed up and compared with the surface area of that MLRA as calculated by the MLRA map theme in ARCVIEW. Table 1 presents the results of the comparison for the STATSGO soil map with the MLRA map, Table 2 presents the results for the comparison of the SSURGO soil map with the MLRA map.

Table 1 Comparison of the surface areas (acres) for the MLRA and STATSGO soil maps.

MLRA		***MLRA***	***STATSGO***			
	SubMLRA	**Surface area (acres)**	**Surface area (acres)**	**Not analyzed area (acres)**	**Total area (acres)**	**Percentage (%)**
52		5.71E+10	5.68E+10	2.02E+08	5.70E+10	99.90
	High	2.54E+10	2.53E+10	5.44E+07	2.53E+10	99.94
	Low	3.17E+10	3.15E+10	1.47E+08	3.17E+10	99.86
53A		2.01E+10	2.01E+10	4.81E+07	2.01E+10	99.92
	High	7.94E+09	7.92E+09	5.85E+06	7.93E+09	99.92
	Low	1.22E+10	1.21E+10	4.23E+07	1.21E+10	99.52
54		5.53E+09	5.53E+09	-	5.53E+09	99.97
	High	1.35E+09	1.35E+09	-	1.35E+09	99.89
	Low	4.18E+09	4.18E+09	-	4.18E+09	100.00
58A		1.12E+11	1.11E+11	9.32E+08	1.12E+11	100.00
	High	6.55E+10	6.55E+10	8.39E+06	6.55E+10	100.00
	Low	4.68E+10	4.59E+10	9.24E+08	4.68E+10	99.99
	High	5.22E+10	5.22E+10	8.39E+06	5.22E+10	100.00
	Low	4.42E+10	4.33E+10	8.95E+08	4.42E+10	100.00
	Forest	1.60E+10	1.59E+10	2.87E+07	1.60E+10	99.98

In Table 1 four columns are identified for the STATSGO soil map. The surface area column includes the surface area for which data on organic matter and pH are available from the STATSGO database and thus for which the means and variances could be calculated. The second STATSGO column "Not analyzed area" indicates the surface area for which these data were not available. These two columns are summed up for the third column "Total area". This column is compared with the MLRA surface area and based on these surface areas, a percentage is calculated that indicates how well the STATSGO database covers the MLRA's. The comparison of the STATSGO surface areas with the ones for the MLRA's results in a nearly complete coverage of the selected areas. For all MLRA's and subMLRA's the coverage is more than 99%.

Table 2 Comparison of the surface areas for the MLRA and SSURGO soil maps.

MLRA		***MLRA***	***SSURGO***			
	SubMLRA	**Surface area (acres)**	**Surface area (acres)**	**Not analyzed area (acres)**	**Total area (acres)**	**Percentage (%)**
52		5.71E+10	5.54E+10	7.61E+08	5.61E+10	98.35
	High	2.54E+10	2.41E+10	3.57E+08	2.45E+10	96.49
	Low	3.17E+10	3.12E+10	4.04E+08	3.17E+10	99.84
53A		2.01E+10	1.95E+10	5.34E+08	2.00E+10	99.62
	High	7.94E+09	7.70E+09	2.24E+08	7.93E+09	99.91
	Low	1.22E+10	1.18E+10	3.10E+08	1.21E+10	99.42
54		5.53E+09	5.50E+09	1.23E+08	5.63E+09	101.73
	High	1.35E+09	1.32E+09	2.74E+07	1.35E+09	100.00
	Low	4.18E+09	4.18E+09	9.58E+07	4.28E+09	102.29
58A		1.12E+11	1.05E+11	7.76E+09	1.12E+11	99.98
	High	6.55E+10	6.23E+10	3.19E+09	6.55E+10	99.97
	Low	4.68E+10	4.23E+10	4.56E+09	4.68E+10	99.99
	High	5.22E+10	4.93E+10	2.86E+09	5.22E+10	99.98
	Low	4.42E+10	3.98E+10	4.43E+09	4.42E+10	100.00
	Forest	1.60E+10	1.55E+10	4.67E+08	1.60E+10	99.93

The comparison of the SSURGO surface areas with the MLRA surface areas also results in a nearly perfect coverage of the MLRA map. Only subMLRA 52 high has a covering that lags behind in comparison with the other MLRA's. As a consequence MLRA 52 is covered just beyond 99%. For all the other MLRA's the SSURGO map units cover the MLRA's by at least 99%. In conclusion it can be said that that the comparison of the soil parameters for the three different soil maps is thus justified as the MLRA's are almost fully covered by the two different soil maps.

Appendix F STATSGO soil map, means and variances

STATSGO soil map

Legend

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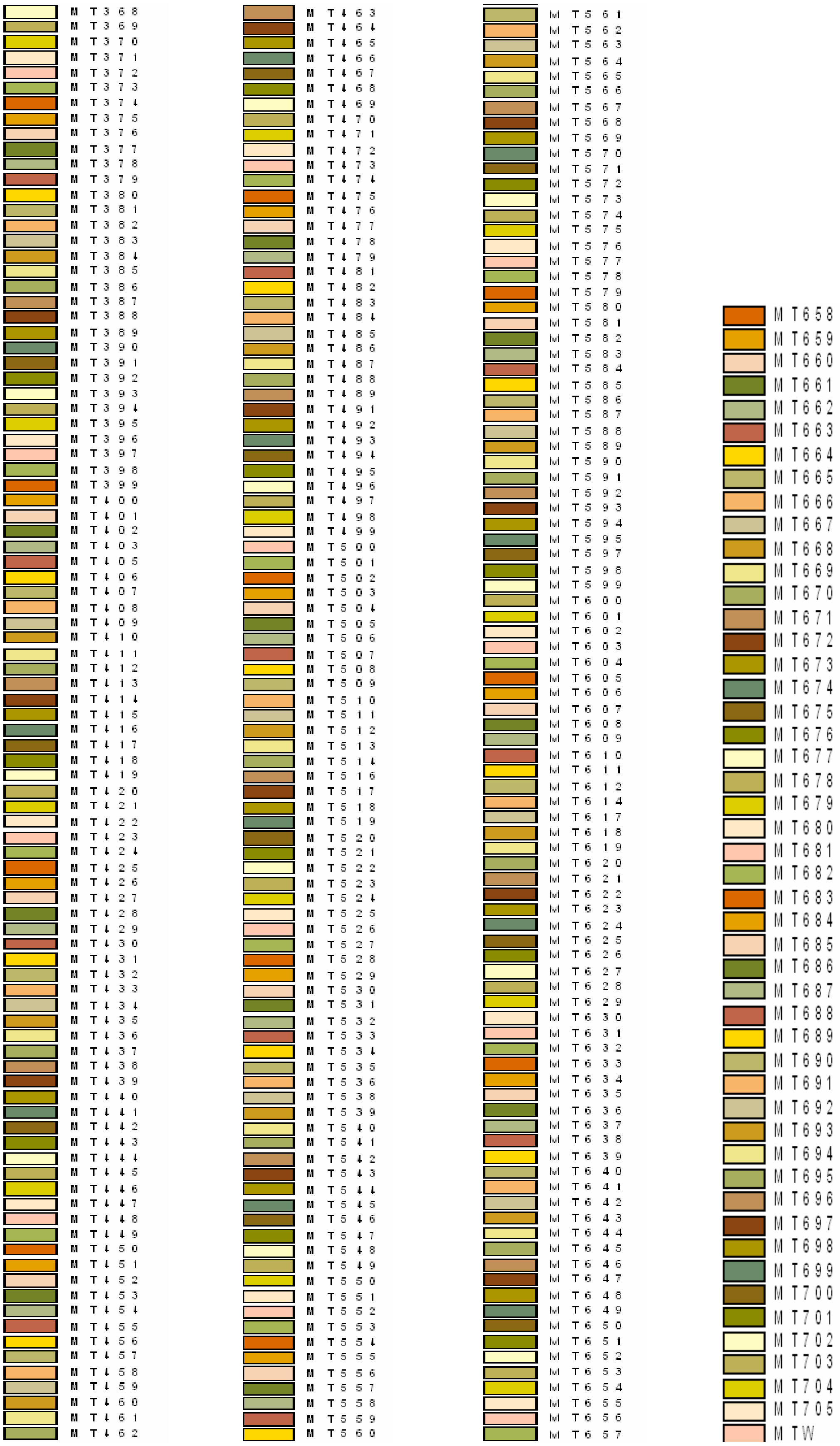
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Means and standard deviation for STATSGO map units

Table 1 Means, standard deviation and coefficients of variance for both the organic matter and pH for the STATSGO database.

MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT001	0.947	0.672	70.979	7.682	0.675	8.783
MT002	0.865	0.484	55.981	7.915	0.711	8.977
MT003	2.399	1.314	54.783	7.140	0.804	11.258
MT004	2.375	1.572	66.195	7.288	0.717	9.843
MT005	2.407	1.326	55.093	7.116	0.773	10.866
MT006	2.605	1.359	52.171	7.090	0.849	11.973
MT007	2.131	1.315	61.698	7.392	0.729	9.857
MT008	2.338	1.285	54.944	7.383	0.738	9.991
MT009	1.011	0.514	50.790	8.188	0.879	10.735
MT010	2.803	1.929	68.803	6.703	0.808	12.048
MT011	1.152	0.626	54.339	8.022	0.512	6.380
MT012	1.014	0.447	44.060	7.776	0.618	7.944
MT013	1.595	0.857	53.701	7.275	0.583	8.011
MT014	1.983	0.740	37.296	6.871	0.667	9.707
MT015	1.779	0.798	44.848	7.090	0.752	10.607
MT016	1.132	0.830	73.321	7.189	1.059	14.735
MT017	0.906	0.528	58.276	7.305	0.821	11.239
MT018	1.278	0.841	65.814	8.021	0.546	6.809
MT019	1.080	0.687	63.673	7.311	0.843	11.529
MT020	1.452	0.746	51.397	7.293	0.796	10.912
MT021	2.503	1.426	56.954	7.314	0.563	7.703
MT022	1.143	0.652	57.005	7.961	0.794	9.977
MT023	0.968	0.558	57.666	7.892	0.859	10.886
MT024	0.808	0.424	52.513	7.809	1.132	14.490
MT025	1.132	0.497	43.893	7.526	1.060	14.079
MT026	0.973	0.606	62.289	7.694	0.759	9.866
MT027	0.983	0.536	54.537	7.851	0.633	8.063
MT028	0.931	0.573	61.600	7.863	0.669	8.509
MT029	1.134	0.546	48.204	7.682	0.612	7.962
MT030	1.986	0.977	49.228	7.805	0.835	10.695
MT031	0.956	0.424	44.328	7.046	1.140	16.183
MT032	1.324	1.047	79.086	5.975	0.685	11.459
MT033	2.095	1.269	60.562	6.704	0.706	10.526
MT034	1.318	0.664	50.362	7.234	0.879	12.157
MT035	1.417	0.713	50.326	7.181	0.858	11.943
MT036	1.424	0.734	51.522	7.339	0.796	10.846
MT037	1.288	1.019	79.093	7.611	0.646	8.492
MT038	1.730	0.841	48.619	7.187	0.666	9.263
MT039	2.104	1.358	64.537	6.735	0.797	11.838
MT040	2.598	1.775	68.321	7.772	1.053	13.545
MT041	1.179	0.348	29.485	7.499	0.550	7.331
MT042	1.757	1.154	65.687	7.555	0.827	10.941
MT043	2.711	1.127	41.560	6.871	0.532	7.736
MT044	2.783	1.123	40.350	6.724	1.309	19.461
MT045	1.267	1.045	82.499	6.248	0.922	14.760
MT046	1.821	1.046	57.460	6.122	0.769	12.567

MT047	1.604	0.778	48.514	7.932	0.461	5.816
MT048	1.830	1.168	63.816	7.702	0.843	10.940
MT049	1.263	0.839	66.463	7.633	0.757	9.921
MT050	1.904	0.994	52.214	7.544	0.743	9.848
MT051	1.016	0.618	60.845	7.320	0.882	12.051
MT052	2.427	1.771	72.968	7.104	0.948	13.345
MT053	0.616	0.365	59.233	6.963	0.913	13.110
MT054	0.902	0.363	40.260	7.685	0.827	10.765
MT055	0.936	0.421	44.979	7.513	0.685	9.118
MT056	15.139	25.890	171.011	7.099	0.728	10.256
MT057	0.991	0.558	56.328	8.187	0.801	9.782
MT058	0.927	0.454	49.003	7.899	0.993	12.567
MT059	1.293	1.077	83.290	7.377	0.780	10.573
MT060	2.354	1.557	66.142	7.050	0.798	11.316
MT061	2.518	1.313	52.144	6.923	0.739	10.678
MT062	3.184	1.493	46.900	7.068	0.667	9.430
MT063	1.208	0.683	56.510	7.953	0.526	6.608
MT064	1.399	0.742	53.087	7.871	0.592	7.525
MT065	1.451	0.777	53.530	7.857	0.579	7.373
MT066	1.460	0.687	47.033	7.918	0.484	6.118
MT067	1.455	0.739	50.804	7.604	0.652	8.570
MT068	1.848	1.466	79.335	7.486	0.718	9.595
MT069	1.539	1.268	82.376	7.658	0.754	9.852
MT070	1.748	1.225	70.091	7.642	0.903	11.813
MT071	3.018	1.453	48.149	7.083	0.666	9.399
MT072	1.310	0.883	67.421	7.930	0.581	7.320
MT073	1.846	1.534	83.072	7.750	0.656	8.469
MT074	0.952	0.555	58.316	7.721	0.733	9.490
MT075	0.973	0.378	38.864	7.783	0.786	10.097
MT076	1.206	0.896	74.238	7.971	0.797	10.003
MT077	1.484	1.134	76.447	7.586	0.776	10.230
MT078	1.138	0.684	60.086	7.476	0.886	11.855
MT079	1.144	0.719	62.872	7.659	0.885	11.553
MT080	0.914	0.515	56.315	7.755	0.841	10.851
MT081	0.918	0.434	47.308	7.901	0.730	9.243
MT082	1.253	0.651	51.974	7.883	0.750	9.520
MT083	1.106	0.762	68.903	7.880	0.822	10.435
MT084	1.334	1.092	81.834	7.768	0.806	10.383
MT085	1.387	0.880	63.436	7.898	0.808	10.232
MT086	1.194	0.822	68.783	7.817	0.709	9.072
MT087	0.919	0.588	63.931	7.880	0.713	9.053
MT088	0.993	0.385	38.775	7.558	1.176	15.563
MT089	1.223	0.669	54.721	7.869	0.743	9.441
MT090	0.840	0.356	42.443	7.793	0.810	10.396
MT091	0.794	0.406	51.106	7.853	0.897	11.420
MT092	0.831	0.448	53.918	7.788	0.844	10.842
MT093	1.214	0.708	58.289	7.469	0.917	12.277
MT094	0.956	0.427	44.597	7.877	0.823	10.451
MT095	0.931	0.373	40.040	7.909	0.711	8.996
MT096	0.837	0.307	36.686	6.907	2.039	29.522
MT097	0.879	0.600	68.237	7.691	0.851	11.059
MT098	0.904	0.486	53.727	7.919	0.801	10.118

MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT099	0.787	0.399	50.692	7.782	0.821	10.556
MT100	0.862	0.492	57.090	7.750	0.793	10.230
MT101	0.826	0.382	46.206	7.766	0.857	11.041
MT102	0.778	0.366	47.003	7.893	0.912	11.554
MT103	0.882	0.427	48.440	7.937	0.862	10.867
MT105	1.585	0.766	48.309	7.262	0.616	8.480
MT106	1.202	0.838	69.716	7.673	0.815	10.616
MT107	1.096	0.844	76.955	7.819	0.794	10.157
MT108	0.978	0.559	57.129	7.848	0.752	9.589
MT109	1.173	0.884	75.401	8.020	0.722	9.001
MT110	2.988	2.089	69.908	7.291	0.759	10.404
MT111	1.722	1.095	63.597	7.493	0.764	10.201
MT112	1.906	1.066	55.951	7.321	0.805	10.989
MT113	2.106	1.137	54.015	7.271	0.757	10.409
MT114	2.109	0.884	41.907	7.438	0.725	9.752
MT115	2.242	0.771	34.397	7.133	0.569	7.977
MT116	1.983	0.851	42.933	7.381	0.720	9.751
MT117	2.476	1.124	45.419	7.274	0.769	10.567
MT118	2.107	1.154	54.772	7.295	0.771	10.574
MT119	1.909	0.978	51.218	7.396	0.841	11.375
MT120	1.487	0.814	54.755	7.677	0.771	10.046
MT121	1.754	0.926	52.824	7.147	0.726	10.157
MT122	2.299	3.502	152.356	6.511	1.747	26.834
MT123	1.272	0.711	55.900	7.483	0.974	13.018
MT124	1.490	1.024	68.688	7.216	0.791	10.961
MT125	0.968	0.776	80.117	7.897	0.662	8.377
MT126	1.032	0.513	49.704	7.763	0.752	9.686
MT127	1.052	0.659	62.618	7.372	0.896	12.153
MT128	1.013	0.504	49.732	7.448	0.794	10.666
MT129	1.189	0.587	49.378	7.773	0.705	9.071
MT130	1.067	0.595	55.724	7.444	1.337	17.955
MT131	1.152	0.709	61.512	7.386	0.911	12.330
MT132	1.009	0.515	51.038	7.396	0.804	10.871
MT133	2.518	1.501	59.635	7.165	0.705	9.843
MT134	1.868	1.069	57.222	6.393	0.895	14.005
MT135	2.823	1.185	41.995	6.631	0.657	9.908
MT136	2.361	1.368	57.951	6.203	0.593	9.559
MT137	2.199	1.454	66.114	6.110	0.607	9.939
MT138	2.075	1.495	72.022	6.170	0.627	10.156
MT139	1.290	0.841	65.201	5.779	1.090	18.865
MT140	0.968	0.836	86.414	5.761	0.726	12.596
MT141	1.309	1.273	97.273	5.272	2.718	51.558
MT142	1.197	1.057	88.249	5.715	2.409	42.160
MT143	1.088	0.760	69.865	7.834	0.576	7.353
MT144	0.978	0.596	61.006	8.023	0.483	6.026
MT145	0.801	0.613	76.494	7.837	0.693	8.840
MT146	0.981	0.750	76.399	7.875	0.708	8.991
MT147	0.893	0.582	65.207	8.026	0.408	5.086
MT148	0.829	0.463	55.852	7.634	0.612	8.012
MT149	1.307	0.627	47.967	7.157	0.657	9.183
MT150	1.850	1.058	57.188	6.005	0.645	10.748

MT151	1.730	1.384	80.040	6.774	2.088	30.829
MT152	0.842	0.533	63.295	7.579	0.612	8.072
MT153	1.694	0.845	49.858	7.357	0.859	11.670
MT154	2.088	0.825	39.540	7.315	0.831	11.355
MT155	1.998	0.747	37.390	7.698	0.741	9.625
MT156	1.061	0.570	53.745	7.786	0.917	11.777
MT157	0.818	0.509	62.237	7.775	0.617	7.935
MT159	0.884	0.500	56.554	7.948	0.588	7.401
MT160	1.037	0.580	55.876	7.580	0.957	12.621
MT161	0.941	0.416	44.198	7.370	0.799	10.835
MT162	0.933	0.617	66.192	7.745	0.919	11.871
MT163	1.125	0.749	66.563	7.783	1.272	16.342
MT164	0.842	0.410	48.732	7.815	0.854	10.929
MT165	0.734	0.551	75.173	7.687	0.573	7.449
MT166	0.989	0.648	65.473	7.477	0.980	13.111
MT167	0.754	0.648	85.902	7.721	0.870	11.264
MT168	0.786	0.446	56.722	7.718	0.872	11.298
MT169	2.596	1.045	40.247	7.406	0.818	11.051
MT170	2.523	1.162	46.056	7.034	0.928	13.195
MT171	2.931	4.024	137.275	6.678	0.896	13.414
MT172	3.731	4.300	115.258	6.933	0.715	10.315
MT173	1.321	0.795	60.175	7.138	0.655	9.180
MT174	1.367	1.001	73.221	7.752	0.766	9.884
MT175	1.121	0.794	70.865	7.704	0.781	10.137
MT176	1.154	1.110	96.217	7.873	0.740	9.404
MT177	1.662	0.893	53.747	7.401	1.035	13.986
MT178	1.645	1.011	61.468	7.329	1.021	13.931
MT179	2.131	1.192	55.941	7.383	0.789	10.685
MT180	2.032	1.524	75.000	6.250	0.709	11.342
MT181	1.081	0.943	87.171	7.824	0.873	11.162
MT182	2.346	1.628	69.398	7.303	0.777	10.636
MT183	0.888	0.643	72.437	7.510	0.705	9.389
MT184	2.346	1.517	64.682	7.243	0.752	10.380
MT185	1.248	0.744	59.611	7.583	0.825	10.876
MT186	1.308	0.676	51.691	7.645	0.820	10.725
MT187	1.500	0.801	53.370	7.392	0.952	12.885
MT188	1.408	0.787	55.889	7.719	0.643	8.330
MT189	1.573	0.756	48.078	7.303	0.768	10.521
MT190	1.529	0.766	50.103	7.257	0.635	8.751
MT191	2.095	1.125	53.696	7.517	0.840	11.172
MT192	1.730	1.711	98.895	7.732	0.817	10.570
MT193	2.439	1.326	54.355	7.796	0.770	9.875
MT194	1.109	0.889	80.167	7.586	0.815	10.736
MT195	1.201	0.817	68.030	7.581	0.782	10.321
MT196	2.079	1.105	53.147	7.409	0.952	12.852
MT197	2.000	1.078	53.901	7.276	0.888	12.200
MT198	2.597	1.364	52.523	5.905	1.614	27.329
MT199	2.516	1.218	48.395	7.124	0.689	9.676
MT200	2.193	0.946	43.130	7.336	0.700	9.541
MT201	2.887	1.413	48.957	7.187	0.621	8.645
MT202	3.295	0.974	29.552	6.853	0.606	8.850
MT203	1.958	1.207	61.663	5.953	2.087	35.059

MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT204	2.434	1.964	80.727	6.795	0.621	9.132
MT205	1.359	0.714	52.577	7.814	0.639	8.176
MT206	1.363	0.673	49.395	7.608	0.766	10.064
MT207	1.126	0.641	56.914	7.579	0.814	10.744
MT208	1.608	1.122	69.793	6.996	0.913	13.048
MT209	0.827	0.459	55.445	7.811	0.820	10.495
MT210	4.133	2.294	55.510	7.154	0.577	8.065
MT211	6.813	12.575	184.575	7.828	0.595	7.601
MT212	2.975	11.992	403.092	5.367	2.540	47.332
MT213	1.480	0.930	62.857	6.048	0.646	10.689
MT214	9.202	20.913	227.282	6.330	0.705	11.131
MT215	5.284	15.155	286.807	5.913	1.548	26.183
MT216	0.492	0.497	101.066	4.076	2.784	68.312
MT217	1.897	1.039	54.747	6.698	0.871	13.006
MT218	0.983	0.745	75.766	5.986	1.638	27.355
MT219	2.147	1.566	72.941	6.395	1.093	17.085
MT220	1.574	0.859	54.605	5.865	1.610	27.448
MT221	1.598	1.143	71.555	7.446	0.704	9.450
MT222	1.640	0.769	46.897	7.610	0.705	9.259
MT223	1.174	0.621	52.950	7.829	0.936	11.960
MT224	0.927	0.532	57.331	7.521	0.812	10.793
MT225	1.047	0.586	55.948	7.600	1.060	13.951
MT226	1.303	0.932	71.504	7.688	0.868	11.289
MT227	1.073	0.607	56.580	8.017	0.821	10.246
MT228	0.975	0.717	73.493	7.645	0.649	8.493
MT229	2.107	1.272	60.354	6.342	1.237	19.512
MT230	2.189	1.344	61.405	6.111	1.661	27.182
MT231	0.050	0.050	100.000	0.000	0.000	
MT232	2.264	0.985	43.492	6.949	0.631	9.078
MT233	1.624	0.818	50.404	7.254	0.643	8.868
MT234	2.171	1.781	82.010	6.132	0.954	15.563
MT235	2.456	1.556	63.364	6.342	1.165	18.371
MT237	2.103	1.127	53.565	7.449	0.782	10.503
MT238	3.074	1.850	60.178	7.410	0.730	9.855
MT239	3.465	1.758	50.730	7.311	0.684	9.362
MT240	2.325	1.682	72.358	7.563	0.671	8.870
MT241	3.299	2.046	62.006	7.473	0.682	9.120
MT242	6.383	14.800	231.876	7.457	0.601	8.063
MT243	2.161	1.045	48.378	6.697	0.585	8.730
MT244	1.083	0.707	65.283	7.771	0.723	9.305
MT245	0.877	0.435	49.623	7.738	0.813	10.508
MT246	1.266	0.932	73.619	7.740	0.818	10.569
MT247	0.967	0.659	68.147	8.122	0.797	9.815
MT248	0.852	0.441	51.729	7.664	0.934	12.192
MT249	0.665	0.429	64.482	7.780	0.511	6.571
MT250	1.743	0.876	50.256	6.487	0.953	14.687
MT251	1.045	0.542	51.900	7.367	0.874	11.865
MT252	0.833	0.505	60.680	8.006	0.641	8.008
MT253	0.941	0.514	54.625	7.678	0.838	10.912
MT254	0.986	0.555	56.254	7.795	1.408	18.057
MT255	1.115	0.608	54.527	7.630	0.890	11.671

MT256	0.912	0.494	54.164	7.619	1.589	20.851
MT257	1.163	0.705	60.601	7.940	0.847	10.670
MT258	0.978	0.559	57.144	7.563	1.379	18.232
MT259	0.958	0.585	61.076	7.461	1.596	21.391
MT260	1.425	0.730	51.217	7.835	0.836	10.672
MT261	1.072	0.579	54.026	7.649	0.978	12.788
MT262	0.871	0.552	63.342	7.166	2.251	31.410
MT263	1.099	0.541	49.224	7.398	1.791	24.203
MT264	1.005	0.600	59.722	7.520	0.945	12.566
MT265	0.866	0.561	64.714	8.019	0.636	7.930
MT266	0.900	0.726	80.619	7.114	2.333	32.797
MT267	0.956	0.563	58.845	7.331	1.613	22.003
MT268	1.002	0.670	66.850	7.686	0.647	8.416
MT269	2.369	2.119	89.432	6.902	0.924	13.389
MT270	3.373	2.374	70.382	7.261	0.758	10.440
MT271	0.823	0.622	75.634	7.868	0.784	9.962
MT272	1.654	1.416	85.661	5.912	1.735	29.355
MT273	1.547	0.984	63.635	7.102	0.915	12.880
MT274	1.934	1.174	60.714	6.960	0.938	13.476
MT275	1.846	0.849	46.008	7.419	0.694	9.352
MT276	0.837	0.602	71.861	7.857	0.760	9.675
MT277	0.915	0.553	60.421	7.764	0.995	12.815
MT278	0.716	0.507	70.824	8.009	0.717	8.957
MT279	2.182	0.984	45.083	6.002	0.728	12.120
MT280	2.161	1.215	56.207	5.668	1.432	25.264
MT281	2.087	1.144	54.826	5.671	1.502	26.486
MT282	1.818	1.316	72.387	4.775	2.342	49.053
MT283	2.224	0.940	42.238	6.080	0.795	13.079
MT284	2.394	1.090	45.539	7.094	0.959	13.518
MT285	2.497	1.514	60.645	7.433	0.748	10.068
MT286	0.884	0.661	74.742	8.255	0.760	9.213
MT287	0.528	0.396	74.899	8.087	0.543	6.719
MT288	2.998	0.982	32.737	6.720	0.603	8.974
MT289	1.876	0.826	44.053	6.291	0.613	9.744
MT290	2.052	1.094	53.282	6.461	0.578	8.939
MT291	1.768	1.205	68.150	6.409	0.843	13.157
MT292	2.052	1.094	53.282	6.461	0.578	8.939
MT293	1.794	1.236	68.912	6.399	0.844	13.188
MT294	1.864	0.769	41.272	7.697	0.732	9.512
MT295	2.036	0.833	40.890	7.814	0.504	6.449
MT296	1.871	0.757	40.461	7.971	0.404	5.067
MT297	0.990	0.634	64.076	6.993	1.485	21.237
MT298	1.905	1.367	71.793	6.823	0.624	9.151
MT299	2.091	0.910	43.502	7.200	0.922	12.812
MT300	1.347	0.552	40.996	7.922	0.518	6.536
MT301	0.758	0.336	44.328	7.567	0.578	7.644
MT302	1.950	1.102	56.509	7.756	0.636	8.202
MT303	1.849	0.810	43.809	7.734	0.648	8.383
MT304	1.940	0.836	43.092	7.749	0.411	5.306
MT305	2.193	1.224	55.806	6.836	0.659	9.633
MT306	1.656	1.241	74.951	7.570	0.798	10.536
MT307	1.332	0.977	73.310	7.248	0.654	9.019

MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT308	3.139	2.436	77.597	6.999	0.661	9.443
MT309	1.209	0.574	47.493	7.527	0.818	10.869
MT310	1.076	0.501	46.536	7.728	0.864	11.184
MT311	1.251	0.778	62.187	7.696	0.787	10.231
MT312	1.221	0.856	70.091	7.449	0.903	12.124
MT313	1.243	0.950	76.461	6.946	0.969	13.950
MT314	0.921	0.407	44.183	7.969	1.204	15.103
MT315	1.108	0.618	55.762	7.999	0.729	9.118
MT316	1.007	0.484	48.031	7.980	0.488	6.112
MT317	1.357	0.703	51.854	7.760	0.706	9.101
MT318	1.104	0.641	58.091	7.803	0.821	10.517
MT319	1.240	0.754	60.827	7.829	0.567	7.238
MT320	0.796	0.557	69.964	7.892	1.325	16.783
MT321	2.146	0.840	39.167	7.049	0.714	10.131
MT322	2.249	0.996	44.298	6.246	0.410	6.559
MT323	2.025	1.123	55.462	7.666	0.575	7.495
MT324	1.142	0.706	61.819	8.178	0.764	9.339
MT325	3.050	2.111	69.207	7.347	0.784	10.669
MT326	3.556	1.965	55.250	6.975	0.603	8.652
MT327	2.308	1.126	48.772	6.913	0.818	11.838
MT328	1.945	1.465	75.340	7.155	0.894	12.500
MT329	2.535	1.624	64.060	7.153	0.691	9.658
MT330	1.854	1.180	63.635	7.067	0.804	11.376
MT331	2.495	1.309	52.483	7.285	0.596	8.186
MT332	2.620	1.567	59.806	7.132	0.700	9.810
MT333	1.718	0.922	53.657	7.013	0.829	11.824
MT334	2.455	1.618	65.892	7.028	0.849	12.077
MT335	1.873	0.954	50.941	6.199	0.598	9.647
MT336	0.903	0.497	55.096	7.591	0.894	11.780
MT337	1.134	0.550	48.520	7.642	0.875	11.451
MT338	0.610	0.520	85.302	7.811	0.875	11.199
MT339	0.732	0.807	110.254	7.586	0.833	10.982
MT340	1.349	0.789	58.481	7.601	0.780	10.256
MT341	2.370	1.456	61.404	6.955	0.913	13.124
MT342	1.776	0.793	44.659	6.066	0.798	13.158
MT343	1.621	1.035	63.895	5.854	1.526	26.070
MT344	1.760	1.336	75.891	6.088	1.743	28.625
MT345	2.250	1.624	72.176	6.362	1.045	16.423
MT346	1.649	1.488	90.256	6.517	1.106	16.967
MT347	2.270	1.621	71.406	6.995	0.995	14.224
MT348	2.779	1.051	37.826	7.064	0.858	12.143
MT349	2.506	1.138	45.427	7.166	0.786	10.968
MT350	2.638	4.699	178.097	4.973	2.142	43.079
MT351	2.376	1.705	71.746	4.462	2.546	57.064
MT352	1.051	0.559	53.197	7.384	0.828	11.207
MT353	1.733	0.751	43.349	7.066	0.547	7.738
MT354	1.019	0.502	49.255	7.889	0.616	7.812
MT355	1.074	0.505	47.025	7.903	0.652	8.248
MT356	1.047	0.547	52.240	7.824	0.695	8.888
MT357	1.202	0.619	51.457	7.886	0.761	9.646
MT358	1.002	0.510	50.911	7.988	0.667	8.351

MT359	1.237	0.596	48.208	7.751	1.025	13.227
MT360	1.277	1.140	89.222	6.697	0.654	9.770
MT361	0.556	0.591	106.434	6.287	2.237	35.584
MT362	1.619	1.278	78.971	6.715	0.627	9.332
MT363	2.372	1.037	43.727	7.217	0.764	10.582
MT364	2.169	1.255	57.835	7.179	0.791	11.017
MT365	2.342	1.243	53.087	7.089	0.777	10.965
MT366	1.304	0.662	50.781	7.438	0.846	11.368
MT367	1.980	1.261	63.698	7.650	0.797	10.414
MT368	1.023	0.571	55.808	7.954	0.698	8.774
MT369	0.986	0.602	60.993	7.575	1.995	26.338
MT370	1.109	0.533	48.099	7.871	0.730	9.277
MT371	1.032	0.561	54.368	7.827	0.686	8.759
MT372	1.031	0.523	50.746	8.161	0.517	6.340
MT373	42.133	23.990	56.938	6.837	0.706	10.326
MT374	2.160	0.926	42.878	7.348	0.767	10.442
MT375	2.712	1.185	43.712	7.262	0.585	8.051
MT376	2.260	0.894	39.548	7.323	0.705	9.626
MT377	2.280	1.089	47.747	7.263	0.781	10.748
MT378	2.685	1.191	44.366	7.251	0.596	8.220
MT379	0.821	0.388	47.198	8.176	0.548	6.698
MT380	2.719	2.785	102.416	7.616	1.022	13.417
MT381	0.980	0.494	50.465	8.108	0.817	10.077
MT382	0.935	0.505	54.021	7.978	0.897	11.244
MT383	1.180	0.723	61.219	8.132	0.767	9.427
MT384	0.918	0.555	60.492	7.620	1.157	15.190
MT385	0.914	0.438	47.843	7.911	0.926	11.711
MT386	1.295	1.281	98.919	6.911	0.855	12.371
MT387	1.386	0.985	71.021	7.204	0.588	8.163
MT388	5.548	14.273	257.267	7.113	0.861	12.106
MT389	2.102	1.627	77.409	7.169	0.692	9.649
MT390	1.650	0.735	44.515	6.103	0.843	13.820
MT391	2.756	1.119	40.596	6.851	0.520	7.596
MT392	0.845	0.395	46.713	7.793	1.027	13.180
MT393	1.083	0.516	47.642	7.801	0.640	8.202
MT394	2.235	1.249	55.863	7.850	0.582	7.421
MT395	3.290	1.892	57.505	6.840	0.943	13.787
MT396	0.734	0.525	71.449	7.895	0.849	10.760
MT397	1.475	1.342	90.980	6.153	0.850	13.806
MT398	1.928	0.971	50.387	7.047	0.460	6.521
MT399	2.677	1.186	44.293	6.896	0.456	6.613
MT400	3.035	1.312	43.228	4.900	0.630	12.851
MT401	3.698	1.621	43.836	6.420	0.886	13.805
MT402	1.782	1.058	59.349	5.925	1.513	25.542
MT403	1.501	1.164	77.543	5.172	2.382	46.067
MT405	1.843	1.247	67.664	6.872	0.558	8.117
MT406	2.408	1.285	53.357	6.686	0.863	12.902
MT407	0.588	0.521	88.646	7.901	0.600	7.590
MT408	0.879	0.520	59.123	7.984	0.591	7.399
MT409	0.764	0.580	76.004	8.061	0.591	7.334
MT410	0.713	0.447	62.721	8.089	0.660	8.164
MT411	0.827	0.505	61.069	8.097	0.615	7.597

MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT412	0.831	0.586	70.554	8.128	0.556	6.844
MT413	1.341	0.732	54.610	8.392	0.620	7.388
MT414	0.981	0.457	46.556	7.252	1.368	18.872
MT415	1.071	0.463	43.197	6.880	1.493	21.697
MT416	0.992	0.501	50.526	7.250	1.127	15.541
MT417	0.976	0.488	50.043	7.393	1.134	15.346
MT418	0.980	0.444	45.274	7.042	1.150	16.333
MT419	0.972	0.429	44.175	7.100	1.145	16.129
MT420	0.930	0.419	45.004	7.119	1.140	16.012
MT421	1.130	0.570	50.432	7.652	0.742	9.700
MT422	0.856	0.494	57.709	6.501	1.191	18.318
MT423	0.914	0.487	53.319	7.469	1.126	15.070
MT424	0.926	0.517	55.771	7.475	1.099	14.708
MT425	0.920	0.517	56.218	6.688	2.371	35.454
MT426	0.709	0.490	69.029	7.197	1.118	15.531
MT427	1.017	0.434	42.660	6.893	1.141	16.555
MT428	1.125	0.578	51.349	7.403	1.077	14.542
MT429	1.016	0.441	43.406	6.828	1.150	16.845
MT430	1.451	0.752	51.842	7.623	0.635	8.336
MT431	1.339	0.884	65.987	7.746	0.720	9.292
MT432	1.644	0.852	51.792	7.370	0.696	9.442
MT433	1.823	0.891	48.890	7.289	0.950	13.037
MT434	3.146	1.716	54.559	6.990	0.546	7.805
MT435	1.812	1.037	57.253	6.352	0.700	11.016
MT436	2.827	6.944	245.638	5.950	1.562	26.246
MT437	1.951	1.368	70.113	6.310	0.753	11.933
MT438	2.769	1.350	48.744	7.276	0.733	10.068
MT439	2.556	1.114	43.588	7.279	0.743	10.208
MT440	1.743	1.376	78.951	7.131	1.217	17.071
MT441	0.808	0.495	61.271	5.754	1.497	26.016
MT442	1.072	0.594	55.388	7.474	0.755	10.097
MT443	1.386	0.691	49.833	8.056	0.382	4.739
MT444	1.408	0.673	47.800	7.828	0.724	9.249
MT445	2.929	1.216	41.531	7.000	0.543	7.754
MT446	2.803	1.071	38.217	6.935	0.519	7.479
MT447	2.490	1.203	48.329	7.010	0.772	11.012
MT448	2.530	1.238	48.939	6.756	0.695	10.291
MT449	2.810	1.236	43.998	5.741	1.454	25.325
MT450	3.000	1.000	33.333	6.050	0.450	7.438
MT451	1.210	0.867	71.679	7.170	1.547	21.578
MT452	1.308	0.687	52.496	7.409	0.948	12.796
MT453	1.378	0.757	54.928	7.371	0.894	12.132
MT454	1.543	0.796	51.588	7.328	0.807	11.010
MT455	2.678	1.521	56.780	7.005	0.973	13.890
MT456	0.846	0.595	70.369	7.665	0.873	11.391
MT457	2.633	1.069	40.605	7.220	0.680	9.422
MT458	1.640	0.927	56.506	7.612	0.521	6.849
MT459	2.865	1.731	60.409	6.983	0.712	10.195
MT460	1.455	0.889	61.107	7.640	0.607	7.946
MT461	1.606	1.041	64.855	7.492	0.815	10.877
MT462	4.390	6.376	145.260	6.197	0.848	13.678

MT463	1.722	1.088	63.173	7.475	0.818	10.939
MT464	1.627	1.134	69.740	7.426	0.889	11.969
MT465	2.133	1.074	50.373	7.271	0.905	12.447
MT466	1.517	0.959	63.230	7.300	0.660	9.046
MT467	1.835	1.268	69.085	7.407	0.853	11.511
MT468	2.155	1.020	47.315	7.295	0.854	11.705
MT469	1.337	0.620	46.370	8.046	0.394	4.896
MT470	1.134	0.621	54.770	7.977	0.561	7.034
MT471	0.907	0.468	51.596	7.809	0.836	10.705
MT472	0.947	0.890	93.977	7.731	0.702	9.087
MT473	2.364	1.255	53.095	7.023	0.855	12.178
MT474	0.851	0.794	93.206	7.627	0.670	8.784
MT475	2.011	1.257	62.515	7.442	0.778	10.459
MT476	1.588	0.839	52.826	7.052	1.750	24.818
MT477	1.281	0.790	61.690	7.797	0.735	9.427
MT478	1.596	1.730	108.400	7.278	0.875	12.026
MT479	1.744	1.391	79.768	7.542	0.940	12.461
MT481	1.229	0.683	55.540	7.816	0.732	9.367
MT482	1.227	0.742	60.495	7.933	0.743	9.371
MT483	1.936	1.387	71.629	5.181	2.002	38.644
MT484	0.669	0.704	105.258	5.425	3.468	63.932
MT485	1.883	0.892	47.395	6.355	0.702	11.041
MT486	2.652	1.722	64.935	7.460	0.728	9.758
MT487	2.213	1.191	53.824	5.921	0.657	11.100
MT488	0.656	0.545	83.071	7.904	0.795	10.059
MT489	0.940	0.517	55.071	7.703	0.922	11.967
MT491	3.667	13.886	378.699	4.660	3.188	68.416
MT492	1.251	1.624	129.837	2.801	2.618	93.478
MT493	1.971	1.763	89.436	3.786	2.911	76.894
MT494	1.248	1.187	95.154	4.116	2.824	68.608
MT495	0.823	1.012	122.966	3.653	3.215	88.005
MT496	1.509	1.114	73.864	4.558	2.945	64.608
MT497	1.823	1.790	98.223	3.483	2.267	65.079
MT498	0.931	0.771	82.908	7.313	0.843	11.528
MT499	0.513	0.416	81.101	7.518	0.657	8.737
MT500	0.655	0.463	70.580	7.883	0.773	9.808
MT501	1.450	0.856	59.003	7.859	0.608	7.733
MT502	1.679	0.806	48.022	7.851	0.555	7.071
MT503	1.590	1.080	67.915	7.650	1.400	18.296
MT504	1.011	1.054	104.333	8.064	1.006	12.480
MT505	1.015	0.890	87.678	7.972	1.067	13.378
MT506	2.078	1.027	49.449	7.200	0.771	10.702
MT507	1.902	1.207	63.461	6.375	1.020	16.004
MT508	3.675	6.567	178.688	6.253	0.822	13.145
MT509	2.192	1.218	55.544	6.164	0.887	14.398
MT510	1.825	1.088	59.625	6.139	0.924	15.054
MT511	1.038	0.514	49.503	7.798	0.687	8.810
MT512	1.192	0.906	75.990	7.058	2.323	32.913
MT513	1.580	0.706	44.665	7.754	0.749	9.661
MT514	1.284	0.691	53.863	8.243	0.741	8.986
MT516	1.123	0.639	56.856	7.830	0.611	7.806
MT517	1.565	1.002	63.999	7.521	0.656	8.723

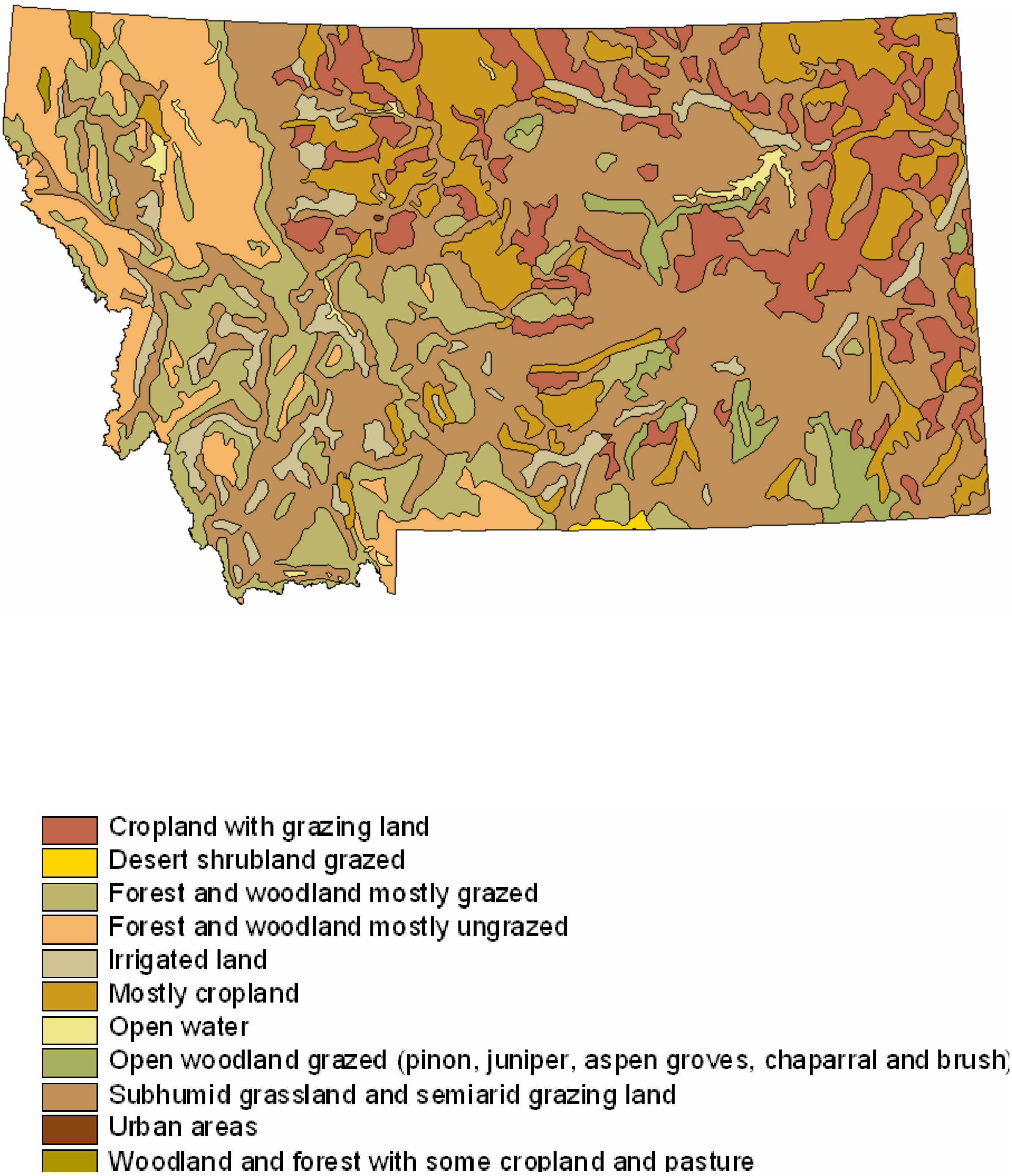
MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT518	1.534	0.714	46.590	7.828	0.646	8.256
MT519	1.894	1.331	70.276	7.614	0.764	10.032
MT520	1.760	1.086	61.692	7.626	0.936	12.279
MT521	2.447	1.289	52.691	7.554	0.865	11.450
MT522	2.242	1.310	58.414	7.158	0.787	11.000
MT523	3.627	6.233	171.864	7.549	0.802	10.623
MT524	8.032	16.312	203.082	7.797	0.557	7.141
MT525	1.213	0.604	49.785	7.295	0.843	11.559
MT526	1.331	0.772	57.998	7.534	0.825	10.956
MT527	1.427	0.726	50.855	7.349	0.839	11.410
MT528	1.512	0.732	48.431	7.307	0.844	11.554
MT529	1.301	0.785	60.346	7.761	0.591	7.616
MT530	1.326	0.695	52.423	7.837	0.642	8.196
MT531	1.373	0.689	50.165	6.347	0.936	14.754
MT532	0.902	1.112	123.299	5.052	2.228	44.099
MT533	1.886	1.543	81.791	6.734	0.804	11.940
MT534	1.461	0.883	60.437	7.485	0.764	10.204
MT535	2.354	0.819	34.799	7.421	0.661	8.903
MT536	1.941	4.436	228.482	5.537	1.017	18.358
MT538	3.543	1.503	42.418	7.680	0.769	10.018
MT539	0.042	0.042	100.000	0.000	0.000	
MT540	13.583	23.217	170.936	7.019	0.927	13.211
MT541	1.434	1.473	102.748	5.814	2.339	40.240
MT542	1.360	1.118	82.253	5.960	2.534	42.520
MT543	3.120	1.443	46.246	7.493	0.809	10.791
MT544	2.475	1.290	52.127	6.838	0.854	12.490
MT545	2.066	0.776	37.593	6.858	0.994	14.488
MT546	1.544	1.028	66.553	6.133	0.880	14.354
MT547	1.098	0.675	61.498	6.020	0.718	11.926
MT548	3.247	2.244	69.108	7.422	0.749	10.094
MT549	1.112	0.639	57.501	7.756	0.759	9.783
MT550	2.174	0.864	39.732	7.317	0.651	8.903
MT551	1.187	2.266	190.965	6.993	0.797	11.397
MT552	1.797	1.187	66.044	6.793	0.699	10.283
MT553	1.698	0.783	46.134	7.331	0.881	12.011
MT554	1.906	1.010	52.976	7.382	0.783	10.603
MT555	2.199	1.154	52.467	7.643	0.663	8.668
MT556	1.893	0.841	44.417	7.204	0.787	10.924
MT557	1.206	0.893	74.007	7.439	0.844	11.345
MT558	1.232	0.934	75.776	7.433	0.733	9.864
MT559	1.338	0.976	72.915	7.595	0.762	10.039
MT560	0.984	0.455	46.179	5.927	1.546	26.085
MT561	1.265	0.849	67.128	7.721	0.782	10.125
MT562	1.257	0.840	66.855	7.696	0.783	10.172
MT563	1.410	0.717	50.873	7.388	0.787	10.655
MT564	1.514	0.773	51.050	7.427	0.764	10.290
MT565	1.605	0.827	51.511	7.326	0.781	10.658
MT566	1.506	0.936	62.173	6.200	0.851	13.730
MT567	1.335	1.041	77.996	6.398	0.827	12.924
MT568	0.765	0.472	61.711	7.590	1.148	15.125
MT569	1.122	1.080	96.246	7.642	0.731	9.560

MT570	3.160	1.690	53.470	7.417	0.687	9.263
MT571	2.967	2.044	68.876	7.369	0.682	9.261
MT572	1.185	0.791	66.778	6.129	0.896	14.624
MT573	2.110	1.066	50.532	7.316	0.875	11.961
MT574	1.614	1.057	65.474	7.383	0.877	11.873
MT575	0.840	0.577	68.629	7.589	0.691	9.107
MT576	2.245	1.008	44.908	6.275	0.810	12.913
MT577	1.817	1.170	64.373	7.068	0.883	12.497
MT578	2.363	1.002	42.428	6.812	0.548	8.043
MT579	1.653	1.133	68.535	6.540	0.913	13.964
MT580	1.717	0.773	45.056	7.679	0.568	7.394
MT581	1.569	0.953	60.733	6.716	1.354	20.163
MT582	1.468	1.068	72.716	6.599	1.970	29.852
MT583	5.088	12.120	238.212	8.106	0.606	7.474
MT584	2.124	1.093	51.464	5.858	0.447	7.636
MT585	2.023	1.079	53.359	7.317	0.880	12.025
MT586	1.945	0.924	47.515	7.264	0.821	11.303
MT587	2.050	0.884	43.104	7.248	0.619	8.546
MT588	1.770	0.837	47.277	7.213	0.782	10.845
MT589	7.933	8.741	110.193	7.391	1.101	14.894
MT590	0.906	0.481	53.050	7.549	0.782	10.360
MT591	2.736	1.330	48.623	7.171	0.608	8.475
MT592	2.109	1.185	56.185	7.049	0.680	9.649
MT593	0.863	0.419	48.489	6.981	1.230	17.617
MT594	1.232	0.615	49.952	8.170	0.814	9.958
MT595	0.991	0.772	77.847	8.074	0.907	11.232
MT597	0.753	0.371	49.325	7.691	0.779	10.132
MT598	1.561	1.350	86.480	7.084	0.950	13.404
MT599	1.911	1.021	53.422	6.456	0.813	12.591
MT600	1.851	0.917	49.548	7.374	0.666	9.035
MT601	1.606	0.917	57.088	7.519	0.693	9.213
MT602	1.399	0.824	58.912	7.661	0.763	9.964
MT603	1.322	0.664	50.215	7.695	0.689	8.947
MT604	1.692	0.920	54.379	8.044	0.790	9.817
MT605	0.183	0.246	134.807	4.712	1.251	26.559
MT606	1.164	0.749	64.301	7.620	0.846	11.105
MT607	1.030	0.550	53.419	7.809	0.878	11.244
MT608	1.375	0.806	58.610	7.578	0.786	10.377
MT609	1.948	1.386	71.169	6.080	0.557	9.156
MT610	2.136	1.246	58.358	6.005	0.617	10.278
MT611	2.215	1.248	56.331	5.970	0.473	7.930
MT612	1.252	0.955	76.305	7.532	0.710	9.423
MT614	1.051	0.537	51.076	6.665	0.644	9.667
MT617	1.580	1.240	78.516	7.580	0.749	9.877
MT618	1.418	1.120	79.000	7.650	0.796	10.401
MT619	1.372	1.076	78.476	7.697	0.680	8.834
MT620	1.093	0.511	46.752	7.419	1.001	13.497
MT621	0.993	0.443	44.652	7.397	1.100	14.875
MT622	1.194	0.717	60.043	7.690	0.582	7.565
MT623	2.019	1.363	67.488	7.346	0.906	12.338
MT624	1.739	1.260	72.430	7.530	0.843	11.201
MT625	1.521	0.955	62.815	7.649	0.905	11.826

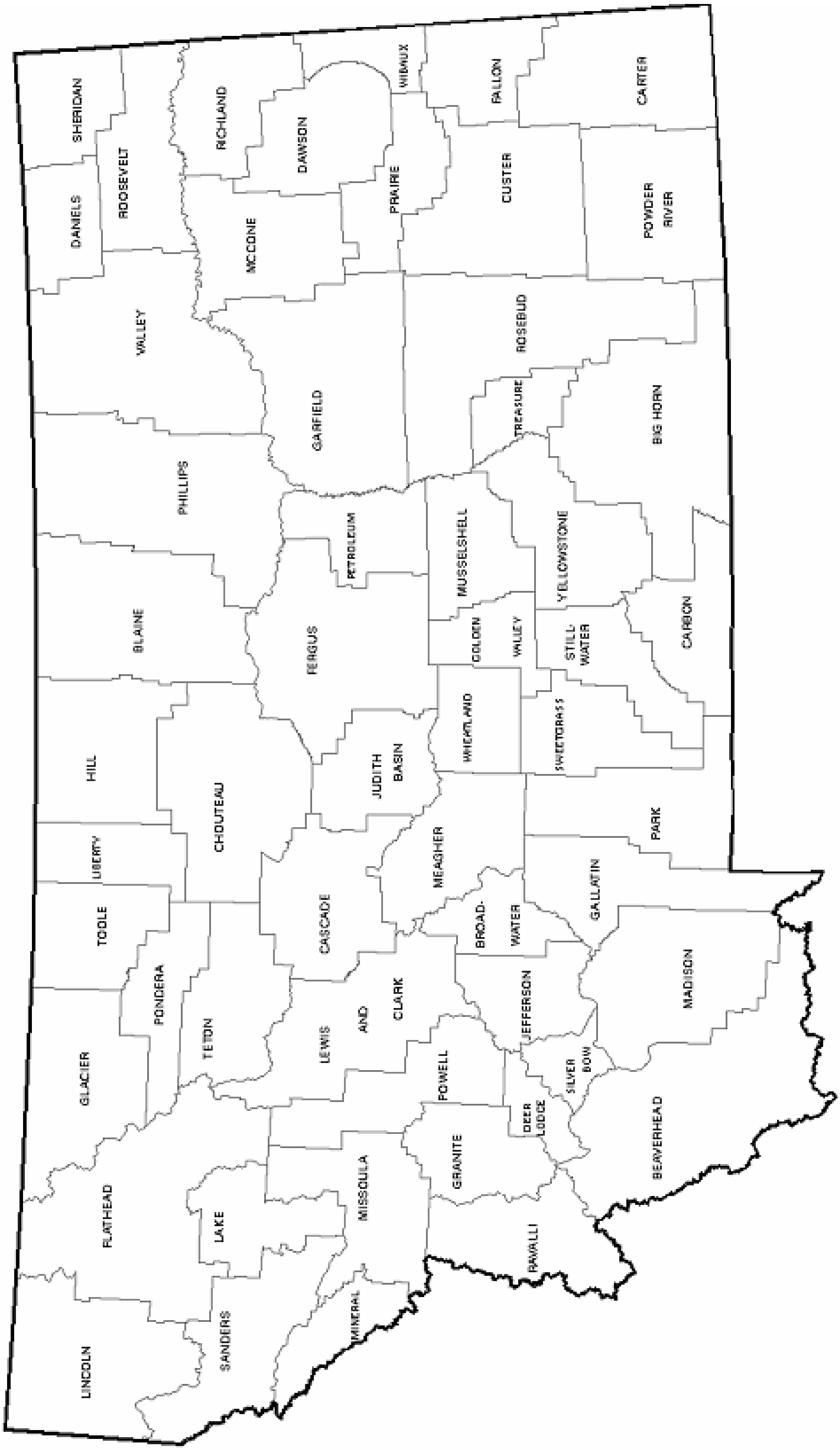
MUID	AVGOM	ST_DEV_OM	CV_OM	AVGPH	ST_DEV_PH	CV_PH
MT626	1.308	0.757	57.828	7.636	0.757	9.916
MT627	2.232	2.074	92.899	6.647	0.953	14.342
MT628	1.720	1.620	94.205	7.560	0.701	9.269
MT629	2.222	1.957	88.047	7.225	0.841	11.639
MT630	1.718	1.329	77.369	6.691	1.982	29.617
MT631	1.442	1.231	85.341	7.613	0.752	9.875
MT632	1.926	1.770	91.867	7.467	0.748	10.017
MT633	2.411	1.016	42.144	6.537	0.746	11.416
MT634	2.074	1.184	57.098	6.416	0.843	13.136
MT635	1.794	0.949	52.911	7.175	0.737	10.278
MT636	1.924	1.131	58.782	7.371	0.682	9.251
MT637	1.889	1.326	70.190	7.447	0.689	9.258
MT638	2.122	1.143	53.836	7.292	0.614	8.423
MT639	1.778	1.248	70.183	7.410	0.707	9.534
MT640	3.105	2.037	65.626	7.472	0.836	11.188
MT641	1.941	0.743	38.297	7.835	0.471	6.006
MT642	2.016	0.820	40.695	8.045	0.430	5.345
MT643	1.528	1.099	71.927	5.909	0.739	12.499
MT644	9.865	11.973	121.368	7.125	1.783	25.018
MT645	1.564	1.215	77.714	7.627	0.652	8.543
MT646	1.905	0.837	43.931	6.399	0.725	11.335
MT647	1.998	0.772	38.636	6.590	0.701	10.631
MT648	1.866	0.902	48.331	6.508	0.722	11.092
MT649	2.016	1.031	51.146	5.828	1.642	28.176
MT650	2.130	1.013	47.577	6.542	0.778	11.890
MT651	1.268	1.049	82.714	7.614	0.732	9.612
MT652	1.929	1.010	52.350	7.786	0.535	6.874
MT653	1.133	1.073	94.710	6.625	0.723	10.911
MT654	3.635	2.821	77.610	6.999	0.759	10.850
MT655	2.098	1.136	54.130	6.234	0.678	10.879
MT656	1.948	0.859	44.097	7.199	0.745	10.348
MT657	1.458	0.644	44.145	7.224	0.708	9.807
MT658	1.631	0.710	43.538	7.090	0.693	9.777
MT659	1.147	0.616	53.684	7.557	0.625	8.268
MT660	1.323	0.861	65.095	5.614	1.590	28.326
MT661	1.762	1.547	87.805	6.159	0.832	13.507
MT662	1.860	1.010	54.292	6.205	0.864	13.927
MT663	3.168	2.341	73.883	6.613	0.970	14.671
MT664	1.769	1.005	56.847	5.990	0.807	13.474
MT665	2.239	1.069	47.748	7.052	1.928	27.343
MT666	1.494	0.606	40.542	7.407	0.507	6.848
MT667	0.977	0.698	71.363	5.501	2.625	47.720
MT668	1.146	0.529	46.194	7.696	0.786	10.216
MT669	1.090	0.552	50.640	7.724	0.792	10.254
MT670	0.939	0.407	43.336	7.692	0.856	11.128
MT671	1.075	0.527	49.016	7.665	0.917	11.964
MT672	0.977	0.746	76.378	7.719	0.664	8.601
MT673	0.688	0.598	86.977	7.881	0.640	8.116
MT674	0.758	0.595	78.528	7.821	0.799	10.213
MT675	0.960	0.732	76.258	7.665	0.762	9.945
MT676	0.646	0.674	104.365	7.666	0.711	9.276

MT677	0.389	0.386	99.216	7.717	0.638	8.273
MT678	0.799	0.856	107.044	7.590	0.721	9.498
MT679	0.675	0.493	73.082	7.633	0.768	10.059
MT680	1.034	0.681	65.912	7.075	1.336	18.878
MT681	1.686	0.619	36.729	6.966	0.470	6.743
MT682	1.333	1.081	81.063	6.324	0.691	10.923
MT683	1.906	0.752	39.431	6.571	0.707	10.761
MT684	0.875	0.773	88.372	6.327	0.852	13.461
MT685	1.276	0.667	52.267	7.461	0.789	10.576
MT686	1.057	0.644	60.878	7.704	0.740	9.611
MT687	1.253	0.846	67.557	7.672	0.706	9.196
MT688	1.193	0.615	51.599	7.803	0.682	8.743
MT689	1.146	0.794	69.268	7.901	0.898	11.360
MT690	0.618	0.706	114.289	7.960	0.614	7.712
MT691	1.178	0.813	69.032	6.485	1.242	19.157
MT692	1.000	0.581	58.062	7.579	0.812	10.710
MT693	0.812	0.544	67.033	7.817	0.827	10.582
MT694	0.650	0.539	82.916	8.013	0.841	10.495
MT695	0.925	0.491	53.088	7.907	0.643	8.134
MT696	2.167	2.030	93.705	4.381	2.760	63.006
MT697	2.466	1.248	50.590	6.426	0.630	9.801
MT698	3.851	1.608	41.758	6.468	0.846	13.083
MT699	2.051	1.072	52.263	6.403	0.737	11.506
MT702	1.333	1.078	80.885	6.377	0.798	12.507
MT703	0.829	0.430	51.814	6.966	1.191	17.095
MT704	1.788	1.466	81.970	7.592	0.697	9.183
MT705	0.901	0.577	64.058	7.664	0.559	7.288

Appendix G Land Use Map for the state of Montana



Appendix H County map



Source: http://mt.gov/liv/brands/forms/countymap.jpg

Appendix I Field samples

Table 1 The results for the field sample analyses.

Location	Sample	OM (%)	PH		Location	Sample	OM (%)	PH
A	1	2.47	8.0		**H**	1	1.49	6.9
A	2	2.68	7.9		**H**	2	2.02	7.6
A	3	4.22	8.2		**H**	3	1.51	6.4
A	4	3.51	8.3		**H**	4	2.30	6.5
A	5	2.28	7.9		**H**	5	1.72	8.2
A	6	0.86	8.2		**H**	6	0.81	8.3
A	7	1.69	8.1		**I**	1	1.60	8.2
A	8	2.48	7.8		**I**	2	1.59	8.2
B	1	2.49	8.1		**I**	3	2.35	7.9
B	2	2.54	8.1		**I**	4	1.48	6.6
B	3	1.89	8.3		**I**	5	2.60	6.8
C	1	0.66	8.3		**I**	6	2.04	7.4
C	2	1.15	8.3		**I**	7	1.34	8.3
C	3	2.94	7.9		**I**	8	2.13	8.2
C	4	2.60	7.9		**I**	9	1.27	9.4
C	5	3.03	8.1		**I**	10	3.06	7.1
C	6	2.99	8.2		**J**	1	3.63	6.8
C	7	0.86	8.1		**J**	2	4.10	6.8
C	8	2.11	8.0		**J**	3	6.93	5.8
C	9	2.44	7.4		**J**	4	1.85	8.1
D	1	1.63	8.1		**J**	5	8.21	6.4
D	2	1.05	8.0		**J**	6	18.63	8.5
D	3	1.90	8.1		**J**	7	5.23	8.4
D	4	1.43	8.2		**J**	8	2.12	8.1
D	5	1.29	8.1		**J**	9	4.04	6.9
D	6	1.56	8.1		**J**	10	2.56	7.0
D	7	1.72	8.1		**K**	1	2.05	7.1
E	1	1.63	8.2		**K**	2	2.51	8.1
E	2	1.66	8.4		**K**	3	2.32	6.5
E	3	1.31	7.7		**K**	4	0.97	7.9
E	4	3.45	7.9		**K**	5	2.15	7.6
E	5	2.43	9.1		**K**	6	3.71	7.0
E	6	1.80	8.2		**K**	7	2.46	7.1
E	7	1.14	7.5		**K**	8	2.95	7.6
E	8	1.19	7.7		**K**	9	1.61	7.8
E	9	1.56	8.3		**K**	10	2.18	7.8
E	10	1.52	8.4		**L**	1	2.36	8.3
E	11	2.34	8.2		**L**	2	2.82	8.0
E	12	1.93	7.3		**L**	3	1.85	6.8
E	13	1.73	8.2		**L**	4	3.70	7.8
E	14	1.77	8.2		**L**	5	5.59	6.9
F	1	2.02	8.2		**L**	6	4.63	7.1
F	2	2.05	8.2		**L**	7	1.26	8.1
F	3	1.59	8.3		**L**	8	1.50	8.3
F	4	1.23	8.3		**L**	9	1.32	8.5
F	5	1.95	8.1		**L**	10	2.01	7.6
F	6	1.60	8.3		**L**	11	0.63	8.5

F	7a	2.16	8.4
F	7	1.71	8.3
F	8	2.39	8.0
F	9	2.45	8.3
F	10	2.02	8.1
G	1	1.35	8.3
G	2	2.81	8.1
G	3	1.59	8.3
G	4	1.76	8.2
G	5	1.84	8.1
G	6	1.23	8.2
G	7	0.86	7.9
G	8	0.72	7.9
G	9	0.80	8.4

Appendix J MLRA – STATSGO

Table 1 Mean, standard deviation and the coefficient of variance organic matter calculated from the STATSGO database for the MLRA's.

MLRA	OM MLRA		OM STATSGO		
	μ	σ	μ	σ	CV
52	1.316	0	1.316	0.812	61.697
53A	1.583	0	1.583	1.031	65.098
54	1.246	0	1.246	0.880	70.639
58A	1.047	0	1.047	0.730	69.725
SubMLRA					
52 high	1.329	0	1.329	0.783	58.928
52 low	1.305	0	1.305	0.834	63.895
53A high	1.471	0	1.471	0.962	65.366
53A low	1.663	0	1.663	1.064	63.978
54 high	1.434	0	1.434	1.122	78.271
54 low	1.185	0	1.185	0.777	65.531
58A high	1.092	0	1.092	0.805	75.788
58A low	0.983	0	0.983	0.600	61.062
58A high	1.074	0	1.074	0.791	73.598
58A low	0.981	0	0.981	0.592	60.403
58A forest	1.136	0	1.136	0.837	73.737

Table 2 Mean, standard deviation and the coefficient of variance for the pH calculated from the STATSGO database for the MLRA's.

MLRA	pH MLRA		pH STATSGO		
	μ	σ	μ	σ	CV
52	7.461	0	7.461	0.956	12.812
53A	7.488	0	7.488	0.888	11.857
54	7.741	0	7.741	0.765	9.883
58A	7.632	0	7.632	0.961	12.588
SubMLRA					
52 high	7.438	0	7.438	0.999	13.432
52 low	7.480	0	7.480	0.919	12.291
53A high	7.574	0	7.574	0.772	10.199
53A low	7.461	0	7.461	0.830	11.118
54 high	7.624	0	7.624	0.790	10.365
54 low	7.779	0	7.779	0.753	9.679
58A high	7.634	0	7.634	0.921	12.059
58A low	7.629	0	7.629	1.015	13.308
58A high	7.629	0	7.629	0.918	12.027
58A low	7.625	0	7.625	1.016	13.324
58A forest	7.661	0	7.661	0.944	12.317

Appendix K MLRA - SSURGO

Table 1 Mean, standard deviation and the coefficient of variance for the organic matter calculated from the SSURGO database for the MLRA's.

MLRA	OM MLRA		OM SSURGO			Difference SSURGO – MLRA (OM%)
	μ	σ	μ	σ	CV	
52	1.316	0	1.372	0.826	60.200	0.056
53A	1.583	0	1.874	1.263	67.421	0.291
54	1.246	0	1.555	1.040	66.913	0.309
58A	1.047	0	1.229	0.847	68.905	0.182
SubMLRA						
52 high	1.329	0	1.405	0.839	59.692	0.076
52 low	1.305	0	1.346	0.815	60.530	0.041
53A high	1.471	0	1.787	1.171	65.532	0.316
53A low	1.663	0	1.930	1.317	68.228	0.267
54 high	1.434	0	1.839	1.127	61.297	0.405
54 low	1.185	0	1.465	0.994	67.886	0.28
58A high	1.092	0	1.286	0.926	71.952	0.194
58A low	0.983	0	1.144	0.707	61.750	0.161

Table 2 Mean, standard deviation and the coefficient of variance for the pH calculated from the SSURGO database for the MLRA's.

MLRA	pH MLRA		pH SSURGO			Difference SSURGO – MLRA
	μ	σ	μ	σ	CV	
52	7.461	0	7.504	0.863	11.499	-0.043
53A	7.488	0	7.510	0.786	10.460	-0.022
54	7.741	0	7.629	1.261	16.531	0.112
58A	7.632	0	7.632	0.892	11.692	0
SubMLRA						
52 high	7.438	0	7.498	0.845	11.272	-0.06
52 low	7.480	0	7.508	0.876	11.671	-0.028
53A high	7.574	0	7.607	0.788	10.360	-0.033
53A low	7.461	0	7.446	0.777	10.439	0.015
54 high	7.624	0	7.547	0.807	10.689	0.077
54 low	7.779	0	7.654	1.373	17.933	0.125
58A high	7.634	0	7.603	0.910	11.978	0.031
58A low	7.629	0	7.673	0.863	11.243	-0.06

Appendix L STATSGO – SSURGO

MLRA Scale

Table 1 Comparison of the mean, standard deviation and coefficients of variance of the organic matter and pH for the STATSGO and SSURGO databases.

		SSURGO				STATSGO			
MLRA	SubMLRA	μ_{om}	μ_{ph}	CV om	CV ph	μ_{om}	μ_{ph}	CV om	CV ph
52		1.372	7.504	60.200	11.499	1.316	7.461	61.697	12.812
	high	1.405	7.498	59.692	11.272	1.329	7.438	58.928	13.432
	low	1.346	7.508	60.530	11.671	1.305	7.480	63.895	12.291
53a		1.874	7.510	67.421	10.460	1.583	7.488	65.098	11.857
	high	1.787	7.607	65.532	10.360	1.471	7.574	65.366	10.199
	low	1.930	7.446	68.228	10.439	1.663	7.461	63.978	11.118
54		1.555	7.629	66.913	16.531	1.246	7.741	70.639	9.883
	high	1.839	7.547	61.297	10.689	1.434	7.624	78.271	10.365
	low	1.465	7.654	67.886	17.933	1.185	7.779	65.531	9.679
58a		1.229	7.632	68.905	11.692	1.047	7.632	69.725	12.588
	high	1.271	7.613	72.210	11.732	1.074	7.629	73.598	12.027
	low	1.133	7.678	58.428	11.124	0.981	7.625	60.403	13.324
	forest	1.340	7.572	74.294	12.890	1.136	7.661	73.737	12.317
	high	1.286	7.603	71.952	11.978	1.092	7.634	73.788	12.058
	low	1.144	7.673	61.750	11.243	0.983	7.629	61.062	13.308
	high forest	1.343	7.566	70.824	12.868	1.158	7.655	73.985	12.175
	low forest	1.322	7.606	90.688	12.993	1.018	7.696	70.346	13.005

Producer point of view

Table 2 Comparison of the mean, standard deviation and coefficients of variance of the organic matter for the STATSGO and SSURGO databases.

STATSGO						SSURGO
MUID	Mean om	St dev om	CV om	Mean om	St dev om	CV om
MT001	0.947	0.672	70.994	1.769	1.093	61.797
MT002	0.865	0.484	55.923	1.134	0.586	51.710
MT003	2.399	1.315	54.795	2.173	1.641	75.543
MT004	2.375	1.572	66.187	2.037	1.126	55.255
MT005	2.407	1.326	55.101	2.448	1.185	48.407
MT006	2.605	1.359	52.156	2.336	1.137	48.680
MT007	2.131	1.315	61.704	5.080	4.570	89.959
MT009	1.011	0.514	50.822	1.156	0.694	60.048
MT010	2.803	1.928	68.800	2.729	1.680	61.550
MT016	1.132	0.829	73.274	1.006	0.515	51.213
MT017	0.906	0.528	58.301	1.528	0.946	61.930
MT019	1.080	0.688	63.681	1.303	0.751	57.608

MT020	1.452	0.746	51.400	1.601	0.855	53.409
MT022	1.143	0.652	57.036	1.342	0.749	55.831
MT023	0.968	0.559	57.703	1.125	0.665	59.069
MT024	0.808	0.424	52.508	1.110	0.569	51.208
MT025	1.132	0.497	43.904	1.061	0.510	48.105
MT026	0.973	0.606	62.262	1.232	0.808	65.598
MT027	0.983	0.536	54.499	1.077	0.630	58.534
MT028	0.931	0.574	61.610	1.026	0.585	57.046
MT029	1.134	0.547	48.219	1.134	0.781	68.879
MT030	1.986	0.978	49.232	2.198	1.224	55.687
MT031	0.956	0.424	44.379	1.045	0.624	59.749
MT034	1.318	0.664	50.385	1.462	0.946	64.718
MT035	1.417	0.713	50.349	1.506	0.799	53.083
MT036	1.424	0.733	51.509	1.563	0.950	60.817
MT037	1.288	1.019	79.101	1.381	1.050	75.996
MT041	1.179	0.348	29.504	1.744	0.800	45.879
MT042	1.757	1.154	65.662	2.157	2.561	118.740
MT047	1.604	0.778	48.532	1.425	1.258	88.279
MT048	1.830	1.168	63.820	1.687	1.085	64.297
MT049	1.263	0.839	66.433	1.645	1.078	65.542
MT050	1.904	0.994	52.231	2.143	1.111	51.855
MT051	1.016	0.618	60.833	1.223	0.639	52.277
MT053	0.616	0.365	59.203	0.721	0.782	108.376
MT054	0.902	0.363	40.279	1.235	0.656	53.147
MT055	0.936	0.421	44.948	1.133	0.523	46.186
MT057	0.991	0.559	56.364	1.224	0.758	61.906
MT058	0.927	0.454	48.961	0.982	0.632	64.384
MT059	1.293	1.077	83.297	1.560	0.916	58.725
MT068	1.848	1.466	79.345	2.299	1.266	55.073
MT069	1.539	1.268	82.370	2.053	1.155	56.273
MT070	1.748	1.225	70.065	1.905	1.245	65.359
MT071	3.018	1.453	48.142	2.926	1.602	54.754
MT074	0.952	0.555	58.296	1.209	0.640	52.907
MT075	0.973	0.378	38.865	1.140	0.621	54.418
MT076	1.206	0.896	74.257	1.752	1.227	70.018
MT077	1.484	1.134	76.416	1.600	1.100	68.717
MT078	1.138	0.683	60.050	1.696	0.642	37.864
MT079	1.144	0.719	62.852	1.457	0.870	59.685
MT080	0.914	0.515	56.322	1.609	0.785	48.796
MT081	0.918	0.435	47.357	1.365	0.823	60.304
MT082	1.253	0.651	51.968	1.559	1.060	67.959
MT083	1.106	0.762	68.918	1.556	0.866	55.677
MT084	1.334	1.092	81.843	1.621	1.455	89.751
MT085	1.387	0.880	63.430	1.473	1.036	70.317
MT086	1.194	0.822	68.809	1.721	1.446	84.019
MT087	0.919	0.587	63.914	1.090	0.572	52.515
MT088	0.993	0.385	38.742	0.992	0.510	51.391
MT089	1.223	0.669	54.728	1.317	0.825	62.676
MT090	0.840	0.356	42.425	1.147	0.608	53.004
MT091	0.794	0.406	51.159	1.374	1.194	86.922
MT092	0.831	0.448	53.951	1.103	0.598	54.243
MT093	1.214	0.708	58.304	1.180	0.608	51.510
MT094	0.956	0.427	44.625	1.062	0.581	54.702
MT095	0.931	0.373	40.046	1.157	0.741	64.024

STATSGO						SSURGO
MUID	Mean om	St dev om	CV om	Mean om	St dev om	CV om
MT096	0.837	0.307	36.630	1.263	0.735	58.164
MT097	0.879	0.599	68.165	1.450	1.005	69.322
MT098	0.904	0.486	53.739	1.273	0.765	60.084
MT099	0.787	0.399	50.667	1.003	0.593	59.122
MT100	0.862	0.492	57.069	1.121	0.656	58.502
MT101	0.826	0.382	46.259	1.288	0.859	66.674
MT102	0.778	0.366	47.051	1.079	0.553	51.272
MT103	0.882	0.427	48.369	1.119	0.668	59.721
MT106	1.202	0.838	69.705	1.435	0.841	58.587
MT107	1.096	0.844	76.989	1.348	0.787	58.376
MT108	0.978	0.559	57.113	1.275	0.701	55.000
MT109	1.173	0.884	75.389	1.395	0.742	53.168
MT110	2.988	2.089	69.922	2.346	1.195	50.952
MT111	1.722	1.095	63.588	2.185	1.046	47.847
MT112	1.906	1.066	55.944	1.298	1.258	96.941
MT113	2.106	1.138	54.014	2.975	3.771	126.726
MT114	2.109	0.884	41.903	2.436	1.048	43.033
MT119	1.909	0.978	51.218	2.129	1.049	49.249
MT120	1.487	0.814	54.758	1.460	0.938	64.230
MT125	0.968	0.775	80.087	1.349	0.816	60.493
MT127	1.052	0.659	62.622	1.272	0.702	55.177
MT128	1.013	0.504	49.752	1.331	0.826	62.097
MT131	1.152	0.709	61.565	1.276	0.816	63.929
MT132	1.009	0.515	51.019	1.190	0.566	47.568
MT133	2.518	1.501	59.624	2.254	1.054	46.781
MT141	1.309	1.273	97.264	1.792	1.108	61.822
MT145	0.801	0.613	76.553	1.494	0.887	59.373
MT146	0.981	0.750	76.419	1.851	1.069	57.736
MT148	0.829	0.463	55.802	1.230	0.627	50.955
MT152	0.842	0.533	63.292	1.006	0.641	63.724
MT153	1.694	0.845	49.881	1.481	0.973	65.671
MT154	2.088	0.825	39.522	1.963	1.029	52.437
MT155	1.998	0.747	37.387	2.040	1.035	50.739
MT156	1.061	0.570	53.731	1.144	0.759	66.342
MT157	0.818	0.509	62.215	1.133	0.762	67.307
MT159	0.884	0.500	56.561	1.133	0.665	58.670
MT160	1.037	0.580	55.897	1.044	0.547	52.441
MT161	0.941	0.416	44.201	1.697	0.630	37.092
MT162	0.933	0.617	66.158	1.479	1.901	128.536
MT163	1.125	0.749	66.578	2.240	6.492	289.837
MT164	0.842	0.410	48.679	1.067	0.583	54.658
MT165	0.734	0.551	75.117	1.098	0.654	59.565
MT166	0.989	0.647	65.450	1.549	0.901	58.151
MT167	0.754	0.648	85.951	1.429	1.081	75.666
MT168	0.786	0.446	56.755	1.151	0.597	51.885
MT173	1.321	0.794	60.133	1.452	0.905	62.326
MT174	1.367	1.000	73.189	2.031	1.190	58.576
MT175	1.121	0.794	70.861	1.572	1.178	74.957
MT176	1.154	1.110	96.183	1.487	1.026	68.966
MT177	1.662	0.893	53.715	2.067	1.055	51.055
MT178	1.645	1.011	61.485	2.133	1.393	65.302
MT179	2.131	1.192	55.939	2.657	1.407	52.942

MT182	2.346	1.628	69.390	2.725	1.393	51.122
MT183	0.888	0.643	72.458	1.296	0.834	64.346
MT184	2.346	1.517	64.673	2.060	1.264	61.365
MT185	1.248	0.744	59.640	1.082	0.659	60.865
MT186	1.308	0.676	51.683	1.369	1.189	86.836
MT187	1.500	0.801	53.375	1.361	0.687	50.456
MT188	1.408	0.787	55.878	1.692	0.866	51.168
MT189	1.573	0.756	48.081	1.392	0.793	57.004
MT190	1.529	0.766	50.109	1.351	0.752	55.654
MT191	2.095	1.125	53.686	2.037	1.316	64.576
MT193	2.439	1.326	54.347	2.427	1.515	62.424
MT194	1.109	0.889	80.197	1.893	1.199	63.365
MT195	1.201	0.817	68.053	1.897	1.186	62.520
MT196	2.079	1.105	53.150	2.236	1.535	68.628
MT197	2.000	1.078	53.898	1.880	1.148	61.090
MT200	2.193	0.946	43.115	2.209	0.930	42.119
MT206	1.363	0.673	49.380	1.293	0.693	53.573
MT207	1.126	0.641	56.935	1.273	0.646	50.791
MT209	0.827	0.458	55.412	1.060	0.582	54.910
MT213	1.480	0.930	62.841	5.953	4.911	82.490
MT217	1.897	1.039	54.757	2.515	1.164	46.291
MT218	0.983	0.745	75.787	2.842	2.177	76.595
MT221	1.598	1.143	71.542	0.985	0.698	70.870
MT222	1.640	0.769	46.876	1.882	0.907	48.207
MT223	1.174	0.621	52.921	1.368	0.764	55.861
MT224	0.927	0.532	57.387	1.181	0.684	57.924
MT225	1.047	0.586	55.937	1.171	0.807	68.912
MT226	1.303	0.932	71.502	1.265	0.757	59.873
MT227	1.073	0.607	56.613	1.096	0.537	49.022
MT228	0.975	0.717	73.532	1.550	0.900	58.083
MT239	3.465	1.758	50.731	3.351	2.011	60.029
MT245	0.877	0.435	49.571	1.102	0.734	66.571
MT246	1.266	0.932	73.591	1.448	0.956	66.012
MT247	0.967	0.659	68.127	1.223	0.698	57.052
MT248	0.852	0.440	51.697	0.991	0.655	66.059
MT249	0.665	0.429	64.504	1.023	0.628	61.339
MT252	0.833	0.505	60.621	1.112	0.696	62.584
MT253	0.941	0.514	54.602	1.266	0.717	56.614
MT254	0.986	0.555	56.286	1.158	0.696	60.062
MT255	1.115	0.607	54.480	1.995	2.357	118.134
MT256	0.912	0.494	54.163	1.121	0.941	83.889
MT257	1.163	0.705	60.618	1.178	0.751	63.792
MT258	0.978	0.559	57.113	2.941	3.796	129.090
MT259	0.958	0.585	61.045	1.118	0.536	47.955
MT261	1.072	0.580	54.072	1.228	0.819	66.718
MT262	0.871	0.551	63.302	1.437	5.247	365.125
MT263	1.099	0.541	49.253	1.149	0.614	53.431
MT264	1.005	0.600	59.701	1.232	0.789	64.042
MT265	0.866	0.560	64.706	1.152	0.752	65.243
MT266	0.900	0.726	80.661	1.304	0.935	71.720
MT267	0.956	0.563	58.894	1.674	1.317	78.668
MT268	1.002	0.670	66.874	1.148	0.919	80.045
MT269	2.369	2.119	89.445	2.614	1.682	64.359
MT270	3.373	2.374	70.389	3.316	2.296	69.232

STATSGO						SSURGO
MUID	Mean om	St dev om	CV om	Mean om	St dev om	CV om
MT271	0.823	0.622	75.588	1.181	0.750	63.501
MT273	1.547	0.984	63.631	1.622	1.842	113.584
MT275	1.846	0.850	46.030	2.729	1.447	53.018
MT276	0.837	0.602	71.883	1.106	0.670	60.607
MT277	0.915	0.552	60.357	1.216	0.732	60.170
MT278	0.716	0.507	70.803	1.243	0.810	65.182
MT285	2.497	1.514	60.643	2.695	1.633	60.606
MT287	0.528	0.395	74.805	1.062	0.561	52.824
MT294	1.864	0.769	41.278	2.188	1.056	48.265
MT296	1.871	0.757	40.458	2.026	3.885	191.801
MT297	0.990	0.635	64.124	1.149	0.704	61.202
MT301	0.758	0.336	44.348	1.178	0.805	68.300
MT302	1.950	1.102	56.503	2.308	5.353	231.959
MT303	1.849	0.810	43.804	2.556	1.357	53.083
MT304	1.940	0.836	43.096	2.073	0.991	47.816
MT306	1.656	1.241	74.938	2.009	1.161	57.781
MT309	1.209	0.574	47.515	1.608	1.205	74.948
MT310	1.076	0.501	46.561	1.252	0.713	56.934
MT311	1.251	0.778	62.227	1.564	0.942	60.248
MT312	1.221	0.856	70.119	2.238	6.022	269.130
MT314	0.921	0.407	44.238	1.732	1.263	72.882
MT315	1.108	0.618	55.782	1.288	0.738	57.301
MT316	1.007	0.484	48.037	1.473	0.884	60.008
MT317	1.357	0.704	51.847	1.723	1.137	65.980
MT318	1.104	0.641	58.070	1.249	0.757	60.599
MT319	1.240	0.754	60.832	1.524	0.969	63.578
MT320	0.796	0.557	69.947	1.006	0.640	63.591
MT321	2.146	0.840	39.154	2.160	0.960	44.452
MT323	2.025	1.123	55.476	2.222	1.087	48.921
MT324	1.142	0.706	61.856	1.438	1.095	76.145
MT325	3.050	2.111	69.203	2.282	2.671	117.054
MT327	2.308	1.126	48.770	3.696	3.264	88.300
MT334	2.455	1.618	65.907	2.662	1.294	48.611
MT336	0.903	0.497	55.038	1.320	0.659	49.928
MT337	1.134	0.550	48.541	1.749	1.330	76.071
MT338	0.610	0.521	85.340	0.804	0.602	74.782
MT339	0.732	0.807	110.225	1.113	0.890	79.943
MT340	1.349	0.789	58.510	2.245	1.459	64.991
MT341	2.370	1.456	61.421	2.697	1.414	52.436
MT343	1.621	1.035	63.873	1.687	1.086	64.405
MT344	1.760	1.336	75.911	1.375	0.625	45.476
MT346	1.649	1.488	90.234	2.114	1.417	67.051
MT347	2.270	1.621	71.415	2.877	4.959	172.387
MT349	2.506	1.138	45.428	2.412	1.173	48.639
MT354	1.019	0.502	49.264	1.226	0.643	52.479
MT355	1.074	0.505	47.018	1.121	0.503	44.848
MT356	1.047	0.547	52.226	1.159	0.551	47.543
MT357	1.202	0.619	51.487	1.228	0.660	53.783
MT358	1.002	0.510	50.888	1.056	0.505	47.816
MT359	1.237	0.597	48.234	1.251	0.659	52.692
MT364	2.169	1.255	57.842	2.500	1.000	40.000
MT365	2.342	1.243	53.091	1.777	1.032	58.066

MT366	1.304	0.662	50.753	2.278	1.163	51.054
MT367	1.980	1.261	63.684	1.781	1.162	65.206
MT368	1.023	0.571	55.813	1.127	0.652	57.869
MT369	0.986	0.602	61.021	1.240	0.851	68.614
MT370	1.109	0.533	48.054	1.142	0.684	59.939
MT371	1.032	0.561	54.385	1.272	0.845	66.431
MT372	1.031	0.523	50.771	1.059	0.538	50.782
MT374	2.160	0.926	42.883	2.242	1.324	59.040
MT376	2.260	0.894	39.552	2.268	1.545	68.129
MT377	2.280	1.089	47.745	2.206	1.032	46.794
MT379	0.821	0.387	47.174	0.947	0.588	62.111
MT380	2.719	2.785	102.426	0.951	0.576	60.609
MT381	0.980	0.494	50.404	1.210	0.688	56.842
MT382	0.935	0.505	54.008	1.121	0.696	62.061
MT383	1.180	0.722	61.228	1.159	0.688	59.391
MT384	0.918	0.555	60.455	1.102	0.631	57.248
MT385	0.914	0.437	47.816	1.093	0.756	69.139
MT392	0.845	0.395	46.742	1.861	1.111	59.715
MT393	1.083	0.516	47.623	1.451	0.881	60.706
MT395	3.290	1.892	57.502	3.602	1.932	53.633
MT396	0.734	0.524	71.445	1.054	0.610	57.930
MT406	2.408	1.285	53.360	2.498	1.167	46.710
MT407	0.588	0.522	88.697	0.947	0.628	66.295
MT413	1.341	0.732	54.595	2.056	1.167	56.740
MT414	0.981	0.457	46.602	1.015	0.533	52.548
MT415	1.071	0.463	43.193	1.000	0.610	61.007
MT416	0.992	0.501	50.504	0.881	0.462	52.417
MT417	0.976	0.488	49.985	1.101	0.654	59.378
MT418	0.980	0.444	45.290	1.034	0.694	67.111
MT419	0.972	0.429	44.131	1.159	0.736	63.558
MT420	0.930	0.418	44.982	1.126	0.727	64.561
MT421	1.130	0.570	50.450	1.096	0.613	55.926
MT422	0.856	0.494	57.706	0.895	0.445	49.769
MT423	0.914	0.487	53.263	1.094	0.627	57.347
MT424	0.926	0.517	55.801	1.053	0.589	55.928
MT425	0.920	0.518	56.270	1.076	0.662	61.497
MT426	0.709	0.490	69.097	1.014	0.583	57.515
MT427	1.017	0.434	42.634	0.980	0.679	69.325
MT428	1.125	0.578	51.371	1.077	0.564	52.312
MT429	1.016	0.440	43.352	0.928	0.477	51.435
MT430	1.451	0.752	51.849	2.742	1.545	56.347
MT431	1.339	0.884	66.000	1.627	1.046	64.312
MT433	1.823	0.892	48.910	1.285	0.831	64.668
MT438	2.769	1.349	48.734	3.160	3.302	104.489
MT440	1.743	1.376	78.957	1.594	1.148	72.038
MT442	1.072	0.594	55.423	1.279	0.820	64.106
MT451	1.210	0.867	71.668	1.338	0.730	54.563
MT452	1.308	0.686	52.469	1.283	0.677	52.784
MT453	1.378	0.757	54.932	1.408	0.823	58.442
MT454	1.543	0.796	51.563	1.436	0.788	54.864
MT456	0.846	0.595	70.328	1.115	0.574	51.499
MT459	2.865	1.731	60.405	2.651	1.857	70.049
MT463	1.722	1.088	63.162	1.687	0.924	54.798
MT464	1.627	1.134	69.727	1.673	0.956	57.108

STATSGO						SSURGO
MUID	Mean om	St dev om	CV om	Mean om	St dev om	CV om
MT465	2.133	1.074	50.363	1.818	1.193	65.602
MT466	1.517	0.959	63.228	1.432	0.947	66.125
MT467	1.835	1.268	69.083	1.615	1.067	66.054
MT468	2.155	1.020	47.323	2.215	1.391	62.822
MT471	0.907	0.468	51.596	0.988	1.517	153.488
MT472	0.947	0.890	93.975	1.326	0.937	70.672
MT474	0.851	0.794	93.270	1.868	2.238	119.822
MT475	2.011	1.257	62.525	2.744	1.023	37.284
MT484	0.669	0.704	105.272	1.691	1.182	69.893
MT485	1.883	0.892	47.381	8.565	5.072	59.219
MT486	2.652	1.722	64.940	2.287	1.264	55.286
MT488	0.656	0.545	83.076	1.095	0.725	66.151
MT489	0.940	0.518	55.073	1.072	0.589	54.973
MT499	0.513	0.416	81.078	0.965	0.771	79.957
MT500	0.655	0.463	70.626	1.129	0.629	55.699
MT501	1.450	0.856	59.005	1.615	0.889	55.019
MT502	1.679	0.806	48.018	2.037	2.717	133.345
MT503	1.590	1.080	67.913	1.885	1.111	58.954
MT506	2.078	1.028	49.452	1.968	1.041	52.907
MT511	1.038	0.514	49.500	1.129	0.603	53.405
MT512	1.192	0.906	75.968	2.052	1.194	58.177
MT513	1.580	0.706	44.664	1.374	0.763	55.503
MT514	1.284	0.691	53.845	1.451	0.986	67.957
MT519	1.894	1.331	70.263	1.834	1.134	61.854
MT520	1.760	1.086	61.694	1.653	1.220	73.784
MT521	2.447	1.289	52.684	2.471	1.167	47.227
MT522	2.242	1.310	58.411	3.339	3.552	106.387
MT524	8.032	16.312	203.093	14.707	25.533	173.610
MT525	1.213	0.604	49.806	1.270	0.541	42.641
MT526	1.331	0.772	58.002	1.464	0.964	65.860
MT527	1.427	0.726	50.872	1.398	0.750	53.678
MT528	1.512	0.732	48.421	1.400	0.703	50.194
MT534	1.461	0.883	60.411	2.187	1.291	59.036
MT536	1.941	4.436	228.530	1.911	1.395	72.991
MT541	1.434	1.473	102.750	1.341	0.739	55.133
MT542	1.360	1.118	82.241	1.886	1.067	56.567
MT543	3.120	1.443	46.247	3.079	1.713	55.636
MT546	1.544	1.028	66.556	2.210	1.237	56.006
MT547	1.098	0.675	61.501	2.439	1.600	65.597
MT549	1.112	0.640	57.512	1.003	0.556	55.497
MT550	2.174	0.864	39.729	2.172	2.330	107.278
MT553	1.698	0.784	46.147	2.006	0.928	46.264
MT554	1.906	1.010	52.988	1.949	1.010	51.812
MT555	2.199	1.154	52.464	2.054	1.111	54.092
MT556	1.893	0.841	44.418	1.600	0.867	54.172
MT557	1.206	0.893	74.026	1.316	0.892	67.791
MT558	1.232	0.934	75.796	1.254	1.173	93.532
MT559	1.338	0.976	72.923	1.367	1.098	80.302
MT560	0.984	0.455	46.237	1.342	0.865	64.444
MT561	1.265	0.850	67.170	1.167	0.758	65.005
MT562	1.257	0.840	66.845	1.221	0.742	60.795
MT563	1.410	0.718	50.896	1.391	0.819	58.903

MT564	1.514	0.773	51.077	1.451	0.770	53.071
MT565	1.605	0.826	51.491	1.586	0.829	52.256
MT568	0.765	0.472	61.729	1.021	0.558	54.656
MT569	1.122	1.080	96.240	1.681	1.267	75.386
MT571	2.967	2.044	68.875	3.913	9.819	250.936
MT572	1.185	0.791	66.768	6.366	4.828	75.836
MT573	2.110	1.066	50.536	2.471	1.414	57.207
MT574	1.614	1.057	65.482	1.670	1.001	59.916
MT575	0.840	0.577	68.698	1.132	0.811	71.638
MT576	2.245	1.008	44.920	2.418	1.168	48.301
MT583	5.088	12.120	238.207	3.752	10.496	279.748
MT585	2.023	1.079	53.354	1.889	1.096	57.998
MT586	1.945	0.924	47.513	2.062	1.135	55.048
MT588	1.770	0.837	47.269	2.361	1.534	64.965
MT590	0.906	0.481	53.049	1.118	0.619	55.355
MT593	0.863	0.418	48.474	0.947	0.515	54.362
MT594	1.232	0.616	49.970	1.424	0.771	54.125
MT595	0.991	0.771	77.837	1.306	1.314	100.655
MT597	0.753	0.371	49.334	1.052	0.545	51.797
MT598	1.561	1.350	86.471	1.741	1.116	64.106
MT600	1.851	0.917	49.544	2.390	2.155	90.144
MT601	1.606	0.917	57.068	1.884	1.133	60.123
MT602	1.399	0.824	58.900	1.475	0.931	63.097
MT603	1.322	0.664	50.233	2.013	1.165	57.846
MT605	0.183	0.247	134.963	0.526	0.504	95.802
MT606	1.164	0.749	64.347	1.684	1.100	65.332
MT607	1.030	0.550	53.442	1.830	1.097	59.931
MT608	1.375	0.806	58.635	1.499	0.859	57.280
MT612	1.252	0.955	76.277	1.421	0.845	59.504
MT617	1.580	1.240	78.491	1.540	1.077	69.917
MT618	1.418	1.120	78.972	1.666	1.381	82.893
MT619	1.372	1.077	78.467	1.576	0.985	62.475
MT621	0.993	0.444	44.698	0.905	0.494	54.598
MT622	1.194	0.717	60.045	2.826	7.683	271.839
MT623	2.019	1.363	67.495	2.420	1.585	65.475
MT624	1.739	1.260	72.442	2.278	1.096	48.128
MT626	1.308	0.756	57.822	1.511	0.965	63.870
MT629	2.222	1.957	88.064	3.414	2.025	59.314
MT630	1.718	1.329	77.374	1.847	1.270	68.752
MT631	1.442	1.231	85.357	2.504	1.866	74.522
MT635	1.794	0.949	52.910	1.598	0.931	58.225
MT636	1.924	1.131	58.780	2.027	1.489	73.477
MT637	1.889	1.326	70.190	2.114	1.217	57.580
MT638	2.122	1.143	53.855	2.089	1.167	55.862
MT639	1.778	1.248	70.202	1.682	1.002	59.568
MT642	2.016	0.820	40.693	2.332	8.930	382.853
MT645	1.564	1.215	77.706	1.633	1.001	61.327
MT651	1.268	1.049	82.714	1.621	1.025	63.211
MT652	1.929	1.010	52.356	3.203	6.966	217.501
MT656	1.948	0.859	44.100	2.244	1.422	63.373
MT659	1.147	0.616	53.673	1.492	0.904	60.624
MT668	1.146	0.529	46.174	1.244	0.705	56.686
MT669	1.090	0.551	50.584	1.235	0.636	51.476
MT670	0.939	0.407	43.390	1.122	0.520	46.303

STATSGO						SSURGO
MUID	Mean om	St dev om	CV om	Mean om	St dev om	CV om
MT671	1.075	0.527	49.047	1.139	0.596	52.326
MT672	0.977	0.746	76.389	1.359	0.817	60.108
MT673	0.688	0.598	86.967	0.966	0.840	86.914
MT674	0.758	0.595	78.493	1.176	0.654	55.558
MT675	0.960	0.731	76.191	1.216	0.948	77.981
MT676	0.646	0.675	104.417	0.925	0.680	73.556
MT677	0.389	0.386	99.230	0.866	0.609	70.267
MT678	0.799	0.856	107.080	0.878	0.805	91.685
MT679	0.675	0.493	73.030	1.097	0.834	76.078
MT680	1.034	0.681	65.878	1.131	0.693	61.237
MT685	1.276	0.667	52.279	1.595	1.336	83.762
MT686	1.057	0.643	60.873	1.627	1.067	65.564
MT687	1.253	0.847	67.578	1.663	1.419	85.361
MT688	1.193	0.616	51.604	1.503	0.924	61.524
MT689	1.146	0.794	69.261	0.999	0.719	71.929
MT690	0.618	0.706	114.304	1.275	0.655	51.384
MT691	1.178	0.813	69.017	1.000	0.486	48.630
MT692	1.000	0.581	58.052	1.113	1.514	135.980
MT693	0.812	0.544	67.002	1.376	1.013	73.670
MT694	0.650	0.539	82.991	1.111	0.655	58.935
MT695	0.925	0.491	53.072	1.185	0.799	67.473
MT703	0.829	0.430	51.884	1.051	0.632	60.075
MT704	1.788	1.466	81.969	1.484	1.093	73.618
MT705	0.901	0.577	64.047	1.338	0.897	67.013

Table 3 Comparison of the mean, standard deviation and coefficients of variance of the organic matter for the STATSGO and SSURGO databases.

STATSGO				SSURGO		
MUID	Mean pH	St dev pH	CV pH	Mean pH	St dev pH	CV pH
MT001	7.682	0.675	8.781	7.692	0.620	8.060
MT002	7.915	0.711	8.978	7.859	0.612	7.788
MT003	7.140	0.804	11.257	7.378	0.811	10.991
MT004	7.288	0.718	9.847	7.525	0.725	9.632
MT005	7.116	0.773	10.867	7.218	0.770	10.665
MT006	7.090	0.849	11.976	7.189	0.805	11.202
MT007	7.392	0.729	9.858	6.963	0.818	11.752
MT009	8.188	0.879	10.738	7.990	0.914	11.446
MT010	6.703	0.807	12.046	6.652	0.734	11.041
MT016	7.189	1.059	14.734	7.440	1.259	16.927
MT017	7.305	0.821	11.239	7.385	0.979	13.256
MT019	7.311	0.843	11.533	7.477	0.873	11.670
MT020	7.293	0.796	10.909	7.286	0.721	9.889
MT022	7.961	0.794	9.978	7.927	0.754	9.512
MT023	7.892	0.859	10.885	7.750	0.792	10.224
MT024	7.809	1.131	14.488	7.759	0.911	11.744
MT025	7.526	1.060	14.081	7.834	0.786	10.029
MT026	7.694	0.759	9.864	7.804	0.799	10.237
MT027	7.851	0.633	8.066	7.814	0.671	8.582
MT028	7.863	0.669	8.512	7.741	0.745	9.631
MT029	7.682	0.612	7.961	7.776	0.724	9.316

MT030	7.805	0.835	10.697	7.741	0.780	10.080
MT031	7.046	1.140	16.182	7.188	1.118	15.550
MT034	7.234	0.879	12.154	7.479	0.884	11.825
MT035	7.181	0.857	11.939	7.275	0.786	10.799
MT036	7.339	0.796	10.849	7.506	0.750	9.987
MT037	7.611	0.647	8.495	7.601	0.723	9.517
MT041	7.499	0.550	7.328	7.627	0.661	8.663
MT042	7.555	0.826	10.939	7.544	0.980	12.995
MT047	7.932	0.462	5.818	7.873	0.616	7.826
MT048	7.702	0.843	10.940	7.589	0.790	10.409
MT049	7.633	0.757	9.917	7.547	0.783	10.372
MT050	7.544	0.743	9.848	7.471	0.741	9.912
MT051	7.320	0.882	12.050	7.581	0.900	11.874
MT053	6.963	0.913	13.108	7.164	0.815	11.374
MT054	7.685	0.827	10.762	7.620	0.838	10.994
MT055	7.513	0.685	9.115	7.533	0.881	11.699
MT057	8.187	0.801	9.779	7.989	0.819	10.254
MT058	7.899	0.992	12.565	7.889	1.003	12.714
MT059	7.377	0.780	10.570	7.484	0.774	10.337
MT068	7.486	0.718	9.596	7.323	0.855	11.676
MT069	7.658	0.754	9.850	7.392	0.776	10.503
MT070	7.642	0.903	11.813	7.599	0.866	11.398
MT071	7.083	0.666	9.397	7.148	0.682	9.544
MT074	7.721	0.733	9.491	7.675	0.806	10.497
MT075	7.783	0.786	10.101	7.676	0.813	10.589
MT076	7.971	0.797	10.005	7.577	0.978	12.912
MT077	7.586	0.776	10.228	7.824	0.790	10.101
MT078	7.476	0.887	11.859	7.729	0.561	7.253
MT079	7.659	0.885	11.553	7.634	0.700	9.169
MT080	7.755	0.841	10.850	7.747	0.491	6.336
MT081	7.901	0.730	9.240	7.759	0.682	8.790
MT082	7.883	0.750	9.518	7.603	0.854	11.236
MT083	7.880	0.822	10.434	7.850	0.437	5.573
MT084	7.768	0.806	10.379	7.740	0.476	6.153
MT085	7.898	0.808	10.232	7.723	0.690	8.932
MT086	7.817	0.709	9.073	7.606	0.729	9.583
MT087	7.880	0.713	9.054	7.785	0.860	11.048
MT088	7.558	1.176	15.565	7.327	1.221	16.660
MT089	7.869	0.743	9.442	7.783	0.705	9.055
MT090	7.793	0.810	10.393	7.731	0.868	11.222
MT091	7.853	0.897	11.418	7.547	0.918	12.163
MT092	7.788	0.844	10.842	7.749	0.804	10.373
MT093	7.469	0.917	12.278	7.543	0.971	12.868
MT094	7.877	0.823	10.453	7.755	0.782	10.083
MT095	7.909	0.711	8.994	7.678	0.771	10.047
MT096	6.907	2.039	29.519	7.570	1.280	16.915
MT097	7.691	0.850	11.056	7.153	1.557	21.763
MT098	7.919	0.801	10.118	7.749	0.665	8.587
MT099	7.782	0.822	10.557	7.726	0.718	9.292
MT100	7.750	0.792	10.225	7.960	0.729	9.159
MT101	7.766	0.857	11.039	7.528	0.951	12.633
MT102	7.893	0.912	11.556	7.746	0.883	11.404

STATSGO				SSURGO		
MUID	Mean pH	St dev pH	CV pH	Mean pH	St dev pH	CV pH
MT103	7.937	0.863	10.868	7.846	0.851	10.848
MT106	7.673	0.814	10.612	7.807	0.688	8.817
MT107	7.819	0.794	10.159	7.837	0.740	9.447
MT108	7.848	0.752	9.586	7.840	0.706	9.005
MT109	8.020	0.722	9.000	7.982	0.522	6.537
MT110	7.291	0.758	10.400	7.068	0.794	11.240
MT111	7.493	0.764	10.199	7.231	0.918	12.702
MT112	7.321	0.804	10.987	6.816	1.990	29.201
MT113	7.271	0.757	10.411	7.308	1.248	17.080
MT114	7.438	0.725	9.751	7.134	0.770	10.794
MT119	7.396	0.841	11.377	7.311	0.834	11.414
MT120	7.677	0.771	10.048	7.617	0.784	10.292
MT125	7.897	0.662	8.381	7.837	0.686	8.755
MT127	7.372	0.896	12.155	7.490	0.878	11.719
MT128	7.448	0.794	10.665	7.502	0.867	11.563
MT131	7.386	0.910	12.327	7.602	0.864	11.368
MT132	7.396	0.804	10.867	7.352	0.725	9.856
MT133	7.165	0.705	9.839	7.337	0.880	11.988
MT141	5.272	2.718	51.564	6.397	0.787	12.301
MT145	7.837	0.693	8.840	7.770	0.799	10.289
MT146	7.875	0.708	8.988	7.686	0.769	10.010
MT148	7.634	0.612	8.011	7.545	0.756	10.025
MT152	7.579	0.612	8.069	7.786	0.667	8.562
MT153	7.357	0.858	11.669	7.139	0.863	12.092
MT154	7.315	0.831	11.356	7.472	0.834	11.165
MT155	7.698	0.741	9.625	7.554	0.794	10.515
MT156	7.786	0.917	11.778	7.835	0.877	11.199
MT157	7.775	0.617	7.939	7.653	0.739	9.657
MT159	7.948	0.588	7.401	7.841	0.637	8.126
MT160	7.580	0.957	12.619	7.696	1.085	14.093
MT161	7.370	0.799	10.838	7.425	0.779	10.494
MT162	7.745	0.919	11.869	7.914	0.675	8.534
MT163	7.783	1.272	16.343	7.774	0.742	9.546
MT164	7.815	0.854	10.933	7.735	0.889	11.497
MT165	7.687	0.573	7.450	7.639	0.651	8.520
MT166	7.477	0.980	13.111	7.556	0.809	10.703
MT167	7.721	0.869	11.261	7.312	1.554	21.255
MT168	7.718	0.872	11.295	7.710	0.816	10.582
MT173	7.138	0.655	9.176	7.677	0.734	9.566
MT174	7.752	0.766	9.883	7.548	0.873	11.571
MT175	7.704	0.781	10.138	7.574	0.815	10.757
MT176	7.873	0.740	9.403	7.679	0.810	10.551
MT177	7.401	1.035	13.983	7.485	0.895	11.958
MT178	7.329	1.021	13.928	7.376	0.863	11.695
MT179	7.383	0.789	10.682	7.494	0.788	10.514
MT182	7.303	0.777	10.633	7.465	0.772	10.348
MT183	7.510	0.705	9.387	7.512	0.676	9.004
MT184	7.243	0.752	10.378	7.357	0.803	10.918
MT185	7.583	0.825	10.875	7.724	0.676	8.758

MT186	7.645	0.820	10.723	7.610	0.782	10.281
MT187	7.392	0.952	12.884	7.643	0.869	11.367
MT188	7.719	0.643	8.326	7.816	0.656	8.388
MT189	7.303	0.768	10.518	7.454	0.773	10.373
MT190	7.257	0.635	8.748	7.485	0.772	10.313
MT191	7.517	0.840	11.170	7.518	0.796	10.585
MT193	7.796	0.770	9.878	7.595	0.925	12.182
MT194	7.586	0.814	10.734	7.496	0.825	11.002
MT195	7.581	0.782	10.319	7.441	0.794	10.670
MT196	7.409	0.952	12.854	7.407	0.873	11.792
MT197	7.276	0.888	12.200	7.555	0.801	10.603
MT200	7.336	0.700	9.542	7.387	0.698	9.451
MT206	7.608	0.766	10.062	7.622	0.769	10.091
MT207	7.579	0.814	10.743	7.610	0.714	9.377
MT209	7.811	0.820	10.495	7.588	0.797	10.499
MT213	6.048	0.647	10.690	6.812	0.893	13.109
MT217	6.698	0.871	13.007	6.917	0.803	11.612
MT218	5.986	1.638	27.359	6.814	0.875	12.838
MT221	7.446	0.704	9.449	7.786	0.711	9.128
MT222	7.610	0.704	9.255	7.559	0.674	8.912
MT223	7.829	0.936	11.962	7.639	0.877	11.484
MT224	7.521	0.812	10.794	7.683	0.796	10.360
MT225	7.600	1.060	13.950	7.644	0.973	12.724
MT226	7.688	0.868	11.287	7.679	0.812	10.568
MT227	8.017	0.822	10.248	7.678	0.889	11.575
MT228	7.645	0.650	8.497	7.784	0.774	9.939
MT239	7.311	0.685	9.367	7.219	0.767	10.624
MT245	7.738	0.813	10.507	7.733	0.812	10.498
MT246	7.740	0.818	10.567	7.690	0.794	10.320
MT247	8.122	0.797	9.811	7.678	0.879	11.442
MT248	7.664	0.934	12.191	7.741	0.789	10.198
MT249	7.780	0.511	6.567	7.894	0.597	7.565
MT252	8.006	0.641	8.008	7.693	0.688	8.948
MT253	7.678	0.838	10.912	7.530	0.943	12.520
MT254	7.795	1.407	18.056	7.798	0.880	11.285
MT255	7.630	0.891	11.671	7.477	0.817	10.932
MT256	7.619	1.589	20.852	7.744	0.944	12.191
MT257	7.940	0.847	10.672	7.927	0.820	10.345
MT258	7.563	1.379	18.230	7.322	0.796	10.874
MT259	7.461	1.596	21.390	7.750	0.484	6.250
MT261	7.649	0.978	12.789	7.628	0.748	9.807
MT262	7.166	2.251	31.409	7.842	0.627	7.994
MT263	7.398	1.791	24.203	7.772	0.737	9.480
MT264	7.520	0.945	12.566	7.553	0.917	12.140
MT265	8.019	0.636	7.926	7.818	0.685	8.762
MT266	7.114	2.333	32.798	7.804	0.723	9.262
MT267	7.331	1.613	22.003	7.594	0.806	10.618
MT268	7.686	0.647	8.412	7.711	0.697	9.040
MT269	6.902	0.924	13.389	7.014	0.830	11.832
MT270	7.261	0.758	10.443	7.218	0.772	10.697
MT271	7.868	0.784	9.959	7.619	0.704	9.242
MT273	7.102	0.915	12.882	7.431	0.776	10.439

STATSGO				SSURGO		
MUID	Mean pH	St dev pH	CV pH	Mean pH	St dev pH	CV pH
MT275	7.419	0.694	9.348	6.938	0.724	10.441
MT276	7.857	0.760	9.676	7.770	0.764	9.829
MT277	7.764	0.995	12.815	7.646	0.917	11.991
MT278	8.009	0.718	8.960	7.778	0.780	10.026
MT285	7.433	0.748	10.068	7.595	0.710	9.353
MT287	8.087	0.543	6.716	7.764	0.980	12.628
MT294	7.697	0.732	9.512	7.740	0.645	8.338
MT296	7.971	0.404	5.065	7.882	0.561	7.112
MT297	6.993	1.485	21.234	7.548	1.194	15.820
MT301	7.567	0.579	7.649	7.580	0.744	9.819
MT302	7.756	0.636	8.205	7.673	0.734	9.560
MT303	7.734	0.648	8.380	6.609	0.799	12.084
MT304	7.749	0.411	5.305	7.018	1.063	15.148
MT306	7.570	0.797	10.535	7.472	0.788	10.551
MT309	7.527	0.818	10.867	7.365	0.843	11.449
MT310	7.728	0.864	11.184	7.723	0.756	9.790
MT311	7.696	0.787	10.231	7.511	0.774	10.310
MT312	7.449	0.903	12.127	7.831	0.710	9.067
MT314	7.969	1.204	15.105	7.650	0.883	11.549
MT315	7.999	0.729	9.118	7.904	0.771	9.757
MT316	7.980	0.488	6.113	7.934	0.678	8.546
MT317	7.760	0.706	9.103	7.823	0.706	9.018
MT318	7.803	0.820	10.513	7.763	0.839	10.808
MT319	7.829	0.567	7.237	7.692	0.645	8.390
MT320	7.892	1.325	16.786	7.822	0.774	9.894
MT321	7.049	0.714	10.131	7.251	0.753	10.385
MT323	7.666	0.574	7.494	7.609	0.648	8.512
MT324	8.178	0.764	9.337	8.168	0.850	10.407
MT325	7.347	0.784	10.665	7.532	0.872	11.574
MT327	6.913	0.819	11.841	7.134	0.891	12.495
MT334	7.028	0.849	12.074	7.032	0.852	12.120
MT336	7.591	0.894	11.783	7.520	0.841	11.184
MT337	7.642	0.875	11.453	7.732	0.768	9.929
MT338	7.811	0.875	11.198	7.732	0.876	11.326
MT339	7.586	0.833	10.982	7.590	0.830	10.934
MT340	7.601	0.780	10.258	7.577	0.840	11.089
MT341	6.955	0.913	13.123	6.987	0.814	11.647
MT343	5.854	1.526	26.069	6.464	0.990	15.322
MT344	6.088	1.743	28.625	6.000	0.900	15.000
MT346	6.517	1.106	16.969	6.421	1.071	16.686
MT347	6.995	0.995	14.224	7.261	0.858	11.814
MT349	7.166	0.786	10.970	7.243	0.788	10.875
MT354	7.889	0.616	7.814	7.779	0.719	9.241
MT355	7.903	0.652	8.249	7.902	0.646	8.176
MT356	7.824	0.696	8.892	7.807	0.629	8.060
MT357	7.886	0.761	9.649	7.735	0.807	10.428
MT358	7.988	0.667	8.351	7.916	0.642	8.114
MT359	7.751	1.025	13.226	7.726	0.723	9.358
MT364	7.179	0.791	11.021	7.200	0.600	8.333

MT365	7.089	0.777	10.963	6.758	0.934	13.821
MT366	7.438	0.846	11.368	7.298	0.735	10.078
MT367	7.650	0.797	10.417	7.637	0.891	11.672
MT368	7.954	0.698	8.774	7.828	0.685	8.757
MT369	7.575	1.995	26.337	7.837	0.705	9.001
MT370	7.871	0.730	9.275	7.766	0.685	8.818
MT371	7.827	0.686	8.759	7.667	0.699	9.121
MT372	8.161	0.518	6.343	7.991	0.678	8.486
MT374	7.348	0.767	10.445	7.426	0.839	11.298
MT376	7.323	0.705	9.627	7.415	0.822	11.090
MT377	7.263	0.780	10.745	7.279	0.754	10.359
MT379	8.176	0.548	6.699	7.888	1.024	12.980
MT380	7.616	1.022	13.416	8.232	0.780	9.473
MT381	8.108	0.817	10.080	7.746	0.978	12.631
MT382	7.978	0.897	11.246	7.628	1.024	13.424
MT383	8.132	0.767	9.430	7.943	0.970	12.207
MT384	7.620	1.158	15.191	7.441	1.072	14.411
MT385	7.911	0.926	11.709	7.741	1.058	13.662
MT392	7.793	1.027	13.180	7.594	0.926	12.197
MT393	7.801	0.640	8.198	7.710	0.695	9.020
MT395	6.840	0.943	13.785	7.055	0.794	11.247
MT396	7.895	0.850	10.763	7.706	0.835	10.832
MT406	6.686	0.863	12.901	6.694	0.850	12.700
MT407	7.901	0.600	7.594	7.488	1.028	13.726
MT413	8.392	0.620	7.384	6.466	1.407	21.763
MT414	7.252	1.369	18.872	7.465	1.202	16.103
MT415	6.880	1.493	21.695	7.488	1.247	16.652
MT416	7.250	1.127	15.544	7.341	1.022	13.918
MT417	7.393	1.134	15.345	7.630	0.961	12.592
MT418	7.042	1.150	16.334	7.271	1.270	17.462
MT419	7.100	1.145	16.133	7.403	1.025	13.844
MT420	7.119	1.140	16.016	7.336	1.017	13.857
MT421	7.652	0.742	9.701	7.816	0.696	8.901
MT422	6.501	1.191	18.317	6.975	1.287	18.445
MT423	7.469	1.126	15.070	7.362	1.186	16.115
MT424	7.475	1.100	14.710	7.798	0.772	9.894
MT425	6.688	2.371	35.456	7.567	0.926	12.238
MT426	7.197	1.118	15.529	6.926	1.409	20.350
MT427	6.893	1.141	16.554	7.334	1.327	18.097
MT428	7.403	1.077	14.542	7.443	1.067	14.334
MT429	6.828	1.150	16.846	7.253	1.247	17.189
MT430	7.623	0.636	8.338	7.579	0.691	9.121
MT431	7.746	0.720	9.292	7.576	0.837	11.046
MT433	7.289	0.950	13.037	7.483	0.807	10.788
MT438	7.276	0.733	10.072	7.106	1.426	20.063
MT440	7.131	1.217	17.072	7.383	0.986	13.350
MT442	7.474	0.755	10.101	7.550	0.728	9.638
MT451	7.170	1.547	21.580	7.448	0.957	12.843
MT452	7.409	0.948	12.797	7.444	0.940	12.632
MT453	7.371	0.894	12.134	7.384	0.915	12.389
MT454	7.328	0.807	11.010	7.417	0.850	11.465
MT456	7.665	0.873	11.388	7.680	0.790	10.284

STATSGO				SSURGO		
MUID	Mean pH	St dev pH	CV pH	Mean pH	St dev pH	CV pH
MT459	6.983	0.712	10.197	7.312	0.793	10.839
MT463	7.475	0.818	10.942	7.551	0.765	10.136
MT464	7.426	0.889	11.969	7.452	0.802	10.756
MT465	7.271	0.905	12.447	7.526	0.696	9.244
MT466	7.300	0.660	9.045	7.530	0.897	11.908
MT467	7.407	0.853	11.511	7.583	0.795	10.480
MT468	7.295	0.854	11.704	7.131	1.439	20.183
MT471	7.809	0.836	10.706	7.766	0.708	9.118
MT472	7.731	0.702	9.082	7.404	0.816	11.023
MT474	7.627	0.670	8.786	7.770	0.637	8.197
MT475	7.442	0.778	10.460	7.393	0.381	5.157
MT484	5.425	3.468	63.932	7.444	0.728	9.774
MT485	6.355	0.701	11.037	6.569	0.744	11.329
MT486	7.460	0.728	9.759	7.502	0.715	9.530
MT488	7.904	0.795	10.058	7.604	1.071	14.081
MT489	7.703	0.922	11.969	7.738	0.778	10.053
MT499	7.518	0.657	8.743	7.540	0.648	8.599
MT500	7.883	0.773	9.810	7.716	0.725	9.398
MT501	7.859	0.607	7.729	7.840	0.579	7.381
MT502	7.851	0.555	7.069	7.913	0.561	7.093
MT503	7.650	1.400	18.296	7.996	0.731	9.139
MT506	7.200	0.771	10.704	7.388	0.822	11.129
MT511	7.798	0.687	8.810	7.667	0.795	10.363
MT512	7.058	2.323	32.912	7.417	0.734	9.899
MT513	7.754	0.749	9.660	7.840	0.877	11.181
MT514	8.243	0.741	8.989	7.980	0.820	10.282
MT519	7.614	0.764	10.028	7.601	0.791	10.404
MT520	7.626	0.936	12.280	7.744	0.813	10.493
MT521	7.554	0.865	11.449	7.687	0.724	9.415
MT522	7.158	0.787	11.000	7.154	1.225	17.126
MT524	7.797	0.557	7.141	7.786	0.607	7.793
MT525	7.295	0.843	11.559	7.250	0.688	9.496
MT526	7.534	0.825	10.953	7.464	0.798	10.686
MT527	7.349	0.838	11.409	7.433	0.802	10.787
MT528	7.307	0.844	11.556	7.401	0.878	11.859
MT534	7.485	0.764	10.201	7.396	0.745	10.072
MT536	5.537	1.016	18.356	6.086	1.108	18.200
MT541	5.814	2.339	40.238	6.541	1.088	16.634
MT542	5.960	2.534	42.516	7.744	0.874	11.289
MT543	7.493	0.809	10.793	7.462	0.762	10.206
MT546	6.133	0.880	14.354	6.385	1.434	22.463
MT547	6.020	0.718	11.921	7.363	0.876	11.892
MT549	7.756	0.759	9.785	7.656	0.780	10.187
MT550	7.317	0.651	8.899	7.413	0.919	12.403
MT553	7.331	0.880	12.008	7.303	0.879	12.042
MT554	7.382	0.783	10.606	7.416	0.770	10.388
MT555	7.643	0.663	8.669	7.678	0.718	9.349
MT556	7.204	0.787	10.921	7.461	0.776	10.398
MT557	7.439	0.844	11.343	7.632	0.851	11.149

MT558	7.433	0.733	9.868	7.427	0.859	11.572
MT559	7.595	0.762	10.036	7.520	0.870	11.566
MT560	5.927	1.546	26.089	6.376	1.515	23.754
MT561	7.721	0.782	10.124	7.766	0.784	10.097
MT562	7.696	0.783	10.173	7.714	0.791	10.259
MT563	7.388	0.787	10.658	7.374	0.891	12.090
MT564	7.427	0.764	10.289	7.486	0.760	10.159
MT565	7.326	0.781	10.661	7.432	0.820	11.038
MT568	7.590	1.148	15.126	7.581	1.154	15.229
MT569	7.642	0.731	9.562	7.625	0.419	5.492
MT571	7.369	0.683	9.264	7.487	0.719	9.607
MT572	6.129	0.896	14.621	6.766	0.819	12.109
MT573	7.316	0.875	11.963	7.178	0.865	12.054
MT574	7.383	0.876	11.870	7.496	0.842	11.232
MT575	7.589	0.691	9.110	7.396	0.778	10.524
MT576	6.275	0.811	12.917	7.094	0.738	10.402
MT583	8.106	0.606	7.474	8.142	0.635	7.797
MT585	7.317	0.880	12.024	7.496	0.738	9.850
MT586	7.264	0.821	11.302	7.283	0.852	11.700
MT588	7.213	0.782	10.846	7.098	0.831	11.706
MT590	7.549	0.782	10.363	7.518	1.029	13.690
MT593	6.981	1.230	17.614	7.132	1.223	17.141
MT594	8.170	0.814	9.959	8.081	0.834	10.317
MT595	8.074	0.907	11.229	7.979	0.917	11.497
MT597	7.691	0.779	10.130	7.645	0.853	11.162
MT598	7.084	0.950	13.407	7.313	0.774	10.589
MT600	7.374	0.666	9.036	7.370	0.727	9.864
MT601	7.519	0.693	9.214	7.584	0.788	10.395
MT602	7.661	0.764	9.967	7.728	0.763	9.875
MT603	7.695	0.688	8.947	7.703	0.770	9.996
MT605	4.712	1.251	26.558	5.225	1.593	30.486
MT606	7.620	0.846	11.105	7.485	0.855	11.418
MT607	7.809	0.878	11.244	7.525	0.724	9.615
MT608	7.578	0.786	10.374	7.695	0.697	9.060
MT612	7.532	0.710	9.426	7.586	0.727	9.588
MT617	7.580	0.749	9.881	7.663	0.718	9.369
MT618	7.650	0.796	10.400	7.635	0.754	9.878
MT619	7.697	0.680	8.831	7.669	0.720	9.389
MT621	7.397	1.100	14.871	7.285	1.136	15.597
MT622	7.690	0.581	7.560	7.733	0.715	9.249
MT623	7.346	0.907	12.342	7.203	0.930	12.905
MT624	7.530	0.843	11.198	6.298	0.760	12.059
MT626	7.636	0.757	9.913	7.174	1.160	16.175
MT629	7.225	0.841	11.638	7.162	0.720	10.053
MT630	6.691	1.982	29.617	7.506	0.923	12.297
MT631	7.613	0.752	9.873	7.557	0.681	9.013
MT635	7.175	0.738	10.280	7.467	0.745	9.978
MT636	7.371	0.682	9.251	7.434	0.716	9.630
MT637	7.447	0.689	9.255	7.330	0.669	9.126
MT638	7.292	0.614	8.420	7.336	0.633	8.636
MT639	7.410	0.706	9.533	7.293	0.639	8.757
MT642	8.045	0.430	5.346	8.103	0.505	6.227

STATSGO				SSURGO		
MUID	Mean pH	St dev pH	CV pH	Mean pH	St dev pH	CV pH
MT645	7.627	0.652	8.548	7.709	0.774	10.036
MT651	7.614	0.732	9.615	7.709	0.767	9.953
MT652	7.786	0.535	6.869	7.749	0.675	8.714
MT656	7.199	0.745	10.348	7.205	0.864	11.994
MT659	7.557	0.624	8.264	7.610	0.696	9.144
MT668	7.696	0.786	10.215	7.746	0.660	8.518
MT669	7.724	0.792	10.252	7.663	0.761	9.932
MT670	7.692	0.856	11.130	7.813	0.786	10.061
MT671	7.665	0.917	11.964	7.667	0.777	10.140
MT672	7.719	0.664	8.603	7.639	0.700	9.160
MT673	7.881	0.640	8.115	7.253	0.967	13.325
MT674	7.821	0.799	10.213	7.673	0.805	10.492
MT675	7.665	0.762	9.944	7.740	0.462	5.974
MT676	7.666	0.711	9.279	7.598	0.701	9.228
MT677	7.717	0.639	8.277	7.685	0.780	10.145
MT678	7.590	0.721	9.501	7.510	0.743	9.895
MT679	7.633	0.768	10.063	7.711	0.394	5.113
MT680	7.075	1.336	18.879	7.568	1.089	14.390
MT685	7.461	0.789	10.579	7.504	0.750	9.993
MT686	7.704	0.740	9.609	7.718	0.804	10.414
MT687	7.672	0.706	9.198	7.573	0.749	9.892
MT688	7.803	0.682	8.739	7.779	0.751	9.650
MT689	7.901	0.898	11.363	7.297	1.480	20.282
MT690	7.960	0.614	7.714	6.536	2.145	32.826
MT691	6.485	1.242	19.155	6.869	1.448	21.078
MT692	7.579	0.812	10.711	7.654	0.643	8.398
MT693	7.817	0.827	10.580	7.641	0.709	9.273
MT694	8.013	0.841	10.493	7.710	1.018	13.202
MT695	7.907	0.643	8.137	7.680	0.662	8.625
MT703	6.966	1.191	17.094	6.986	1.082	15.487
MT704	7.592	0.697	9.183	7.746	0.763	9.847
MT705	7.664	0.559	7.288	7.720	0.733	9.497

User point of view

Table 4 Means and variances for SSURGO delineated areas within a selected STATSGO delineated area i.e. map unit 162.

		μ_{om}	Perc. (%)	σ^2_{om}	μ_{pH}	Perc. (%)	σ^2_{pH}
MT162	STATSGO	0.93		0.38	7.75		0.85
	146781	1.09	-17.04	0.14	7.90	-2.00	0.25
	146782	1.09	-17.04	0.14	7.90	-2.00	0.25
	146789	1.08	-16.08	0.20	7.90	-2.00	0.25
	146790	1.08	-16.08	0.20	7.90	-2.00	0.25
	146798	***5.50***	-489.50	6.25	7.60	1.87	0.04
	146839	***2.40***	-157.23	1.00	7.72	0.32	0.10
	146845	***2.34***	-150.48	0.95	7.72	0.32	0.10
	146848	***1.50***	-60.77	0.49	7.66	1.10	0.55
	146849	***1.50***	-60.77	0.49	7.66	1.10	0.55
	146871	0.92	1.71	0.34	7.63	1.45	0.59
	146903	0.75	19.61	0.06	7.90	-2.00	0.25
	146918	***0.50***	46.41	0.06	8.50	-9.75	0.30
	146923	***1.38***	-47.37	0.39	8.05	-3.94	0.14
	146955	0.68	26.80	0.22	***8.70***	-12.33	0.81
	146959	***4.80***	-414.47	2.56	6.82	11.94	0.25
	348291	***69.31***	-7329.15	265.41	7.55	2.56	0.45
	348292	0.79	15.54	0.35	7.96	-2.79	0.25
	348293	***1.45***	-54.98	0.43	7.55	2.50	0.49
	348307	***2.08***	-123.26	0.76	7.45	3.86	0.33
	348312	***1.71***	-83.17	0.63	7.75	-0.06	0.30
	348313	***1.71***	-83.17	0.63	7.75	-0.06	0.30
	348314	***1.71***	-83.39	0.63	7.74	0.08	0.30
	348319	***2.21***	-136.44	0.61	7.92	-2.27	0.23
	348344	1.32	-41.69	0.43	7.71	0.45	1.01
	348368	1.00	-7.18	0.25	7.90	-2.00	0.25
	348392	1.04	-11.36	0.17	8.16	-5.35	0.43
	348407	***2.03***	-117.36	0.59	7.72	0.30	0.30
	348434	0.91	2.79	0.22	7.95	-2.61	0.25
	348437	***1.67***	-78.67	0.69	7.95	-2.65	0.21
	348452	***1.65***	-76.96	0.56	8.07	-4.20	0.13
	348453	***1.65***	-76.96	0.56	8.07	-4.20	0.13
	348459	***1.32***	-41.59	0.35	7.90	-2.00	0.25
	348470	1.00	-7.18	0.25	7.40	4.45	1.05
	348473	***2.18***	-134.08	0.99	7.93	-2.41	0.23
	348480	***2.00***	-114.36	0.45	7.90	-2.00	0.25
	348484	***2.50***	-167.95	1.00	7.70	0.58	0.49
	348511	***2.85***	-205.47	0.95	7.87	-1.61	0.15
	348520	1.04	-11.47	0.21	7.80	-0.74	0.44
	348534	***1.98***	-112.33	0.55	7.74	0.06	0.30
	348552	1.30	-39.34	0.19	8.07	-4.20	0.13
	348566	***1.80***	-92.93	0.64	8.02	-3.55	0.16
	348567	***1.80***	-92.93	0.64	8.02	-3.55	0.16
	348595	***2.75***	-194.75	0.56	***8.75***	-12.98	0.33
	348626	0.62	33.55	0.14	***9.12***	-17.69	0.88

	348627	***2.00***	-114.47	1.88	7.62	1.56	0.46
	348630	***2.04***	-119.08	0.58	***8.61***	-11.16	0.34
	348633	1.29	-38.48	0.33	7.90	-1.96	0.71
	348635	1.13	-20.58	0.14	7.90	-2.00	0.25
	348677	***1.32***	-41.69	0.43	8.11	-4.66	0.25
	348701	***1.75***	-87.57	0.56	8.05	-3.94	0.14
	348704	***1.50***	-60.77	0.49	7.90	-2.00	0.25
	348713	***2.54***	-172.45	0.77	8.25	-6.52	0.09
	348720	***2.10***	-125.08	0.81	7.72	0.32	0.10
	348724	1.06	-13.29	0.37	7.51	3.09	0.40
	348728	1.15	-23.47	0.26	8.08	-4.35	0.31
	348760	***1.96***	-110.40	0.91	7.92	-2.27	0.23
	348768	***1.55***	-65.70	0.51	7.98	-3.07	0.20
	348769	***1.53***	-64.42	0.51	7.98	-3.02	0.20
	348789	***1.96***	-109.97	0.92	8.08	-4.26	0.20
	348796	1.20	-28.19	0.28	8.20	-5.87	0.33
	348815	***1.46***	-56.48	0.74	8.20	-5.91	0.37

Table 5 Means and variances for SSURGO delineated areas within a selected STATSGO delineated area i.e. map unit 652.

		μ_{om}	Perc. (%)	σ^2_{om}	μ_{pH}	Perc. (%)	σ^2_{pH}
MT652	STATSGO	1.93		1.02	7.79		0.29
	348291	***69.31***	-3493.26	265.41	7.55	3.07	0.45
	348291	***69.31***	-3493.26	265.41	7.55	3.07	0.45
	348292	***0.79***	59.15	0.35	7.96	-2.25	0.25
	348292	***0.79***	59.15	0.35	7.96	-2.25	0.25
	348293	1.45	25.04	0.43	7.55	3.02	0.49
	348294	2.63	-36.08	0.77	***7.32***	6.02	0.34
	348294	2.63	-36.08	0.77	***7.32***	6.02	0.34
	348297	***0.83***	56.82	0.25	7.63	1.97	0.59
	348297	***0.83***	56.82	0.25	7.63	1.97	0.59
	348298	***0.53***	72.32	0.17	7.79	-0.05	0.41
	348298	***0.53***	72.32	0.17	7.79	-0.05	0.41
	348310	***39.54***	-1949.92	1672.13	7.66	1.57	0.08
	348310	***39.54***	-1949.92	1672.13	7.66	1.57	0.08
	348327	0.95	50.86	0.24	***8.20***	-5.29	0.23
	348327	0.95	50.86	0.24	***8.20***	-5.29	0.23
	348368	1.00	48.16	0.25	7.90	-1.46	0.25
	348368	1.00	48.16	0.25	7.90	-1.46	0.25
	348383	***3.19***	-65.27	0.68	8.02	-3.01	0.16
	348383	***3.19***	-65.27	0.68	8.02	-3.01	0.16
	348395	1.36	29.34	0.41	7.78	0.13	0.79
	348395	1.36	29.34	0.41	7.78	0.13	0.79
	348402	1.95	-1.14	1.53	***7.49***	3.85	0.32
	348402	1.95	-1.14	1.53	***7.49***	3.85	0.32
	348407	2.03	-5.13	0.59	7.72	0.82	0.30
	348407	2.03	-5.13	0.59	7.72	0.82	0.30
	348413	***0.77***	60.24	0.26	7.81	-0.35	0.28
	348413	***0.77***	60.24	0.26	7.81	-0.35	0.28
	348423	***3.71***	-92.38	4.21	***7.21***	7.39	0.46
	348423	***3.71***	-92.38	4.21	***7.21***	7.39	0.46

	348424	***3.15***	-63.14	1.35	7.61	2.31	0.26
	348424	***3.15***	-63.14	1.35	7.61	2.31	0.26
	348426	2.80	-44.95	2.72	***7.44***	4.48	0.61
	348426	2.80	-44.95	2.72	***7.44***	4.48	0.61
	348428	4.17	-116.33	4.13	***7.08***	9.08	0.40
	348434	0.91	52.98	0.22	7.95	-2.07	0.25
	348434	0.91	52.98	0.22	7.95	-2.07	0.25
	348439	***0.87***	54.69	0.18	7.80	-0.19	0.39
	348447	1.29	33.02	0.33	7.94	-1.98	0.05
	348452	1.65	14.41	0.56	8.07	-3.65	0.13
	348452	1.65	14.41	0.56	8.07	-3.65	0.13
	348453	1.65	14.41	0.56	8.07	-3.65	0.13
	348473	2.18	-13.22	0.99	7.93	-1.88	0.23
	348511	2.85	-47.74	0.95	7.87	-1.08	0.15
	348511	2.85	-47.74	0.95	7.87	-1.08	0.15
	348517	1.51	21.93	0.52	7.83	-0.58	0.80
	348534	1.98	-2.70	0.55	7.74	0.59	0.30
	348534	1.98	-2.70	0.55	7.74	0.59	0.30
	348547	***4.22***	-118.71	3.16	***6.79***	12.79	0.44
	348547	***4.22***	-118.71	3.16	***6.79***	12.79	0.44
	348549	***3.16***	-63.92	4.37	***7.33***	5.87	0.48
	348549	***3.16***	-63.92	4.37	***7.33***	5.87	0.48
	348552	1.30	32.61	0.19	8.07	-3.65	0.13
	348552	1.30	32.61	0.19	8.07	-3.65	0.13
	348553	1.30	32.61	0.19	8.07	-3.65	0.13
	348553	1.30	32.61	0.19	8.07	-3.65	0.13
	348556	1.68	12.70	0.77	7.46	4.16	0.39
	348571	2.09	-8.40	0.47	8.06	-3.51	0.29
	348571	2.09	-8.40	0.47	8.06	-3.51	0.29
	348572	2.12	-9.75	0.47	8.04	-3.28	0.28
	348572	2.12	-9.75	0.47	8.04	-3.28	0.28
	348575	2.63	-36.08	0.77	7.95	-2.11	0.21
	348595	2.75	-42.56	0.56	*8.75*	-12.38	0.33
	348610	2.47	-28.10	1.54	***7.17***	7.92	0.37
	348610	2.47	-28.10	1.54	***7.17***	7.92	0.37
	348611	2.47	-28.10	1.54	***7.17***	7.92	0.37
	348616	2.32	-20.48	0.86	7.55	3.03	0.51
	348616	2.32	-20.48	0.86	7.55	3.03	0.51
	348644	2.38	-23.38	0.73	8.07	-3.60	0.24
	348644	2.38	-23.38	0.73	8.07	-3.60	0.24
	348665	2.63	-36.08	0.80	***8.27***	-6.22	0.46
	348673	1.63	15.71	0.62	8.07	-3.66	0.43
	348676	2.04	-5.91	0.57	7.79	-0.01	0.29
	348676	2.04	-5.91	0.57	7.79	-0.01	0.29
	348684	0.99	48.83	0.27	***7.32***	6.05	1.46
	348705	1.63	15.40	0.51	7.97	-2.30	0.64
	348708	1.02	47.02	0.26	***7.48***	3.90	0.65
	348720	2.10	-8.86	0.81	7.72	0.85	0.10
	348722	2.40	-24.42	0.36	8.02	-3.01	0.16
	348725	1.23	36.34	0.43	7.91	-1.54	0.60
	348728	1.15	40.28	0.26	8.08	-3.80	0.31
	348737	2.32	-20.27	1.05	7.51	3.58	0.44

	348743	1.67	13.22	1.31	7.57	2.76	0.40
	348750	1.97	-1.87	0.45	8.01	-2.83	0.18
	348754	1.54	20.11	0.48	7.85	-0.83	0.31
	348768	1.55	19.85	0.51	7.98	-2.53	0.20
	348773	***3.00***	-55.52	0.64	8.02	-3.01	0.16
	348780	1.92	0.41	2.95	***7.46***	4.20	0.55
	348793	2.01	-4.20	0.45	7.95	-2.14	0.25
	348796	1.20	38.00	0.28	***8.20***	-5.32	0.33
	348815	1.46	24.31	0.74	***8.20***	-5.36	0.37

Appendix M Field data and SSURGO

Table 1 Comparison of the field data for the organic matter percentage with the SSURGO data base for the corresponding map unit.

		Field data			SSURGO			
Map unit ID	Number of field samples	μ_{OM}	σ_{OM}	CV OM	μ_{OM}	σ_{OM}	CV OM	Percentage[1)]
348483	6	1.53	0.31	20.14	0.90	0.46	50.79	170.00
345283	2	1.47	0.23	15.39	1.09	0.38	34.39	134.86
345215	3	2.51	0.90	35.73	1.17	0.50	42.85	214.53
345164	4	1.51	0.27	18.14	1.15	0.68	59.25	131.30
345172	3	1.95	0.34	17.53	1.49	0.61	40.77	130.87
344234	4	1.76	0.64	36.48	1.03	0.41	40.27	170.87
344156	2	1.41	0.26	18.05	0.98	0.64	64.83	143.88
344155	2	1.66	0.08	4.70	1.06	0.66	62.10	156.60
344175	2	2.24	0.30	13.60	1.18	0.69	58.43	189.83
344212	6	1.76	0.56	31.95	1.05	0.55	52.42	167.62
344139	2	0.79	0.10	12.53	0.83	0.50	60.02	95.18
346876	8	1.85	0.50	26.80	1.50	0.68	45.39	123.33
346877	2	2.33	1.04	44.71	1.52	0.69	45.22	153.29
346745	6	1.64	0.51	31.24	1.53	0.71	46.39	107.19
348379	2	3.45	1.09	31.56	1.17	0.84	71.71	294.87
348627	2	2.90	0.87	30.04	2.00	1.37	68.58	145.00
348378	4	1.88	0.77	41.13	1.23	0.85	69.45	152.85
348627	3	2.31	0.36	15.68	2.00	1.37	68.58	115.50
348501	2	0.91	0.35	38.29	0.76	0.49	64.63	119.74
348711	2	2.77	0.24	8.68	1.24	0.56	44.90	223.39
348434	2	3.01	0.03	0.94	0.91	0.47	51.83	330.77
346300	3	5.66	3.36	59.40	1.28	0.67	52.56	442.19
346343	2	3.30	1.05	31.71	1.49	0.66	44.14	221.48
347583	2	2.59	0.33	12.56	1.01	0.51	50.19	256.44
347603	4	2.92	1.49	51.16	1.59	0.72	45.56	183.65
347583	2	3.43	3.06	89.40	1.01	0.51	50.19	339.60
347636	4	1.96	0.69	35.06	1.06	0.54	50.77	184.91
347794	6	2.51	0.73	29.19	0.86	0.40	46.60	291.86

[1)] $(\mu_{Field\ data}-\mu_{SSURGO})*100\%$

Table 2 Comparison of the field data for the pH with the SSURGO data base for the corresponding map unit.

		Field data			SSURGO			
Map unit ID	Number of field samples	μ_{pH}	σ_{pH}	CV pH	μ_{pH}	σ_{pH}	CV pH	Percentage[1)]
348483	6	8.1	0.04	0.51	7.97	0.47	5.84	101.63
345283	2	8.0	0.35	4.45	7.55	0.86	11.35	105.96
345215	3	8.5	0.60	7.12	8.80	0.25	2.85	96.59
345164	4	8.1	0.41	5.04	7.66	0.61	7.93	105.74
345172	3	8.2	0.00	0.00	7.62	0.61	7.94	107.61
344234	4	8.3	0.12	1.39	7.68	0.87	11.36	108.07
344156	2	8.3	0.00	0.00	7.83	0.55	7.03	106.00
344155	2	8.3	0.00	0.00	7.99	0.44	5.49	103.88
344175	2	8.2	0.14	1.73	7.55	0.84	11.08	108.61
344212	6	8.2	0.09	1.09	8.14	0.52	6.38	100.74
344139	2	7.9	0.00	0.00	8.30	0.53	6.42	95.18
346876	8	7.9	0.90	11.52	7.20	0.75	10.46	109.72
346877	2	7.7	0.78	10.17	7.14	0.68	9.50	107.84
346745	6	7.3	0.84	11.45	7.45	0.66	8.84	97.99
348379	2	8.1	0.21	2.64	7.78	0.61	7.81	104.11
348627	2	8.1	0.28	3.49	7.62	0.68	8.91	106.30
348378	4	8.0	0.17	2.13	7.74	0.62	8.04	103.36
348627	3	8.2	0.12	1.41	7.62	0.68	8.91	107.61
348501	2	8.3	0.00	0.00	8.19	0.47	5.72	101.34
348711	2	7.9	0.00	0.00	7.25	0.59	8.19	108.97
348434	2	8.2	0.07	0.87	7.95	0.50	6.32	103.14
346300	3	6.8	1.19	17.63	7.78	0.65	8.40	87.40
346343	2	7.0	0.07	1.02	7.41	0.77	10.42	94.47
347583	2	8.2	0.21	2.60	8.10	0.70	8.59	101.23
347603	4	7.5	0.68	9.04	7.25	0.72	9.97	103.45
347583	2	7.5	0.85	11.31	8.10	0.70	8.59	92.59
347636	4	7.4	0.74	9.99	8.02	0.72	9.014	92.27
347794	6	7.5	0.35	4.66	8.20	0.86	10.49	91.46