Patterns of Soil Health for Prime Agricultural Lands in the Greater City of Sudbury Area

By

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Abstract

At the regional scale, soil information regarding commonly employed land uses allows for improved negotiations between land owners, land managers and city planners, and also guides the adoption of sustainable policies and management practices to maintain the finite soil resources required for the on-going preservation of the local agricultural industry under stresses of a changing climate. The increasing management intensity of agricultural soils in the Greater Sudbury region, as elsewhere around the world, is placing negative pressure on the critical soil resource. This pressure is a result of reduced land availability from encroaching non-agricultural land uses, more powerful farming equipment, and a heavy reliance on chemical fertilizers. These diverse pressures are also intensified in the study area due to the strong local demand for topsoil and sod for urban development on the shallow rocky soils of much of the nearby urban area. In this study, a novel geo-referenced database was developed from measured soil health properties sampled in locally significant prime agricultural lands. Using Kruskal-Wallis comparisons, descriptive statistics and coefficients of variation, seven common land uses of the region were evaluated. Soil health properties were found to reflect land use cover and varied along a land use intensity gradient. The results from this study suggest that intensive land management practices in the region decreased topsoil total C concentrations, increased bulk density, narrowed the soil C to N ratio, increased total and available soil major nutrient levels, whilst triggering decreased micronutrient availability. Furthermore, in combination to contrasting soil health differences between dominant land uses, continuous predicted surfaces of soil properties created using GIS software, proved to be useful to highlight spatial patterns of soil properties influenced by local land use decisions. The results in this study confirm that soil resources in the prime agricultural lands of the region are at greater risk of ongoing loss of soil health due to management intensification.

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Chapter 1

Introduction

Presently, as many important decisions at the farm and regional scale are primarily based on the available soil information and the associated auxiliary data, an improved comprehension for the health of local soil resources is needed. Acton and Gregorich (1995), define soil health as "*the soil's fitness to support crop growth without becoming degraded or otherwise harming the environment".* The term soil health is often used synonymously with soil quality and includes both inherent and dynamic soil properties. From a soil management perspective, the four greatest threats to soil resource degradation in Ontario are erosion, compaction, the loss of organic carbon in surface horizons and surface soil acidification induced primarily by nitrogenous fertilizer application (Miller, 1986). From the perspective of a community, Miller and Wali (1995) state that the requirements to adopt a gold standard in promoting regional agriculture sustainability, economic and agricultural development should go hand in hand with the ecological and social-political realities. As well, the conservation of resources and the restoration of disturbed and degraded lands in an agro-ecosystem should be a priority.

Soil resource degradation caused by conflicting land uses is becoming a concern in the region of Greater Sudbury. The finite arable soil resources in the Sudbury area are limited to several small pockets within a bedrock dominated landscape. With no shortage of food, conflicting land use issues have arisen in the region with a comparatively wealthy and growing urban population placing greater pressures on soil resources for non-agricultural purposes such as housing, construction, transportation and recreation (Bouma, 2001). Therefore, to improve the prospects of regional viability of the agricultural industry, it would either require local operations to improve yields using less land, which often requires more intensive management practices, or decisions at the municipal level that guarantees the long-term preservation of the entire region's arable land.

Limiting the capacity to make suitable decisions at the farm and regional scale is the lack of detailed soil information. Soil information of the region is solely based on the published soil survey map series by Gillespie *et al.* (1982*a*), with an associated unpublished report (Gillespie *et al*., 1982*b*). A soil survey is a continually developing process that should reflect our current knowledge and societal needs for soil resources (Indorante *et al.* 1996). Since the Sudbury Soil Survey map series by Gillespie *et al*. (1982*a*) has not been regularly updated, the product has become less relevant as survey techniques improve (*i.e.* time favors more detailed work, improved statistical analyses, refinements in the classification systems), as new technology emerges (Geographic Information Systems, Remote Sensing, Precision Agriculture), as the perception of soil changes (*i.e.* from agriculturally focused to conservation focused information) and as soil management techniques cause significant changes in the soil morphology (*i.e.* artificial drainage, topsoil mining, liming and cultivation), (Bouma *et al*. 1986; Brus *et al.* 1992; Rogowski and Wolf, 1994; Indorante *et al.* 1996; Brannon and Hayek, 2000; Heuvelink and Webster, 2001; Anderson and Smith, 2011). None the less, the usefulness of the regional soil surveys by Gillespie *et al.,* (1982) should not be underestimated as the map provides an understanding of the distribution of soil resources, conveys soil information in an easily accessible and understandable visual fashion, and organizes pertinent data for land management and planning purposes (Simonsons, 1991). Information of the variability of soil resources can thus be applied to regional land use decisions to protect threatened arable lands, guide the expansion of agricultural activities onto marginal lands, to aid in provision of a local shelf reliant food supply and guide the prevention of environmental degradation (Bouma *et al*. 1986; Vogel *et al*. 2001; Akumu and McLaughlin, 2013; Lark *et al*. 2014). From a producer's perspective, this information can be interpreted to predict a soil's capacity to host the proposed land use, or to tailor land management strategies for resource conservation. The newly derived soil health information of this study, incorporated within the framework of the previous work by Gillespie *et al.* (1982*a*), will provide decision makers and land managers with a detailed representation of soil resource requirements of the local agricultural industry to support the expansion of the agricultural production in the region.

The provision of detailed soil health information to support agricultural production in the Sudbury region is further of importance since commonly found land uses in the region often involve intensive management practices which have the potential to exhaust limited local soil resources. These land uses include the mining and the exploitation of non-renewable organic-carbon rich topsoil resources (*i.e*. topsoil removal or topsoil stripping), sod production, potato rotations and other intensive cropping systems. When considering the soil variability at the field scale, the most relevant factors controlling spatial variability are parent material, topography, biota and management history (Brady and Weil, 2008). By studying the effect of similar management strategies over contrasting soil types, a range of expected soil properties typical of the management strategies can be inferred. Many studies use such empirical differences in management strategies to hypothesize their sustainability and effects on soil health (Droogers *et al.* 1996). Such information then becomes of practical use for local producers by improving the prediction of changes in soil health properties of a given soil under differing land management strategies (Bouma and Finke, 1992). The derived soil health information can then be included to the farm scale decision making to balance socio-economic conditions whilst improving management techniques for resource conservation (Bouma, 2001).

By improving the understanding of soil health properties under common found agricultural land uses, decision making processes at the regional scale would also likely be advanced. At regional scale, topography, parent materials and/or management history are important landscape attributes to predict soil variation (Brady and Weil, 2008). Soil variation between two soil types is commonly found to be more closely related to land use history than to their inherent chemical and physical characteristics (Bouma and Finke, 1992). For instance, better predictions soil organic carbon content were found to occur at the regional scale with the inclusion of land management history in the predictive model (Schulp and Verberg, 2009). As well, practical applications for regional soil health information in the Greater City of Sudbury Region can be applied to direct municipal or regional land-use decisions concerning prime agricultural lands by outlining typical 'operating' ranges of soil properties needed for commonly found agricultural land uses in the region. These ranges in soil properties could then be used to guide the inclusion or exclusion of a given soil within prime agricultural lands. Furthermore, if the success of restoration activities carried out by topsoil removal operations were to be based on capability of a specific soil to return to continual crop production, regional soil health information could then be useful to assess reference sites needed for the eventual development of restoration guidelines.

The objective of this study is to provide an improved understanding of prime agricultural soil resources within Sudbury, ON, region using a newly developed geo-referenced database of selected soil properties. The results provide a definitive baseline of quantitative soil variability data of soil health parameters within the Greater Sudbury region. Given the importance of the impact of human activity across the landscape, trends are discussed in relation to regional soil response under the dominant land use cover. Soil attributes such as topsoil C content, bulk density, C to N ratio and total or plant available nutrient stocks were quantified and evaluated to give indications of land use intensity. Differences in these soil properties in the Sudbury region are predicted to coincide with a land use intensity gradient as commonly found throughout the literature (Wilson et al. 2011). In addition to these findings, the utility of a GIS method used to visualize soil properties over a continuous surface to model future recommendations to improve this novel database as a decision making tool is discussed. Results in this study do confirm that soil resources in the prime agricultural land of the region are at greater risk of ongoing loss of soil health due to management intensification. The criticality of the long-term preservation and protection of ALL prime agricultural soils in the region should not be underestimated in the effort to encourage the adoption of improved management and conservation techniques to maintain regional soil health.

Chapter 2

Literature Review

In the subsections below, brief historical overviews of the local agriculture community and the creation of Agricultural Reserves are provided. A literature review was also compiled consisting of the available background information pertinent to the study area soil types and commonly found land uses. Included in the these subsections are summaries of available map products (*i.e.* soil information), descriptions of soil forming factors that control local soil development and research that highlight the effects of commonly employed land management practices on soil health properties.

2.1 History of the Farming Community in the Sudbury Area

In 1856, the Provincial Land Surveyor Albert Pellew Salter was the first to survey the Sudbury area as having good land with both agricultural and timber value (Salter, 1856). As the arrival of settlers was accelerated with the construction of the Trans-Canada railway in 1883, many settlers would find the favorable climate and easily worked soils of the Sudbury basin to be some of the most productive soils in region (Bélanger, 1949). Many of these settlers would work in regional lumber camps during winter months, returning to the Sudbury basin and the surrounding smaller pockets of fertile soils during the summer to work the land on their homesteads.

Since the beginning the community, the economic and cultural importance of local agricultural production has been overshadowed by the much larger mining industry. As mining activities grew in the beginning of the 20^{th} century, a common practice was the smelting sulphide ores in local roast yards. From these roast yards, the low-lying smoke high in sulfur dioxide fumigated the surrounding landscapes reportedly had devastating effects on surrounding crop yields on the agricultural lands. The following summary for the legal battles between local farmers and mining companies was originally summarized by Dewees and Halewood (1992). The earliest record of crop damages was in 1909, with affected farmers approaching local companies to seek compensation for lost income brought about by smelting activities. By 1915 farmers were presenting their claims before the Supreme Court of Ontario. In two joined actions, the Black and Lindala cases, the courts ruled in favor of the mining companies with plaintiffs being awarded up to 75% less than what was previously offered to them by the company, effectively attempting to force local farmers to accept any offer which the company saw fit. By 1916 crop damage claims had peaked. In hopes to reduce their local impact on the community, the mining companies moved their roast yards a further distance from the agricultural fields. By 1921, renewed legal actions from local farmers caused the swift enactment in the legislature of the infamous Damage by Fumes Arbitration Act. The act eliminated the right of farmers to either seek court injunctions or appeal the settlements decided upon by the provincially appointed arbitrator. The Act was abolished in 1924, only to be replaced with a similar drafted Act under the same name. The only considerable difference between the two Acts was the transfer of power from the Ministry of Agriculture to the Ministry of Lands, Forests and Mines. In the years that followed, the awarded claims were substantially reduced under Robert Murray, the newly appointed arbitrator. No compensation was given throughout these years for long-term damage to private agricultural lands in the region. Arguably, given these hardships, local farmers in the Sudbury area earned their place in history as they were one of the first groups to fight for the more modern and strict polluter-pays Regulations and Laws, both here in Ontario and across Canada.

Since the 1950's the number of active farms has been drastically reduced in the Greater Sudbury region. The 1951 census reported 68,869 acres as farmland, with 33,009 acres of this land being classified as improved. Of this improved land, 23,181 acres were under crops (Agricultural Economics Research Council of Canada, 1979). At the time, the loss of farmland in the former municipality of Sudbury was found to be the greatest in all northern Ontario (Hill, 1975). By 1976 census, only 33% of the reported farmland remained, with the land under cropping use being reduced by 61 %. (Agricultural Economics Research Council of Canada, 1979). The 2006 census revealed a further similar decline in agriculture in the region. During the 2006 to 2011 census period the total farmed area dropped from 9,264 ha to 8,121 ha, a 12.3% decrease. During 2006 and 2011 census period, cropped land had decreased from 3507 ha to 3247 ha, a 7.4% decrease.

2.2 Sudbury's Agricultural Reserve

In attempts to safeguard the local industry from outside pressures, the Agricultural Reserve was created through a 1978 bylaw, preserving 31 475 ha of the region's most arable soil for agricultural use. Delineation of the Agricultural Reserve lands were heavily based on the Sudbury Soil Map series by Gillespie *et al*., (1982*a*), with the boundaries being set to encompass most soils having an agricultural capability of Class 2, 3 and 4. Despite having developed stricter policies, the use of these lands for agricultural purposes continued to be threatened due to relaxed wording concerning property severances, urban expansion and topsoil removal.

In essence, the policy failed to protect farmland from the reach of topsoil removal operations, land segregation for single detached family dwellings, and rising property values. On top of all these disadvantages to local operations, both the community and the regional politicians continued to have a negative perception of the economic potential of local agriculture industry, in spite of the documented value of Sudbury regional agricultural production at $9,576,636 (Harry Cummings and Associates, 2009).

In attempts to curtail many of these issues, an agricultural background study of the Greater Sudbury area was commissioned in the year 2003. Using a combination the Gillespie *et al*., (1982*a*) Sudbury Soil Map Series that rated the agricultural capability using the Canada Land Inventory ratings, aerial photography, expert and local knowledge, prime and non-prime agricultural lands were differentiated within the Greater Sudbury City Plan. These findings were presented to the municipality in a report that utilized Land Evaluation and Area Review (LEAR) system. LEAR uses several weighted factors such as the CLI soil agricultural capability, drainage, road access, land use and parcel size in consideration of recommended land use. From these LEAR results, with accompanying GIS maps, the Agricultural Reserve boundaries were revised in 2006 to an inexplicably low area of 5869 hectares, with the extent of delineated arable land being mostly found within the Rayside-Balfour and Valley East communities of the Greater City of Sudbury (Figure 1). Along with these new boundaries, stricter policies concerning parcel severance and topsoil removal were implemented.

The future of the Agricultural Reserve still has many challenges ahead. The revision of the Agricultural Reverse lands has sparked criticism from both the non-agricultural and the agricultural communities. Most opponents to the Agricultural Reserve say the new policies limit their rights as property owners to severe their property into smaller parcels (White, 2012). In 2010, for example, a group of property owners with the intent on severing their properties or had local vested interests in topsoil removal successfully appealed to remove their properties and a large portion of surrounding land from the Agricultural Reserve, effectively reducing the Agricultural Reserve to 5366 ha (Figure 1; Whitehouse, 2010; Bradley, 2010). On the other side, in a region were land is hard to come by, local farm operators have said the new boundaries failed to protect some of the most productive soils in the region (Soenens, M. and Found, J., personal communications, 2010). Shortcomings with the Agricultural Reserve boundaries has been attributed to minimal ground-truthing, a lack of quantitative data of soil properties, a disregard to the integration of local producer knowledge, and a failure to include valuable farmland in close proximity to conflicting land-uses such as the ever-encroaching expansion of suburbia. As well, criticism towards the LEAR procedure highlighted that the procedure was developed for southern Ontario, and thus might not be effective for the bedrock ridden northern landscape. Furthermore, up to 10 percent of the newly protected land is reported to be, or have been, under the management of topsoil removal operations at the time of enactment, allowing the grandfathering' of parcels of land already been slated for stripping prior to the enactment of the bylaw. Although, topsoil removal was allowed to continue for 5 years after the enactment of the new boundaries of the Agricultural Reserve, stricter policies concerning rehabilitation guidelines were supposed to be developed by 'undescribed bodies' to ensure that the agricultural capabilities of these 'stripped' lands are restored once mining the topsoil ceased. As of today, no criteria or reclamation strategies have been developed

(Ferrigan, J., personal communications, 2015). The lack of oversight by municipal government means that the Topsoil Removal industry will be able to reclaim these lands, either as they see fit or consider financially viable, effectively allowing the continuation of this resource damaging business as usual.

2.2.1 The Geographical Extent of Sudbury's Agricultural Reserve

The Agricultural Reserve lands are located within the former municipalities of Rayside-Balfour and Valley East of the Greater City of Sudbury. Nearby community centers include Chelmsford, Azilda, Val Caron and Hanmer (Figure 1). The area of the Agricultural Reserve lands includes four distinct regions. The portion of the Agricultural Reserve surrounding Bradley Rd. is located to the extreme south-west of the area, with boundaries consisting of Joanette Rd. to the east, Vermillion Lake Rd. to the west, and the Whitson River to the south. The north boundary was set approximately at 440 m to the south of Hwy. 144, with the total area of the region surrounding Bradley Rd being 588 ha. The distinct region in the south-central Agricultural Reserve zone encompasses the lands surrounding Bonin Rd. and Montée Principale, with boundary extents largely controlled by the CN rail line and Labine St. to the south as well as Rural Road 15 and the Whitson River to the north. The total area of this region is 1651 ha. The north-central region includes area surrounding Seguin St., Rural Road 15, Vern Dr. and Martin Rd, with the boundaries of the north-central region to the south and east being relatively limited the extent of arable land along the banks of the Whitson River, with the northern boundary extending to Dominion Dr. The area of this region is 2733 ha. The final distinct region of the Agricultural Reserve is located north of Radar Rd. surrounding a portion the Côté Blvd and Dupuis Rd. The total area of this region is 357 ha. Additionally, the area removed from the Agricultural Reserve in 2010, was located south of the CN rail line and north of St. Agnes St along both sides of Rural Road 35 spanning an area of 503 ha.

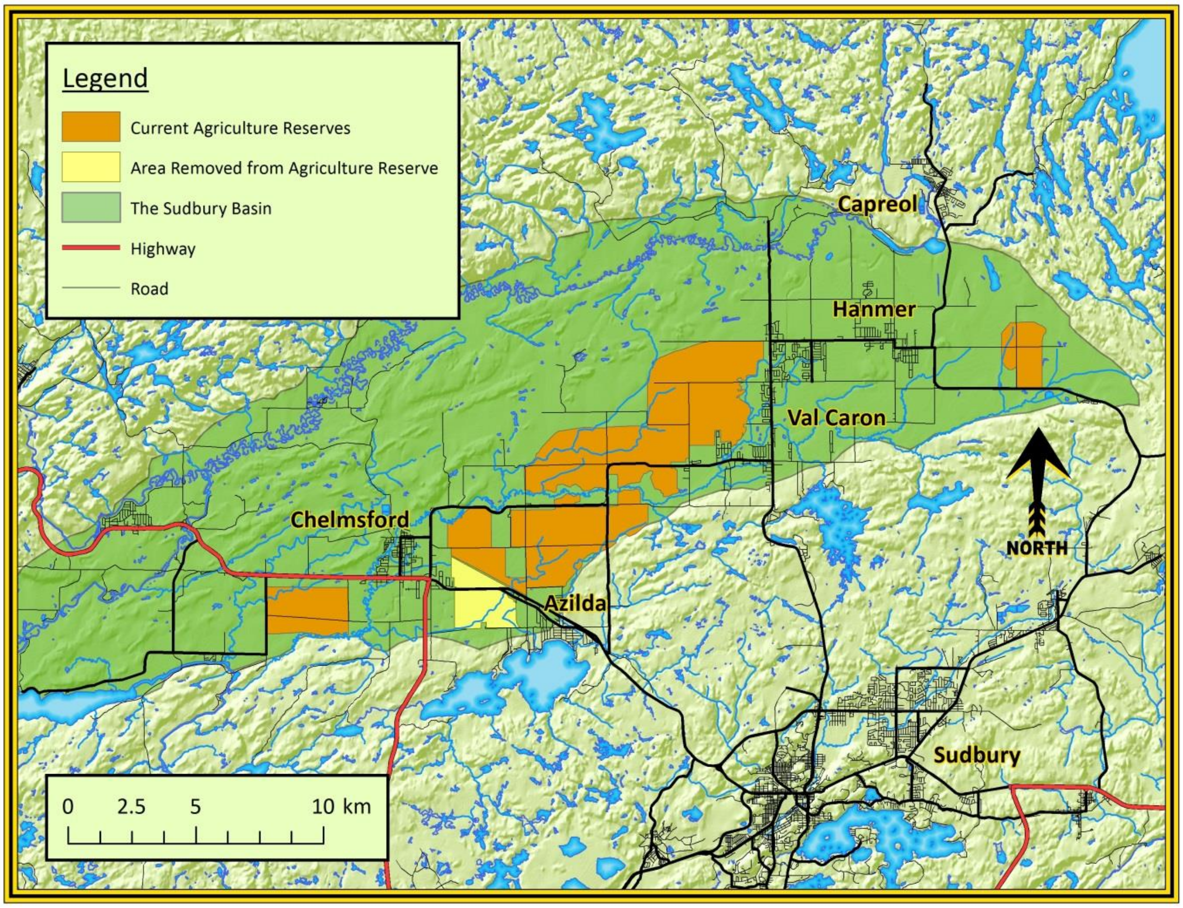


Figure 1. The geographical extent of the current City of Greater Sudbury's Agricultural Reserve lands are presented in orange ( ), the area removed from the Agricultural Reserve in yellow ( ) and the area of the Sudbury Basin in green ( ). Data courtesy of City of Greater Sudbury (Scale 1:211500).

2.3 Background Knowledge of Sudbury's Agricultural Soils

Under the Soil Survey of Ontario, the soils in the Sudbury Basin were originally surveyed by D.W. Hoffman in the summers of 1966 and 1967. In later years, using the soil survey data, a series of soil maps were published by Gillespie *et al.,* (1982*a*), the prime source of our knowledge of the spatial distribution of local soils. The accompanying report, with an isolated draft copy found in an office cleanout on the retirement of Tin Chee Wong of the Planning

Department, City of Greater Sudbury, was obviously prepared but remains unpublished today (Gillespie *et al*., (1982*b*).

2.3.1 The Sudbury Soil Survey and the Canada Land Inventory

During the Sudbury soil survey, in areas with adequate road access, D. W. Hoffman employed reconnaissance survey techniques with intermediate intensity ground checking. According to Valentine and Lidstone (1985) typically reconnaissance survey techniques meant one site inspection per 25 – 300 ha. As part of the routine soil survey protocol, the typical site selection process was largely based on the knowledge and experience of the pedologist completing the survey to choose a position where the modal pedon was representative of the entire landscape unit (Heuvelink and Webster, 2001). In the field, the surveyors used their formal training, their knowledge of the factors influencing soil formation, and their experience in the region of study to delineate landscape units. Therefore, a considerable amount of experience was needed to be effective in choosing representative pedons to describe and sample for any subsequent physical and chemical analyses. On selection of a suitable site by the surveyor, the pedon was described using the Canadian System of Soil Classification (Agriculture Canada, 1974). During the field survey, Hoffman sampled representative soil profiles of mapped soil series by horizon, and submitted soil horizon samples to the Ontario Soils Laboratory for specified analyses. These analytical results for these pedons were all presented in the unpublished report by Gillespie *et al.,* (1982*b*).

Once the survey was completed and the field data compiled, aerial photography and most current surficial geological information of the time were used to create the soil maps of the Sudbury Area, including the area within Agricultural Reserve, at a reconnaissance level (scale of 1:50,000), with soil type being defined at the soil series level (Gillespie *et al*., 1982*a*). At this level, soil series boundaries are broadly delineated based on internal pedon drainage characteristics, soil parent material texture and provenance (Evans and Cameron, 1983). Further, more than 90 % of soil boundaries were probably delineated using aerial photography (Valentine and Lidstone, 1985), with only limited ground truthing. Exploratory soil survey techniques were used for areas in the regions with limited road access, with the soil maps being produced at a larger scale (1:250 000). Soil map unit delineations at this scale were heavily weighted on aerial photographic interpretation (>95% of total boundary), with low intensity survey soil site investigation (> 1 every 1200 ha) providing irregular to minimal ground checking (Valentine and Lidstone, 1985). The map of Gillespie *et al*., (1982*a*) provides a pedological description individual soil series, with the information relevant for the Agricultural Reserve lands being summarized in Table 1. Figure 2 illustrates the spatial extent of soil series within and immediately surrounding the Agricultural Reserve.

2.3.2 Soil Agricultural Capability Classification

Initiated in the 1960's, the Canada Land Inventory (CLI) was a massive country wide soil resource inventory undertaking during an era when the Canadian economy was shifting from a rural and agricultural base dominance to a developing urban and industrial country society. The objectives of the CLI were to aid Provincial and Regional government agencies at the forefront of regional planning to better manage and protect their natural resources from the emerging environmental and land use change threats found within these changing communities.

The predicted soil capabilities were determined through interpretation using expert knowledge, climatic characteristics and other published environmental data on the region (Environment Canada, 1972). Soil series delineated in the Gillespie *et al.*, (1982*a*) soil map of the Sudbury Area were interpreted for the CLI program to provide an estimation of associated agricultural capabilities. Figure 3 displays the CLI agricultural rating across the area Sudbury Agricultural Reserve. Table 1 provides more detailed description of individual soil series found within the Agricultural Reserve lands, indicating their CLI Agriculture rating.

The CLI ranks soil in 7 broad agriculture productivity and/or suitability classes based on soil attributes of individual mapping units and regional climate. The agricultural capability progresses from Class 1, with no significant limitations for crop production, to Class 7 being considered unsuitable for agriculture. The Greater City of Sudbury mainly consist of soils derived from a thin veneer glacial till that cover a knobby to rolling bedrock ridden landscape. Under the CLI agricultural rating system these soils are a Class 7. Though, due to the variety of surficial geological deposits in the region, small pockets of arable soil are found intermittently within the low-lying areas. The largest area of arable soil in the region is found within the Sudbury Basin (Figure 1). While there are no Class 1 soils due the cooler climate of the region, all Class 2 soils in the Sudbury Basin are limited to small pockets mainly in the western portion. These Class 2 soils have moderate limitations for crop selection and/or need modest conservation practices, with a large fraction of the soil area remaining outside the Agricultural Reserve boundaries. The majority of the lands in the Agricultural Reserve of the City of Greater Sudbury have an agricultural capability designated as of Class 3 and 4 (Figure 3). These soils have moderate to severe limitations for crop production, possibly requiring site specific conservation practices. The soils having a coarse sand to gravelly parent material located in the north-east portion of the basin along the fluvial deposits of the Whitson River of the Sudbury Basin were designated as Class 5 and 6.

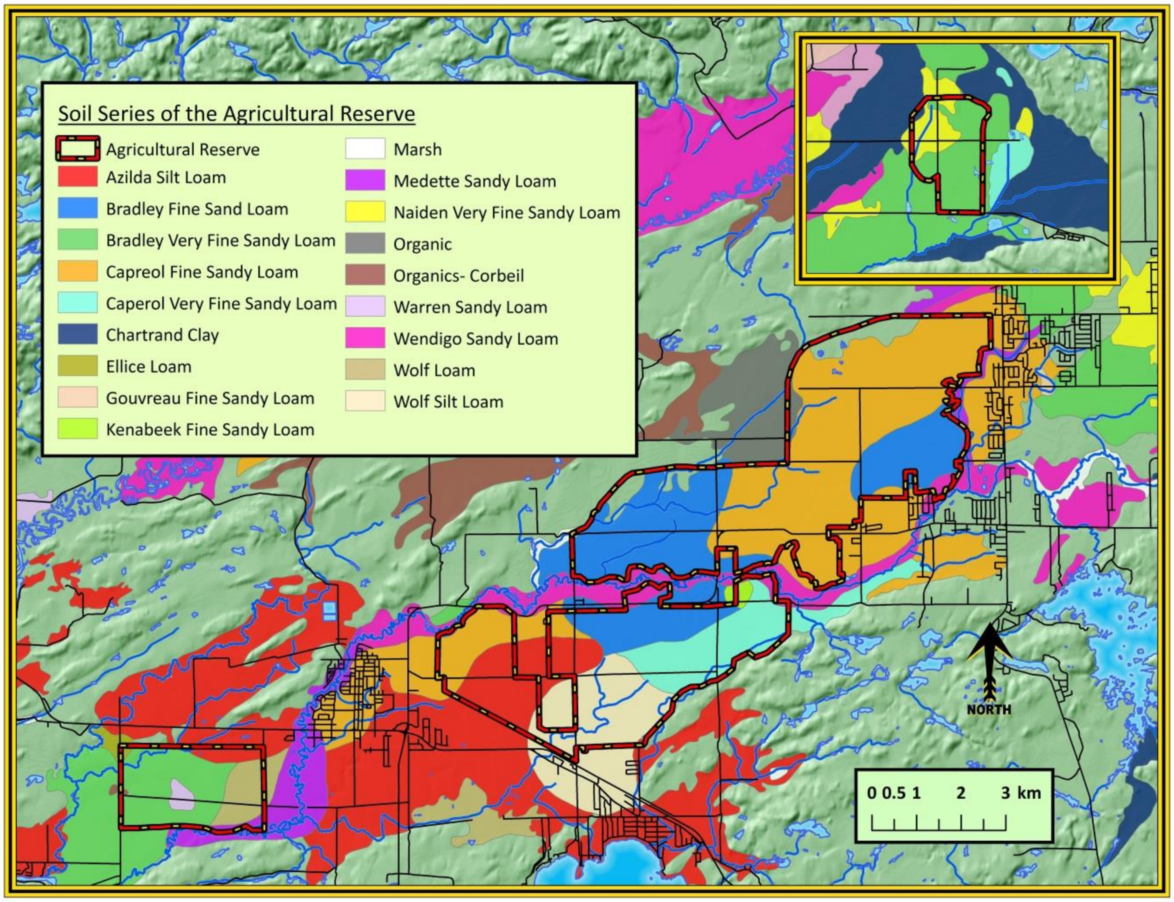


Figure 2. Map depicting the extent of various soil series found within and surrounding the Agricultural Reserve lands ( ) of the City of Greater Sudbury, ON. The soil series (soil mapping units) of the Agricultural Reserve are the Azilda Silt Loam ( ), the Bradley Fine Sandy Loam ( ), the Bradley Very Fine Sandy Loam ( ), the Capreol Fine Sandy Loam ( ), the Capreol Very Fine Sandy Loam ( ) and the Wolf Silt Loam ( ). Map scale (1:105,750). Data courtesy of Canadian Land Inventory (1998) and City of Greater Sudbury.

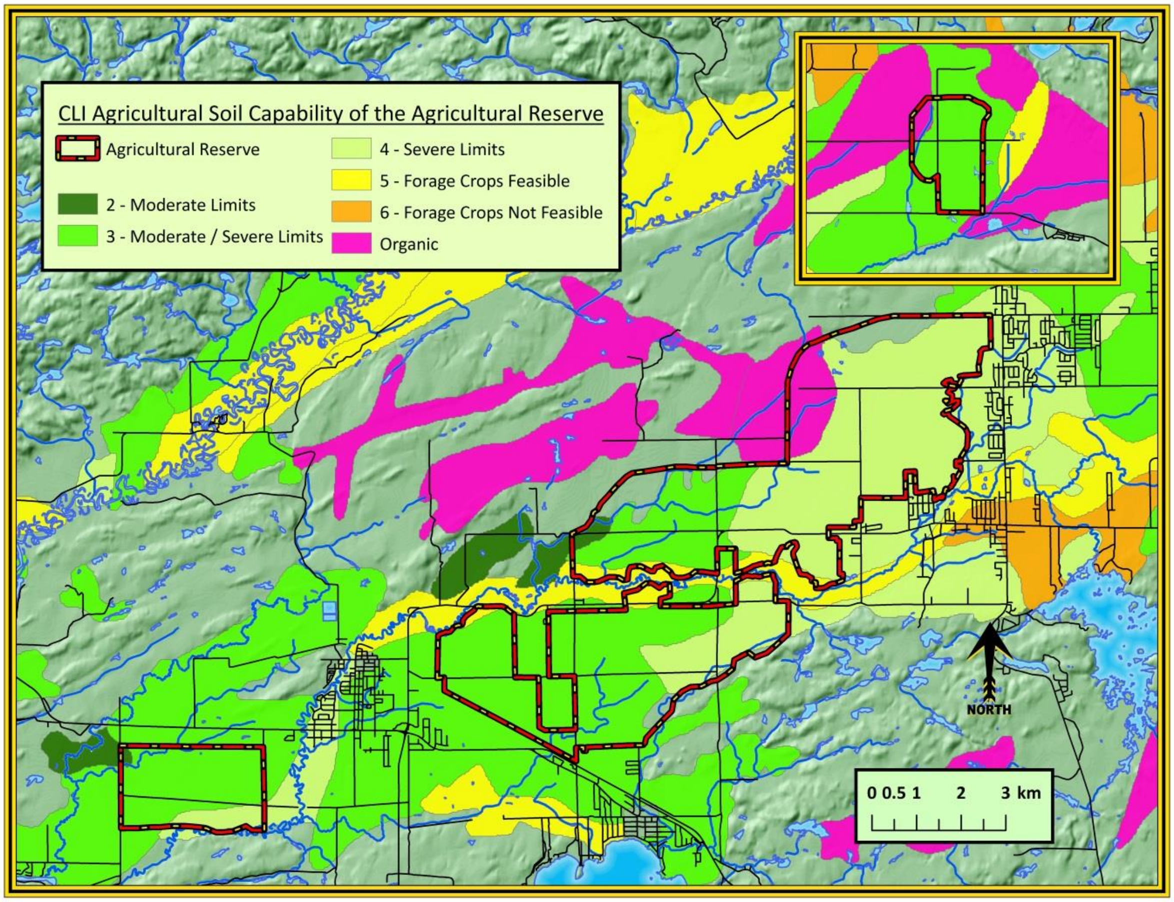


Figure 3. Map Depicting the CLI Agricultural Soil Capability Classes found with the Agricultural Reserve ( ) of the City of Greater Sudbury. The dominant soils capability classes found within the Agricultural Reserve lands were Moderate / Severe Limits ( ) and Severe Limits ( ). Map scale (1:105,750). Data courtesy of Canadian Land Inventory and City of Greater Sudbury.

Table 1. Summary of relevant information concerning soil series found in the Agricultural Reserve (AR) lands. For individual soil series their associated catena (information sometimes not available), subgroup, soil material, drainage, agriculture capability (AC) and their extent of the AR are shown.

Catena	Soil Series	Soil Subgroup	Soil Material	Drainage	Slope	AC	Extent of AR (ha)
	Azilda Silt Loam	Rego Humic Gleysol	calcareous silt loam lacustrine deposits	Poor	Level	3W	368
	Bradley Fine Sandy Loam	Gleyed Humo - Ferric Podzol	noncalcareous very fine sandy outwash or deltaic deposits	Imperfect	Gently undulating	2C	1177
	Bradley Very Fine Sandy Loam						605
Nairn	Capreol Fine Sandy Loam	Orthic Humic Gleysol	noncalcareous very fine sandy outwast or deltaic deposits	Poor	Level	4W	1757
Nairn	Capreol Very Fine Sandy Loam					4W	390
Chartrand	Chartrand Clay	Gleyed Gray Luvisol	noncalcareous clay loam, silty clay over clay lacustrine deposits	Imperfect	Gently to moderatly rolling	3D	6.8
Ellice	Ellice Loam	Ortho Humo - Ferric Podzol	calcareous stony sandy glacial till	Good	Moderately sloping	3P	6.7
Westmeath	Kenabeek Fine Sandy Loam	Orthic Gleysol	noncalcareous medium and coarse sand and gravelly sand outwash	Poor	Level	5WF	18
	Marsh	undifferentiated	periodically flooded or continously wet area not deeply submerged				4.3
Dokise	Medette Sandy Loam	Gleyed Humo-Ferric Podzol	noncalcareous fine sand outwash or deltaic deposits	Imperfect	Level to undulating	4FM	36
	Naiden Very Fine Sandy Loam	Orthic Humic Gleysol	noncalcareous very fine sandy outwash or deltaic deposits	Good	Gently sloping	3F	96
	Organic	Unclassified	undifferentiated organic material	Very Poor	Level		36
	Organic - Corbeil	Terric Humisol	humic peat with mineral layers, 90-160 cm thick, overlying silty clay material	Very Poor	Level	4HK	1.6
	Rockland		less than 10 cm soil material overlying bedrock and exposed bedrock		Moderately rolling to very hilly	7R	192
Dokise	Warren Sandy Loam	Orthic Humic Gleysol	noncalcareous fine sand outwast or deltaic deposits	Poor	Level	5W	30
Wendigo	Wendigo Sandy Loam	Orthic Humo - Ferric Podzol	non calcareous medium to coarse sand and gravelly sand outwash of Precambrian materials	Good	Gently sloping	4FS	97
Baldwin	Wolf Loam	Orthic Humic Gleysol	noncalcareous silt loam over silty clay loam lacustrine deposits	Poor	Nearly level to slightly undulating	3W	121
Baldwin	Wolf Silt Loam	Orthic Humic Gleysol		Poor			387

2.3.3 Soil Types of the Agricultural Reserve Lands

The Canadian System of Soil Classification (CSSC) provides a framework for the classification of pedons across Canada based on their measurable and observable differences in morphological, chemical and physical characteristics. Introduced in 1955, the CSSC is constantly evolving to reflect the current knowledge of soil formation (Soil Classification Working Group, 1998). Today, the CSSC classifies soils under five hierarchical categorical levels, with the Order being at the highest level of abstraction, enabling the pedon described on a site to be classified into one of the Canadian soil taxa which best reflects the integration of the dominant soil-forming processes. The dominant pathway of soil development can be hypothesized from the distinct arrangement of horizons or key properties resulting from the persistence of either current or historical dominant processes acting within the pedon over time. Furthermore, Quaternary soils may be polymorphic soils, reflecting several pathways of soil development (Simonson, 1978). The second broadest category is the Great Group, created to describe the degree to which the dominant soil forming process effected the pedon, indicating the presence of an important secondary process contributing to the formation of the polymorphic soils. The Subgroup, the third level of abstraction defined in the CSSC, builds on the Great Group, being based of soil horizon sequence and specific soil properties present within the pedon. The Great Group may also indicate the presence of an unusual horizon or the slight evidence of a previously unconsidered soil-forming factor, leading to the recognition of the Subgroup. At the Subgroup level to which the soils in the Sudbury Area were classified in the report by Gillespie *et al*., (1982*a*), our hypothesized knowledge of soil genesis processes enables suitable management of individual mapping units to be predicted.

The majority of soil profiles surveyed in the Agricultural Reserve are classified in Humic Gleysols, Gleysols or Humo– Ferric Podzol Great Groups, with minor areas of Humisols and Gray Luvisolic soils being present. The geographic distribution of these individual soil bodies in the Agricultural Reserve lands is largely controlled by landscape position, topography and parent material, with the wettest soils occurring in areas of fine texture and low relief. These inherently poorly drained soils were mainly classified in the Gleysolic order. The coarser textured soils are generally classified in the Podzolic order. Podzolic soils have improved internal drainage capabilities in comparison to Gleysols and in the Agricultural Reserve lands Podzols are classified as imperfectly drained. Figure 4 depicts the predicted CLI drainage classes of soil series in the Agricultural Reserve.

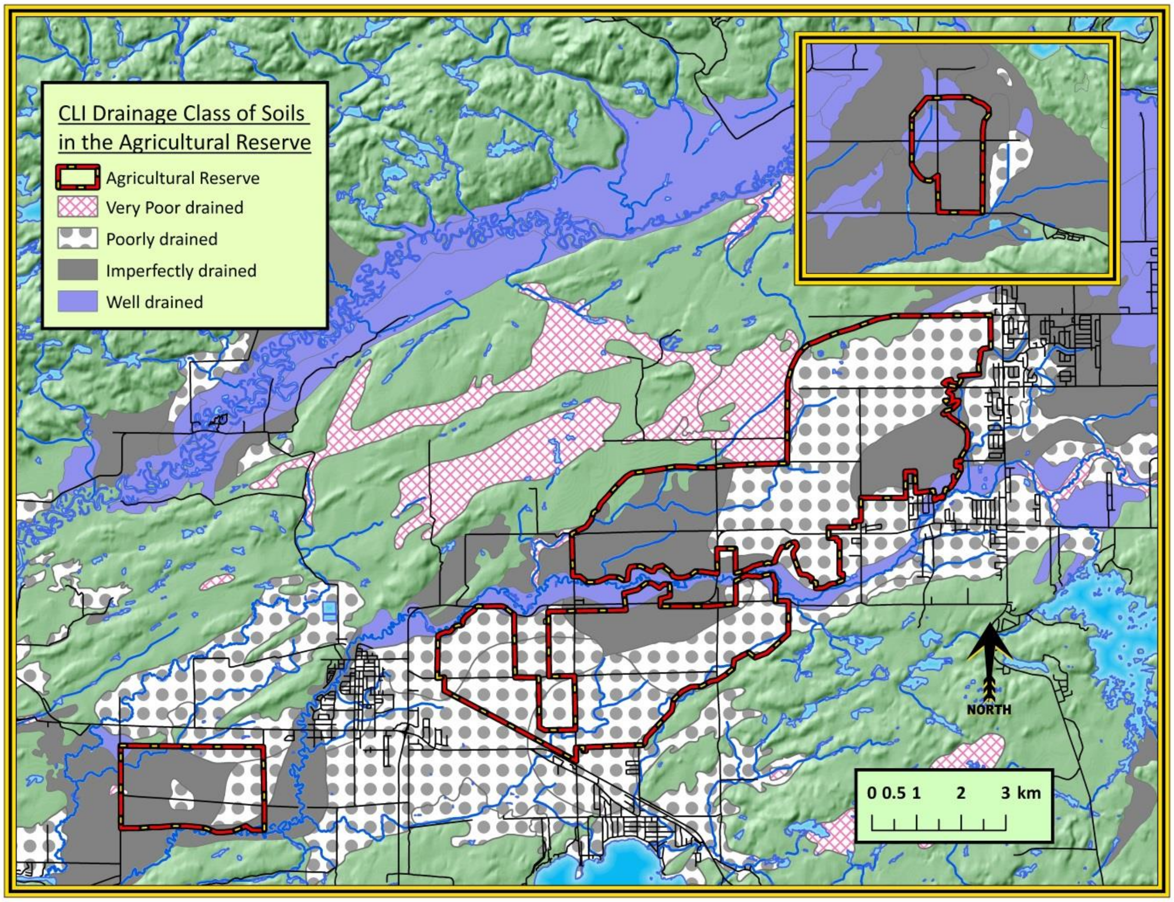


Figure 4. Map Depicting the CLI Agricultural Soil Drainage Classes found with the Agricultural Reserve ( ) of the City of Greater Sudbury. The dominant drainage classes found within the Agricultural Reserve lands were poorly drained soils ( ) and imperfectly drained soils ( ). Map Scale (1:105,750). Data courtesy of Canadian Land Inventory and City of Greater Sudbury.

2.3.3.1 Gleysolic Soils

The following is a summary of the description provided by the Soil Classification Working Group (1998). Soils belonging to the Gleysol order are distinguished by dull colors of low chroma. During their genesis, Gleysols form under periodic anoxic conditions, generally due to a shallow and fluctuating groundwater table, oxidation-reduction reactions controlling their dominant soil forming processes. When high groundwater tables persist, oxygen is quickly depleted as a primary oxidizing agent for the decomposition of available soil organic matter by heterotrophic microorganisms. As soil environments become anoxic, microorganisms called facultative anaerobes become more important for the decomposition of organic matter. These microorganisms are specialized in using oxidizing agents such as Mn^{4+}, NO_3^- and Fe^{3+} to facilitate the decomposition of organic matter. As a result of the different pathway for decomposition of organic matter in these wetter soils, decomposition is often slowed, favoring the rapid accumulation of organic matter (Bedard-Haughn, 2011).

Furthermore, redoximorphic features, such as mottling, are common in the Gleysolic soils. Mottles form in two steps: firstly, under anaerobic conditions, Fe^{3+} is reduced to Fe^{2+} by facultative microorganisms giving the soil matrix a dull color and an associated increased mobility of Fe^{2+} in comparison to Fe^{3+} within the soil matrix (Bedard-Haughn, 2011). Furthermore, the increased mobility of Fe^{2+} ions within the soil matrix in comparison to Fe^{3+} over time potentially reduces Fe_{total} within the soil matrix. As saturated conditions subside with evapotranspiration or internal dropping of the water table, Fe^{2+} in solution is oxidized to Fe^{3+} which, in turn, precipitates as secondary minerals in localized areas. This secondary minerals form mottles with their brighter reddish to yellow colors, leading to increased soil chroma within a dull grey background matrix.

The Humic Gleysol is differentiated from the Gleysol Great Group by the presence of Ah(g) horizon (≥ 10 cm) or Ap horizon (≥ 15 cm) with an organic carbon content greater than 2 %. The formation of Humic Gleysols in the region is likely due to paludification and/or melanification processes (Bedard-Haughn, 2011). Many soils in the Agricultural Reserve are classified as Orthic Humic Gleysols, simply indicating that the pedon characteristics correspond closely to those described for the Great Group.

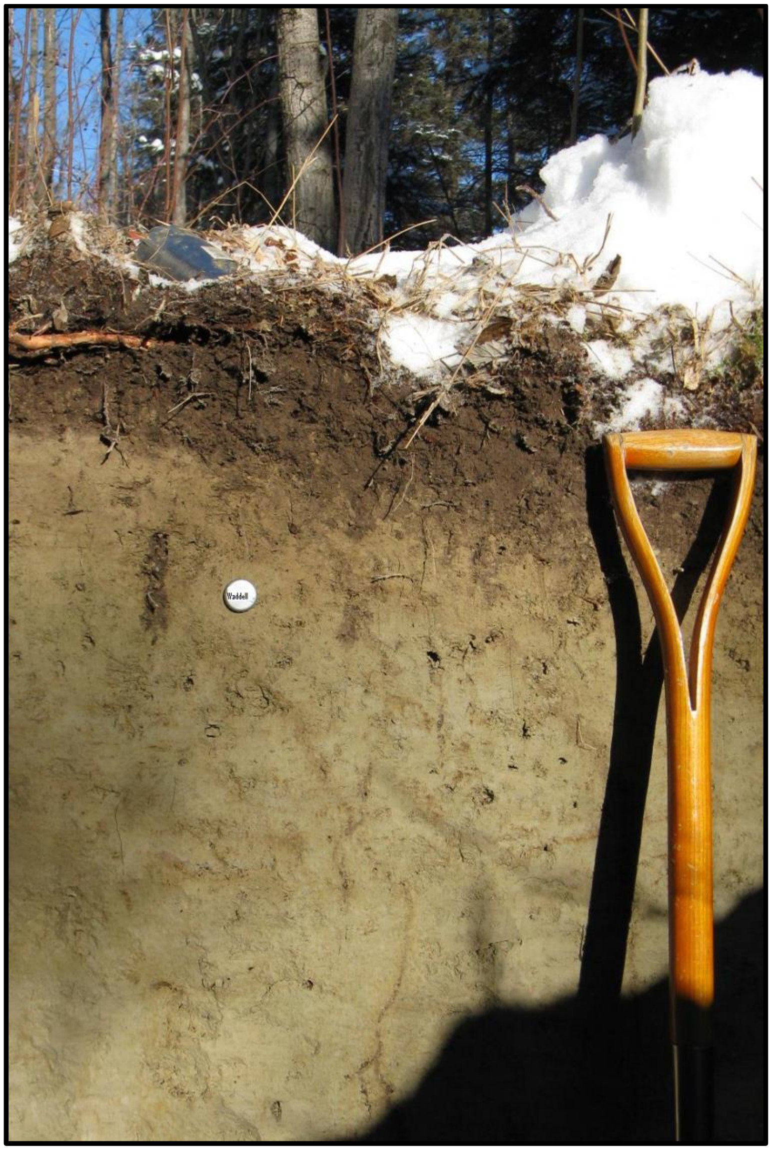


Figure 5. Silt Loam Humic Gleysol soil profile under a forested upland site typical of the Azilda Silt Loam Soil Series.

Extensively used in northern and southern Ontario within the forestry and agriculture industries, Gleysolic soils have proved to be productive soils due to their high organic matter contents (Bedard-Haughn, 2011). Evans (1982*b*) documented that the cation exchange capacities of multiple Orthic Humic Gleysols in Ontario under cultivation varied with organic matter content and clay contents. Without proper management, the inherent high moisture contents of Gleysols potentially provide unfavorable growing conditions for agriculture purposes (Bedard-Haughn, 2011). Therefore, their land use potential and their practicality are somewhat limited without careful management. For instance, if the necessary precautions are not taken, wet soils under intense management can be adversely affected by compaction with use of heavy machinery (Kenney *et al*. 2002). Compaction under wet conditions reduces soil porosity, thus limiting aeration and internal drainage which, in turn, therefore reduce plant growth. A common practice to overcome the problems associated with managing a periodically saturated soil is to provide artificial drainage systems to create a more aerobic environment in the plant-rooting zone. With such agronomic improvements, vegetation communities are altered, soil structure improves and nutrient cycling is enhanced. Thus planned drainage of Gleysolic soil areas allows different agricultural land uses to take place (Bedard-Haughn, 2011).

2.3.3.2 Podzolic Soils

Generally, the Podzolic soils in the Agricultural Reserve lands have formed in medium textured parent materials, having mineral topsoil layers with a low pH buffering capacity. The Humo – Ferric Podzol Great Group soils of the region can easily be distinguished from their dull colored Gleysolic counterparts, having a distinguishing reddish-brown B Horizon enriched in both humic substances and Fe and Al sesquioxides (Soil Classification Working Group, 1998). Wang *et al.* (1991) proposed that landscape position and moisture regimes have an important influence over the intensity of the coloration of the B horizon and therefore the classification of the pedon. The Humo – Ferric Podzol is distinguished from other Podzols with a slightly less brown B horizon than the Ferro Humic Podzol. Even though, the Humo-Ferric Great Group soils can develop over a wide variety of topographic positions and water regimes, they generally form in a lower landscape position than the Ferro-Humic Podzol, resulting in a B horizon with less intense coloration. Furthermore, areas of Podzolic soils commonly have Gleyed Subgroup associated pedons, indicative of the presence of redoximorphic features resulting from periodic saturated conditions during pedogenesis. Consequently, these Gleyed soils formed in a lower and wetter landscape position have an even duller B horizon than those of the Humo-Ferric Podzols. Furthermore, commonly present in the Podzolic pedons is a grey eluvial horizon rich in quartz, found between the illuvial B horizon and the organic rich A horizon. However, under cultivation the grey eluvial horizon of these soils is commonly destroyed and incorporated into the Ap (*i.e*. plow) horizons (Wang *et al.* 1984).

Figure 6. Soil cores (2.5 cm diameter) of a Gleyed Humo-Ferric Podzols in the Bradley Very Fine Sand Soil Series near Radar Rd. Cores (A), (B) and (C) have evidence of a historic plowed A horizon and a newly developing LHF horizon. Core (C) was taken from a lowland position in comparison to (A) and (B) and has evidence of redoxomorphic mottling.

The formation of Podzols is due to a combination of processes collectively called podsolization. There are several factors that promote podzolization: a cool and humid climate with adequate precipitation, a medium to coarse textured parent material to insure adequate water infiltration through the soil profile, a low buffering capacity in the topsoil horizons which enhances the mineral weathering process, and the addition of forest litter rich in organic acids to favor release and translocation of water soluble organo-mineral complexes. These organic acids leach soluble Fe, Al and Si ions from the eluvial horizon to the B horizon where they are precipitated (Lunsdrom *et al.* 2000) to give the B horizon a characteristic color. Evans (1982*a*) provides a detailed characterization of a Podzolic solum in the Chapleau-Foyelet area NW of Sudbury which has developed within a similar parent material. In an earlier publication Evans (1980) also studied the effects of parent material and vegetation on the effects on Podzolic soil development in the near the Aubrey Falls region along Ontario Highway 129.

Many studies have documented agronomic issues with the management of Podzolic soils. In Eastern Canada, for example, Podzols are considered to have a relatively low fertility (MacLeod and Suzuki, 1972). The gradual removal of nutrients from these soils as a result of harvesting lumber has been a core focus of the forestry industry for over 30 years (Sanborn *et al.* 2011). Management techniques for agricultural use of Podzols are often intensive. Common management techniques to ameliorate Podzolic soils include the addition of lime to raise the pH, with incorporation of chemical fertilizers to improve fertility (Simard *et al*. 1988). As well, Podzolic soils have been documented as having a high P fixing capacity (Laverdiere, 1982). Other management issues arise due to their low organic matter content and low water availability (Sanborn *et al.* 2011). As a result, the use of organic amendments and irrigation may benefit the agronomic potential of these soils (Lalande *et al*. 1998; MacKay and Eaves, 1962). Also, these soils under cultivation are subject to compaction with Carter (1990) suggesting that regular plowing may be needed to alleviate the negative effects of compaction.

2.3.4 Limitations of Conventional Local Soil Survey Data

The purpose of the Sudbury soil survey in the late 1960’s was to document the soil resources in the area for the first time for a rapidly changing society. The power of soil surveys should not be underestimated since they provides a greater understanding of soil resources, convey soil information in an easily accessible fashion, and organize pertinent data for land management and planning purposes (Simonson, 1991). Although, a soil survey is a continually developing process that should reflect our current knowledge and needs for soil resources (Indorante *et al.* 1996). As society's perception of soil changes, so too does the need for different types of soil information (Bouma, *et al*. 1986). For instance, agriculturally focused information might not be best suited for efforts to conserved resources or mitigate climate change. Emerging technologies such as Geographic Information Systems, Remote Sensing and Precision Agriculture in conjunction combined with more accurate survey techniques, improved statistical analyses and refinements to soil classification systems are further driving the need for soil information to be applicable for a diversity of disciplines and users (Indorante *et al.* 1996). Furthermore, if soil surveys are not regularly updated, previous derived soil information, may become inaccurate as soil management techniques, such as artificial drainage, liming and cultivation causes a soil to be misrepresented changes to soil forming processes and soil morphology (Bouma and Finke, 1993).

New developments in technology and standards have caused the representation of local and regional soil variation by Gillespie *et al*. (1982*a*) to become inadequate. With improved data acquisition, coupled with manipulation and presentation of soil property parameters, conventional soil maps do not adequately provide the level of detail needed for sophisticated uses of soil information to meet today's standard requirements (Cook *et al.* 1996). New developments are responsible for an eruption in quantity of soil data as a result of easy acquisition by remote sensing, by use of proximal sensors and improved analytical devices, use of the relatively user friendly visualization and manipulation tools available with GIS software, and improvements in regional data sources such digital elevation models, with a wide availability of online data libraries (McBratney *et al.* 2003).

The unpublished Gillespie *et al*., (1982*b*) map series data for the Sudbury Region is also becoming of limited use because of societal demand for more quantitative data, reflecting the approach of the traditional survey techniques to represent soil information in a qualitative manner. The common practices of the time were to require few direct observations and supplementary horizon analyses. The final results highlighted in the published maps were heavily based on indirect evidence obtained from aerial photographs, available surficial geologic information, coupled with vegetation and land use observations (Heuvelink and Webster, 2001; Fortin and Moon, 1999). As a result, soil variation reflected the surveyor's expert knowledge and formal training (Hudson, 1992). The traditional 'knowledge system' of the soil survey used to delineate soil series did not limit usefulness as the purpose was to familiarize users with soil-landscape units and the associated factors of soil formation dominant within those units (Bui, 2004). The understanding that conventional soil maps produced vary significantly in their accuracy, detail complexity, and output is critically important, especially as there is no associated indication of predictive errors (Rogowski and Wolf, 1994; Fortin and Moon, 1999). This understanding was especially true for the Gillespie *et al*., (1982*b*) map series since minimal supplementary data describing the variation of specific soil properties across the region and no accompanying prediction error limits were provided. These limitations affect the use of conventional soil maps for the use of other studies that require more quantitative data such as land evaluations, environmental risk assessments and land use negotiations (Bouma *et al*. 1986; Fortin and Moon, 1999; Webb and Lilburn, 2005). The only indication of soil map unit variation with Gillespie *et al*., (1982*a*) is within compounded mapping units that represent two closely related soil series in which their individual percentage importance coverage is approximated. This type of representation of soil variation leaves the user with only a vague impression of how soils do vary in actuality (Heuvelink and Webster, 2001).

The scale of the Gillespie *et al*. (1982*a*) maps provides an unavoidable error, with the variations depicted in the map series being largely controlled by the low variability of the surficial geological deposits with minimal availability of surficial geology maps at the time to provide critical supporting data. At the scale and intensity of field observations during the field survey phase, the inherent soil variation caused by the underlying parent material variability can go unnoticed by the surveyor since the underlying deposits have been covered by windblown sediment or reworked by water over time. Therefore, small land pockets may have different sub-soil properties reflecting changes in soil development may be misrepresented in the coarse map unit delineations, an observation especially true for deposits of fluvial origin. Furthermore, differences in slight changes in topography and drainage can cause differences in soil development not represented at the scale of the mapped units. Wang and McKeague (1986) found short range variability caused by differences in topography in Ferro-Humic Podzols to be significant at finer scales than that represented in maps produced at a semi-detailed scale of 1:50,000. This observation is especially true for lacustrine deposits in a gently undulating landscape where a slight difference in topography on the order of a few decimeters can have a significant effect on both internal and external soil moisture regimes, and hence on soil profile development (Figure 10).

Another potential source of error in use of the maps produced by Gillespie *et al*. (1982*a*) arises as they may not now reflect our current knowledge of the state of soils in the Agricultural Reserve lands. Land management has been shown to greatly affect the current state of a soil, often enough to completely shift the dominant soil forming process (Bouma and Finke, 1993). Such intensive land management techniques can include cultivation, liming, irrigation, drainage and topsoil removal. Importantly, a possible limitation of the genetic soil classification approach within the CSSC is that the current soil forming process does not dictate the soil profile classification. The CSSC classification approach classifies soils based the dominant soil forming factor that contributed to a pedon's morphological characteristics irregardless of the current dominant soil forming process guiding the pedon classification (Soil Classification Working Group, 1998). In the case of Podzolic soils, Wang *et al.* (1984) found the B horizon characteristic necessary for the Podzol classification was commonly not met because of the disturbance of cultivation (Wang *et al.* 1984). These soils would now either be reclassified as Regosols or Brunisols. Furthermore, potential future revisions of the CSSC may one day include a new Order, the Anthroposols. Anthroposols are soils significantly affected or altered by man (Naeth *et al.* 2012). Such alteration could include the removal of, or the construction of, one or more horizons. This development in classification may be especially relevant to the Sudbury region since topsoil removal is common, both in the Agricultural Reserve and surrounding farm land.

Current knowledge of local drainage represented by the Gillespie *et al*., (1982*a*) map series might also misrepresent certain areas. Approximately 60 % of the soils in Agricultural Reserve lands were predicted as having an Agricultural Capability limited by poor or imperfect drainage. McKeague and Topp (1986), highlight the serious limitations for interpretation of internal and external drainage classes in Ontario as described by Chisholm *et al*., 1984. Soil drainage classes in Ontario were largely based on soil texture and described soil structures. According the findings of McKeague and Topp (1986), these criteria for predicting a soils drainage class are severely limited since the soil drainage status is not related directly to texture (McKeague *et al*., 1982). As well, soil structure was not consistently described, with subjective differences between surveyors being noted. McKeague and Topp (1986) suggested that soil drainage classes were better predicted by saturated hydraulic conductivity measurements, accompanied by improved soil morphological descriptions. They also noted that land use had an influence on measured soil saturated hydraulic conductivities. Further, the drainage classes assigned to mapped soil units do not take into consideration the improved conditions created by the development of municipal drains throughout the Agricultural Reserve.

2.3.5 Upgrading Conventional Soil Surveys

Brus *et al.* 1992 summarizes the merits and efficiencies of four potential strategies for updating a conventional soil survey. The four strategies studied were revision, upgrading, revision plus upgrading, and upgrading by two-phase sampling. Revision refers to changing the boundaries of map units, while upgrading refers incorporating statistical estimates such as means and variance of soil within the mapping unit. Brus *et al.* 1992 concluded the merits of upgrading over revision to be a cost effective manner to update a conventional soil map when funding is limited, especially as upgrading also provides an advantage when studying the variability caused by human activities. Furthermore, in certain cases upgrading provided a superior prediction of spatial means of studied soil properties.

2.4 Soil Variation at the Regional Scale

Soil variation is a complex phenomenon where little remains constant over space and time, stretching from the microscopic to the megascopic scales and fluctuating in both the short and the long terms. The study of variability in soils is multifaceted as it is not merely an academic question, but is a real landscape attribute that is commonly poorly understood (Wilding, 1985). The ability to predict soil behavior is claimed to be restricted by our ability to accurately represent soil variability (Cook *et al.* 1996; Finke and Wosten, 1996). Potential sources of soil variation can either be natural (*i.e.* geologic and pedogenic processes) or anthropogenic (*i.e.* management strategies, pollution, introduced species) (Goderya, 1998). In today's world, a good comprehension of soil variability is essential as many important decisions are primarily based on the available information and the associated auxiliary data. This information is regularly used in agronomic land management decisions to develop effective and sustainable practices, to promote local resource conversation, to negotiate municipal land uses and to conduct environmental and health risk assessments (Bouma, 2001; Fortin and Moon, 1999; Webb and Lilburne, 2005; Wosten *et al*. 1999).

2.4.1 The Formation of Soil and its Inherent Variability

From a land management perspective, soil variation becomes important from scales ranging from a few meters to several kilometres (Brady and Weil, 2008). Across all scales, spatial variations in soil properties and morphology differences can be explained by the degree of influence of the five factors of soil formation originally proposed by Vasil'evich Dokuchaev (circa. 1846-1903) of Russia, and subsequently validated by the more famous work of Hans

Jenny (1941). These key factors are parent material, biota, climate, topography and time. Of note is the important consideration that anthropogenic disturbances equally influence soil variation, with the effect able to be measured on the short to long-term scales. Since all the factors of soil formation are directly or indirectly related to one another, their importance only differs depending on the scale of analysis (Wysocki *et al*. 2000). When analyzing the soil variability in relation to fertility at the field scale, the most relevant factors are parent material, topography, biota and management history. The recent innovations in the field of precision agriculture are driving to provide a better understanding and an improved ability to predict these small-scale landscape features. At regional level of an agricultural landscape, topography, parent materials and or management history are also very important in aiding the understanding of inherent soil variability. The information at this scale helps to improve our abilities to manage soil as a finite natural resource, especially given the complex demands of our modern communities. While at the largest scale, the provincial or countrywide level, soil variability depicts soil patterns driven largely due to differences in climate, vegetation and to a lesser extent parent material. The information provided at this scale also advances our knowledge of resources inventory (Brady and Weil, 2008).

As soil is an open system, soil formation is a complex combination of processes occurring in the regolith that are responsible for horizon differentiation and differences across the soil continuum. A more useful model for the conceptualizing of soil variation at the regional scale and for classification is contained in the model proposed by Roy W. Simonson (1959) (Wysocki *et al*. 2000). This model categorizes all processes of soil formation into four core groups: additions, losses, transfers and transformations. Examples of additions to a given soil include heat, water, oxygen, organic matter, fertilizers, air-born particulates and rain water impurities, to name but a few. Examples of processes occurring to soil constituents resulting in losses are leaching, volatilization and erosion. Transfers refer to the upward and downward movement of a given substance within a pedon. For example, the transfer of soluble soil nutrients by deep root systems to the above ground plant matter is eventually re-deposited on the soil surface as leaf litter. Finally, transformations encompass any or all the soil assemblage that has been altered in either chemical form or appearance (Simonson, 1978). Examples of transformations include, but are not restricted to, mineral weathering, the formation of secondary minerals, and the breakdown of organic matter to the most stable form (humus).

The following is a brief description the dominant landscape processes that have contributed to the present soil properties of the Agricultural Reserve.

2.4.1.1 The Geological Landscape of Sudbury Basin

The physical and chemical spatial variability of the parent materials are largely a result of past pro-glacial depositional environments. The mineralogical composition and, therefore, secondary weathering products are a result of the earlier era weathering of surrounding rock formations and associated erosional sediments. In such depositional environments, water transported sediments are generally found to be highly variable (Goderya, 1998).

The Sudbury structure is an impact crater formed approximately 1850 Ma ago on the boundary between the Superior and the Southern geological province of the Canadian Shield (Rousell *et al.* 2002). As well, approximately 10 km to the east is the Greenville Front. The Superior Province to the north hosts large areas of Archean felsic plutonic rock formations, dominated by granite, granodiorite and quartz monazite, with minor areas along the structure's northern boundaries containing migmatites and gneisses (Rousell *et al*., 2002). To the south, The Southern Province mainly consists of Proterozoic arkosic sedimentary rocks of the Hough Lake Group of the Huronian Supergroup, with extensive intrusions of Nippissing diorite.

The Sudbury Structure encompasses both the Sudbury Igneous Complex and the Sudbury Basin (Rousell *et al*., 2002). Shaped as an elliptical band, the Sudbury Igneous Complex (SIC) surrounds the Sudbury Basin, measuring 58 by 28 km. From the deepest extreme, the SIC consists of a brecciated footwall, a contact layer, Norite (*i.e.* the famous ore rich rock), quartz gabbro and granophyre. Overlying the SIC is the younger Whitewater Group contained within the Sudbury Basin. The stratigraphic sequence of the Whitewater group from oldest to youngest consists of the Onaping, Vermillion, Onwatin and Chelmsford Formations. The Agricultural Reserve lands are underlined by the Onwatin Formation which is largely comprised of pyritic and carbonaceous argillite, siltstone, with minor greywacke bedrock of an unknown age (Rousell *et al*., 2002).

The post-glacial deposits of the Sudbury Basin formed during the Michigan Subperiod of the Wisconsin Glaciation, 10,000 to 11,000 years ago (Barnett and Bajc, 2002). Ice sheets covering the basin are predicted to have disintegrated quickly by calving margins into Glacial Lake Algonquin, a once vast pro-glacial lake that flooded the Sudbury basin, extending past the present extents of both Lake Michigan and Lake Huron (Barnett and Bajc, 2002). These retreating ice margins then stabilized where now lies the Cartier I and Cartier II moraines along the north and east rims of the Sudbury Basin, respectively (Barnett and Bajc, 2002). As a result, these major sources of sediment were carried into the Basin along the North Rim near the Onaping River, Sandcherry Creek, Nelson River and the Hanmer flats. Along these areas of high water flows, numerous outwash deltas and subaqueous fans deposits were formed in the Basin (Barnett and Bajc, 2002). These sediments progressively fine in a southwest direction due to the occurrences of deeper subaqueous low energy depositional conditions. The bedrock outcrops in the Sudbury Basin protected these low energy zones. The glaciolacustrine deposits in the region progress from sandier near shore environments deposited in the northeast to massive silt deposits of the distal fans that occur to the southwest, with, finally, silt and clay rhythmites to the extreme southwest (Barnett and Bajc, 2002). Once the waters of Glacial Lake Algonquin subsided, the deposits of the Sudbury Basin dried and were subsequently reworked by wind energy. As a result, aeolian sand deposits developed in the far eastern portion of the Basin developed ranging in grain size from very fine to fine sand, with several rolling, low-relief parallel dune deposits being found (Figure 7). Also, fluvial sediments along the Whitson reveal a once larger river system that deposited sandier material along both banks. The majority of the extent of Agricultural Reserve is situated in the finer massive silt glaciolacustrine deposits, with minor areas in the west over sandier glaciolacustrine deposits.

Figure 7. An aeolian landform in the Agriculture Reserve lands consisting of linear dunes located in the Côté Blvd and Dupuis Rd region.

2.4.1.2 Topography and Drainage of the Sudbury Basin

Topography is known to affect soil variability at both the small local to large regional scale as it controls drainage and local climate, affecting, in turn, the biota communities of the soil systems. Topography will likely have the greatest influences at the very small scale (Brady and Weil, 2002). A detailed digital elevation model illustrating the topography of the study area is depicted in Figure 8. The area immediately to the south-west surrounding Bradley Dr. is likely the most topographically variable while the south central-region along Bonin Rd. is likely the least.

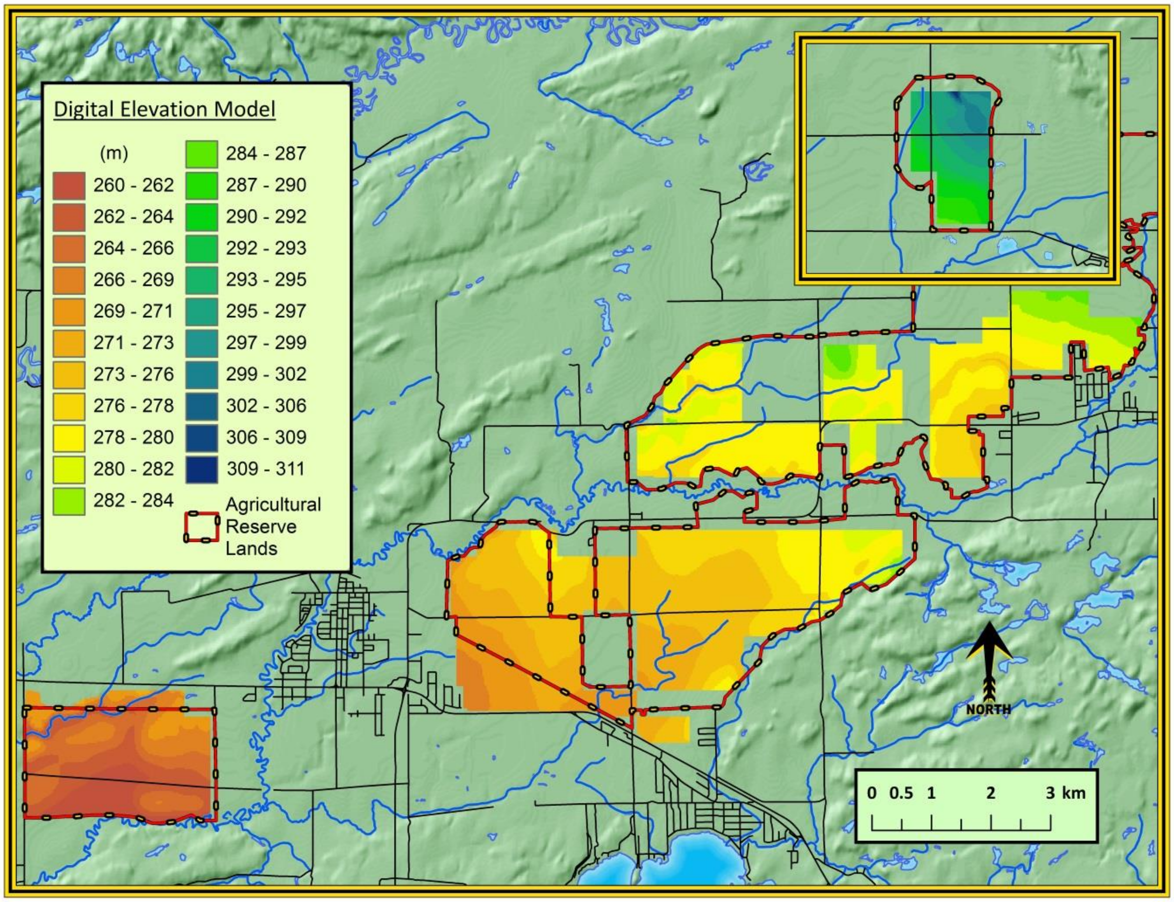


Figure 8. Digital elevation model of the study area within the Agricultural Reserve lands of the City of Greater Sudbury. Differences in elevation over the study ranged from 260 m to 311 m increasing in a North-East direction. Areas ranging from red to orange were the lowest, yellow to green were intermediate and turquoise to blue were the highest (Scale 1:105,750). Data courtesy of Natural Resources Canada and City of Greater Sudbury.

The glaciolacustrine deposits found within the Agricultural Reserve form flat plains with a slope between 0 - 1 % that ranges from micro reliefs of less than a meter to a gently undulating landscape. Figure 9 highlights an area with minimal topographic differences in the Agricultural Reserve lands. Topography, in combination with the inherent fine grain size, causes these soils to be adversely affected by both poor internal and local drainage. The images of Figure 10 exhibit the effects of micro-relief and drainage had on soil development of both an upland soil profile and a lowland soil profile in an undulating landscape located in the north-west portion of the Bradley Rd. region of the Agricultural Reserve lands.

Figure 9. Typical flat plain with micro-reliefs of a few decameters found on a glaciolacustrine landform. Picture taken looking south-east over a sod farm on the north side of Bonin Rd in the eastern portion of the south-central region of the Agricultural Reserve lands.

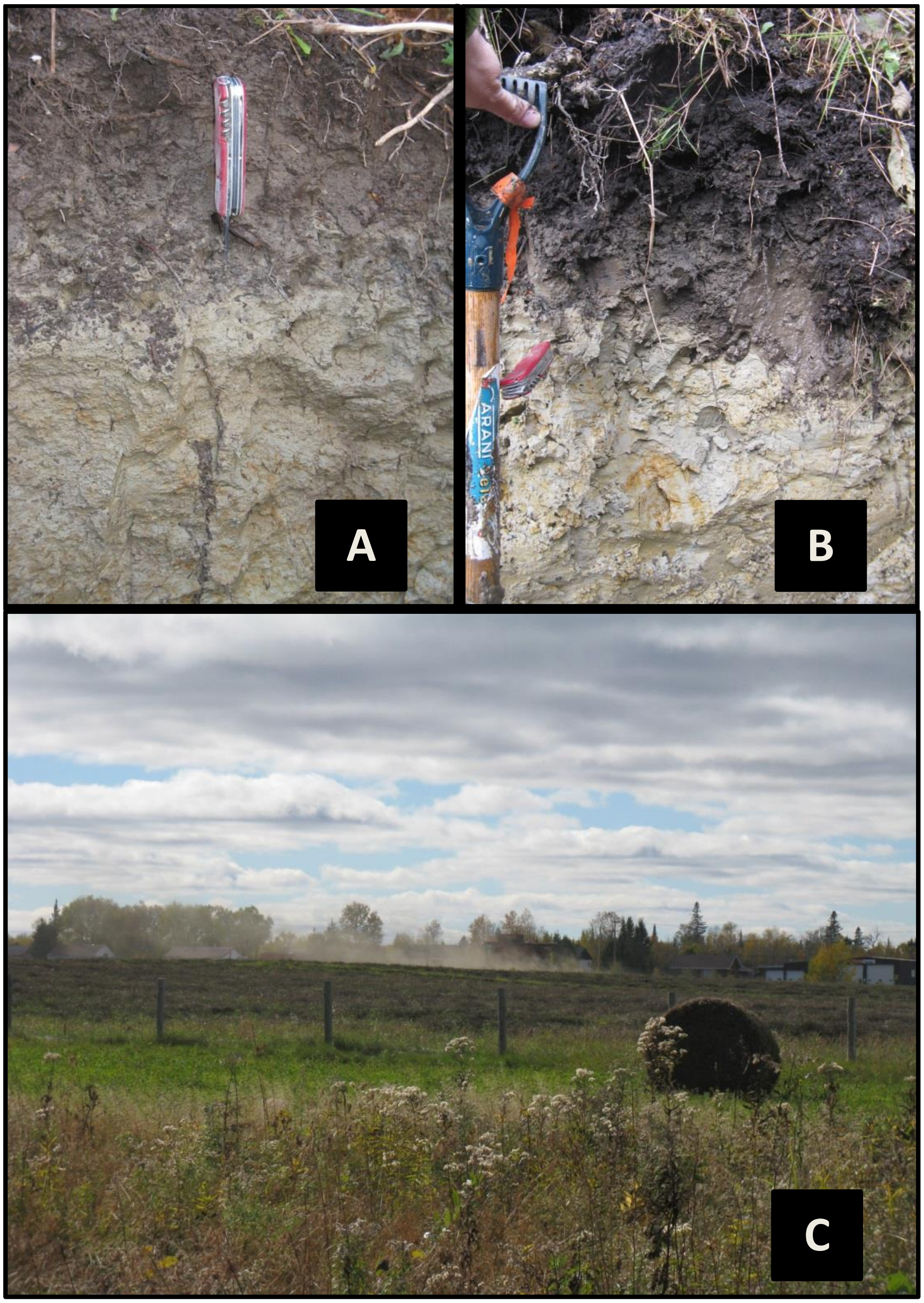


Figure 10. These photographs depict the short-range variation in soil development of two Humic Gleysols caused by slight difference in topography and hence a different moisture regime within a glaciolacustrine landform. Photograph A is of a dryer upland soil profile and taken 30 m away in a gently undulating landscape (Photograph C) is photograph B of a low lying site with a perched water table. Photos taken looking west in the north-west portion of the Bradley, Rd. region of the Agricultural Reserve lands.

The Sudbury Basin drains to the southwest through subsystems of Spanish Watershed. The Agricultural Reserve lands are located within the Whitson River watershed, a tributary of the Vermillion River that flows along the North Rim of the Sudbury Basin. The stream gradient of the meandering Whitson River is 0.4 m/km (Burwasser, 1979). Furthermore, under the Drainage Act of Ontario (1975), the Greater City of Sudbury has developed and maintains an extensive network of municipal drains through the regions wetter agricultural soils.

2.4.1.3 Climate

Climate is an important variable affecting soil development at the larger scale, providing the necessary energy and moisture in the form of sunlight and precipitation to drive soil formation through a combination of chemical reactions and biological activities. Soils developed within similar parent material under different climatic zones can vary greatly in their properties.

Situated along the North Shore corridor of the Great Lakes, Sudbury is characterized with having some of the best agricultural crop growing conditions in northern Ontario (Chapman and Thomas, 1968). The local climate is influenced by various air masses throughout the growing season, namely the continental tropical and warm-moist maritime tropical (Gunn, 1995). Historically, the region receives annual average precipitation of 899 mm, and has 1704 growing degree days, with a normal growing season from April 25 to October 24 giving a mean growing season length of 183 days for some of the hardier, frost tolerant crops (Chapman and Thomas, 1968), with an average of 1280 hours of bright sunshine. The frost-free period ranges between 125 days and 145 days subject to the lay of the land, proximity to open water and soil type (Roddy, 2010). The region has characteristically less precipitation during April, facilitating field preparation and planting. Conversely, higher rainfall in September can have negative effects for use of harvesting equipment and drying of crops. Figure 11 summarizes the typical meteorological conditions of the Sudbury region.

A change in soil moisture budgets caused by a warming regional climate is the most significant factor that will probably impact the future of agricultural practices in Sudbury, ON. Compiled from over 50 years of climatic data, trends in the Sudbury region indicate annual mean temperatures have warmed by 1.5°C, with mean precipitation has increasing by 100 mm (OCCIAR, 2015). The winter months have warmed by 2.4°C, with an associated increase in precipitation. During the summer months, temperatures have warmed by 1.0°C with an accompanying slight decrease in total summer precipitation (OCCIAR, 2015). If these trends continue, soil moisture budgets will likely be adversely affected, with by the shortened seasonality of the snowpack causing an increase in soil evaporation and plant evapotranspiration. For the wetter soils of the region, however, these climatic changes could allow for advanced field preparation, earlier planting dates and reduced moisture stress. Further, the likelihood of warmer temperatures and reduced precipitation in the mid-summer months will likely increase the likelihood of drought crop stress in regions of dryer soils, perhaps encouraging more use of irrigation for selected horticultural crops.

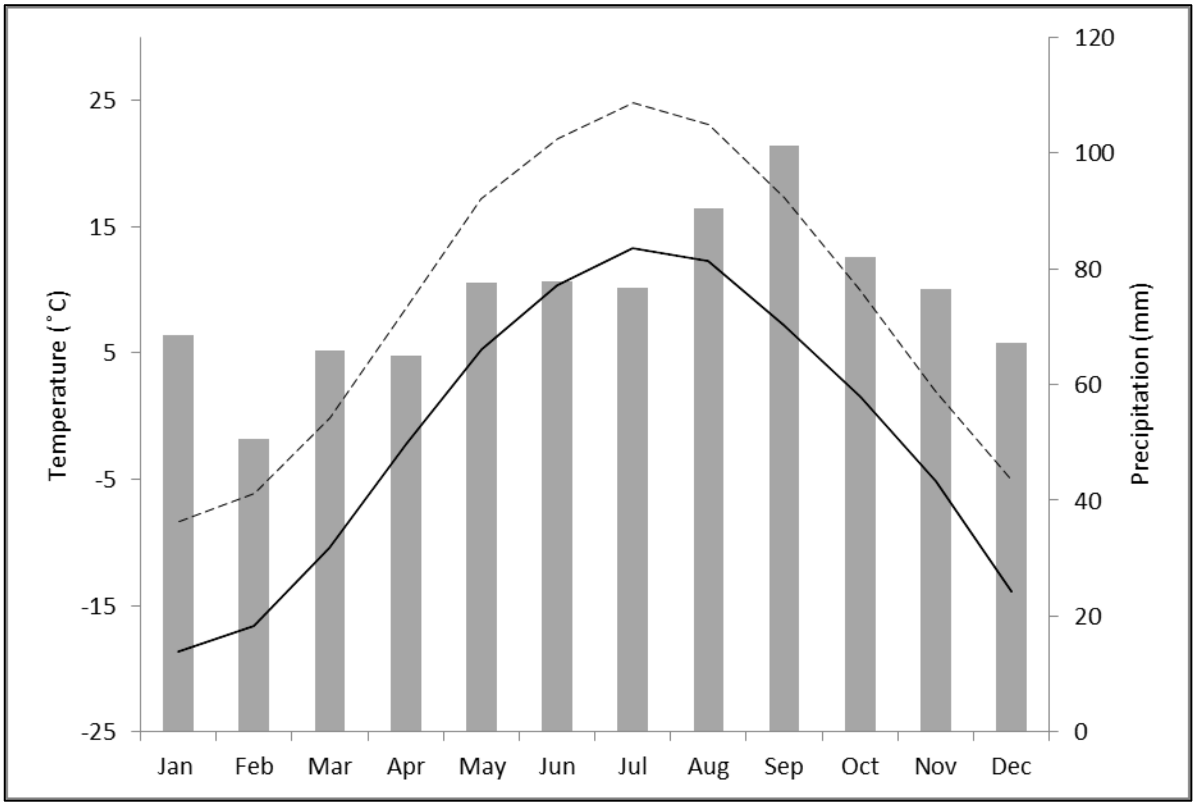


Figure 11. Climate normalcy for the Sudbury region (meteorological station ID: 6068150, Longitude: 80°47'52.0" W Latitude: 46°37'32.0" Elevation 348.4 m) between the years 1971 and 2000 (Environment Canada, 2012). Dashed line represents daily maximum temperature (˚C) while solid line represents mean daily minimum temperature. Grey bars represent precipitation (mm).

2.4.1.4 Vegetation and Land Use History

The type and quantity of a given soil organisms can significantly affect the development of soils over a given landscape at the small scale due to different modes of organic matter input, the chemical properties of the various types of organic matter, the alteration of soil structure by bioturbation, the creation of local microclimates and the effects on nutrient cycling.

Soil variation between two soil types is commonly more closely related to land use history then to inherent characteristics (Bouma and Finke, 1992). For instance, better predictions soil organic carbon content were found to occur at the regional scale with the inclusion of land management history in the predictive model (Schulp and Verberg, 2009). After studying the effect of similar management practices over contrasting soil types, a range of expected soil properties typical of the management technique can be deduced. Such information then becomes of practical use when making predictions of soil behaviour under different land management strategies (Bouma and Finke, 1992). Many studies use such empirical differences in management strategies to hypothesize their sustainability and effects on soil health (Droogers *et al.* 1996).

Today various types of land use exist across the Agricultural Reserve lands. Therefore, soils are subject to increased variability as a result of land use change and differences in management strategies. Often the variability between fields under different land uses found on the same soil type is greater than for similar land uses on different soil types (Oberthur *et al*. 1996). Land use changes often produce considerable differences in soils properties both spatially and temporally. As a result of land uses changes vegetation communities are altered, non-native species are introduced, and the upper most soil horizons are admixed by plowing processes. The Sudbury Basin region is checkered by numerous medium sized farm parcels, with current land uses for active farms in the region being dominantly Potato Rotation, Sod Production, livestock pastures and forage crops. The production of annual crops such as oats, barley, silage corn and canola are also common, with many hobby farms dotting the landscape with pastures and horse racing tracks. A large percentage of the less fertile soils in the region have been abandoned in recent years, leading to a decline in the importance of the agriculture industry over the last several decades. Managed woodlots and Forested lands are also common.

2.4.1.4.1 Forested Soils Response to Cultivation

Within the Agricultural Reserve lands, forested sites occur intermittently across the landscape. Some sites are left untouched, while others are under woodlot management practices. From general observations while sampling soil in the region, most of the low-lying areas were found to be covered by the Forested land use type. As well, a larger area east of Martin Rd. was left forested. The forest communities of the Sudbury basin have been significantly altered since the pre-settlement era. Currently managed forests reveal that a common vegetation assemblage for the regions Gleysolic soils likely consisted of spruce (*Picea* spp.), eastern white cedar (*Thuga occidentalis* L.) and balsam fir (*Abies balsamea* L.). Under wetter conditions hardwood swamps containing ash (*Fraxinus* spp.) and elm (*Ulmus* spp.) persisted, with alder (*Alnus* spp.) swamps dominating under the wettest conditions. Logging in the area has removed most of the large white pine (*Pinus Strobus* L.) stands described by locals to have straddled the well-drained sandy banks of the Whitson River. Furthermore, small fragmented stand remains still exist today of a once extensive jack pine (*Pinus Banksiana* Lamb.) and spruce forest that blanketed the sandy plains in the northern eastern portion of the Agricultural Reserve lands.

When a native forested soil becomes actively cultivated, generally a decrease is soil C occurs for a period up to several decades depending on the management intensity (Davidson and Ackerman, 1993). The major soil carbon loss from Boreal soils has been reported to occur during the initial years of the conversion from forest to agricultural land (Grunzweig *et al*., 2004). Balester *et al*. (2000) found that many site dependent factors influence the amount of C will be lost from a given native soil system as a result of the onset of cultivation. These agro-ecosystem factors include a change in C input into the soil (*i.e*. type of organic matter, quantity, timing, etc.,), increased erosion, and an increase in microbial biodegradation of organic matter. Microbial biodegradation processes of soil C is highly altered, and often enhanced, by tillage that causes a reduction in the physical protection of soil structure created by soil organic matter. Modifications to the soil climate, the types of crop residue inputs, nutrient availability, and a change in pH, have all been shown to contribute to a different soil microenvironment for microbial communities (Balester *et al.* 2000).

The ephemeral nature of soil organic carbon with respect to land use changes in the Gleysolic and Podzolic soils has been well documented (Martel and Deschene, 1976; Gregorich *et al.* 1995; Carter *et al.* 1998). In these studies, with comparisons of cultivated soils to their paired native forested soils, both Gleysolic and Podzolic soils were found to have significantly less soil organic C. Here in Ontario, Ellert and Gregorich (1996), found a 30 – 34 % loss in soil C as a result of cultivation. Similar to this study, Foote and Grogan (2010) observed an average of 32 % decrease in three common soils types in southern Ontario when comparing marginal agricultural soils to mature forest stand soils. Other studies in Ontario have also found a 15 % to 19 % decrease in soil organic carbon when comparing forested soils to associated cultivated soils (Coote and Ramsey, 1983; Gregorich *et al*., 1995). Furthermore, the threat of C loss of agriculture soils is increased for coarser textured soils in comparison to finer soils (Coote and Ramsey, 1983; Foote and Grogan, 2010). Although, with proper conservation management techniques such as with the use of forages and reduced tillage, these former soils have been shown to become important carbon sinks over the short-term (Carter *et al.* 1998; Boisonette *et al*. 2001; Grunzweig *et al*., 2004). For instance, Millette *et al*., (1980) found that two Podzolic soils in Quebec used for pastures and under cultivation for 60 years significantly increased in internal organic matter content in comparison to related forested soils.

The effects of soil cultivation are not limited to soil C. Physical properties are also drastically altered on the onset of cultivation, with studies documenting that cultivated Gleysolic and Podzolic soils increased in soil bulk density in comparison to their forested counterparts (Martel and MacKenzie, 1980; Millette *et al*. 1980; Coote and Ramsey, 1983; Carter *et al.,* 1998; Foote and Grogan, 2010). Soil tillage tends to break down stable soil aggregates to improve planting of seeds, but the use of heavy machinery tends to compact soils.

As well, many studies observed that N levels are significantly altered (Murty *et al.*, 2002). For one study, Foote and Grogan (2010) observed an average of 18 % loss of N in comparison to a 32 % loss of C on cultivation, an effect that, in turn, narrows the C to N ratio of soils (Grunzweig *et al*., 2004). Carter *et al*., (1998) suggested that this observed narrowing of the C to N ratio of agricultural soils is due to the preferential maintenance of total N levels through N fertilizer additions.

2.4.1.4.2 Abandoned Farm Land

Agricultural Abandonment within the Agricultural Reserve occurs somewhat intermittently across the landscape. The highest concentration of abandoned land was found within the south-central region and in the region surrounding Cote Blvd. and Dupuis Dr.

Abandoned lands are also commonly found in poorly drained sites. These abandoned fields have an early successional woody species composition in the Agricultural Reserve lands, being generally dominated by alders and willows (*Salix* spp.). As a secondary forest community develops on this land, species composition tends to include trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.) and, to a lesser extent, balsam fir and spruce dominated cover. Furthermore, small pockets of land have been converted to red pine (*Pinus resinosa* Ait.) plantations, probably planted in the 1980's and early 1990's as part of a Ministry of Natural Resources initiative for local landowners.

Farmland, once abandoned, undergoes secondary succession, with the lasting effects of soil cultivation on soil properties being dependent on the historical land use and the intensity of the disturbance. For instance, Tillman (1987) found that, within nutrient poor fields undergoing secondary succession, soil N was the best predictor of species composition and richness. From observations of fields recently abandoned in the Agricultural Reserve lands, species composition includes many types of herbaceous annuals and perennials. As time progresses these fields transition to a vegetation community dominated by woody species. Gill and Marks (1991) found that tree emergence progressively improved in fields dominated by perennial herb in comparison to fields dominated by biennial herbs or bare soil. Successional low forest biodiversity and poor soil chemical properties have been shown to persist after abandonment for very long periods (Dambrine *et al*., 2007) which, in turn, influences the carbon input, nutrient cycling and light availability (Dolle and Schimdt, 2009). For instance, Langanière *et al*., (2011) found that, in eastern Canada’s Boreal region, soils under black spruce accumulated more organic in comparison to trembling aspen.

Multiple physical and chemical factors influence soil properties during secondary succession. Soil texture, for example, has been shown to influence soil C. A study in southeastern Ontario found that finer soils lost less organic C than coarser soils (Foote and Grogan, 2010). Finer soils are hypothesized to reduce organic C turnover rates because of the physical protection created from stable organic bonds with non-crystalline soil minerals (Torn *et al*., 1997; Richter *et al*., 2001). However, Foote and Grogan (2010) found that with time, finer soils did not sequester soil C more quickly than coarser soils. They hypothesized that abandoned fields in southeastern Ontario would continue to sequester soil C for 100 years, since 80 years had passed since abandonment. Further, the accumulation of soil N through symbiotic nitrogen fixation and atmospheric deposition has been suggested to influence the accumulation of soil carbon in abandoned agricultural soils (Knops and Tilman, 2000). Foote and Grogan (2010) found that, in southeastern Ontario soils under abandonment, Total N increased in the uppermost 5 cm with an associated increase in C to N ratio. The study also found a significant decrease in bulk density in the upper 10 cm of soil since abandonment.

2.4.1.4.3 Forage Crops and Other Crop Rotations

Pastures and fields under forage production were found to commonly occur throughout the Agricultural Reserve lands. More intensive grain crop rotations (canola, maize, barley and oats) were more sporadic across the landscape, with the greatest concentration occurring in the Bradley Rd. region.

Multiple other studies have successfully demonstrated or observed that, with the proper management, the threat of organic carbon loss within Podzolic and Gleysolic soils can be reversed (Millette *et al.*, 1980; Carter *et al.,* 1998; Bissonnette *et al*., 2001). These studies attribute the use of conservation management practices such as reduced tillage, shallow tillage, manure application, and perennial forage species as possible ways to alleviate soil organic matter losses. Research throughout the agronomic literature commonly indicates that the use of perennial forages provides greater below ground organic matter inputs than annual crops (Bolinder *et al*., 1997; Bolinder *et al*., 2002; Grunzweig et al., 2004; Bolinder *et al*., 2007). Additionally, Carter and Gregorich (2010), found that growing tall fescue (*Lolium arundinaceum*) for 7 years on a fine sandy loam Orthic Podzol significantly increased soil organic C at the 0-10 cm and 40-60 cm depths. Similar findings were also found by Franzluebblers and Stuedemann (2009), who hypothesized that perennial pastures grazed by cattle have improved soil C storage in the upper 90 cm of the soil profile. However, their findings also suggest that these benefits of improved soil organic C and soil organic N are lost during the continuous harvesting of forages in hay crops.

In comparing effects various cropping systems on soils to associated undisturbed forested soils in southern Ontario, Gregorich *et al*., (2001) found that, when maize crop rotations are grown with legumes, soil organic matter content is improved. As well, in the same study the authors found that continuous grassland treatment had the overall greatest C inputs and exhibited the lowest overall soil C loss when compared to maize cropping treatments. The authors further hypothesized in their study that soil C levels under the grassland may not return to the levels documented in the undisturbed forested sites.

2.4.1.4.4 Potato Rotation

In the Agricultural Reserve lands, most fields under the Potato Rotation land use are located along, or near, the Whitson River where the light to medium textured soils occur. The majority of the fields under the Potato Rotations land use in the area are found within the Agricultural Reserve lands utilizing soil classified by Gillespie *et al*. (1982*a*) as Bradley Fine Sandy Loam, Capreol Very Fine Sandy Loam or Capreol Fine Sandy Loam Soil Series. These soil series are classified as either Gleyed Humo-Ferric Podzols or Orthic Humic Gleysols (Soil Classification Working Group, 1998). Other studies have found that, as a result of erosion and mixing of the Ap horizon, the majority of Podzolic soils under long-term potato rotation were not able to meet the B horizon morphological and chemical criteria to be classified in the Podzol order (Wang *et al*., 1984).

Conventional potato cropping systems are generally regarded has being highly intensive, with a reliance on high chemical fertilizer inputs and intensive cultivation. Common conservation techniques include an emphasis on adequate crop residue management and crop rotations to maintain or improve the nutrient status of a given soil (Stark and Porter, 2005). Soils under potato cropping systems generally have characteristically low soil organic carbon resulting in poor soil physical conditions (Carter *et al*., 2004). The reduced soil organic matter within conventional potato cropping systems has been attributed to the need for both primary and secondary tillage prior to seeding, leading to the dilution of surface soil horizons and relatively low crop residue inputs (Angers *et al*., 1999; Carter and Sanderson, 2001). Soil compaction is also important as a result of the extensive use of heavy equipment for harvesting, sometimes under unfavourable wet fall conditions (Edwards, 1988). Wang *et al*., 1984 found that compaction had occurred within Podzolic profiles under long-term potato rotation in comparison to adjacent sites.

Commonly used in the potato cropping rotations in the region were red clover (*Trifolium pratense* L.) and barley (*Hordeum vulgare* L.) in a 2-3 year rotation period, depending on the availability of land. Anger *et al.,* 1999 found that a potato rotation with red clover improved both soil organic matter content and soil physical parameters such as aggregate stability. Carter *et al*., 2003, however, found that soils under a potato / ryegrass and red clover rotation lost 16 % of the initial soil organic C over an 11 year period. In an additional study, Carter *et al*., (2009) found that, over a 10 year period, a three year potato rotation compared to a two year rotation on similar soils had increased soil organic C, reduced bulk density, increased Total N and increased microbial biomass C. Also, long-term studies have found improved soil physical properties associated with the addition of organic amendments at different phases of the potato rotation (Carter *et al.,* 2004).

2.4.1.4.5 Sod Production

The literature on the effects of commercial sod (turf grass) production on soil properties is very limited in comparison to that available for other Dominant Land Uses in the Agricultural Reserve lands. The only peer-reviewed study found at the time this literature review was compiled was by Millar *et al*., (2010). In this study the removal of sod from agriculture fields resulted in a net loss of C of 74 to 114 $t \cdot ha^{-1} \cdot yr^{-1}$. This value is considerably greater than the erosion threshold loss of 6 $t \cdot ha^{-1} \cdot yr^{-1}$ for maintaining long-term sustainable crop production in

Canada (van Vliet *et al*., 2005). The study by Millar *et al*., (2010) also found that the rate of soil thickness loss is 0.833 cm · yr^{-1}. Through the study of multiple sod farms, they also found that the soil loss is proportional to the number of years under Sod Production. At this rate of topsoil loss, the authors discuss the possible implications of loss of agriculture productivity, but did not measure any fertility parameters. They found that the bulk densities of the top 10 cm of sod production and forested soils were 1.34 and 0.77 g·cm^3, respectfully. On the other hand, OMAFRA reports that the 1 cm of topsoil lost at each sod harvest will not deplete the topsoil reserves (Charbonneau, 2003).

2.4.1.4.6 Topsoil Removal

Since the 1950's topsoil in the Greater Sudbury area has been used for various municipal projects such as creating parks, mine site reclamation, covering and regreening of slag heaps, residential landscaping and beautification, and development sport fields. These activities have resulted in a substantial loss of arable land both within and surrounding the Agricultural Reserve lands. With the complete removal of the organic matter-rich uppermost A horizons, and, sometimes, partial removal of the B horizon, these soils would likely be classified within the Anthroposolic Order when introduced to the Canadian Soil Classification System (Naeth *et al*., 2012). As a result of these disturbances, small parcels of the Agricultural Reserve lands will likely be left infertile, thus creating an even greater fragmented landscape. From personal observations, these sites area are left completely without topsoil or with topsoil thickness variation across the site from non-existent to a thin horizon of less than several centimetres. There were attempts by some property owners to rehabilitate sites by planting grass mixes or trees, with limited success. Many property owners who did not know Topsoil Removal practices had impacted their properties at the time of purchase have shown interest in better understanding potential rehabilitation techniques.

The negative effect of topsoil removal can be attributed to the low organic matter content of the remaining surface soil layers. Without reclaiming these soils, their use for agriculture (and maybe forestry) is not practical over the long-term. To sustain long-term agricultural practices, the mineralization of soil organic matter (SOM) is essential for soil fertility (Tiessen *et al*., 1994). Under different management practices, a positive relationship has been shown between soil organic matter content and the resilience to anthropogenic disturbances (Gregory *et al*., 2009; Carter, 2002). Due to the importance of SOM, many investigations have found that site productivity decreases with increasing topsoil removal (Malhi *et al*., 1994; Larney *et al*., 1995; Wairiu and Lal, 2003). Decreased SOM levels following topsoil removal has been shown to create unfavourable growing conditions because of poor soil structure, increased soil strength, slower spring warming, lowered biological activity, reduced water holding capacity, and lowered nutrient availability (Malhi *et al*., 1994; Izaurralde *et al., 2006*; Loveland and Webb, 2003; Oyedele and Aina, 2006). For example, in a long-term soil productivity study on an Orthic Gleyed Luvisol silt loam soil in which the forest floor was mechanically removed and subjected to compaction, a short-term increase in N mineralization and nitrification occurred (Tan *et al.*, 2005). In this same study, the C and N microbial biomass pools were reduced due to the lack of organic substrate for microbial metabolism. There was a resultant net loss of soil N over time due to leaching and de-nitrification.

Chapter 3

Methods

3.1 Site Sampling and Sample Preparation

Soil samples from a total of 193 sites were collected for this study between mid-July 2009 and early December 2009. A regular 20 ha grid (origin: 17 T 479595 m East, 5155885 m North) was superimposed over the Agricultural Reserve lands (Figure 12) as designated in the City of Greater Sudbury (COGS) Planning document (COGS, 2008). To better document any sampling error, 20 sites were systematically chosen across the study area and replicated (Table E1 in the Appendices). Current land use information and vegetation type were recorded at time of sampling. The site sample consisted of one bulk soil sample containing 20 distinct 20 cm cores collected using a 2.5 cm diameter SS Soil Sampler (Star Quality, AB, CA). Cores were taken in a “W” pattern across the entire sampling cell, with the large support area chosen to reduce within-field variation and enable extraction of a better understanding of between-field variation (Beckett and Webster, 1971). The subsoil was sampled between the depths of 80 to 100 cm at a point approximating the cell centroid with a Dutch auger. The position of the each subsoil sample was recorded using a Colorado 300 in UTM coordinates (Garmin, 2008; ± 3 m).

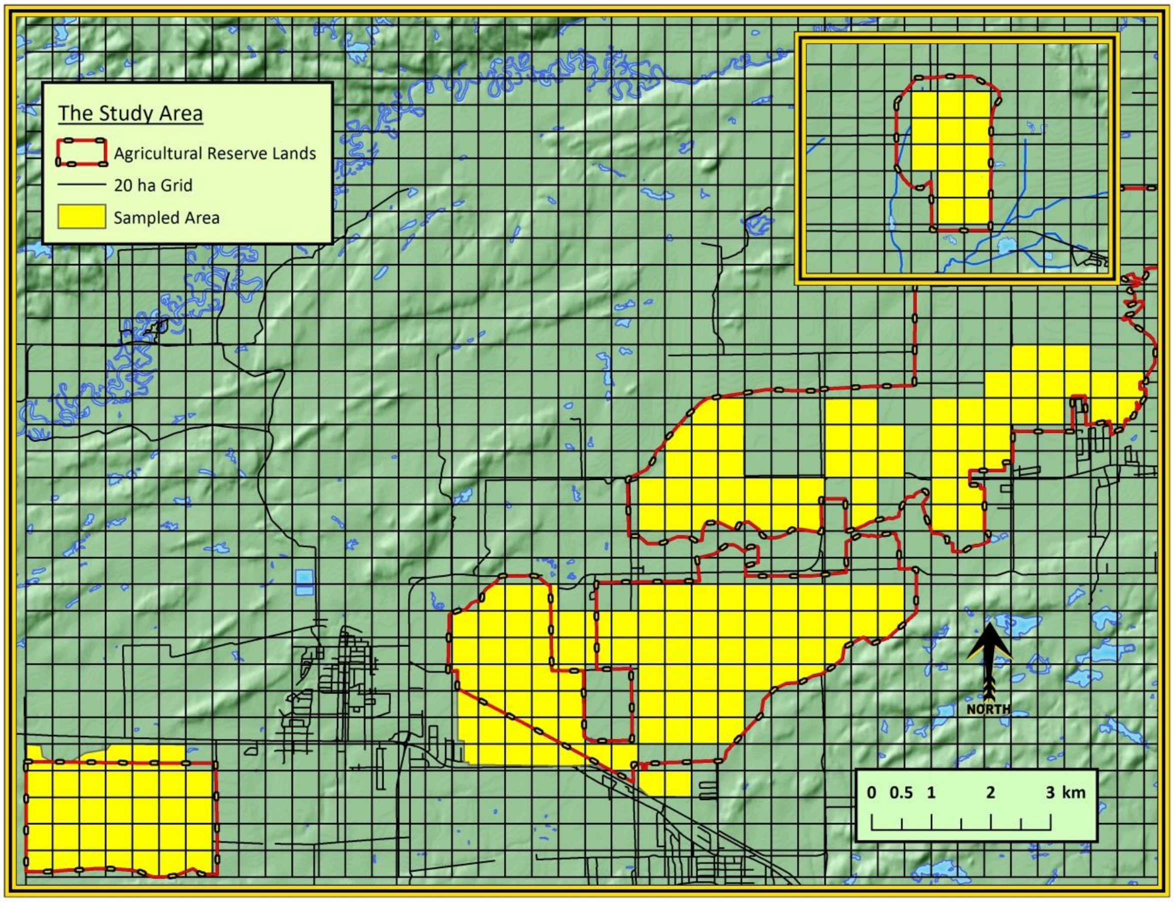


Figure 12. A 20 ha grid was superimposed over the Agricultural Reserve lands outlined with a red black dotted line ( ). The study area consists of all areas highlighted in yellow ( ). Map scale (1:105,750). Data courtesy of Natural Resources Canada and City of Greater Sudbury.

Samples were brought back into the laboratory daily, air dried initially prior to being oven dried at 105°C. The dried samples were disaggregated with a mortar and pestle, passed through a 2 mm mesh using the Pulverisette 8 (Fritsch, DE).

Multiple soil samples were taken for one 20 ha site when the field had experienced mechanical removal of topsoil with two separate samples being taken, with one from the 'stripped' area and one from the adjacent unstripped area. This selective sampling approach was employed as the land use significantly alters soil properties and would thus provide a misrepresentation of regional soil health prediction. Where the entire cell area was affected by the Topsoil Removal land use, with no significant proportion of native topsoil remaining within the cell, the paired and ‘unstripped’ cell sample was not available for use in the predictive mapping. To access the within site variability, two sites were chosen that had equal areas under the Forested, Low Intensity and Sod Production land uses. Within each of these sites, a total of three separate samples were taken, one for each respective land use.

3.2 Laboratory Analysis

Subsamples were weighed (5 ± 0.02 g) into 50 ml centrifuge tubes using an APX-100 analytical scale (0.1 mg) (Denver Instrument, CO, US). Extraction of the soil samples with 20 ml of 0.01M $LiNO_3$ provided at estimate of phytoavailable nutrients (Abedin *et al*., 2012). Samples were shaken for 24 h at 60 rpm at room temperature, centrifuged at 3000 rpm for 10 minutes, with the supernatant then being filtered through 0.45 µm filter paper, acidified with 100 µL of concentrated trace metal grade HNO_3 (Caledon Scientific, product code: 7525-8, ON, CA) with the filtrates being then placed into a refrigerator at 3°C for storage prior to elemental analysis using a Liberty Axial ICP-AES (Varian, AUS) by the ISO 17025 accredited laboratories of Elliot Lake Research Field Station, Laurentian University. Two potentiometric pH determinations were conducted using distilled water and 0.01 M $CaCl_2$ with 5 ± 0.02 g of soil in a liquid volume to soil weight ratio of 1:1. The $CaCl_2$ method was utilized to give an indication of the exchangeable acidity (Brady and Weil, 2008). All pH measurements were completed using a Model 215 (±0.002) (Denver Instruments, NY, US).

The total soil elemental concentrations of the soil samples were determined by weighing 0.5 ± 0.02 g of ground soil into 50 ml centrifuge tubes for digestion with 6 ml HNO3 trace metal grade and 2 ml of HCl trace metal grade (Fisher Scientific, product code: A508-4, ON, CA). A Vulcan 84 digestion system (±1.0°C) (Questron Technologies, ON, CA) was used to heat samples to 105°C for 2.5 hrs. Digestates were diluted to 50ml using ultrapure water from a Nanopure Ultrapure Water System (Barnstead, MA, US) for final analysis by ICP-AES. The addition of reagents and ultrapure water to the digestion solution was executed with the Vulcan 84 (±0.5 ml). Total carbon, nitrogen and sulfur were analyzed through dry combustion with infra-red detection using a CNS-2000 (LECO Corporation, St. Joseph. MI, USA).

All samples were pretreated for the removal of organic matter and carbonate minerals by using a 35 % hydrogen peroxide and an acetic acid / sodium acetate buffer solution having a pH of 5, washed with distilled water to a final electric conductivity reading < 0.4 µs (Checkmate II, Corning, MA, US) for particle size distribution quantification by laser diffraction using a LA-910 (Horiba, JP).

3.3 Soil Attribute Calculations

All data was stored and manipulated using Excel (Microsoft, 2010). As care was taken to minimize soil compression while sampling and core length was accurately measured to 10^{-1} cm, both topsoil bulk density (ρ_{bulk}; 1) and area based nutrient estimates (2) were calculated were calculated for each site,

$$\rho_{bulk} = m_{dry} / \text{volume} \quad (1)$$

where: ρ_{bulk} = soil bulk density (g/cm^3),

m_{dry} = oven dried mass (g),

volume = volume of combined soil cores for site (cm^3)

$$Soil_{nc} = conc * \rho_{bulk} * T * 10\,000 \text{ m}^2 \text{ ha}^{-1} * 10^{-6} \text{ Mg kg}^{-1} \quad (2)$$

where: $Soil_{nc}$ = Soil Nutrient Content (kg ha^{-1}),

conc = elemental concentration (mg kg^{-1}),

ρ_{bulk} = soil bulk density (g/cm^3),

T = mean core length (cm)

3.4 Statistical Analysis

Mean ranks measured soil properties were compared using the Kruskal-Wallice Test (probability level of 0.05) independent samples procedure for soils and landforms to gain a better understanding of differences between individual soil series and Dominant Land Use Covers. All statistical calculations were done using SPSS 19 (IBM, 2010).

3.5 Spatial Representation of Soil Database Attributes

Soil attributes were visualized using the Geostatistical Analyst toolbox of ArcGIS 10.1 (ESRI, 2012), with all topsoil attributes surfaces being predicted using the Areal Interpolation Tool. All parameters were manipulated to keep prediction errors to a minimum. The best model was chosen to have a standardized mean nearest to zero, with a minimized root mean squared error, and an average standard error nearest to the root mean squared error, and the standardized root mean squared error was closest to zero. For each soil property having a generated surface in the results section, parameters and errors are listed in Appendix B. Soil attributes from point sample locations (*i.e*. the subsoil dataset) were predicted using the Inverse Distance Weighting tool.

Chapter 4

Results

4.1 Statistical Comparison of Dominant Land Uses

In the following subsections, statistical comparisons of soil health properties between studied Dominant Land Uses were summarized and their supplementary descriptive statistics tabled. The predicted spatial distributions of soil properties were also visualized using GIS software. For each predicted surface, spatial patterns were compared to the overlying Dominant Land Use Cover. All *p*-values used to determine the statistical significant differences between the measured topsoil properties of Dominant Land Uses are tabled in the Appendices.

4.1.1 Topsoil Total C Variability across Land Use Patterns

Regional and Dominant Land Use summary statistics of TS Total C (%) and TS Total C ($kg \cdot ha^{-1}$) for soils sampled within the study area are presented in Table 2. The median TS Total C (%) content for the study area was 2.42 %. Overall, the Forested land use had the greatest TS Total C (%), with a median content of 3.34 % which was found to be significantly greater than all other land uses. The land use with second overall greatest TS Total C (%) was Abandoned, having a median content of 2.76 %, significantly greater than all other land uses with the exception of the Intensive (p=0.129) land use that had a median TS Total C (%) of 2.47 %. In contrast, the Topsoil Removed and Sod Production land uses were found to have the lowest overall TS Total C (%), with median contents of 1.31 % and 1.51 %, respectfully. Both were found to have significantly less TS Total C (%) in comparison to all other land uses, with no significant difference being found between the Topsoil Removed and Sod Production land uses (*p*=0.202). And finally, the Potato Rotation land use with a median TS Total C (%) of 1.83 %, was found to have significantly less TS Total C (%) in comparison to both the Low Intensity (*p*=0.000) and Intensive (*p*=0.000) land uses with median contents of 2.45 % and 2.47 %, respectively.

The median TS Total C (kg·ha^{-1}) in the surface 20 cm of topsoil within the study area was 5355 kg·ha^{-1}. When comparing land use TS Total C (kg·ha^{-1}), significance differences were less pronounced in comparison to the TS Total C (%) results. The Topsoil Removed land use remained the overall lowest TS Total C (kg·ha^{-1}), with a median content of 2879 kg·ha^{-1}. However, the Topsoil Removed land was found to be no longer significantly less than the Low Intensity (*p*=0.056), Intensive (*p*=0.073) and Potato Rotation (*p*=0.559) land uses which had median TS Total C (kg·ha^{-1}) of 5600 kg·ha^{-1}, 5622 kg·ha^{-1} and 4353 kg·ha^{-1}, respectfully. Similarly, the Forested land use was found to have the overall greatest median TS Total C (kg·ha^{-1}) of 6304 kg·ha^{-1}, but was no longer significantly greater (*p*=0.060) than the Abandoned land use with a median content of 5790 kg·ha^{-1}. Also, the Abandoned land use was no longer found to be significantly different than the Low Intensity (*p*=0.345) and Intensive (*p*=0.594) land uses.

For the entire study area, CV values for TS Total C (%) and TS Total C (kg·ha^{-1}) were 51 % and 31 %, respectfully. For TS Total C (%), individual land use CV values were lower in comparison to the obtained CV values for TS Total C (kg·ha^{-1}) with the sole exception of the Intensive land use. For Total C (kg·ha^{-1}), CV values for individual land uses were ranked from greatest to lowest as follows: Topsoil Removed > Abandoned = Forested > Intensive = Sod Production > Low Intensity > Potato Rotation. Whereas the CV values of individual land use Total C (%) were ranked from the greatest to lowest as follows: Forested > Topsoil Removed > Abandoned > Sod Production > Low Intensity > Intensive > Potato Rotation. Overall, the Potato Rotation land use was the least variable land use.

Table 2. Summary statistics for the Total C (kg·ha^{-1}) and Topsoil Total C (%) of topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (>*p*=0.050) using the Kruskal-Wallace comparison.

Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
					Total C						
Region	kg·ha^{-1}	5355		1354	13708	5494	119	1677	31	1.5	5.1
Abandoned	kg·ha^{-1}	5790	*ac*	4237	13388	6137	272	1721	28	2.2	7.1
Forested	kg·ha^{-1}	6304	*c*	3795	13708	6774	301	1927	28	1.5	3.3
Low Intensity	kg·ha^{-1}	5600	*ad*	3617	7931	5604	135	864	15	0.26	0.48
Intensive	kg·ha^{-1}	5622	*a*	3794	7172	5643	250	935	17	-0.22	-0.19
Topsoil Removed	kg·ha^{-1}	2879	*bde*	1354	7083	3931	795	2103	53	0.39	-1.5
Sod Production	kg·ha^{-1}	3653	*b*	2943	5950	3814	135	664	17	1.5	3.4
Potato Rotation	kg·ha^{-1}	4353	*e*	3555	5498	4412	81	451	10	0.23	-0.35
Region	%	2.42		0.397	13.0	2.64	0.097	1.4	51	3.85	23
Abandoned	%	2.76	*a*	1.73	10.3	3.09	0.22	1.4	44	4.06	21
Forested	%	3.34	*b*	1.81	13.0	3.80	0.31	2.0	52	3.09	12
Low Intensity	%	2.45	*c*	1.77	3.51	2.51	0.07	0.43	17	0.29	-0.5
Intensive	%	2.47	*ac*	2.13	3.37	2.59	0.11	0.41	16	0.74	-0.7
Topsoil Removed	%	1.31	*d*	0.397	2.47	1.33	0.25	0.67	51	0.46	0.5
Sod Production	%	1.51	*d*	1.18	2.61	1.57	0.07	0.32	20	1.44	3.4
Potato Rotation	%	1.83	*e*	1.52	2.49	1.88	0.04	0.24	13	0.80	0.5

4.1.1.1 Spatial Relationship between Topsoil Total C and Land Use

The predicted surface of TS Total C (%) in relation to the Dominant Land Use Cover is presented in Figure 13. When taking into consideration spatial patterns within the spatial distribution of TS Total C (%) and the superimposed Dominant Land Use Cover, similarities exist to findings relation to the land use comparisons. Predicted TS Total C (%) was found to be lowest along the Whitson River where both the Sod Production and Potato Rotation land uses commonly located. Furthermore, in the extreme southwest corner of the Agricultural Reserves, in the Bradley Rd region, an area having low predicted TS Total C (%) conforms well to the spatial extent of the Sod Production land use. A steep gradient is observed between the low TS Total C (%) under Sod Production in comparison to neighbouring parcels, the Forested and Intensive land uses. Further, the few Topsoil Removed land use sites represented on the predicted surface were found to have the overall lowest Total C (%). These sites can be found in the south –central region of the Agricultural Reserve lands, immediately north of the town of Azilda.

Localized areas having greater predicted TS Total C (%) were found under the Forested and Abandoned land uses. These areas included along the western portion of Bonin Rd., north of Bradley Rd and to a lesser degree in the south-central area. In addition, all areas having greater TS Total C (%) were located within close proximity to small drainage features represented by blue lines on the predicted surface. Furthermore, the area found to be elevated in TS Total C (%) along the western portion of Bonin Rd. has a drainage feature not presented in Figure 13. In addition to these areas, other lower-lying areas were also confirmed to have greater Topsoil C (%) when compared to the digital elevation model of the study area found in Figure 8.

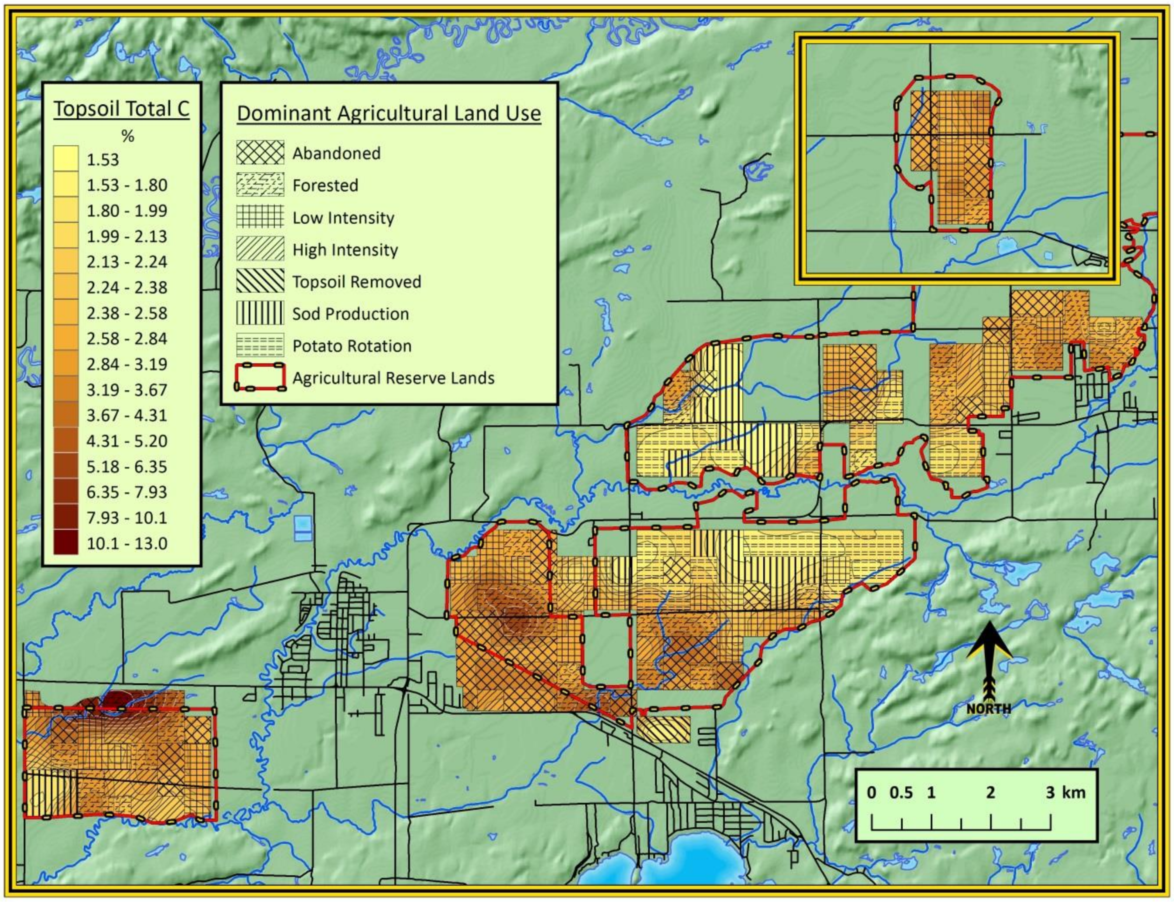


Figure 13. The predicted spatial distribution of topsoil (0-20 cm) Total C (%) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.2 Topsoil ρ_{bulk} Variability across Land Use Patterns

The median TS ρ_{bulk} of topsoil layers (0 – 20 cm depth) in the study area was 1.11 g·cm^{-3}. All the land use TS ρ_{bulk} values were found to be significantly different from one another, with TS ρ_{bulk} values for individual land uses being ranked from the greatest to lowest TS ρ_{bulk} as follows: Topsoil Removed >Sod Production > Potato Rotation > Low Intensity > High Intensity > Abandoned > Forested, having median TS ρ_{bulk} values of 1.48 g·cm^{-3}, 1.24 g·cm^{-3}, 1.18 g·cm^{-3}, 1.13 g·cm^{-3}, 1.09 g·cm^{-3}, 1.06 g·cm^{-3} and 0.95 g·cm^{-3}, respectfully.

The regional TS ρbulk CV was found to be 14 %, with CV values for land uses across the region being ranked as follows: Forested > Abandoned > Intensive > Topsoil Removed > Sod Production = Potato Rotation > Low Intensity with values of 15 %, 9.0%, 8.7 %, 7.2 %, 6.2 %, 6.2 % and 6.0 %, respectively.

Table 3. Summary statistics for the Bulk Density (ρbulk; g·cm^{-3}) of topsoil (0-20 cm) sampled in the City of Greater Sudbury's Agricultural Reserve lands. Land use medians having similar corresponding letters indicate are not significant differences (>*p*=0.050) from one another using the Kruskal-Wallace comparison of medians.

Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	g·cm^{-3}	1.11		0.54	1.70	1.11	0.011	0.15	14	0.02	2.19
Abandoned	g·cm^{-3}	1.06	*a*	0.67	1.23	1.04	0.015	0.094	9.0	-1.48	5.35
Forested	g·cm^{-3}	0.95	*b*	0.54	1.27	0.96	0.022	0.14	15	-0.46	1.09
Low Intensity	g·cm^{-3}	1.13	*c*	0.98	1.28	1.13	0.011	0.068	6.0	0.04	-0.45
Intensive	g·cm^{-3}	1.09	*c*	0.89	1.29	1.10	0.026	0.10	8.7	-0.15	1.57
Topsoil Removed	g·cm^{-3}	1.48	*d*	1.39	1.70	1.51	0.041	0.11	7.2	0.90	0.45
Sod Production	g·cm^{-3}	1.24	*e*	1.04	1.36	1.23	0.016	0.077	6.2	-0.68	0.56
Potato Rotation	g·cm^{-3}	1.18	*f*	1.02	1.29	1.18	0.013	0.073	6.2	-0.44	-0.62

4.1.2.1 Spatial Relationship between Topsoil ρ_{bulk} and Land Use

The predicted surface of TS ρ_{bulk} in relation to the Dominant Land Use Cover is presented in Figure 14. The spatial patterns with the spatial distribution of TS ρ_{bulk} appear to have a inversed pattern in comparison to those of TS Total C (%) (Figure 13). For instance, areas found to have lower predicted TS Total C (%) were in most cases found to have greater predicted TS ρ_{bulk}. This includes the large area dominated by the Sod Production and Potato Rotation land uses along the Whitson River in the central region of the Agricultural Reserve lands, the small area under the Topsoil Removed land use in the south central region immediately north of town of Azilda, and the area under Sod Production in south-westerly most corner of Agricultural Reserve lands.

The patterns within the spatial distribution of TS ρ_{bulk} appear to conform to the superimposed Dominant Land Uses Cover. As well, the spatial distribution of TS ρ_{bulk} coincides to finding relating significant differences between land uses. Sharp gradients were found between areas having greater predicted TS ρ_{bulk} to areas having lower predicted TS ρ_{bulk}. These gradients were found to exist between adjacent land uses found to have significantly different median TS ρ_{bulk}. For instance, multiple areas within the predicted surface under the Forested land use were found to have lower TS ρ_{bulk} than adjacent land uses such as Topsoil Removed, Sod Production and Potato Rotation. An example is located in the extreme southwest corner of the Agricultural Reserve lands where an area of soil under the Sod Production land use was found to have greater predicted ρ_{bulk} than for neighbouring soils to the east under the Forested land use. Furthermore, similar results were found within the north and south-central areas of the Agricultural Reserve lands where the Abandoned and Forested land uses were found to have lower predicted TS ρ_{bulk} relative to adjacent land uses such as Low Intensity, Intensive, Topsoil Removed, Sod Production and Potato Rotation. In the Cote Blvd. and Dupuis Dr. region only a slight increase in predicted TS ρ_{bulk} was observed when comparing the Low Intensity land use to the Abandoned and Forested.

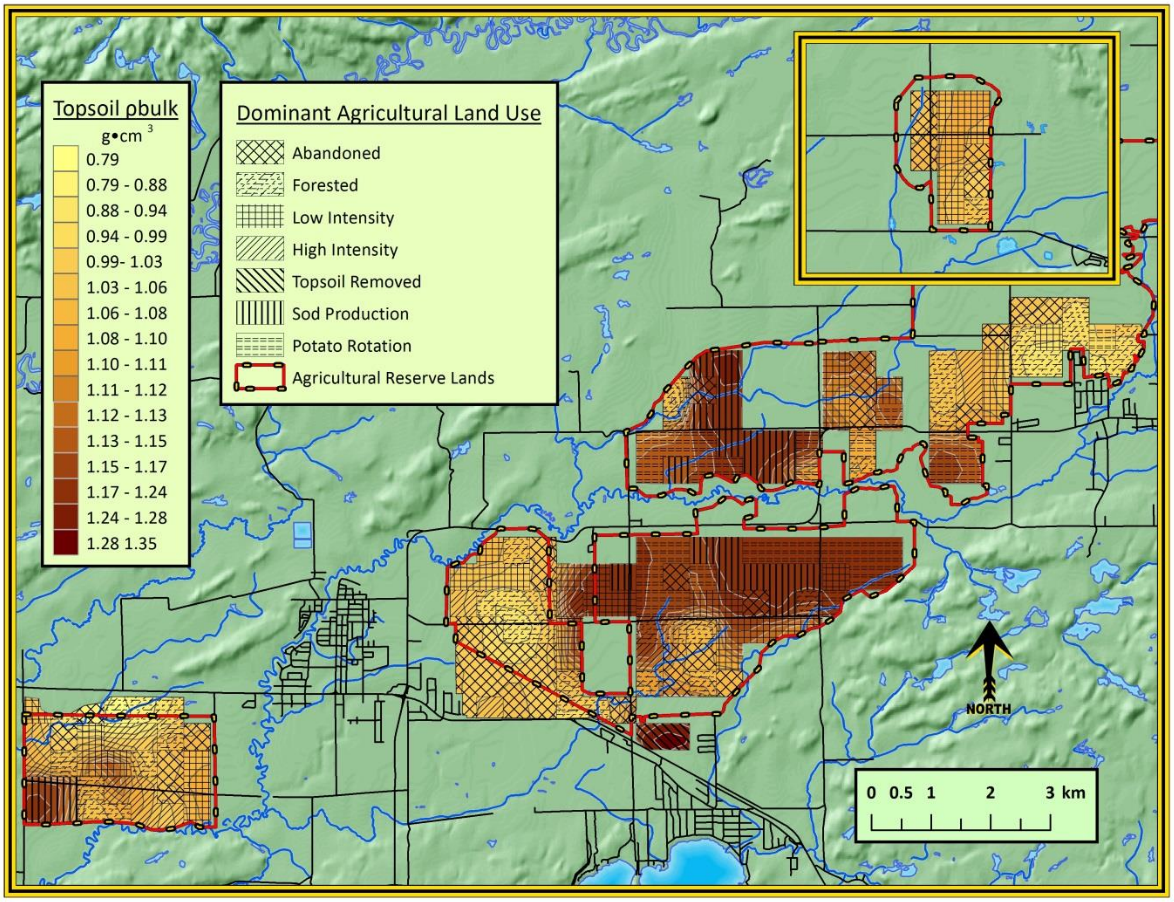


Figure 14. The predicted spatial distribution of topsoil (0-20 cm) bulk density (g·cm^3; ρ_{bulk}) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.3 Topsoil Total N Variability across Land Use Patterns

The median TS Total N (kg·ha^{-1}) of topsoil layers (0 – 20 cm depth) of the study area was found to be 379 kg·ha^{-1}. Sod Production had the lowest TS Total N (kg·ha^{-1}) of all land uses, with a median of 280 kg·ha^{-1}, being significantly lower than all other land uses with the exception of Topsoil Removed (p=0.741), which has a median TS Total N (kg·ha^{-1}) of 361 kg·ha^{-1}. Additionally, the Abandoned and Low Intensity land uses have median TS Total N (kg·ha^{-1}) contents of 394 kg·ha^{-1} and 415 kg·ha^{-1}, respectfully. Both results were significantly greater in median TS Total N (kg·ha^{-1}) content relative to the Potato Rotation land use, which had median of 354 kg·ha^{-1}. No other significant differences were found for the Forested and Intensive land uses, with median TS Total N (kg·ha^{-1}) contents of 388 kg·ha^{-1} and 409 kg·ha^{-1}, respectfully.

The median TS Total N (%) for the study area was 0.174 %., with Sod Production having the lowest overall median TS Total N (%) with a concentration of 0.118 %, an observation similar to that for TS Total N (kg·ha-1). The Sod Production land use was found to be significantly less than all other land uses with the exception of Topsoil Removed that had a median concentration of 0.147 %. As well, the Potato Rotation land use was found to have a median TS Total N (%) of 0.148 %, significantly less in comparison to the Abandoned (p=0.003) and Low Intensity (p=0.001) land uses having median contents of 0.192 % and 0.185 %, respectfully. With a p=0.052, a possible relationship might exist between the Potato Rotation and Intensive land uses. Although not significantly different from one another, the Intensive land use had a greater median TS Total N (%) of 0.173 %. No other significant differences TS Total N (%) were found for the Forested land use which had a median Total N concentration of 0.192 %.

The obtained CV values of Total N (kg·ha^{-1}) and Total N (%) for the study area were 28 % and 36 %, respectfully. With CV values of 61 % and 53 %, Topsoil Removed was the overall most variable land use within both datasets. Furthermore, the Intensive land use was the least variable in both datasets with CV values of 16 % and 15 %.

Table 4. Summary statistics for the Total N (kg·ha^{-1}) and Total N (%) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (>p=0.050) using the Kruskal-Wallace comparison.

Total N												
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	379		145	1072	388	7.9	110	28	2.0	9.0
Abandoned	kg·ha^{-1}	394	*a*	295	717	413	13	83	20	1.5	3.5
Forested	kg·ha^{-1}	388	*ac*	230	562	389	13	85	22	0.37	-0.42
Low Intensity	kg·ha^{-1}	415	*a*	251	1072	434	23	141	32	3.0	12
Intensive	kg·ha^{-1}	409	*ac*	273	488	394	17	63	16	-0.54	-0.57
Topsoil Removed	kg·ha^{-1}	361	*abc*	145	764	373	86	227	61	0.80	-0.15
Sod Production	kg·ha^{-1}	280	*b*	213	474	300	13	65	22	1.1	0.98
Potato Rotation	kg·ha^{-1}	354	*c*	242	765	365	18	98	27	2.5	9.4
Region	%	0.174		0.0460	0.554	0.182	0.0047	0.065	36	2.3	9.6
Abandoned	%	0.192	*ad*	0.133	0.554	0.206	0.011	0.066	32	4.0	21
Forested	%	0.192	*ac*	0.129	0.515	0.213	0.012	0.077	36	2.0	5.1
Low Intensity	%	0.185	*ac*	0.123	0.445	0.194	0.0089	0.056	29	2.7	11
Intensive	%	0.173	*bc*	0.146	0.231	0.181	0.0073	0.027	15	0.37	-1.1
Topsoil Removed	%	0.147	*bdef*	0.0460	0.224	0.128	0.026	0.068	53	0.064	-1.7
Sod Production	%	0.118	*e*	0.0855	0.175	0.123	0.0054	0.027	22	0.58	-0.6
Potato Rotation	%	0.148	*f*	0.107	0.306	0.155	0.0074	0.040	26	2.2	6.5

4.1.3.1 Spatial Relationship of Topsoil Total N to Land Use

The predicted surface of Total N (%) in relation to the Dominant Land Use Cover is presented in Figure 15. As was the case for TS ρbulk, the predicted surface of TS Total N (%) was found to have similar spatial patterns over the study area, reflecting those found within the spatial distribution of TS Total C (%) in Figure 13. In certain cases, areas having greater TS Total C (%) were also found to have greater TS Total N (%). For example, the Forested soils north of Bradley Rd. and along the western portion of Bonin Rd. were both found to have greater localized predicted TS Total N (%) and TS Total C (%). As well, similar to the spatial distribution of TS Total C (%), TS Total N (%) was found to be greater in certain low-lying areas adjacent to drainage features.

Areas of low predicted Total C (%) were also found to have low Total N (%). For example, the large areas having lower predicted Total N (%) contents along both the north and south banks of the Whitson River within the central region of the Agricultural Reserve lands were also found to have a lower predicted Total C (%). The similar patterns between both predicted surfaces appears more pronounced in to the north of the Whitson River since the zone of low predicted Total N (%) to the south of the river was found to be smaller in comparison to the low zone of predicted Total C (%).

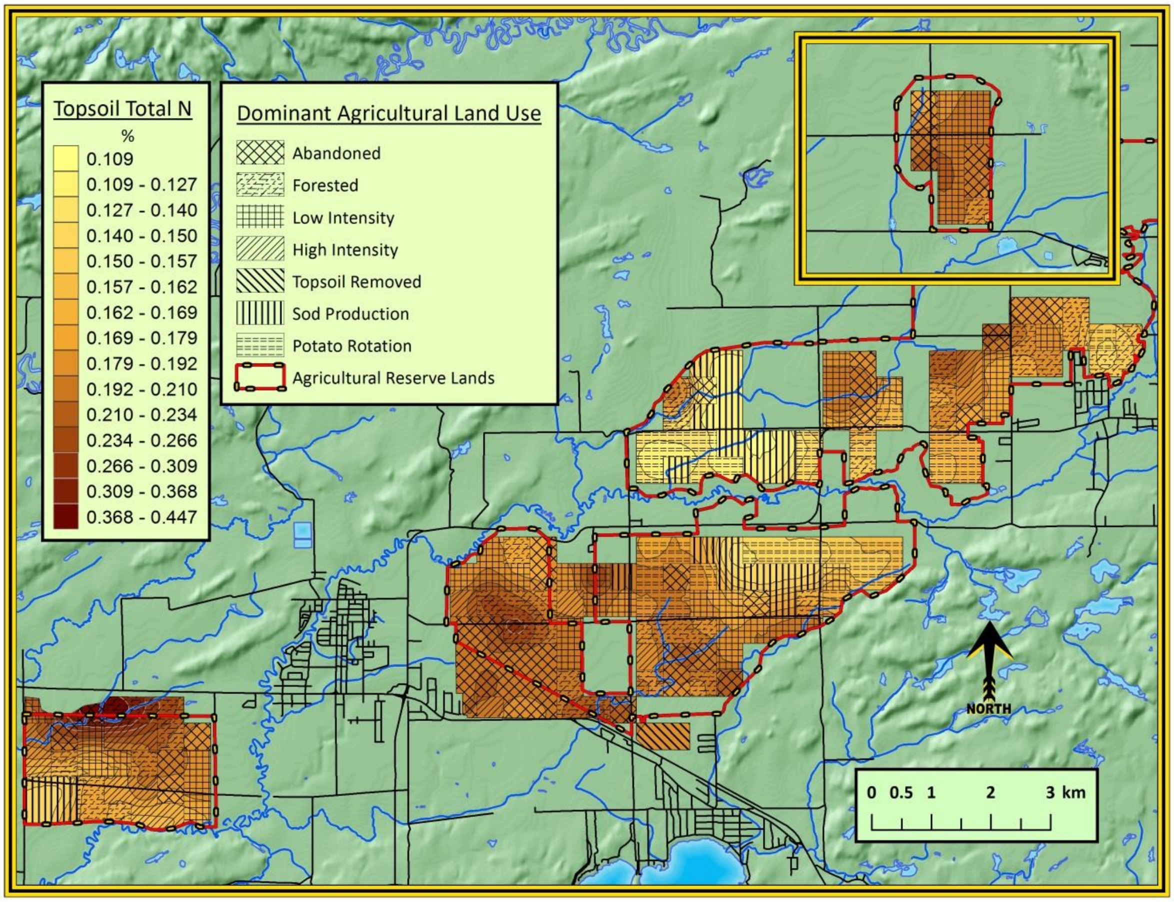


Figure 15. The predicted spatial distribution of topsoil (0-20 cm) Total N (%) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.4 Topsoil Total C to N Ratio Variability across Land Use Patterns

The median regional TS C to N Ratio was 14.1. Overall, areas under the Forested land use had the greatest TS C to N Ratio with a median of 17.0. It was significantly greater than all other land uses with the exception of Topsoil Removed (p=0.072). As well, areas under the Abandoned land uses were found to have a median TS C to N Ratio of 14.7, significantly greater than Low Intensity (p=0.002), Sod Production (p=0.000) and Potato Rotation (p=0.000) with median values of 13.7, 13.2 and 12.5, respectfully. Low Intensity was also significantly greater than Potato Rotation at a *p*= 0.018. Finally, having a median TS C to N Ratio of 13.7, the Intensive land use was significantly greater than both, the Sod Production (*p*=0.025) and the Potato Rotation (*p*=0.003) land uses that were found to have the lowest TS C to N Ratio in comparison to all other studied land uses.

The regional CV value for the TS C to N Ratio within the study area was found to be 25 %. Overall, the Topsoil Removed land use was found to have the greatest CV with a value of 80 %. The obtained CV for the Topsoil Removed land use was considerably larger than other land uses. The remaining land uses ranked according to their CV value from greatest to lowest were as follows: Forested = Low Intensity > Potato Rotation > Abandoned > Sod Production having values of 18 %, 18 %, 17 %, 15 %, 14 % and 10 %.

Table 5. Summary statistics for the C to N ratio of topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (>*p*=0.050) using the Kruskal-Wallace comparison.

	C to N Ratio									
Dominant Land Use	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	14.1		1.77	37.8	14.5	0.26	3.6	25	1.6	11
Abandoned	14.7	*a*	9.62	20.5	15.0	0.35	2.2	15	0	0.84
Forested	17.0	*b*	12.5	27.6	17.5	0.50	3.2	18	1.3	2.7
Low Intensity	13.7	*cd*	5.35	20.3	13.6	0.40	2.5	18	-0.65	5.1
Intensive	14.0	*ad*	12.6	18.0	14.4	0.39	1.5	10	1.1	1.8
Topsoil Removed	11.2	*bdf*	1.77	37.8	14.5	4.4	12	80	1.5	2.9
Sod Production	13.2	*cf*	7.73	16.1	13.0	0.37	1.8	14	-0.87	1.6
Potato Rotation	12.5	*ef*	6.63	16.5	12.5	0.39	2.1	17	-0.81	1.9

4.1.4.1 Spatial Relationship of Topsoil C to N Ratio to Land Use

The predicted surface of the TS C to N ratio with the Dominant Land Use Cover superimposed of the study area is presented in Figure 16. The spatial distribution of C to N ratio appears to conform well to the overlying Dominant Land Use Cover layer. The areas under the Forested land use and Abandoned land uses were found to contain the majority of areas having the greatest predicted TS C to N Ratios. Examples of these areas include: the Forested areas east of Martin Rd., the area along the most north-eastern portion of the Whitson River, the area along the western half of Bonin Rd., the area south of the eastern half of Bonin Rd, and the area north of the Bradley Rd.

Areas not under the Forested or Abandoned land use were found to have lower predicted TS C to N ratios. For instance, an area having lower TS C to N ratio was found south of the Whitson River within central region of the study area. This area, largely managed under the Low Intensity, Sod Production and Potato Rotation land uses, was generally lower than the area immediately south-west which displays a greater TS C to N ratio under the Forested and Abandoned land uses.

Another area of interest is a cluster of three 20 ha sites under the Low Intensity land use centrally located to the north of Bradley Rd. The two sites that were side by side in a north – south direction were found to have a much greater TS C to N ratio than the third site immediately located to the east. Of note, these two sites having greater TS C to N ratios were recently cleared Forested sites and are now planted under a Low Intensity crop system.

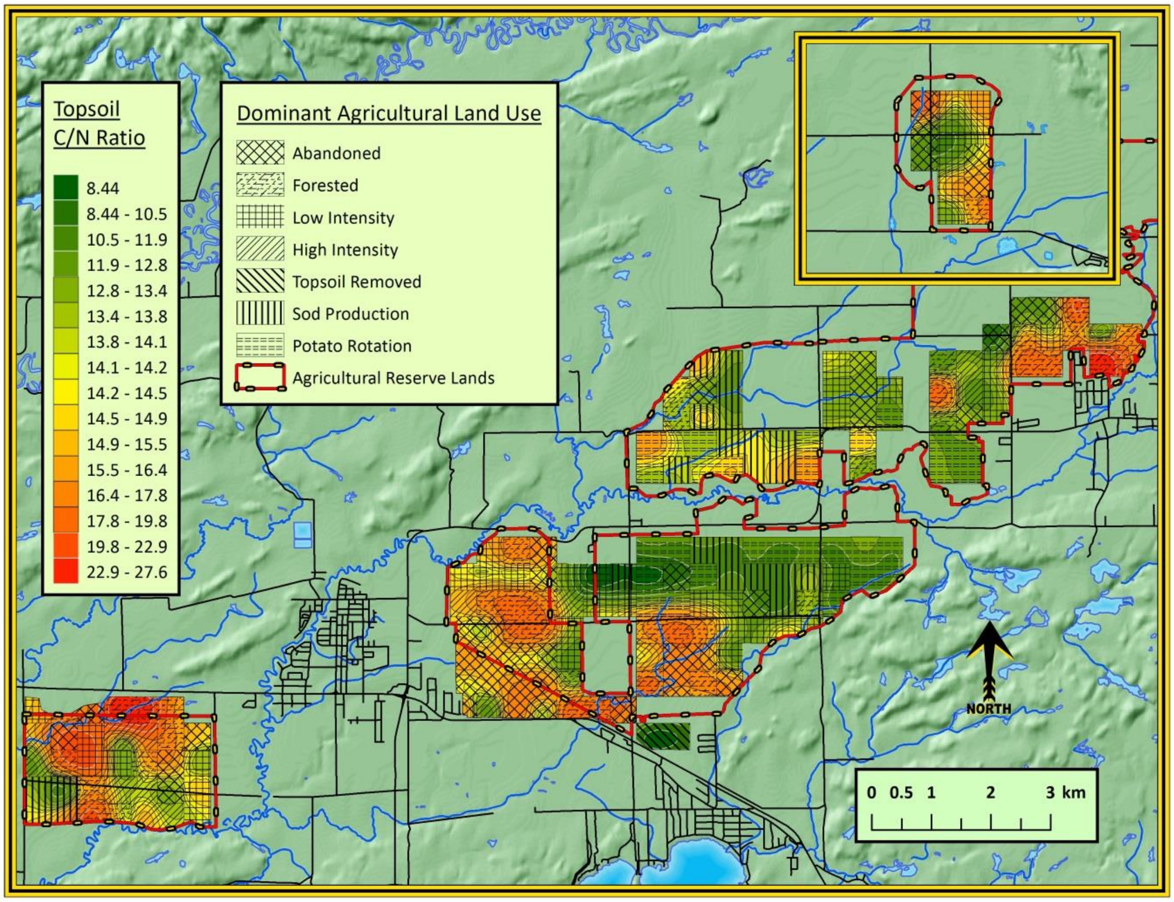


Figure 16. The predicted spatial distribution of topsoil (0-20 cm) C to N ratio in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.5 Topsoil Total Available P Variability across Land Use Patterns

The median TS Available P (kg·ha^{-1}) for the study area was 0.824 kg·ha^{-1}. Overall, the Topsoil Removed land use was found to have a median TS Available P (kg·ha^{-1}) of 0.225 kg·ha^{-1}, a level significantly lower than all other land uses which ranged from 0.792 kg·ha^{-1} to 0.973 kg·ha^{-1}. No other significances differences were found between land uses for TS Available P (kg·ha^{-1}). The median TS Available P (kg·ha^{-1}) content for the Abandoned, Low Intensity, Intensive, Sod Production and Potato Rotation land uses were 0.794 kg·ha^{-1}, 0.792 kg·ha^{-1}, 0.959 kg·ha^{-1}, 0.922 kg·ha^{-1}, 0.818 kg·ha^{-1} and 0.973 kg·ha^{-1}, respectfully.

Measurements for TS Available P (kg·ha^{-1}) and TS Available P (mg·kg^{-1}) were similar, with a median TS Available P (mg·kg^{-1}) within the study area being 4.06 mg·kg^{-1}. The Topsoil Removed land, with a median TS Available P (mg·kg^{-1}) of 1.02 mg·kg^{-1}, was found to be significantly lower than all other land uses. No other significant differences were found. The median Available P (mg·kg^{-1}) for the Abandoned, Forested, Low Intensity, Intensive and Sod Production and Potato Rotation land uses were 3.96 mg·kg^{-1}, 4.48 mg·kg^{-1}, 4.35 mg·kg^{-1}, 4.37 mg·kg^{-1}, 3.29 mg·kg^{-1} and 4.02 mg·kg^{-1}, respectfully.

Over the study area CV values for both the Available P (kg·ha^{-1}) and Available P (mg·kg^{-1}) datasets were 44 % and 42 %. For Available P (kg·ha^{-1}), Land uses CV values were ranked from the most variable to the least variable as follows: Topsoil Removed > Sod Production > Low Intensity >Abandoned = Potato Rotation > Forested > Intensive, having CV values of 61 %, 50 %, 46%, 43%, 43%, 38 % and 25 %. Similarly, land use CV values within the Available P (mg·kg^{-1}) dataset were ranked from most variable to least variable as follows: Topsoil Removed > Sod Production > Low Intensity > Potato Rotation > Abandoned > Forested > Intensive, having CV values of 58%, 48%, 41%, 40%, 39%, 38% and 25 %. With the exception of the Intensive land in which CV values remained identical, land use TS Available P (kg·ha^{-1}) was slightly more variable than land use TS Available P (mg·kg^{-1}).

Table 6. Summary statistics for the $LiNO_3$ plant available P content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (*p*=0.050) using Kruskal-Wallace comparison.

Available P												
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	0.824		0.163	2.61	0.916	0.029	0.41	44	1.0	1.5
Abandoned	kg·ha^{-1}	0.794	*a*	0.252	1.84	0.882	0.061	0.38	43	0.79	-0.02
Forested	kg·ha^{-1}	0.792	*a*	0.389	1.75	0.888	0.053	0.34	38	0.97	0.25
Low Intensity	kg·ha^{-1}	0.959	*a*	0.176	2.61	0.975	0.069	0.44	46	1.5	4.0
Intensive	kg·ha^{-1}	0.922	*a*	0.606	1.34	0.960	0.063	0.24	25	0.11	-1.3
Topsoil Removed	kg·ha^{-1}	0.225	*b*	0.163	0.704	0.360	0.084	0.22	61	1.0	-0.94
Sod Production	kg·ha^{-1}	0.818	*a*	0.354	2.11	0.931	0.095	0.47	50	0.98	0.32
Potato Rotation	kg·ha^{-1}	0.973	*a*	0.351	2.04	1.01	0.078	0.43	43	0.99	0.53
Region	mg·kg^{-1}	4.06		0.515	10.2	4.22	0.13	1.8	42	0.63	0.47
Abandoned	mg·kg^{-1}	3.96	*a*	1.27	8.15	4.27	0.26	1.6	39	0.59	-0.29
Forested	mg·kg^{-1}	4.48	*a*	1.95	9.38	4.79	0.28	1.8	38	0.90	0.45
Low Intensity	mg·kg^{-1}	4.35	*a*	0.806	10.2	4.27	0.27	1.8	41	1.1	2.6
Intensive	mg·kg^{-1}	4.37	*a*	2.45	6.21	4.38	0.29	1.1	25	-0.17	-0.7
Topsoil Removed	mg·kg^{-1}	1.02	*b*	0.515	2.35	1.25	0.27	0.73	58	0.86	-1.0
Sod Production	mg·kg^{-1}	3.29	*a*	1.42	7.78	3.83	0.38	1.9	48	0.68	-0.60
Potato Rotation	mg·kg^{-1}	4.02	*a*	1.50	8.05	4.26	0.31	1.7	40	0.73	-0.02

4.1.5.1 Spatial Relationship of Topsoil Available P to Land Use

The spatial distribution of TS Available P (mg·kg^{-1}) in relation the overlying land use cover within the study area is presented in Figure 17. The spatial distribution of TS Available P (mg·kg^{-1}) had a complex mottled pattern, with certain areas having the greater predicted TS Available P (mg·kg^{-1}) being under the Potato Rotation and Sod Production land uses south of the Whitson River. These complex patterns overlying this region make any patterns in relation to the Dominant Land Use Cover difficult to discern. In some instances low-lying Forested areas near drainage pathways were found to have greater predict Available P (mg·kg^{-1}) in comparison to adjacent areas.

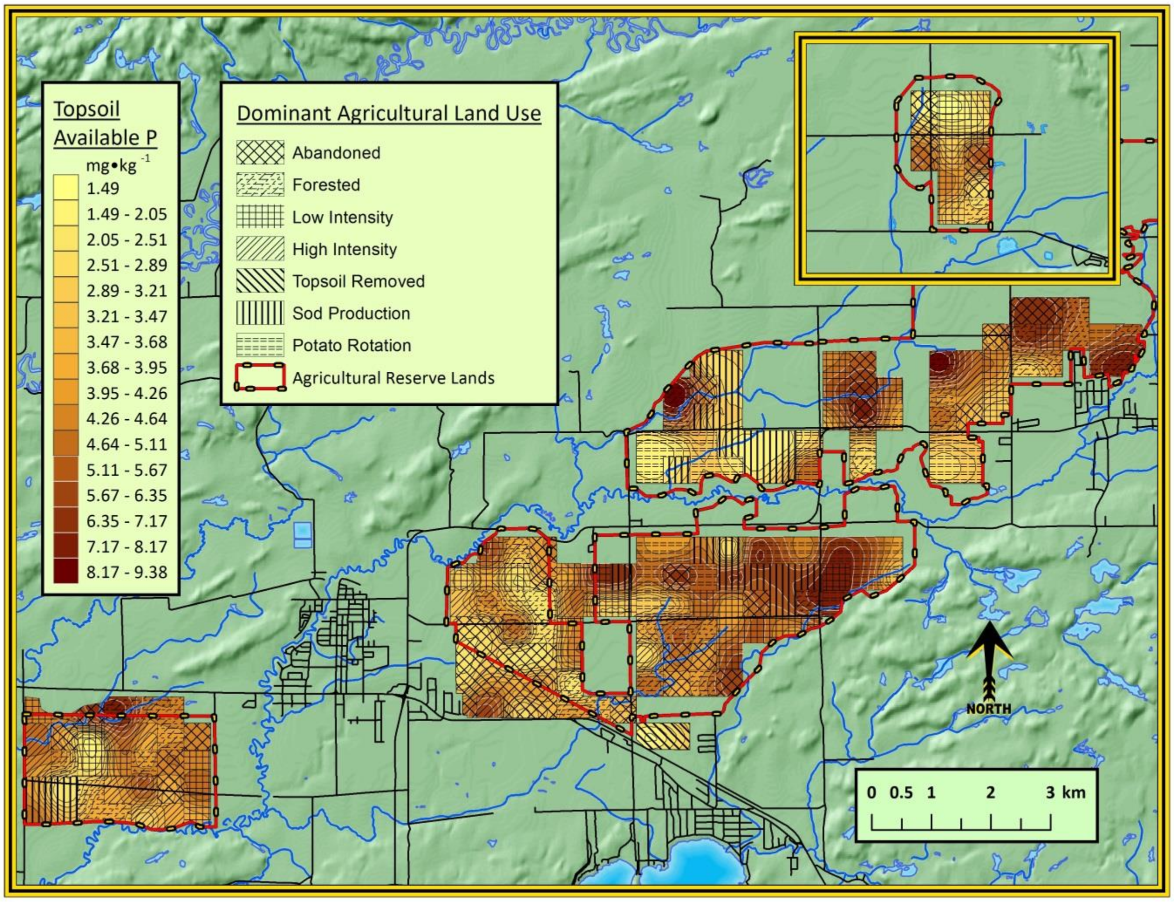


Figure 17. The predicted spatial distribution of topsoil (0-20 cm) Available P (mg·kg-1) in relation to Dominant Land Uses of lands surveyed within the Agricultural Reserve ( ) Lands of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.6 Topsoil Total P Variability across Land Use Patterns

The median TS Total P (kg·ha^{-1}) of the study was 61.3 kg·ha^{-1}, with the Forested land use having the overall lowest TS Total P (kg·ha^{-1}) with a median content of 45.9 kg·ha^{-1}. This median content was significantly less than that observed for all other land uses except for the

Abandoned (p=0.450) land use that had a median of 50.7 kg·ha^{-1}. The Forested land use was found to be significantly less than Low Intensity (p=0.020), Intensive (p=0.002), Topsoil Removed (p=0.004), Sod Production (p=0.000) and Potato Rotation (p=0.000) which had median TS Total P (kg·ha^{-1}) contents of 55.8 kg·ha^{-1}, 71.5 kg·ha^{-1}, 68.9 kg·ha^{-1}, 67.4 kg·ha^{-1}, and 78.2 kg·ha^{-1}, respectfully. As well, the Abandoned land use, with the second lowest median TS Total P (kg·ha^{-1}), was significantly lower than Intensive (p=0.001), Topsoil Removed (p=0.003), Sod Production (p=0.000) and Potato Rotation (p=0.000). Additionally, the Low Intensity land use was significantly less than Intensive (p=0.041), Sod Production (p=0.008) and Potato Production (p=0.000). Overall, the Potato Rotation land, having the greatest TS Total P (kg·ha^{-1}) with a median of 78.2 kg·ha^{-1}, was significantly greater than the Abandoned (p=0.000), Forested (p=0.000), Lower Intensity (p=0.000) and Sod Production (p=0.006) land uses, respectively. Finally, the Low Intensity land use was found to be significantly less in comparison to the Sod Production (p=0.008) land use.

The median TS Total P (mg·kg^{-1}) for the study area was 272 mg·kg^{-1}. Overall, the two land uses with the greatest TS Total P (mg·kg^{-1}) were the Intensive and Potato Rotation land uses having median values of 311 mg·kg^{-1} and 339 mg·kg^{-1}, respectfully. Both were found to be significantly greater than the Abandoned, Forested and Low Intensity land uses that had median TS Total P (mg·kg^{-1}) of 252 mg·kg^{-1}, 248 mg·kg^{-1} and 262 mg·kg^{-1}, respectively Furthermore, the Topsoil Removed land use was found to have a median TS Total P (mg·kg^{-1}) of 269 mg·kg^{-1}, 13.5 % less than the Intensive land use. Although the TS Total P relationship with the Intensive land use was not found to be significantly different (p=0.052), a possible relationship might exist, but will only be revealed by a more intensive sampling program.

Finally, the Sod Production land use, with a median TS Total P (mg·kg^{-1}) of 283 mg·kg^{-1}, was found to be significantly greater than only the Abandoned (*p*=0.019) land use.

For the entire study area, CV values for TS Total P (kg·ha^{-1}) and TS Total P (mg·kg^{-1}) were 32 % and 26 %, respectfully. When comparing land uses of both datasets, Forested was found to be the most variable land use having CV values of 35 % and 30 %. Furthermore, in both cases Sod Production was the least variable land use having CV values of 16 % and 15%.

Table 7. Summary statistics for the Total P content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (*p*=0.050) using Kruskal-Wallace comparison.

Total P											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	61.3		26.4	128	61.6	1.4	19	32	0.65	0.37
Abandoned	kg·ha^{-1}	50.7	*ac*	28.1	105	52.0	2.2	14	27	1.4	4.1
Forested	kg·ha^{-1}	45.9	*a*	26.4	105	50.6	2.8	18	35	1.1	1.2
Low Intensity	kg·ha^{-1}	55.8	*c*	32.3	106	59.0	2.7	17	29	0.79	0.24
Intensive	kg·ha^{-1}	71.5	*bd*	31.9	87.8	68.3	4.1	15	22	-0.99	0.99
Topsoil Removed	kg·ha^{-1}	68.9	*bd*	53.6	104	74.2	7.5	20	27	0.63	-1.3
Sod Production	kg·ha^{-1}	67.4	*b*	50.6	102	68.5	2.3	11	16	0.98	2.55
Potato Rotation	kg·ha^{-1}	78.2	*d*	51.3	128	80.9	3.4	19	23	0.72	0.22
Region	mg·kg^{-1}	272		148	539	281	5.2	73	26	0.85	0.93
Abandoned	mg·kg^{-1}	252	*a*	162	539	260	12	74	28	1.9	5.3
Forested	mg·kg^{-1}	248	*ac*	148	524	263	12	78	30	1.0	1.6
Low Intensity	mg·kg^{-1}	262	*ac*	182	433	265	9.6	61	23	0.77	0.065
Intensive	mg·kg^{-1}	311	*bd*	225	415	313	16	59	19	0.038	-1.0
Topsoil Removed	mg·kg^{-1}	269	*ad*	187	305	256	20	52	20	-0.40	-2.0
Sod Production	mg·kg^{-1}	283	*cd*	195	376	285	9	43	15	0.24	-0.061
Potato Rotation	mg·kg^{-1}	339	*b*	226	508	342	13	73	21	0.39	-0.34

4.1.6.1 Spatial Relationship of Topsoil Total P to Land Use

The spatial distribution of TS Total P (mg·kg^{-1}) in relation to Dominant Land Use cover is presented in Figure 18. The spatial distribution of TS Total P (mg·kg^{-1}) in comparison to TS Available P (mg·kg^{-1}) displays a smoother and less erratic pattern. Areas having the greatest predicted Total P (mg·kg^{-1}) were mostly situated along the Whitson River floodplain under the Potato Rotation land use, with apparent slight differences to neighboring Sod Production lands. In the eastern portion of the north-central region of the Agricultural Reserve lands lower predicted Total P (mg·kg^{-1}) concentrations were found under the Forested and Abandoned land uses in comparison to the nearby Potato Rotation lands. Similarly within south-eastern portion of the Bradley Rd. region, slightly lower TS Total P (mg·kg^{-1}) occurred under the Forested land uses than under adjacent Intensive and Low Intensity land uses. Not all areas under the Forested land use over the study area were found to have low predicted TS Total P (mg·kg^{-1}) in comparison to neighboring land uses. For example, localized areas located north of Bradley Rd. and in the south central region in close proximity to drainage features under the Forested land use were found to have greater predicted Total P (mg·kg^{-1}). Additionally, no clear pattern seems to exist for the Intensive and Low Intensity land uses, with some areas having a relatively greater predicted TS Total P (mg·kg^{-1}).

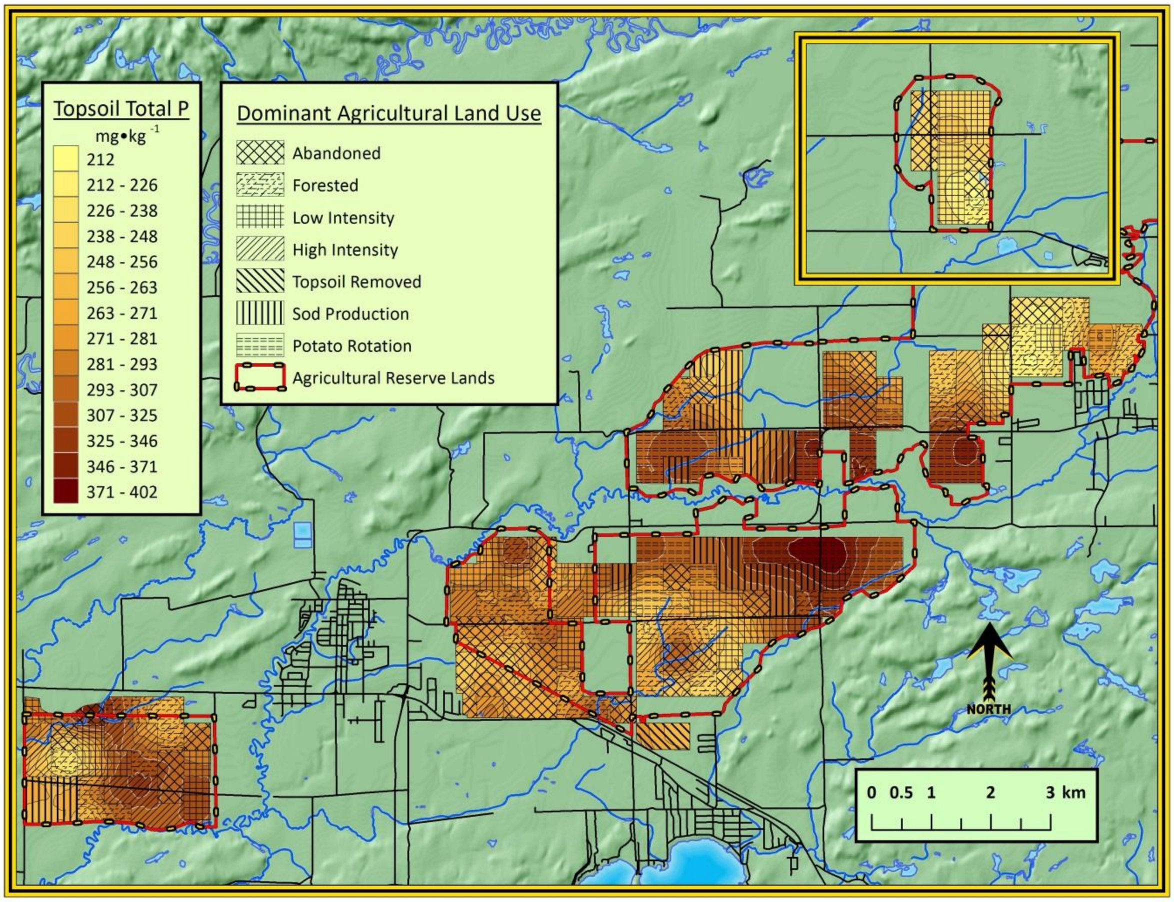


Figure 18. The predicted spatial distribution of topsoil (0-20 cm) Total P (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.7 Topsoil Available K Variability across Land Use Patterns

The median TS Available K (kg·ha^{-1}) of the study area was found to be 2.38 kg·ha^{-1}, with the Potato Rotation land use having the greatest TS Available K (kg·ha^{-1}), with the median content of 11.0 kg·ha^{-1} being a significantly greater level than for all other land uses. The Sod Rotation land use had a median TS Available K (kg·ha^{-1}) of 4.71 kg·ha^{-1}, a level significantly greater than Abandoned (*p*=0.000), Forested (*p*=0.000), Low Intensity (*p*=0.000), Intensity (*p*=0.000) and Topsoil Removed (*p*=0.000) that had median contents of 1.40 kg·ha^{-1}, 2.33 kg·ha^{-}

^{1}, 2.22 kg·ha^{-1}, 1.82 kg·ha^{-1} and 1.03 kg·ha^{-1}, respectfully. Of obvious importance, the Topsoil Removed land use had the lowest overall median TS Available K (kg·ha^{-1}) content of 1.03 kg·ha^{-1}, a level significantly lower than the median levels for Forested (*p*=0.045), Low Intensity (*p*=0.0042) and Sod Production (*p*=0.001) and Potato Rotation (*p*=0.000) land uses. Additionally, the Abandoned land use, with a median TS Available K (kg·ha^{-1}) of 1.40 kg·ha^{-1}, was found to be significantly lower than the Forested (*p*=0.022) and Low Intensity (*p*=0.023) land uses which had median values of 2.33 kg·ha^{-1} and 2.22 kg·ha^{-1}, respectfully.

The median TS Available K (mg·kg^{-1}) of the study area was 11.5 mg·kg^{-1}, with the Potato Rotation land use having the overall greatest TS Available K (mg·kg^{-1}) with a median of 45.5 mg·kg^{-1}, a level significantly greater than for all other land uses. Additionally, the Sod Production land use, with the second greatest TS Available K (mg·kg^{-1}) and a median concentration of 18.7 mg·kg^{-1}, was found to be significantly greater than the Abandoned (*p*=0.000), Forested (*p*=0.015), Low Intensity (*p*=0.000), Intensive (*p*=0.001), Topsoil Removed (*p*=0.000) land uses that had median values of 6.61 mg·kg^{-1}, 12.0 mg·kg^{-1}, 9.29 mg·kg^{-1}, 8.79 mg·kg^{-1} and 3.39 mg·kg^{-1}, respectively. The Topsoil Removed land use had the overall lowest TS Available K (mg·kg^{-1}) with a median of 3.39 mg·kg^{-1}, being significantly less than the Abandoned (*p*=0.022), Forested (*p*=0.002), Low Intensity (*p*=0.011), Intensive (*p*=0.025), Sod Production (*p*=0.000) and Potato Rotation (*p*=0.000) land uses. The Abandoned land TS Available K (mg·kg-1) level was also significantly less in comparison to the Forested (*p*=0.002) land use.

The CV values for TS Available K (kg·ha^{-1}) and TS Available K (mg·kg^{-1}) of the study area were 100 % and 95 %, respectfully. For both the TS Available K (kg·ha^{-1}) and TS Available K (mg·kg^{-1})datasets, individual land uses CV values were ranked from greatest to lowest in the identical order as follows: Low Intensity > Topsoil Removed > Forested > Abandoned > Intensive > Sod Production > Potato Rotation.

Table 8. Summary statistics for the $LiNO_3$ plant available K content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land use medians indicate no significant difference (>*p*=0.050) using the Kruskal-Wallace comparison.

Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
					Available K						
Region	kg·ha^{-1}	2.38		0.497	20.3	4.02	0.29	4.0	100	1.74	2.50
Abandoned	kg·ha^{-1}	1.40	*a*	0.602	5.11	1.84	0.19	1.2	65	1.25	0.84
Forested	kg·ha^{-1}	2.33	*bc*	0.650	8.05	2.74	0.29	1.9	68	1.08	0.58
Low Intensity	kg·ha^{-1}	2.22	*be*	0.684	20.3	3.09	0.51	3.3	107	3.83	18.68
Intensive	kg·ha^{-1}	1.82	*ace*	0.692	4.78	1.87	0.28	1.1	56	1.55	3.64
Topsoil Removed	kg·ha^{-1}	1.03	*a*	0.497	4.47	1.53	0.53	1.4	92	1.97	3.83
Sod Production	kg·ha^{-1}	4.71	*d*	0.812	13.3	5.69	0.63	3.1	55	0.60	0.01
Potato Rotation	kg·ha^{-1}	11.0	*f*	0.766	17.1	10.0	0.88	4.9	49	-0.53	-0.92
Region	mg·kg^{-1}	11.5		1.96	83.2	17.8	1.2	17	95	1.7	2.2
Abandoned	mg·kg^{-1}	6.61	*a*	2.74	22.2	8.81	0.89	5.6	64	1.0	0.18
Forested	mg·kg^{-1}	12.0	*b*	3.18	38.7	15.0	1.58	10	68	0.87	-0.12
Low Intensity	mg·kg^{-1}	9.29	*a*	2.87	83.2	12.6	2.12	14	108	3.8	18
Intensive	mg·kg^{-1}	8.79	*a*	3.43	21.6	9.48	1.46	5.5	58	1.2	1.1
Topsoil Removed	mg·kg^{-1}	3.39	*c*	1.96	15.6	5.27	1.84	4.9	93	2.1	4.3
Sod Production	mg·kg^{-1}	18.7	*d*	3.13	58.2	23.2	2.72	13	58	0.86	0.61
Potato Rotation	mg·kg^{-1}	45.5	*e*	3.64	72.5	42.4	3.77	21	49	-0.47	-0.93

4.1.7.1 Spatial Relationship of Topsoil Available K to Land Use

The predicted surface of TS Available K (mg·kg^{-1}) in relation to the Dominant Land Use Cover is presented in Figure 19 with soils along both the northern and southern banks of the Whitson River in the central region of the Agricultural Reserve being found to have the greatest predicted TS Available K (mg·kg^{-1}). Similar to TS Available K (mg·kg^{-1}) findings, areas having the greatest Topsoil K (mg·kg^{-1}) were dominantly under the Sod Production and Potato Rotation land uses. To a lesser degree, predicted TS Available K (mg·kg^{-1}) also increases nearest the Whitson River in two locations where the Forested land use occurred east of Martin Rd. and south of Bradley Rd. The lowest predicted TS Available K (mg·kg^{-1}) content were found south of Bonin Rd, with the exception of one extremely high localized area under the Low Intensity land use. Of note, this area under Low Intensity Land Use feeds cull potatoes from local potato operations directly to livestock, suggesting that there is considerable nutrient transport in the large tonnages of material moved between the land parcels. Additionally, within both the Bradley Rd. and, Cote Blvd. and Dupuis Dr. regions TS Available K (mg·kg^{-1}) remains fairly uniform with no discernable patterns between land uses.

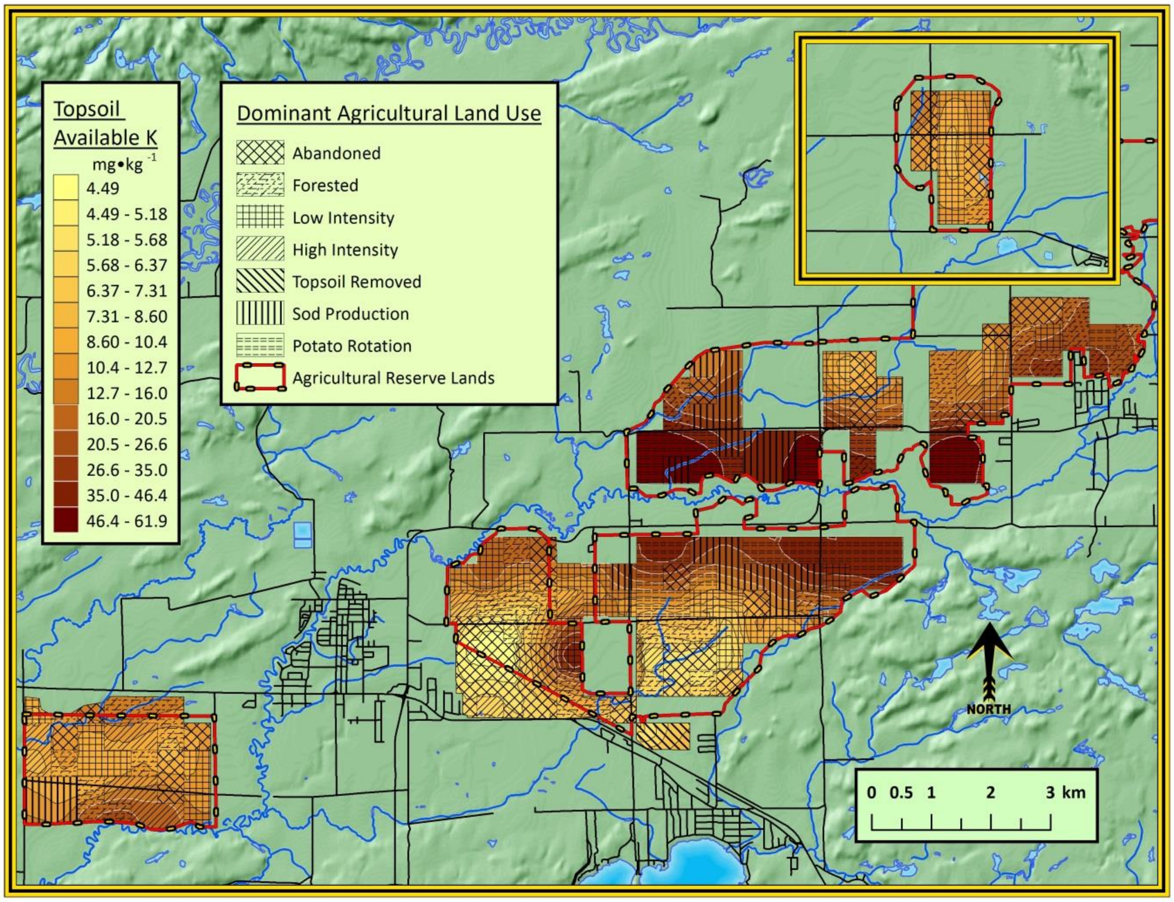


Figure 19. The predicted spatial distribution of topsoil (0-20 cm) Available K (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.8 Topsoil Total K Variability across Land Use Patterns

The median TS Total K (kg·ha^{-1}) of the region was 126 kg·ha^{-1}, with the Abandoned and Forested land uses having the lowest TS Total K (kg·ha^{-1}), with median contents of 112 kg·ha^{-1} and 101 kg·ha^{-1}, respectfully. The Forested land use was found to have significantly less TS Total K (kg·ha^{-1}) than the Low Intensity (*p*=0.001), Topsoil Removed (*p*=0.000), Sod Production (*p*=0.000) and Potato Rotation (*p*=0.000) land uses which had median contents of 124 kg·ha^{-1}, 179 kg·ha^{-1}, 147 kg·ha^{-1} and 149 kg·ha^{-1} respectively. Furthermore, with a significance value of *p*=0.058, a possible relation might exist between the Forested and Abandoned land uses with the Abandoned land use having a greater median TS Total K (kg·ha^{-1}) content. Additionally, the Abandoned land use TS Total K (kg·ha-1) content was significantly less than the Intensive (*p*=0.031), Topsoil Removed (*p*=0.002), Sod Production (*p*=0.000) and Potato Rotation (*p*=0.000) land uses. The Topsoil Removed land use had the greatest overall TS Total K (kg·ha^{-1}), having a significantly greater median TS Total K (kg·ha^{-1}) than only the Low Intensity (*p*=0.014) land use. As well, the Sod Production and Potato Rotation land were both found to have significantly greater median TS Total K (kg·ha^{-1}) contents than the Low Intensity land use.

The median TS Total K (mg·kg^{-1}) for the study area was 580 mg·kg^{-1}. The Topsoil Removed land uses, with the greatest overall TS Total K (mg·kg^{-1}) with a median content of 623 mg·kg^{-1}, was not significantly different than any other land uses. The Potato Rotation land use had the second overall greatest TS Total K (mg·kg^{-1}) with a value of 620 mg·kg^{-1} was found to be significantly greater than the Abandoned (*p*=0.004), Forested (*p*=0.001), Low Intensity (*p*=0.001) land uses that had median TS Total K (mg·kg^{-1}) contents of 548 mg·kg^{-1}, 553 mg·kg^{-1}, 544 mg·kg^{-1}, respectively. Additionally, the Sod Production land uses was found to have a median TS Total K (mg·kg^{-1}) content of 594 mg·kg^{-1}, a level significantly greater than the Forested (*p*=0.029) and Low Intensity (*p*=0.014) land uses. Finally, no significant differences were found for the Intensive land use which had a median TS Total K (mg·kg^{-1}) concentration of 597 mg·kg^{-1}.

For the entire study area, TS Total K (kg·ha^{-1}) and TS Total K (mg·kg^{-1}) were found to have CV values of 25 % and 18 %, respectively, with land use CV values being ranked from greatest to lowest as follows: Topsoil Removed > Low Intensity > Abandoned > Forested > Intensive > Potato Rotation > Sod Production, having CV values of 26 %, 24 %, 23 %, 22%, 20 %, 14 % and

13 %, respectively. Land use CV values for TS Total K (mg·kg^{-1}), on the other hand, were ranked from greatest to lowest as follows: Topsoil Removed > Low Intensity> Abandoned > Intensive > Forested > Sod Production > Potato Rotation, having CV values of 23 %, 21 %, 20 %, 18 %, 16 %, 13 % and 11%.

Table 9. Summary statistics for the Total K content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (*p*=0.050) using Kruskal-Wallace comparison.

Total K											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	126		55.9	234	126	2.2	31	25	0.48	0.55
Abandoned	kg·ha^{-1}	112	*ac*	66.4	205	115	4.2	26	23	0.90	2.3
Forested	kg·ha^{-1}	101	*a*	55.9	139	102	3.5	22	22	0.02	-0.89
Low Intensity	kg·ha^{-1}	124	*cd*	83.1	234	124	4.6	30	24	1.3	3.2
Intensive	kg·ha^{-1}	127	*bd*	90.9	174	131	6.9	26	20	0.15	-0.97
Topsoil Removed	kg·ha^{-1}	179	*b*	119	221	171	17	45	26	-0.12	-2.3
Sod Production	kg·ha^{-1}	147	*b*	106	189	147	3.8	19	13	0.41	1.1
Potato Rotation	kg·ha^{-1}	149	*b*	105	188	146	3.6	20	14	-0.23	-0.43
Region	mg·kg^{-1}	580		382	963	573	7.2	101	18	0.47	1.1
Abandoned	mg·kg^{-1}	548	*ac*	388	963	559	18	112	20	0.99	2.9
Forested	mg·kg^{-1}	553	*a*	406	730	549	13	86	16	0.044	-0.85
Low Intensity	mg·kg^{-1}	544	*a*	382	961	547	18	114	21	1.1	2.8
Intensive	mg·kg^{-1}	597	*ac*	457	802	603	30	111	18	0.52	-0.45
Topsoil Removed	mg·kg^{-1}	623	*ab*	408	778	594	52	138	23	-0.42	-0.91
Sod Production	mg·kg^{-1}	594	*bc*	462	785	604	16	76	13	0.55	0.52
Potato Rotation	mg·kg^{-1}	620	*b*	492	745	618	12	66	11	0.05	-0.62

4.1.8.1 Spatial Relationship of Topsoil Total K to Land Use

The predicted surface of TS Total K (mg·kg^{-1}) in relation to the Dominant Land Use Cover is presented in Figure 20. With a few exceptions, the spatial distribution of TS Total K (mg·kg^{-1})

displays little similarity to that of TS Available K ($mg \cdot kg^{-1}$) (Figure 19). Similar areas that were found to have greater predicted TS Total K ($mg \cdot kg^{-1}$) include several areas north and south of the Whitson River. As well, a small pocket exists just south of Bonin Rd where cull potatoes were used to feed livestock. Additionally, the areas with the lowest predicted TS Total K ($mg \cdot kg^{-1}$) were located in the northeastern region of the Agricultural Reserve lands. This area includes the regions north of the Whitson River and along Cote Blvd. and Dupuis Dr. The spatial distribution of TS Total K ($mg \cdot kg^{-1}$) appears to be greater to the south of the Whitson River, with the predicted TS Total K ($mg \cdot kg^{-1}$) content increases in a north-westerly direction along Bradley Rd. as distance increases from the Whitson River.

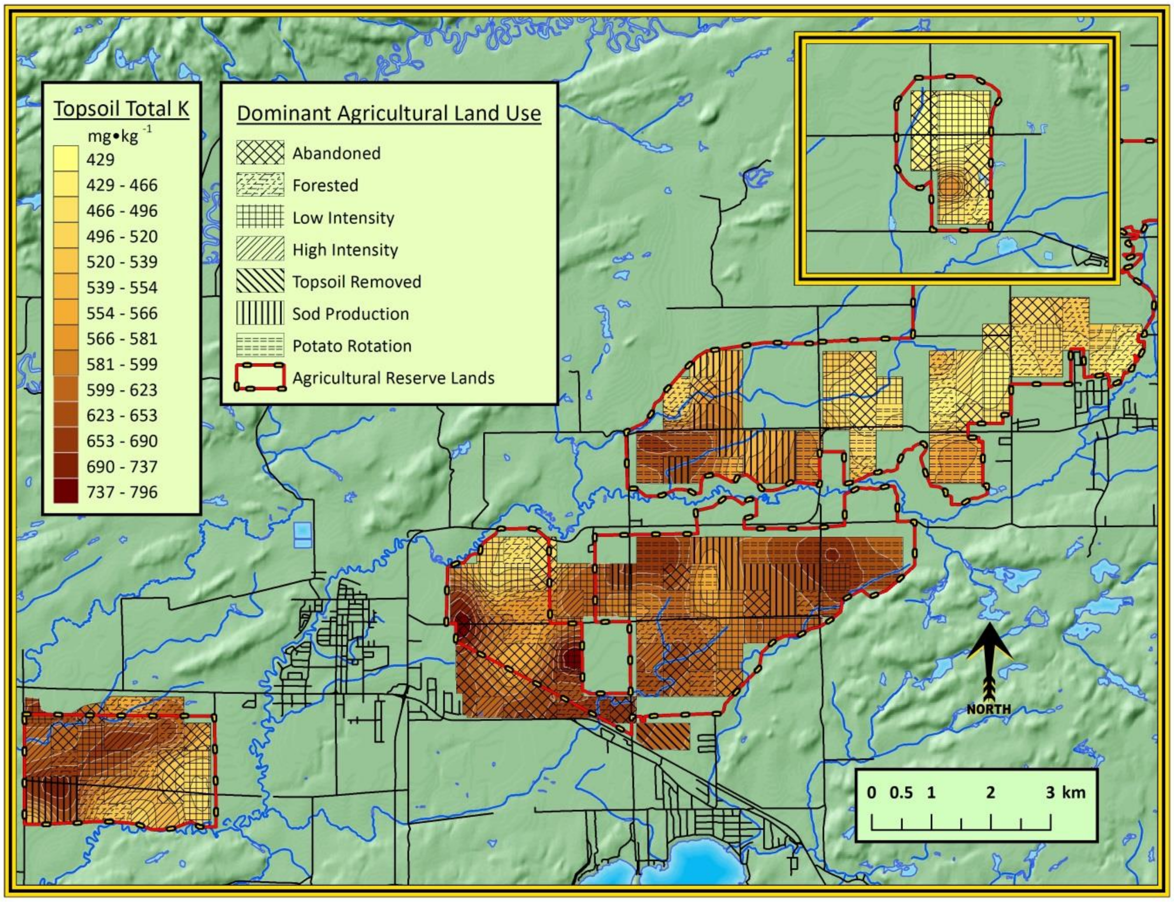


Figure 20. The predicted spatial distribution of topsoil (0-20 cm) Total K (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.9 Topsoil Available Zn Variability across Land Use Patterns

The median TS Available Zn (kg·ha^{-1}) for the study area was 0.0214 kg·ha^{-1}. With a median TS Available Zn (kg·ha^{-1}) of 0.0384 kg·ha^{-1}, the Potato Rotation land use had the overall greatest TS Available Zn (kg·ha^{-1}) content, a level significantly greater than for the Abandoned (*p*=0.012), Low Intensity (*p*=0.022), Intensive (*p*=0.006) and Sod Production (*p*=0.015) land uses (median TS Available Zn (kg·ha^{-1}) contents of 0.0182 kg·ha^{-1}, 0.0178 kg·ha^{-1}, 0.0118 kg·ha^{-1}and 0.0123 kg·ha^{-1}, respectively). Also, no significant differences were found between other land uses and the Forested and Topsoil Removed land uses, having a median TS Available Zn (kg·ha^{-1}) content of 0.0265 kg·ha^{-1} and 0.0517 kg·ha^{-1}, respectively.

The median TS Available Zn (mg·kg^{-1}) of the study area was 0.0957 mg·kg^{-1}, with the Potato Rotation land use was having the overall greatest median TS Available Zn (mg·kg^{-1}) content with a value of 0.156 mg·kg^{-1}. Potato Rotation land use TS Available Zn (mg·kg-1) was significantly greater than the Abandoned (p=0.037), Low Intensity (p=0.004), Intensive (p=0.003) and Sod Production (p=0.032) land uses which had median TS Available Zn (mg·kg^{-1}) of 0.0875 mg·kg^{-1}, 0.0630 mg·kg^{-1}, 0.0460 mg·kg^{-1} and 0.0601 mg·kg^{-1}, respectively. Furthermore, having a median TS Available Zn (mg·kg^{-1}) of 0.140 mg·kg^{-1}, the Forested land use was found to be significantly greater than the Low Intensity land use. Finally, the Topsoil Removed land use which had a median TS Available Zn (mg·kg^{-1}) of 0.185 mg·kg^{-1} was found to have no significant differences to other land uses.

The CV values for the TS Available Zn (kg·ha^{-1}) and TS Available Zn (mg·kg^{-1}) datasets within the study area were 104 % and 110 %, respectfully. For the TS Available Zn (kg·ha^{-1}) dataset, land use CV values were ranked from greatest to lowest as follows: Sod Production > Low Intensity > Forested > Abandoned > Topsoil Removed > Intensive > Potato Rotation, having CV values of 150 %, 111%, 96 %, 92 %, 91 %, 83 % and 78 %. Whereas the land use CV values for TS Available Zn (mg·kg^{-1}) were ranked from greatest to lowest as follows: Sod Production > Low Intensity > Forested > Abandoned > Topsoil Removed > Potato Rotation > Intensive, having CV values of 137 %, 119%, 102 %, 95 %, 85%, 81 % and 75 %.

Table 10. Summary statistics for the $LiNO_3$ plant available Zn content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (*p*=0.050) using Kruskal-Wallace comparison.

Available Zn											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	0.0214		0.00096	0.189	0.0355	0.0030	0.037	104	1.5	2.2
Abandoned	kg·ha^{-1}	0.0182	*a*	0.00096	0.076	0.0249	0.0043	0.023	92	0.90	-0.25
Forested	kg·ha^{-1}	0.0265	*ab*	0.00114	0.138	0.0447	0.0073	0.043	96	0.81	-0.64
Low Intensity	kg·ha^{-1}	0.0178	*a*	0.00100	0.138	0.0298	0.0058	0.033	111	1.6	2.3
Intensive	kg·ha^{-1}	0.0118	*a*	0.00180	0.041	0.0153	0.0042	0.013	83	1.1	0.76
Topsoil Removed	kg·ha^{-1}	0.0517	*ab*	0.00930	0.133	0.0614	0.028	0.056	91	0.71	-1.4
Sod Production	kg·ha^{-1}	0.0123	*a*	0.00220	0.189	0.0306	0.011	0.046	150	3.1	10
Potato Rotation	kg·ha^{-1}	0.0384	*b*	0.00270	0.141	0.0465	0.0066	0.036	78	1.1	0.72
Region	mg·kg^{-1}	0.0957		0.00439	0.766	0.161	0.014	0.18	110	1.7	2.3
Abandoned	mg·kg^{-1}	0.0875	*ac*	0.00743	0.389	0.123	0.023	0.12	95	1.1	0.34
Forested	mg·kg^{-1}	0.140	*ad*	0.00790	0.766	0.236	0.040	0.24	102	0.97	-0.28
Low Intensity	mg·kg^{-1}	0.0630	*c*	0.00439	0.565	0.110	0.023	0.13	119	2.1	4.4
Intensive	mg·kg^{-1}	0.0460	*ac*	0.00828	0.122	0.056	0.015	0.042	75	0.74	-0.81
Topsoil Removed	mg·kg^{-1}	0.185	*ace*	0.03140	0.421	0.205	0.088	0.18	85	0.47	-2.1
Sod Production	mg·kg^{-1}	0.0601	*ac*	0.00845	0.713	0.130	0.046	0.18	137	2.8	8.7
Potato Rotation	mg·kg^{-1}	0.156	*bde*	0.0127	0.666	0.199	0.029	0.16	81	1.3	1.5

4.1.10 Topsoil Total Zn Variability across Land Use Patterns

The median TS Total Zn (kg·ha^{-1}) of the study area was 6.74 kg·ha^{-1}. The Forested land use, with the overall lowest median TS Total Zn (kg·ha^{-1}) with a value of 5.75 kg·ha^{-1}, was significantly less than the Low Intensity (*p*=0.008), Intensive (*p*=0.002), Sod Production (p=0.003) and Potato Rotation (*p*=0.000) land uses which had median TS Total Zn (kg·ha^{-1}) contents of 6.95 kg·ha^{-1} and 7.55 kg·ha^{-1}, 6.79 kg·ha^{-1} and 7.23 kg·ha^{-1}. The Abandoned land use, with a median TS Total Zn (kg·ha^{-1}) content of 6.47 kg·ha^{-1}, was also significantly less than the Intensive (p=0.012) and Potato Rotation (p=0.023) land uses. Also, the Topsoil Removed, with a median TS Total Zn ($kg \cdot ha^{-1}$) of 6.57 $kg \cdot ha^{-1}$, and was not found to be significantly different to any other land use. No other significance differences were found between other land uses.

The median TS Total Zn ($mg \cdot kg^{-1}$) of the study area was 30.2 $mg \cdot kg^{-1}$. Overall, the Topsoil Removed land use had the lowest TS Total Zn ($mg \cdot kg^{-1}$), with a median of 21.9 $mg \cdot kg^{-1}$, was significantly less than the Abandoned (p=0.003), Forested (p=0.004), Low Intensity (p=0.001), Intensive (p=0.001), Sod Production (p=0.002) and Potato Rotation (p=0.000) land uses that had median TS Total Zn ($mg \cdot kg^{-1}$) contents of 31.8 $mg \cdot kg^{-1}$, 30.9 $mg \cdot kg^{-1}$, 30.2 $mg \cdot kg^{-1}$, 33.8 $mg \cdot kg^{-1}$, 28.4 $mg \cdot kg^{-1}$ and 29.6 $mg \cdot kg^{-1}$. Overall, the Intensive land use had the overall greatest TS Total Zn ($mg \cdot kg^{-1}$) and was found to be significantly greater in comparison to the Sod Production (p=0.010) and Potato Rotation (p=0.042) land uses.

The CV for the TS Total Zn ($kg \cdot ha^{-1}$) and the TS Total Zn ($mg \cdot kg^{-1}$) datasets were 28 % and 27 %, respectively. For TS Total Zn ($kg \cdot ha^{-1}$), land use CV values were ranked from greatest to lowest as follows: Low Intensity > Forested > Abandoned > Intensive > Sod Production = Potato Rotation, having values of 41 %, 28 %, 22 %, 21 %, 16 %, 14 % and 14 %. Whereas the land use CV values for TS Total Zn ($mg \cdot kg^{-1}$) were ranked from greatest to lowest as follows: Low Intensity > Forested > Abandoned > Topsoil Removed > Sod Production > Intensive > Potato Rotation, having values of 43 %, 23 %, 22 %, 20 %, 15 %, 14 % and 12 %.

Table 11. Summary statistics for the Reverse Aqua Regia Total Zn content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (p=0.050) using Kruskal-Wallace comparison.

Total Zn											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	6.74		2.88	22.5	6.61	0.13	1.8	28	3.1	28
Abandoned	kg·ha^{-1}	6.47	*ac*	2.88	9.25	6.29	0.22	1.4	22	-0.49	0.30
Forested	kg·ha^{-1}	5.75	*a*	3.21	8.84	5.72	0.25	1.6	28	0.16	-1.2
Low Intensity	kg·ha^{-1}	6.95	*cd*	3.43	22.5	7.02	0.45	2.9	41	4.0	22
Intensive	kg·ha^{-1}	7.55	*bd*	4.40	8.50	7.23	0.31	1.2	16	-1.4	1.7
Topsoil Removed	kg·ha^{-1}	6.57	*ad*	4.26	7.82	6.22	0.50	1.3	21	-0.30	-1.5
Sod Production	kg·ha^{-1}	6.79	*cd*	5.65	8.95	6.99	0.20	1.0	14	0.69	-0.68
Potato Rotation	kg·ha^{-1}	7.23	*bd*	4.82	10.3	7.15	0.18	1.0	14	0.53	2.4
Region	mg·kg^{-1}	30.2		14.4	107	30.4	0.6	8	27	4.3	39
Abandoned	mg·kg^{-1}	31.8	*ac*	16.6	44.0	30.7	1.1	6.8	22	-0.16	-0.64
Forested	mg·kg^{-1}	30.9	*ac*	18.9	48.0	30.3	1.1	7.0	23	0.38	-0.007
Low Intensity	mg·kg^{-1}	30.2	*ac*	15.2	107	31.8	2.1	13	42	4.5	25
Intensive	mg·kg^{-1}	33.8	*c*	26.2	41.3	33.0	1.2	4.5	14	-0.18	-0.52
Topsoil Removed	mg·kg^{-1}	21.9	*b*	14.4	26.5	21.7	1.6	4.2	20	-0.62	0.090
Sod Production	mg·kg^{-1}	28.4	*a*	21.5	37.8	28.6	0.88	4.3	15	0.47	-0.18
Potato Rotation	mg·kg^{-1}	29.6	*a*	23.6	40.6	30.2	0.66	3.6	12	0.73	1.0

4.1.10.1 Spatial Relationship of Topsoil Total Zn to Land Use

The predicted surface of TS Total Zn (mg·kg^{-1}) in relation to the Dominant Land Use Cover is presented in Figure 21. The predicted surface reveals that TS Total Zn (mg·kg^{-1}) contents increases in a south-westerly direction over the study area with the exception of narrow swaths of land south of Bradley Rd. along the Whitson River. Additionally, a localized area of greater predicted TS Total Zn (mg·kg^{-1}) content was found near the western end of Bonin Rd. The spatial distribution of TS Total Zn (mg·kg^{-1}) north of the Whitson River was found to be uniformly low in comparison to southwest region of the study area. With the exception of the Topsoil Removed land use in the south-central region, the spatial pattern within the predicted surface of TS Total Zn (mg·kg^{-1}) did not appear to be coincide to the superimposed Dominant Land Use Cover. Similarities in patterns exist between the spatial distribution TS Total Zn (mg·kg^{-1}) and TS $pH_{(H_2O)}$ in Figure 26.

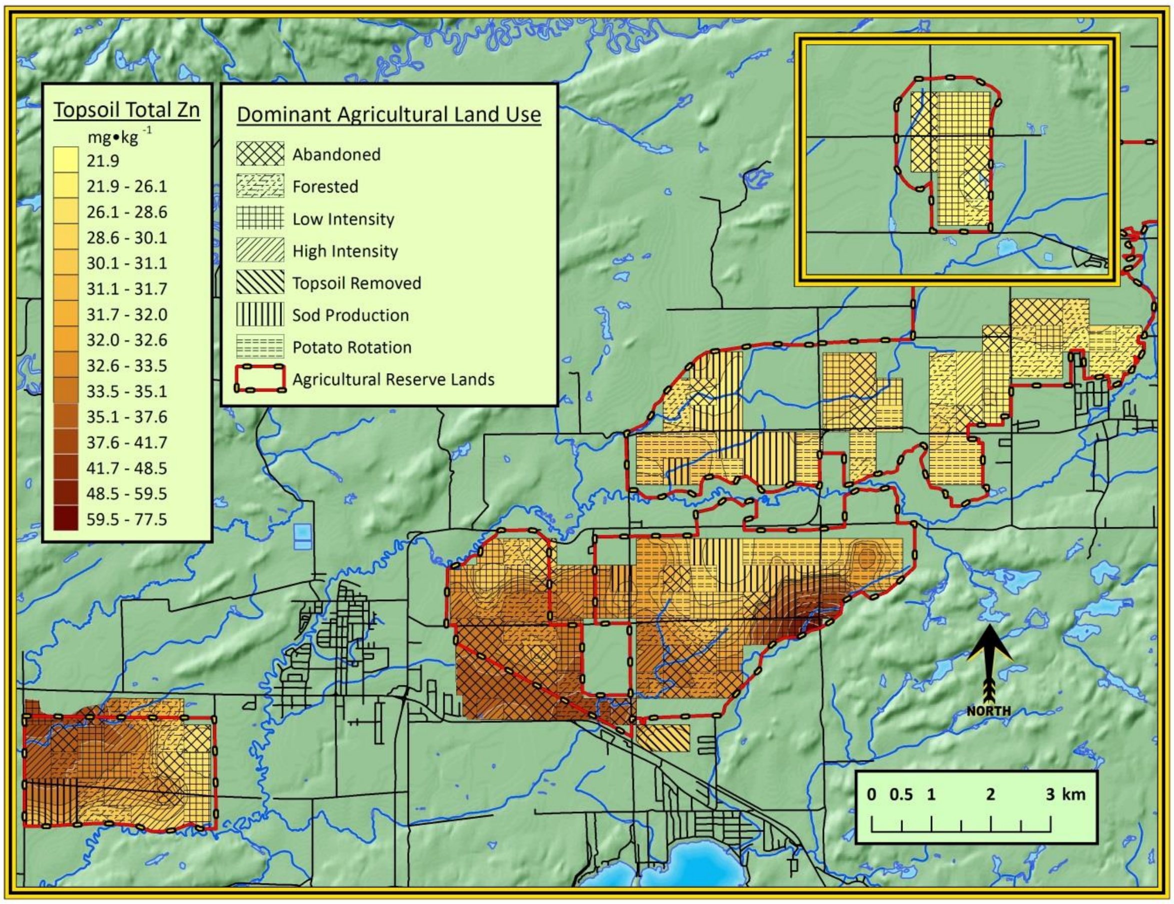


Figure 21. The predicted spatial distribution of topsoil (0-20 cm) Total Zn (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.11 Topsoil Available Cu Variability across Land Use Patterns

The median TS Available Cu (kg·ha^{-1}) of the study area was 0.079 kg·ha^{-1}. Overall, the Topsoil Removed land use had the lowest TS Available Cu (kg·ha^{-1}) with a median content of

0.044 kg·ha^{-1}, a level significantly less than the Abandoned (p=0.029), Forested (p=0.017), Low Intensity (p=0.009), and Potato Rotation (p=0.006) land uses which had median contents of 0.079 kg·ha^{-1}, 0.074 kg·ha^{-1}, 0.086 kg·ha^{-1} and 0.089 kg·ha^{-1} respectfully. In contrast, the Potato Rotation land use had the greatest median TS Available Cu (kg·ha^{-1}) level, with a value of 0.089 kg·ha^{-1} , a level significantly greater than the Intensive (p=0.013) and Sod Production (p=0.018) land uses that had median TS Available Cu (kg·ha^{-1}) contents of 0.060 kg·ha^{-1} and 0.059 kg·ha^{-1}, respectively.

The median TS Available Cu (mg·kg^{-1}) of the study area was 0.079 mg·kg^{-1}. As for TS Available Cu (kg·ha^{-1}), the Topsoil Removed land use had the lowest overall TS Available Cu (mg·kg^{-1}) with a median of 0.175 mg·kg^{-1}, a concentration significantly lower than for the Abandoned (p=0.001), Forested (p=0.000), Low Intensity (p=0.000), Intensive (p=0.016), Sod Production (p=0.042) and Potato Rotation (p=0.001) land uses which had median TS Available Cu (mg·kg^{-1}) concentrations of 0.384 mg·kg^{-1}, 0.435 mg·kg^{-1}, 0.388 mg·kg^{-1}, 0.315 mg·kg^{-1}, 0.239 mg·kg^{-1} and 0.414 mg·kg^{-1}, respectively. With a median TS Available Cu (mg·kg^{-1}) concentration of 0.239 mg·kg^{-1}, the Sod Production land use was also significantly less than the Abandoned (p=0.009), Forested (p=0.000), Low Intensity (p=0.010) and Potato Rotation (p=0.001) land uses. The Intensive land use median TS Available Cu (mg·kg^{-1}) concentration of 0.315 mg·kg^{-1} was significantly less than that of the Forested (p=0.007) and Potato Rotation (p=0.025). The Abandoned and Intensive land uses the relationship was not significant (p=0.056), the Abandoned land use had a median TS Available Cu (mg·kg^{-1}) of 0.384 mg·kg^{-1} that was 21.9 % greater than that of the Intensive land use.

The regional CV values for the TS Available Cu (kg·ha^{-1}) and TS Available Cu (mg·kg^{-1}) datasets were 43 % and 44 %, respectively. For TS Available Cu (kg·ha^{-1}) , land use CV values were ranked from greatest to lowest as follows: Sod Production > Forested > Topsoil Removed > Potato Rotation > Abandoned > Intensive > Low Intensity, having values of 50 %, 46 %, 43%, 42 %, 40 %, 38 % and 35 %. Whereas CV values for land use TS Available Cu (mg·kg^{-1}) were ranked from greatest to lowest as follows: Sod Production> Forested = Potato Rotation > Topsoil Removed > Abandoned > Low Intensity = Intensive, having values of 50 %, 44 %, 44 %, 40 %, 37 %, 34 % and 34 %.

Table 12. Summary statistics for the $LiNO_3$ plant Available Cu content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (p=0.050) using Kruskal-Wallace comparison.

Available Cu											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	0.079		0.024	0.239	0.0870	0.0027	0.037	43	0.85	0.70
Abandoned	kg·ha^{-1}	0.079	*ace*	0.031	0.165	0.0850	0.0054	0.034	40	0.59	-0.43
Forested	kg·ha^{-1}	0.074	*ace*	0.027	0.205	0.0905	0.0065	0.041	46	0.74	0.091
Low Intensity	kg·ha^{-1}	0.086	*ae*	0.039	0.154	0.0898	0.0049	0.031	35	0.39	-0.77
Intensive	kg·ha^{-1}	0.060	*cd*	0.040	0.114	0.0712	0.0076	0.027	38	0.73	-1.3
Topsoil Removed	kg·ha^{-1}	0.044	*bd*	0.034	0.103	0.0569	0.0092	0.024	43	1.3	1.2
Sod Production	kg·ha^{-1}	0.059	*ad*	0.031	0.170	0.0788	0.0080	0.039	50	0.93	-0.39
Potato Rotation	kg·ha^{-1}	0.089	*e*	0.024	0.239	0.1013	0.0077	0.043	42	1.1	2.3
Region	mg·kg^{-1}	0.361		0.102	1.13	0.399	0.013	0.18	44	1.1	2.2
Abandoned	mg·kg^{-1}	0.384	*ac*	0.156	0.731	0.404	0.024	0.15	37	0.42	-0.60
Forested	mg·kg^{-1}	0.435	*a*	0.207	1.13	0.479	0.033	0.21	44	1.1	1.0
Low Intensity	mg·kg^{-1}	0.388	*ac*	0.184	0.711	0.400	0.022	0.14	34	0.52	-0.29
Intensive	mg·kg^{-1}	0.315	*cd*	0.209	0.510	0.320	0.030	0.11	34	0.84	-0.82
Topsoil Removed	mg·kg^{-1}	0.175	*b*	0.108	0.343	0.198	0.030	0.079	40	0.11	0.96
Sod Production	mg·kg^{-1}	0.239	*d*	0.130	0.710	0.316	0.032	0.16	50	1.1	0.02
Potato Rotation	mg·kg^{-1}	0.414	*a*	0.102	1.13	0.429	0.034	0.19	44	0.24	1.7

4.1.11.1 Spatial Relationship of Topsoil Available Cu to Land Use

The predicted surface of TS Available Cu (mg·kg^{-1}) in relation to the Dominant Land Use Cover is presented in Figure 22. The spatial distribution of TS Available Cu (mg·kg^{-1}) reveals that predicted contents tend to increase in a south-easterly direction, with the greatest predicted contents of TS Available Cu (mg·kg^{-1}) being located to the east of Martin Rd. In the western portion of the study area along Bradley Rd., the predicted TS Available Cu (mg·kg^{-1}) contents are uniformly low with no discernable patterns relating to the Dominant Land Use Cover. However, within the Cote Blvd. and Dupuis Dr. region TS Available Cu (mg·kg^{-1}) was found to be more variable, with the spatial distribution having a ‘mottled’ pattern ranging from medium to low values. The spatial distribution of TS Available Cu (mg·kg^{-1}) does appear to be slightly influenced by the Sod Production land use north of the Whitson river, an area found to be slightly lower. However, a similar trend was not found under the Sod Production land use to the south of the river. Finally, no patterns were found associated to the spatial patterns of other soil variables or spatial extents of drainage features.

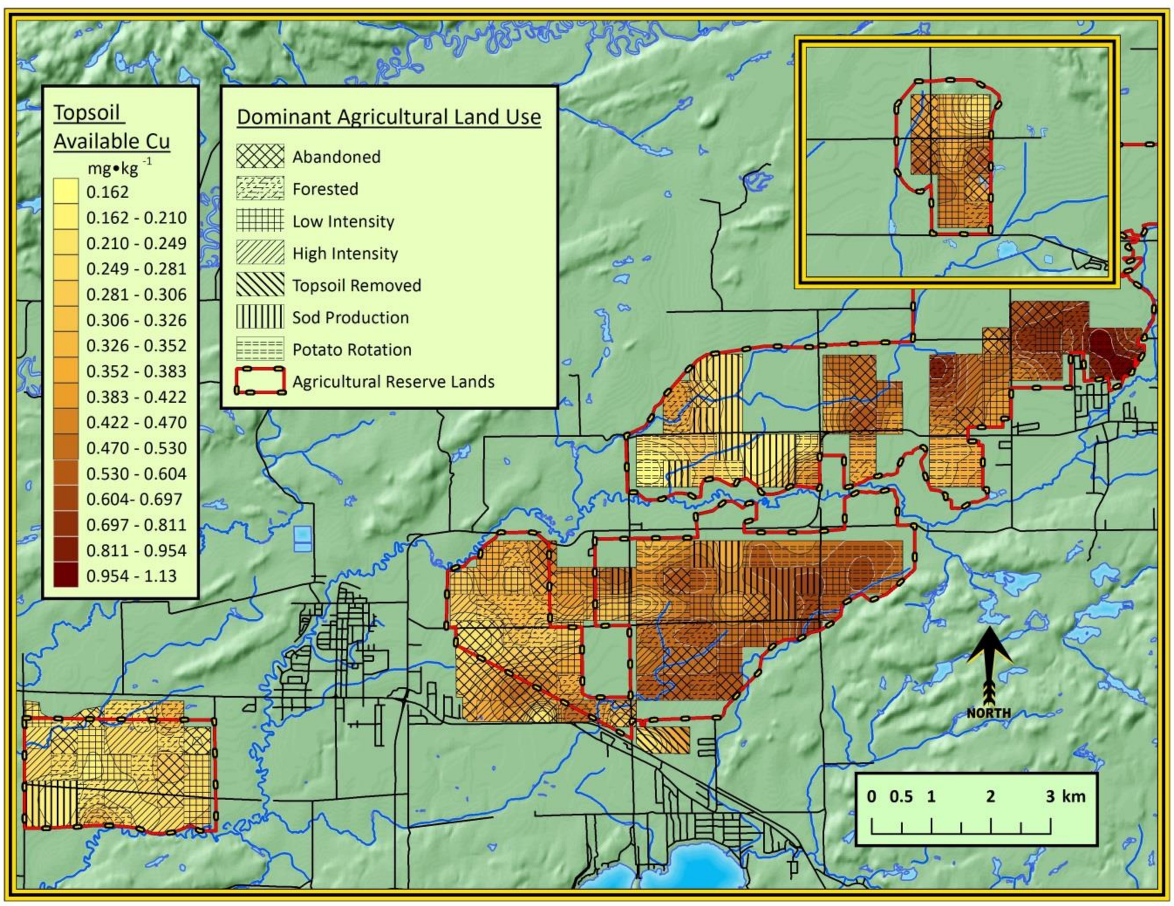


Figure 22. The predicted spatial distribution of topsoil (0-20 cm) Available Cu (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.12 Topsoil Total Cu Variability across Land Use Patterns

The median TS Total Cu (kg·ha^{-1}) of the study area was 7.85 kg·ha^{-1}. As was the case for TS Available Cu, the Topsoil Removed and Sod Production land uses had the overall least TS Total Cu (kg·ha^{-1}), with median contents of 4.29 kg·ha^{-1} and 5.41 kg·ha^{-1}, respectfully. Both land uses TS Total Cu levels were found to be significantly less than the Abandoned, Forested, Low Intensity and Potato Rotation land uses, with median TS Total Cu (kg·ha^{-1}) of 7.62 kg·ha^{-1}, 8.12 kg·ha^{-1}, 8.05 kg·ha^{-1} and 8.21 kg·ha^{-1}, respectively. Also, the Potato Rotation land use, with the overall greatest median TS Total Cu (kg·ha^{-1}), was found to be significantly greater (p=0.037) than the Intensive land use. No other significant differences were found between land uses with respect to TS Total Cu (kg·ha^{-1}) contents.

The median TS Total Cu (mg·kg^{-1}) of the study area was 35.5 mg·kg^{-1}. Overall, the Topsoil Removed land use had the lowest TS Total Cu (mg·kg^{-1}) content with a median of 17.5 mg·kg^{-1} was significantly less than the Abandoned (p=0.000), Forested (p=0.000), Low Intensity (p=0.000) Intensive (p=0.009) and Potato Rotation (p=0.001) land uses, with median TS Total Cu (mg·kg^{-1}) concentrations of 36.9 mg·kg^{-1}, 43.6 mg·kg^{-1}, 36.1 mg·kg^{-1} 30.1 mg·kg^{-1}, and 35.3 mg·kg^{-1}, respectively. Also, the Sod Production land use had a median TS Total Cu (mg·kg^{-1}) of 22.1 mg·kg^{-1}, significantly less than the Abandoned (p=0.000), Forested (p=0.000), Low Intensity (p=0.020), Intensive (p=0.000) and Potato Rotation (p=0.000) land uses. Also, the Forested land use had the overall greatest median TS Total Cu (mg·kg^{-1}) of 43.5 mg·kg^{-1}, a concentration significantly greater in comparison to the Low Intensity (p=0.006), Intensive (p=0.001) and Potato Rotation (p=0.001) land uses. Additionally, the Abandoned and Low Intensity land uses, with median Total Cu (mg·kg^{-1}) concentrations of 36.9 mg·kg^{-1} and 36.1 mg·kg^{-1}, were also found to be significantly greater than the Intensive land use which had a median of 30.1 mg·kg^{-1}.

The regional CV values for the TS Total Cu (kg·ha^{-1}) and the TS Total Cu (mg·kg^{-1}) datasets were 30 % and 32 %, respectively. For TS Total Cu (kg·ha^{-1}), land use CV values were ranked from greatest to lowest as follows: Topsoil Removed > Sod Production > Low Intensity > Forested > Abandoned > Intensive > Potato Rotation, having values of 48 %, 33 %, 30 %, 39 %, 27 %, 26 % and 20 %, respectively. The land use CV values for Total Cu (mg·kg^{-1}) were ranked from greatest to lowest as follows: Topsoil Removed > Sod Production > Low Intensity > Forested > Abandoned > Intensive > Potato Rotation, having CV values of 48 %, 33 %, 32 %, 27 %, 26 %, 21 % and 17 %, respectively.

Table 13. Summary statistics for the Total Cu content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land use medians indicate no significant difference (p=0.050) using Kruskal-Wallace comparison.

Total Cu												
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	7.84		3.05	20.5	7.73	0.16	2.30	30	0.86	3.7
Abandoned	kg·ha^{-1}	7.62	*ac*	3.17	12.8	7.91	0.34	2.16	27	0.49	0.40
Forested	kg·ha^{-1}	8.12	*ac*	4.49	12.5	7.93	0.36	2.32	29	0.079	-1.0
Low Intensity	kg·ha^{-1}	8.05	*a*	4.92	20.5	8.38	0.40	2.53	30	2.7	12
Intensive	kg·ha^{-1}	6.67	*c*	4.42	10.1	6.91	0.48	1.80	26	0.18	-1.10
Topsoil Removed	kg·ha^{-1}	4.29	*b*	3.05	10.2	5.46	0.99	2.61	48	1.3	0.60
Sod Production	kg·ha^{-1}	5.41	*b*	3.42	9.91	6.41	0.44	2.15	33	0.49	-1.3
Potato Rotation	kg·ha^{-1}	8.21	*a*	5.52	11.5	8.28	0.29	1.63	20	0.020	-0.62
Region	mg·kg^{-1}	35.5		10.3	97.4	35.9	0.82	11	32	1.0	4.1
Abandoned	mg·kg^{-1}	36.9	*ac*	18.0	64.8	38.6	1.7	11	27	0.46	0.25
Forested	mg·kg^{-1}	43.6	*c*	22.0	72.2	42.8	1.8	11	26	0.52	0.45
Low Intensity	mg·kg^{-1}	36.1	*a*	22.8	97.4	37.3	1.9	12	32	3.2	16
Intensive	mg·kg^{-1}	30.1	*d*	23.1	41.4	31.4	1.7	6.4	21	0.22	-1.4
Topsoil Removed	mg·kg^{-1}	17.5	*b*	10.3	35.6	19.2	3.5	9.1	48	1.1	0.41
Sod Production	mg·kg^{-1}	22.1	*b*	14.1	39.5	25.8	1.7	8.4	33	0.40	-1.4
Potato Rotation	mg·kg^{-1}	35.3	*ad*	23.6	45.4	35.0	1.1	6.0	17	-0.34	-0.46

4.1.12.1 Spatial Relationship of Topsoil Total Cu to Land Use

The predicted surface of TS Total Cu (mg·kg^{-1}) in relation the Dominant Land Use Cover is presented in Figure 23. In general, predicted TS Total Cu (mg·kg^{-1}) contents increases in a southeasterly direction with the greatest predicted TS Total Cu (mg·kg^{-1}) contents being located in the south-central area in close proximity to superimposed drainage features. As well, predicted TS Total Cu (mg·kg^{-1}) increased in concentration along the drainage feature north of Bradley Rd. The remaining of the area of Bradley Rd. is uniformly low, with no discernable patterns in relation to the Dominant Land Use Cover. Furthermore, in the central region of the

Agricultural Reserve lands, the area north of the Whitson River predicted TS Total Cu ($mg{\cdot}kg^{-1}$) also is uniformly low. In the area surrounding Martin Rd. a slight increase in predicted TS Total Cu ($mg{\cdot}kg^{-1}$) under the Forested land use is discerned. The Topsoil Removed land use within the south-central region of the study area has predicted TS Total Cu ($mg{\cdot}kg^{-1}$) considerably lower than surrounding soils under contrasting land uses.

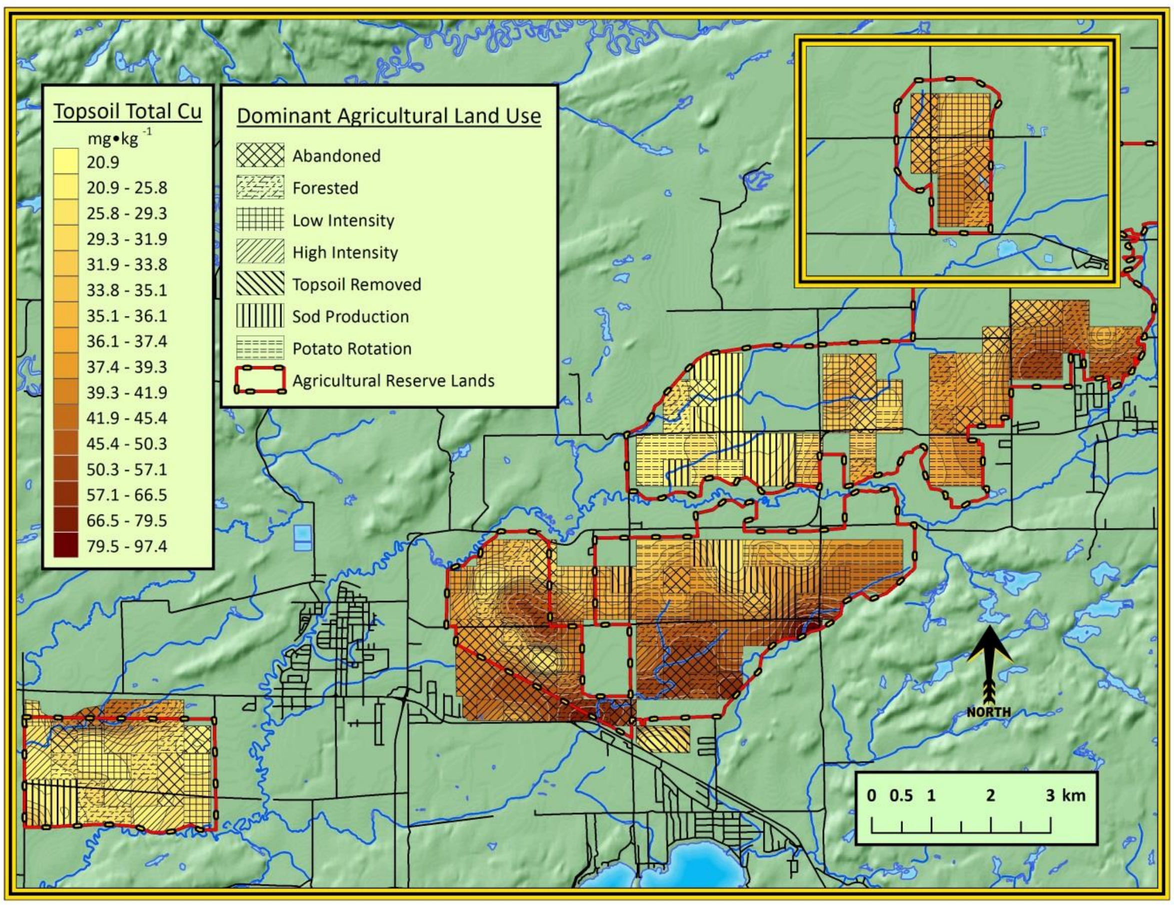


Figure 23. The predicted spatial distribution of topsoil (0-20 cm) Total Cu (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.13 Topsoil Available Mn Variability across Land Use Patterns

The median TS Available Mn ($kg \cdot ha^{-1}$) of the study area was 0.607 $kg \cdot ha^{-1}$. The Topsoil Removed land use had the overall lowest TS Available Mn ($kg \cdot ha^{-1}$), with a median of 0.177 $kg \cdot ha^{-1}$, an extractable concentration significantly lower than for the Abandoned (p=0.020), Forested (p=0.003), Low Intensity (p=0.016) Sod Production (p=0.008) and Potato Rotation (p=0.001) land uses which had median TS Available Mn ($kg \cdot ha^{-1}$) contents of 0.508 $kg \cdot ha^{-1}$, 0.738 $kg \cdot ha^{-1}$, 0.526 $kg \cdot ha^{-1}$, 0.853 $kg \cdot ha^{-1}$ and 1.02 $kg \cdot ha^{-1}$, respectively. Also, the Intensive land use, with a median TS Available Mn ($kg \cdot ha^{-1}$) content of 0.297 $kg \cdot ha^{-1}$, was found to be significantly lower than the Abandoned (p=0.046), Forested (p=0.005), Sod Production (p=0.018) and Potato Rotation (p=0.000) land uses. Also, the Potato Rotation land use had the greatest overall median TS Available Mn ($kg \cdot ha^{-1}$), a level found to be significantly greater than Abandoned (p=0.012) and Low Intensity (p=0.004).

The median TS Available Mn ($mg \cdot kg^{-1}$) of the study area was 2.86 $mg \cdot kg^{-1}$. Overall, the Topsoil Removed land use had the lowest median TS Available Mn ($mg \cdot kg^{-1}$) with a concentration of 0.502 $mg \cdot kg^{-1}$, a level significantly lower than for all other land uses. Furthermore, the Forested land use had overall greatest median TS Available Mn ($mg \cdot kg^{-1}$) with a concentration of 4.07 $mg \cdot kg^{-1}$, a level significantly greater than the Abandoned (p=0.011), Low Intensity (p=0.002), Intensive (p=0.000), Topsoil Removed (p=0.000) land uses which had median TS Available Mn ($mg \cdot kg^{-1}$) concentrations of 2.25 $mg \cdot kg^{-1}$, 2.53 $mg \cdot kg^{-1}$, 1.50 $mg \cdot kg^{-1}$ and 0.502 $mg \cdot kg^{-1}$, respectively. Similarly, the Potato Rotation land use had the second greatest TS Available Mn ($mg \cdot kg^{-1}$) concentration with a median value of 4.02 $mg \cdot kg^{-1}$, with the Potato Rotation land use being found to have a significantly greater concentration than the

Abandoned (p=0.040), Low Intensity (p=0.006), Intensive (p=0.000) and Topsoil Removed (p=0.000) land uses. Also, the Abandoned land use TS Available Mn was found to be significantly greater (p=0.042) in comparison to the Intensive land use. Two possible relationships might exist between the Sod Production land use with the Forested (p=0.058) and Intensive (p=0.051) land uses, with both having a median TS Available Mn ($mg \cdot kg^{-1}$) less than that of the Sod Production land use.

The regional CV values for the TS Available Mn ($kg \cdot ha^{-1}$) and TS Available Mn ($mg \cdot kg^{-1}$) datasets were 101 % and 111 %, respectively. For TS Available Mn ($kg \cdot ha^{-1}$), land use CV values were ranked from greatest to lowest as follows: Forested > Topsoil Removed > Abandoned > Low Intensity > Sod Production > Intensive = Potato Rotation, having values of 121%, 102 %, 87 %, 81 %, 70 % 63 % and 63 %, respectively. Whereas, the CV values for individual land uses in the TS Available Mn ($mg \cdot kg^{-1}$) dataset were ranked from greatest to lowest as follows: Forested > Topsoil Removed > Abandoned > Low Intensity > Sod Production > Potato Rotation > Intensive , having CV values of 121 %, 103 %, 89 %, 77 %, 76 %, 68 % and 52 %, respectively.

Table 14. Summary statistics for the $LiNO_3$ plant available Mn content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (p=0.050) using Kruskal-Wallace comparison.

Available Mn												
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	0.607		0.032	7.91	0.903	0.065	0.910	101	3.77	22.61
Abandoned	kg·ha^{-1}	0.508	*a*	0.042	3.02	0.833	0.115	0.728	87	1.44	1.51
Forested	kg·ha^{-1}	0.738	*ac*	0.174	7.91	1.24	0.234	1.498	121	3.24	11.78
Low Intensity	kg·ha^{-1}	0.526	*ad*	0.127	2.51	0.744	0.094	0.605	81	1.39	1.29
Intensive	kg·ha^{-1}	0.297	*bd*	0.184	1.14	0.455	0.077	0.288	63	1.22	0.93
Topsoil Removed	kg·ha^{-1}	0.177	*b*	0.032	0.769	0.285	0.110	0.290	102	0.92	-0.65
Sod Production	kg·ha^{-1}	0.853	*ae*	0.097	2.64	0.888	0.126	0.618	70	1.01	1.25
Potato Rotation	kg·ha^{-1}	1.025	*ce*	0.218	3.79	1.116	0.127	0.707	63	1.83	5.63
Region	mg·kg^{-1}	2.86		0.100	43.7	4.17	0.33	4.6	111	4.6	32
Abandoned	mg·kg^{-1}	2.25	*a*	0.212	15.5	3.86	0.54	3.4	89	1.6	2.4
Forested	mg·kg^{-1}	4.07	*b*	1.08	43.7	6.60	1.25	8.0	121	3.4	13
Low Intensity	mg·kg^{-1}	2.53	*ac*	0.582	12.0	3.18	0.38	2.5	77	1.7	3.2
Intensive	mg·kg^{-1}	1.50	*c*	0.715	3.75	1.92	0.26	0.99	52	0.55	-1.1
Topsoil Removed	mg·kg^{-1}	0.520	*d*	0.100	2.68	0.972	0.38	1.0	103	1.0	-0.39
Sod Production	mg·kg^{-1}	3.25	*abc*	0.400	11.8	3.58	0.56	2.7	76	1.2	2.0
Potato Rotation	mg·kg^{-1}	4.02	*b*	0.863	17.9	4.83	0.59	3.3	68	2.1	7.2

4.1.13.1 Spatial Relationship of Topsoil Available Mn to Land Use

The predicted surface of TS Available Mn (mg·kg^{-1}) in relation to the Dominant Land Use Cover is presented in Figure 24. Soils bordering the Whitson River have greater predicted TS Available Mn (mg·kg^{-1}), with the greatest predicted TS Available Mn (mg·kg^{-1}) contents being located near the Whitson River to the east of Martin Rd. To a lesser degree, most of the northern half of the central region was found to have elevated TS Available Mn (mg·kg^{-1}). Furthermore, a swath of land immediately south along the Whitson River within the central region, as well as an area to the south of Bradley Rd. nearest the Whitson River, were found to have greater TS Available Mn (mg·kg^{-1}). In contrast to these areas, soils generally along and to the south of Bonin Rd. were found to host the majority of the area having relatively lower predicted the TS Available Mn (mg·kg^{-1}). The soils surrounding the western end of Bradley Rd. were also found to have low predicted TS Available Mn (mg·kg^{-1}) contents. Finally, the area surrounding Cote Blvd. and Dupuis Dr. have to have moderate concentration of TS Available Mn (mg·kg^{-1}).

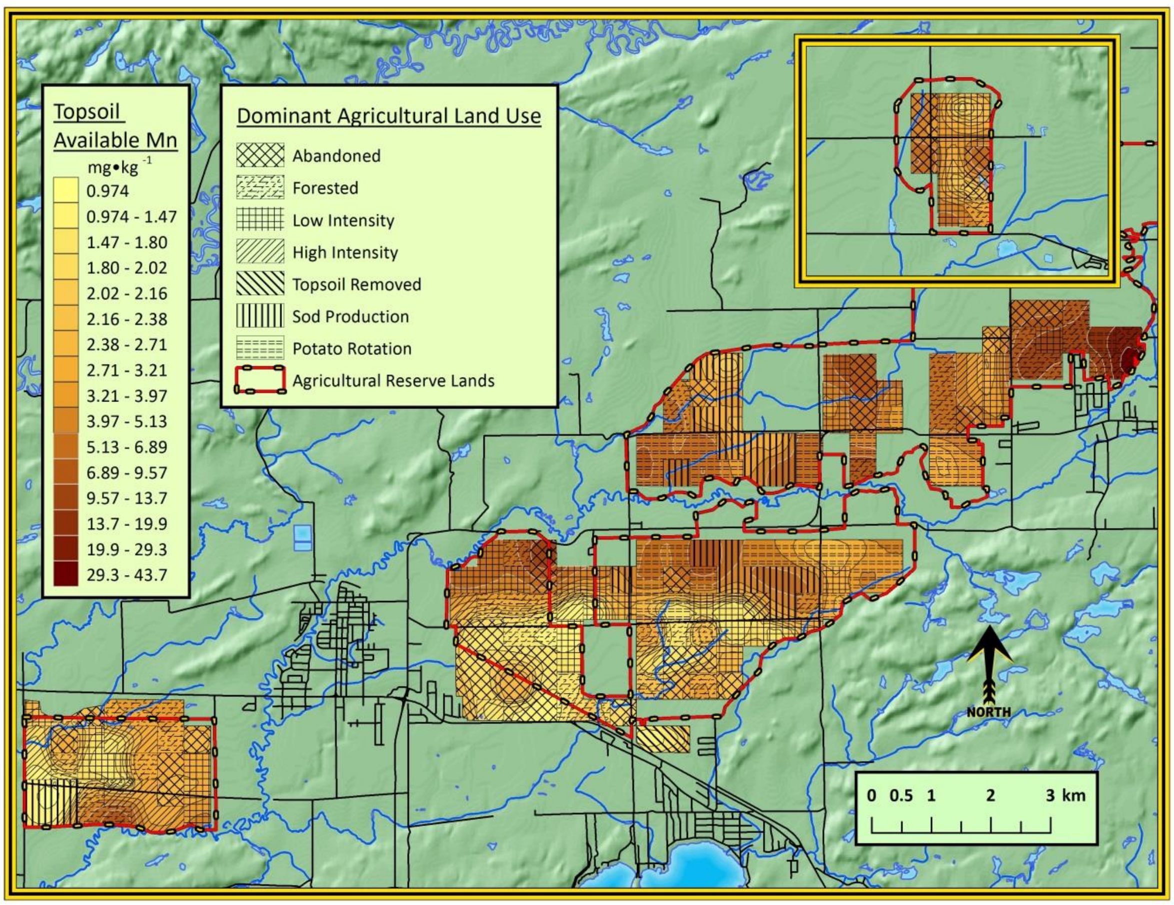


Figure 24. The predicted spatial distribution of topsoil (0-20 cm) Available Mn (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.14 Topsoil Total Mn Variability across Land Use Patterns

The median TS Total Mn (kg·ha^{-1}) of the study area was 47.7 kg·ha^{-1}. The Forested land use with a median TS Total Mn (kg·ha^{-1}) of 42.2 kg·ha^{-1} was significantly less than the Intensive (p=0.026), Topsoil Removed (p=0.049) and Sod Production (p=0.050) land uses which had medians values of 56.1 kg·ha^{-1}, 79.7 kg·ha^{-1} and 48.5 kg·ha^{-1}, respectfully. As well, the Potato Rotation land use had the lowest overall median TS Total Mn (kg·ha^{-1}) with a content of 39.3 kg·ha^{-1}, a level significantly lower than only the Sod Production (p=0.013) land use that had a median value of 48.5 kg·ha^{-1}. Finally, no significant differences were found for the Abandoned and Low Intensity land uses in comparison to other land uses, with the respective median TS Total Mn (kg·ha^{-1}) contents being 47.7 kg·ha^{-1}and 51.7 kg·ha^{-1}.

The median TS Total Mn (mg·kg^{-1}) of the study area was 219 mg·kg^{-1}. Overall, the Potato Rotation land use had the lowest TS Total Mn (mg·kg^{-1}) concentration with a median of 167 mg·kg^{-1}, a level significantly less than the Abandoned (p=0.019), Forested (p=0.013), Low Intensity (p=0.043), Intensive (p=0.006) and Sod Production land uses which had median TS Total Mn (mg·kg^{-1}) concentrations of 236 mg·kg^{-1}, 239 mg·kg^{-1}, 228 mg·kg^{-1}, 252 mg·kg^{-1} and 199 mg·kg^{-1}, respectively. Furthermore, the Topsoil Removed land use had a median TS Total Mn (mg·kg^{-1}) of 266 mg·kg^{-1}, a level not significantly different to any other land use.

The regional CV values for the TS Total Mn (kg·ha^{-1}) and TS Total Mn (mg·kg^{-1}) datasets were 43 % and 39 %, respectively. For TS Total Mn (kg·ha^{-1}), CV values for individual land use ranked from greatest to lowest are as follows: Topsoil Removed > Forested = Sod Production >

Low Intensity > Potato Rotation > Abandoned > Intensive, having values of 50 %, 45 %, 45 %, 44 %, 37 %, 36 % and 29 %, respectively. Whereas the obtained CV values for individual land use for TS Total Mn (mg·kg^{-1}) ranked from greatest to lowest are as follows: Topsoil Removed > Sod Production > Low Intensity > Forested >Potato Rotation > Abandoned > Intensive, having CV values of 45 %, 44 %, 41 %, 40 %, 39 % 36 % and 24 %, respectively.

Table 15. Summary statistics for the Reverse Aqua Regia Total Mn content (kg·ha^{-1}) and concentration (mg·kg^{-1}) of the topsoil (0-20 cm) sampled within the City of Greater Sudbury's Agricultural Reserve lands. Similar corresponding letters associated to Dominant Land Use medians indicate no significant difference (p=0.050) using Kruskal-Wallace comparison.

Total Mn											
Dominant Land Use	Units	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
Region	kg·ha^{-1}	47.7		13.8	151	49.4	1.5	21	43	1.3	3.5
Abandoned	kg·ha^{-1}	47.7	*ab*	13.8	80.0	47.5	2.7	17	36	0.024	-0.64
Forested	kg·ha^{-1}	42.2	*a*	15.9	106	44.1	3.1	20	45	0.76	0.74
Low Intensity	kg·ha^{-1}	51.7	*ab*	17.9	133	50.5	3.4	22	44	1.2	3.6
Intensive	kg·ha^{-1}	56.1	*b*	31.7	82.3	56.1	4.4	17	29	0.11	-1.2
Topsoil Removed	kg·ha^{-1}	79.7	*bc*	24.9	123	71.3	13	36	50	0.0002	-1.19
Sod Production	kg·ha^{-1}	48.5	*b*	30.6	151	56.6	5.2	25	45	2.6	8.2
Potato Rotation	kg·ha^{-1}	39.3	*ac*	21.9	94.8	43.9	2.9	16	37	1.4	2.4
Region	mg·kg^{-1}	219		79.1	607	225	6.2	88	39	0.98	2.0
Abandoned	mg·kg^{-1}	236	*a*	79.6	400	229	13	83	36	0.17	-0.53
Forested	mg·kg^{-1}	239	*a*	89.3	517	237	15	94	40	0.63	0.87
Low Intensity	mg·kg^{-1}	228	*a*	79.1	545	224	14	91	41	1.0	2.6
Intensive	mg·kg^{-1}	252	*a*	156	328	242	15	57	24	0.082	-1.4
Topsoil Removed	mg·kg^{-1}	266	*ad*	86.9	362	245	41	109	45	-0.56	-1.2
Sod Production	mg·kg^{-1}	199	*a*	121	607	232	21	101	44	2.5	7.6
Potato Rotation	mg·kg^{-1}	167	*bd*	102	444	187	13	73	39	1.6	3.9

4.1.14.1 Spatial Relationship of Topsoil Total Mn to Land Use

The predicted surface of TS Total Mn ($mg \cdot kg^{-1}$) relative to Dominant Land Use Cover is presented in Figure 25 indicates the spatial distribution of TS Total Mn is inverse to that of TS Available Mn ($mg \cdot kg^{-1}$). For instance, areas of low predicted TS Available Mn ($mg \cdot kg^{-1}$) in the south-central region of the Agricultural Reserve lands have the greatest predicted TS Total Mn ($mg \cdot kg^{-1}$), an observation particularly true for soils immediately north-west of the town of Azilda along the drainage feature. Another example of this pattern was found in the Bradley Rd region. In this region, the western portion was found to have greatest predicted TS Total Mn ($mg \cdot kg^{-1}$) while low predicted values were observed for TS Available Mn ($mg \cdot kg^{-1}$) surface. The area of Cote Blvd. and Dupuis Dr. was also found to generally have a moderately low and uniform concentration of TS Total Mn ($mg \cdot kg^{-1}$) in comparison to most other areas of the Agricultural Reserve lands.

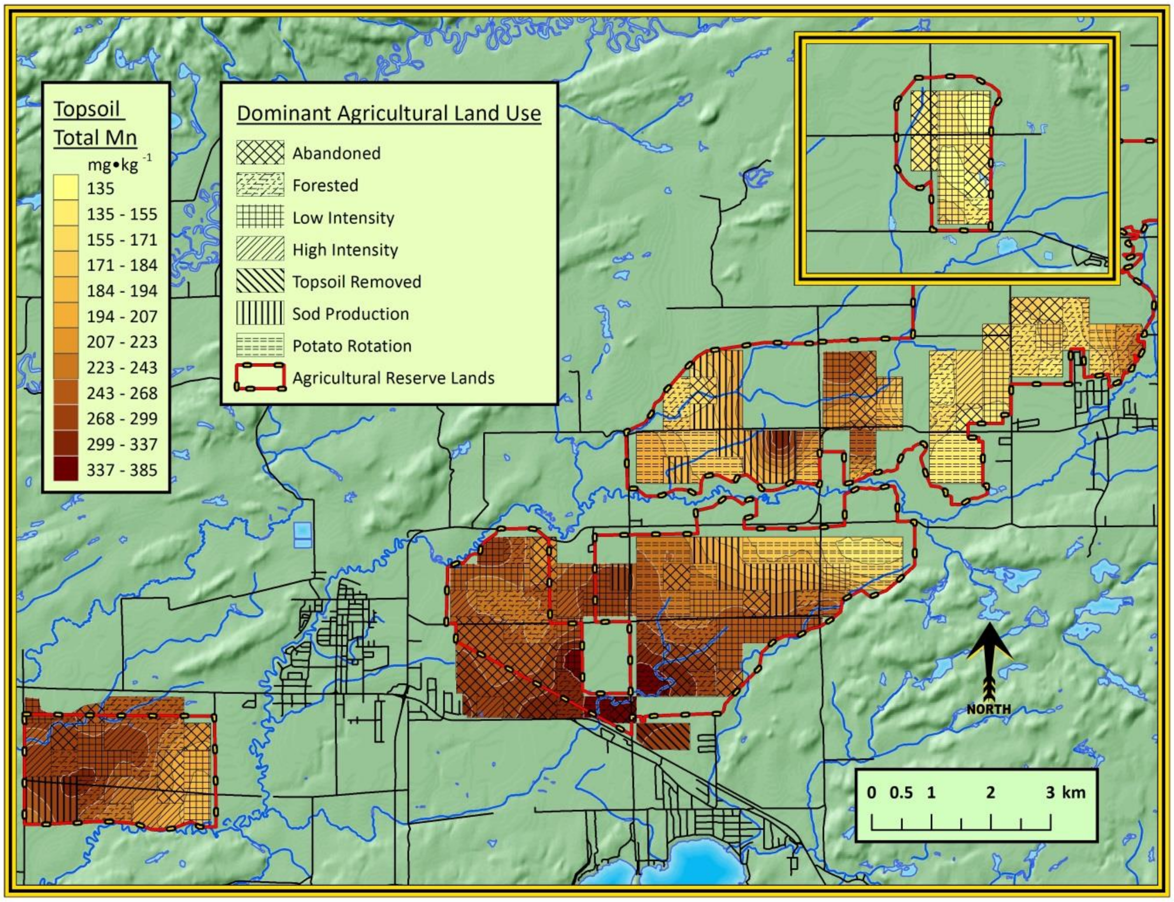


Figure 25. The predicted spatial distribution of topsoil (0-20 cm) Total Mn (mg·kg-1) in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.1.15 Topsoil pH Variability across Land Use Patterns

The median TS $pH_{(H_2O)}$ of the study area was 5.5. The Potato Rotation land use had the overall lowest TS $pH_{(H_2O)}$ with a median value of 5.1, significantly lower than the Abandoned (*p*=0.001), Low Intensity (*p*=0.001), Intensive (*p*=0.000), Topsoil Removed (*p*=0.004) and Sod Production (*p*=0.000) land uses which had median TS $pH_{(H_2O)}$ values of 5.7, 5.5, 6.2, 6.9 and 5.6, respectfully. In contrast, the Topsoil Removed land use, with the greatest median TS $pH_{(H_2O)}$, was found to be significantly greater than the Abandoned (*p*=0.013), Forested (*p*=0.003), Low Intensity (*p*=0.012), Sod Production (*p*=0.014) and Potato Rotation (*p*=0.004) land uses. Also, the Forested land use, with a median TS $pH_{(H_2O)}$ of 5.4, was found to be significantly less than the Low Intensity (p=0.048) and Intensive (p=0.006) land uses. Although there was no significant differences from one another, (p=0.051), a relationship might exist between the Sod Production and Forested land uses, in which Forested soils were found to have a lower TS $pH_{(H_2O)}$. Finally, the Intensive land use was found to have significantly greater TS $pH_{(H_2O)}$ than Low Intensity (p=0.028)

The median TS $pH_{(CaCl_2)}$ of the study area was 5.2. Overall, Topsoil Removed, with the highest TS $pH_{(CaCl_2)}$ with a median of 6.3, was found to be significantly greater than the Forested (p=0.011), Low Intensity (p=0.044) and Potato Rotation (p=0.006) land uses which had median $pH_{(CaCl_2)}$ values of 5.1, 5.4 and 4.8, respectively. Additionally, the Intensive land use had the second greatest median TS $pH_{(CaCl_2)}$, with a value of 6.0, was found to be significantly greater than the Intensive (p=0.021), Forested (p=0.001), Low Intensity (p=0.023), Sod Production (p=0.038) and Potato Rotation (p=0.000) land uses. Furthermore, the Abandoned and Low Intensity land uses were both found to have a median TS $pH_{(CaCl_2)}$ of 5.4 and significantly different than the Forested and the Potato Rotation land uses. In the case of the Sod Production land use, with a median TS $pH_{(CaCl_2)}$ of 5.3, no other significant differences were found in comparison to other land uses.

Regional CV values for the TS pH H_2O and TS pH $CaCl_2$ datasets were 13 % and 14 %, respectively. For TS pH H_2O, the CV values for individual land use were ranked from greatest to lowest as follows: Low Intensity > Topsoil Removed > Forested > Abandoned > Sod Production > Intensive > Potato Rotation, having values of 17 %, 16 %, 15 %, 12 %, 9.8 %, 8.4 % and 8.2 %, respectively. Whereas. the CV values for individual land use TS pH $CaCl_2$ were ranked from greatest to lowest as follows: Forested = Topsoil Removed > Abandoned > Low Intensity = Sod Production > Intensive > Potato Rotation, having CV values of 17 %, 17 %, 13 %, 12 %, 12 %, 9.4 % and 9.0 %, respectively.

Table 16. Table describing the variability of topsoil (0-20 cm) pH(H_2O) and pH($CaCl_2$) in the City of Greater Sudbury's Agricultural Reserve lands. Dominant Land Use medians having similar corresponding letters indicate are not significantly different (*p*=0.050) from one another using Kruskal-Wallance comparison of medians.

Dominant Land Use	Method	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
					pH H_2O						
Region	pH H_2O	5.5		3.8	7.1	5.5	0.05	0.71	13	-0.04	-0.52
Abandoned	pH H_2O	5.7	*ac*	4.3	6.8	5.6	0.10	0.66	12	-0.22	-0.75
Forested	pH H_2O	5.4	*a*	3.8	6.5	5.2	0.12	0.79	15	-0.28	-1.1
Low Intensity	pH H_2O	5.5	*cd*	1.8	3.5	2.5	0.07	0.43	17	0.29	-0.50
Intensive	pH H_2O	6.2	*b*	5.0	6.7	6.0	0.14	0.51	8.4	-0.78	-0.09
Topsoil Removed	pH H_2O	6.9	*b*	4.4	7.1	6.4	0.38	1.0	16	-1.8	2.8
Sod Production	pH H_2O	5.6	*ad*	4.8	6.7	5.7	0.11	0.56	9.8	0.59	-0.45
Potato Rotation	pH H_2O	5.1	*e*	4.6	6.7	5.1	0.08	0.42	8.2	1.8	5.1
Region	pH $CaCl_2$	5.2		3.5	6.7	5.2	0.05	0.74	14	-0.13	-0.69
Abandoned	pH $CaCl_2$	5.4	*ac*	4.0	6.5	5.3	0.11	0.69	13	-0.21	-0.73
Forested	pH $CaCl_2$	5.1	*be*	3.5	6.3	4.9	0.13	0.85	17	-0.25	-1.2
Low Intensity	pH $CaCl_2$	5.4	*c*	4.2	6.5	5.3	0.10	0.65	12	0.01	-1.3
Intensive	pH $CaCl_2$	6.0	*df*	4.6	6.5	5.8	0.15	0.55	9.4	-0.95	0.62
Topsoil Removed	pH $CaCl_2$	6.3	*af*	3.8	6.7	5.9	0.37	0.98	17	-1.8	3.2
Sod Production	pH $CaCl_2$	5.3	*ace*	4.6	6.5	5.4	0.13	0.64	12	0.42	-1.1
Potato Rotation	pH $CaCl_2$	4.8	*g*	4.2	6.4	4.8	0.08	0.43	9.0	1.5	4.1

4.1.15.1 Spatial Relationship of Topsoil pH$_{(H_2O)}$ to Land Use

The predicted surface of TS pH$_{(H_2O)}$ in relation to the Dominant Land Use Cover is presented in Figure 26. The area east of Martin Rd. was found to have the lowest predicted TS

$pH_{(H_2O)}$ within the study area. Areas having lower TS $pH_{(H_2O)}$ were found along the lands bordering the north and south banks of the Whitson River. Areas under Sod Production north of the Whitson River also appear to have slightly greater TS $pH_{(H_2O)}$ values than the nearby soils of the Potato Rotation and Forested land uses. As well, TS $pH_{(H_2O)}$ was found to be lower within the region surrounding Cote Blvd. and Dupuis Dr.

The highest predicted TS $pH_{(H_2O)}$ values were in the south-central and Bradley Rd regions, with the highest TS $pH_{(H_2O)}$ values occurring under the Topsoil Removed and Sod Production lands uses. Another example of lower predicted TS $pH_{(H_2O)}$ under Sod Production management is south-western corner of the Bradley Rd. region where the lowest regional values occurred.

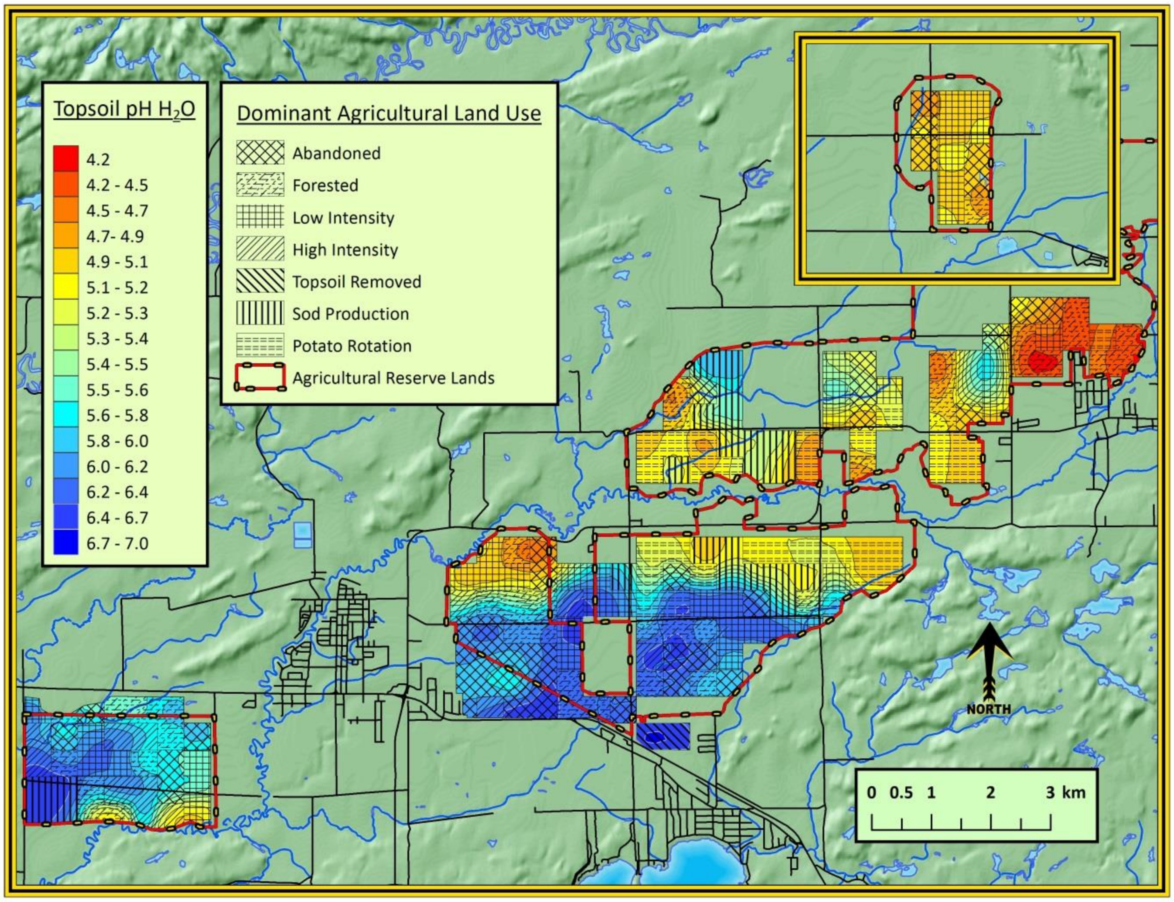


Figure 26. The predicted spatial distribution of topsoil (0-20 cm) $pH_{(H2O)}$ in relation to Dominant Land Use of areas surveyed within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2 Statistical Comparison of Soil Series

In the following subsections, statistical comparisons of soil health properties between studied soil series were summarized and their supplementary descriptive statistics tabled. The predicted spatial distributions of soil properties were also visualized using GIS software. For each predicted surface, spatial patterns were compared to the overlying soil series cover. All *p*-values used to determine the statistical significant differences between the measured topsoil properties of soil series are tabled in the Appendices.

4.2.1 Sand Content Variability across Soil Series

The median TS % Sand content of the study area was 2.44 %. TS % Sand within the Wolf SiL was the lowest in comparison to all other soil series with a median content of 0.368 %, being significantly lower than the Bradley FSaL (p=0.000), Bradley VFSaL (p=0.000), Capreol FSaL (p=0.000), Capreol VFSaL (p=0.000) Series which had median TS % Sand contents of 5.33 %, 5.01 %, 7.74 %, 1.85 %, respectfully. The Azilada SiL Series had the second lowest TS % Sand content, with a median content of 0.485 %, a value also significantly lower than the Bradley FSaL (p=0.000), Bradley VFSaL (p=0.000), Capreol FSaL (p=0.000) and Capreol VFSaL (p=0.001) Series. Furthermore, the Capreol VFSaL Series had a median TS % Sand content of 1.85 %, a content significantly lower than that of the two soil series with the greatest TS % Sand content, namely the Bradley FSaL (p=0.001) and Capreol FSaL (p=0.000) Series which had TS % Sand contents of 5.33 % and 7.45 %, respectfully.

The median SS % Sand content of the study area was 7.75 %. Overall, the Azilda SiL Series had the lowest SS % Sand content with a median of 0.642 %, a level significantly lower than the Bradley FSaL (*p*=0.000), Bradley VFSaL (*p*=0.003), Capreol FSaL (*p*=0.000) and Capreol VFSaL (*p*=0.018) Series which had median SS % Sand contents of 14.3 %, 20.5 %, 18.8 % and 3.61 %, respectively. The only soil series which was not significantly greater (*p*=0.367) than the Azilda SiL Series was the Wolf SiL Series which had a median of SS % Sand Content of 2.49 %. The SS % Sand Content of the Wolf SiL Series was also found to be significantly lower than the Bradley FSal (*p*=0.014), Capreol FSaL (*p*=0.002) and Capreol VFSaL (*p*=0.002) Series, respectively. The Capreol FSaL and Capreol VFSaL Series have median SS % Sand contents of 18.8 % and 3.61 % respectively.

Over the study area the TS % Sand and SS % Sand datasets had CV values of 135 % and 125 %, respectively. For TS % Sand, the CV values of individual soil series were ranked from greatest to lowest as follows: Azilda SiL > Wolf SiL > Bradley VFSaL >Bradley FSaL > Capreol FSaL > Capreol VFSaL, having values of 161 %, 123 %, 104 %, 76.7 %, 59.0 % and 46.0 %, respectively. Whereas for SS % Sand, the CV values for individual soil series were ranked from greatest to lowest as follows: Azilda SiL > Wolf SiL > Capreol VFSaL > Bradley FSaL > Bradley VFSaL > Capreol VFSaL, having CV values of 258 %, 172 %, 137 %, 106 %, 103 % and 82.0 %, respectively.

Table 17. Table describing the variability of the % Sand content within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS; 75-100 cm) summaries are shown for the region and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

% Sand												
Soil Depth	Soil Series	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	2.44		0.0	44.4	5.50	0.53	7.42	135	2.4	7.1
	Azilda SiL	0.485	*a*	0.127	8.72	1.22	0.37	2.0	161	2.8	8.3
	Bradley FSaL	5.33	*bd*	0.734	18.7	6.59	0.84	5.05	76.7	0.89	-0.011
	Bradley VFSaL	5.01	*cde*	0.0	31.2	7.75	1.64	8.03	104	1.3	1.6
	Capreol FSaL	7.74	*be*	0.396	16.1	7.36	0.89	4.34	59.0	0.12	-0.98
	Capreol VFSaL	1.85	*c*	0.863	3.67	2.01	0.25	0.92	46.0	0.58	-0.77
	Wolf SiL	0.368	*a*	0.0	3.15	0.605	0.19	0.74	123	3.0	10.0
75-100 cm	Region	7.75		0.0	88.5	19.0	1.8	23.5	123	1.3	0.84
	Azilda SiL	0.642	*a*	0.0	64.1	6.0	2.8	15.6	258	3.1	8.8
	Bradley FSaL	14.3	*b*	0.151	88.0	21.1	3.9	22.3	106	1.5	2.4
	Bradley VFSaL	20.5	*bc*	0.0	86.4	25.8	4.6	26.6	103	0.91	-0.14
	Capreol FSaL	18.8	*b*	0.396	79.0	24.2	4.1	19.9	82.0	1.2	1.3
	Capreol VFSaL	3.61	*bd*	0.169	61.5	16.6	5.7	22.8	137	1.2	-0.05
	Wolf SiL	2.49	*acd*	0.0	65.1	11.3	4.6	19.5	172	2.14	3.8

4.2.1.1 Spatial Relationship of Percent Sand to Soil Series

The predicted surface of TS % Sand is in relation to soil series is presented in Figure 27. The soils in area surrounding Cote Blvd. and Dupuis Dr. were found to contain the overall greatest predicted TS % Sand. The Naiden VFSaL Series and the Wendigo SaL Series had the greatest TS % Sand contents. For the most part, the soils of the region north of the Whitson River and along the eastern part of Bradley Rd. were found to have greater predicted TS % Sand in comparison to the south-central region. The Azilda SiL and the Wolf SiL Series were found to contain the majority of the soils with the lowest predicted TS % Sand. As well, these soil series were also found not to be uniformly low in composition, with several localized areas having greater predicted TS % Sand. Also, the spatial distribution of TS % Sand in the Capreol VFSaL Series appeared to be the most uniform.

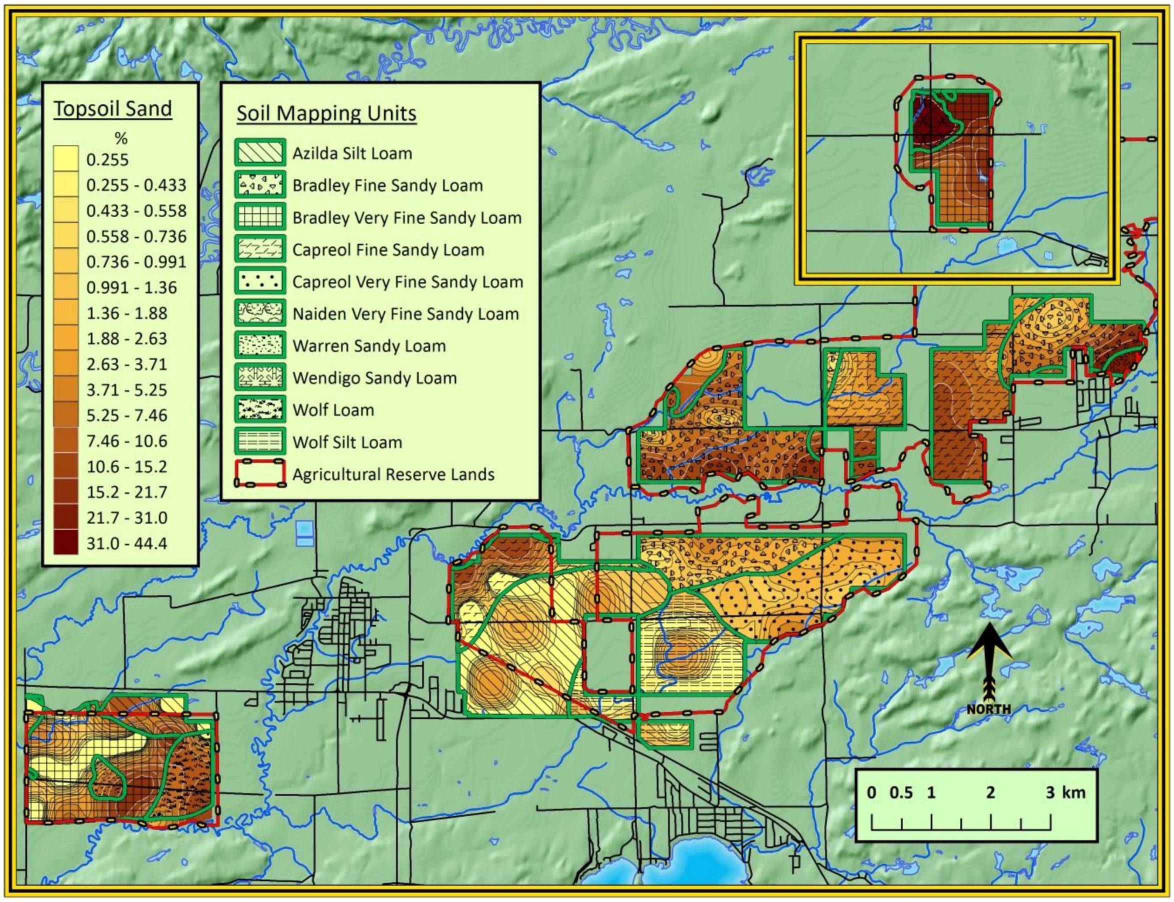
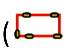


Figure 27. The predicted spatial distribution of Topsoil (0-20 cm) sand content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands () of the Greater City of Sudbury, ON (Scale 1:105,750).

The predicted surfaces of SS % Sand in relation to soil series is presented in Figure 28. Although a smoother surface was generated, patterns within the spatial distribution of SS % Sand reflect well those found of TS % Sand. For instance, the greatest predict SS % Sand contents and TS % Sand were found in the region surrounding Cote Blvd. and Dupuis Dr. Other similarities include greater predicted SS % Sand content to north of the Whitson River in comparison the south-central region. Furthermore, discrete areas having been identified under the under the same soil series were found for vary considerably in their SS % Sand predictions. For instance, this was found to be the case the Bradley FSaL, Bradley VFSaL and Capreol FSaL Series.

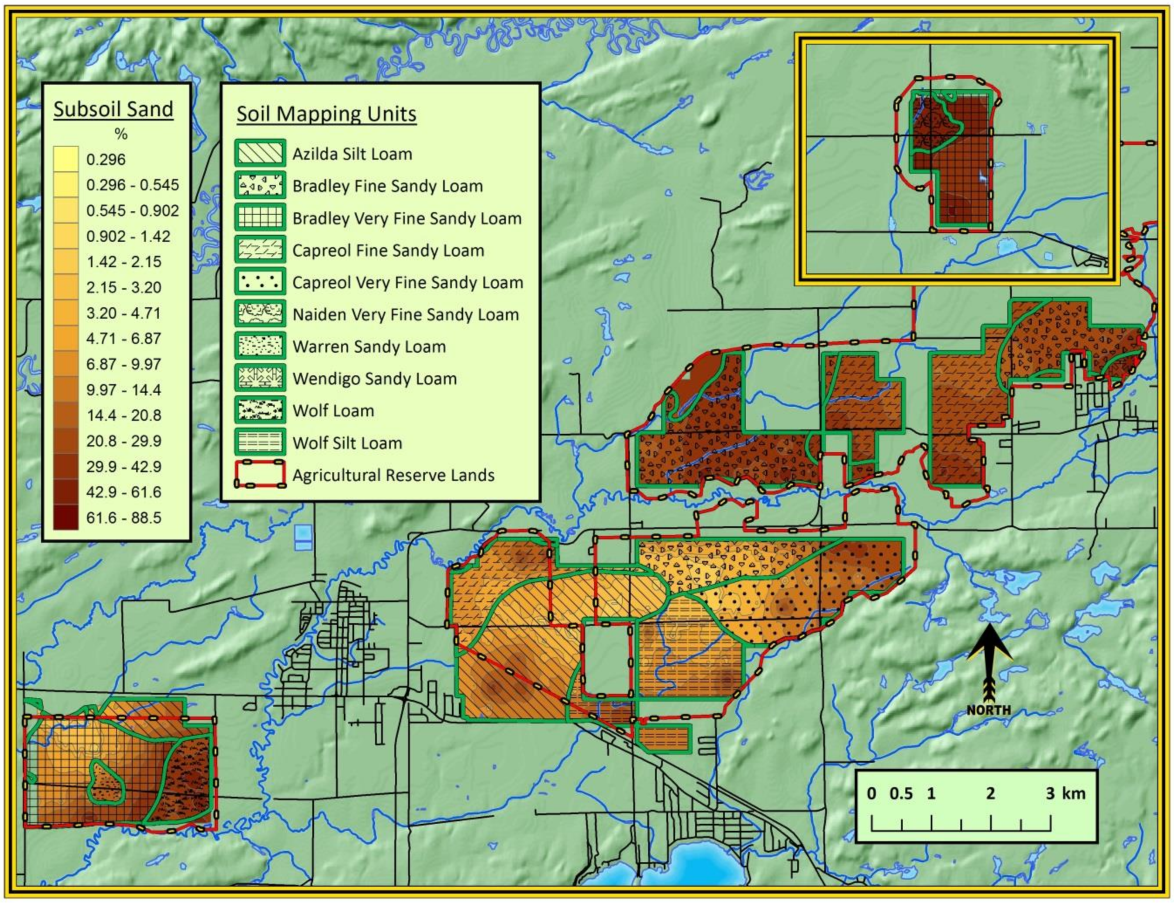


Figure 28. The predicted spatial distribution of subsoil (75-100 cm) sand content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2.2 Silt Content Variability across Soil Series

The median TS % Silt content of the study area was 81.8 %. The Capreol VFSaL Series had the greatest overall TS % Silt content, with a median value of 84.0%, a content significantly greater than the Bradley FSaL (p=0.014), Bradley VFSaL (p=0.000) and Capreol FSaL (p=0.000)

Series, with median TS % Silt contents of 81.5%, 80.3% and 80.7%, respectfully. As well, the Azilda SiL Series had a median TS % Silt content of 84.0%, a level also significantly greater than that of the Bradley FSaL (*p*=0.010), Bradley VFSaL (*p*=0.000) and Capreol FSaL (*p*=0.000) Series. In contrast, the Bradley VFSaL Series had the lowest TS % Silt, with a median of 80.3%, a content significantly lower in TS % Silt than the Azilda SiL (*p*=0.000), Bradley FSaL (*p*=0.026) and Wolf SiL (*p*=0.000) Series with median contents of 84.0 %, 81.5%, and 82.8%, respectively. Finally, the Capreol FSaL Series, with a median TS % Silt of 80.7%, was significantly less (*p*=0.011) than the median content of 82.8% of the Wolf SiL Series.

The median SS % Silt of the study area was 89.0 %. Overall, the Azilda SiL Series had the greatest SS % Silt content with a median of 86.0 % was found to be significantly greater than the content of the Bradley FSaL (*p*=0.003), Bradley VFSaL (*p*=0.000), Capreol FSaL (*p*=0.000) Series, with median SS % Silt contents of 77.4 %, 72.6 % and 73.4 %, respectively. As well, the Wolf SiL Series had a median SS % Silt content of 85.1 %, a content found to be significantly greater than the Bradley VFSaL (*p*=0.007) and Capreol FSaL (*p*=0.008) Series. Furthermore, the Capreol VFSaL Series had a median SS % Silt content of 85.0 % and was not significantly difference to any other soil series.

Over the study area, the TS % Silt and SS % Silt datasets had CV values of 7.20 % and 28 %, respectively. For TS % Silt, the CV values for individual soil series were ranked from greatest to lowest as follows: Bradley VFSaL >Bradley FSaL > Capreol FSaL > Wolf SiL > Azilda SiL >Capreol VFSaL, having values of 6.8 %, 4.9 %, 3.6 %, 2.9 %, 2.5 % and 2.0 %, respectively. Whereas for SS % Silt, the CV values for individual soil series were ranked from greatest to lowest as follows: Bradley VFSaL >Bradley FSaL > Capreol FSaL = Capreol VFSaL > Wolf SiL > Azilda SiL, having CV values of 35 %, 28 %, 26 %, 26 %, 22 % and 16 %, respectively.

Table 18. Table describing the variability of the % Silt content within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the region and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

% Silt											
Soil Depth	Soil Series	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	81.8		47.8	87.6	80.6	0.42	5.8	7.2	-2.9	10
	Azilda SiL	84.0	*a*	78.9	87.6	83.6	0.39	2.1	2.5	-0.66	0.17
	Bradley FSaL	81.5	*b*	70.1	86.2	81.0	0.66	4.0	4.9	-0.82	0.35
	Bradley VFSaL	80.3	*c*	59.7	83.0	78.1	1.1	5.3	6.8	-2.0	5.2
	Capreol FSaL	80.7	*bc*	72.6	84.2	80.3	0.59	2.9	3.6	-0.80	0.67
	Capreol VFSaL	84.5	*a*	79.8	85.5	84.0	0.45	1.67	2.0	-1.5	1.8
	Wolf SiL	82.8	*ab*	77.1	85.9	82.7	0.59	2.4	2.9	-0.65	0.29
75-100 cm	Region	81.9		9.4	89.0	71.6	1.6	20.4	28	-1.5	1.3
	Azilda SiL	86.0	*a*	32.6	88.2	82.0	2.4	13.3	16	-3.1	9.1
	Bradley FSaL	77.4	*bc*	9.50	87.4	70.7	3.5	19.9	28	-1.7	3.1
	Bradley VFSaL	72.6	*b*	11.3	88.7	65.3	4.0	22.7	35	-1.1	0.19
	Capreol FSaL	73.4	*b*	17.8	87.2	68.5	3.6	17.8	26	-1.4	1.7
	Capreol VFSaL	85.0	*ab*	35.0	87.7	73.6	4.9	19.5	26	-1.3	0.04
	Wolf SiL	85.1	*ac*	30.5	89.0	78.0	4.0	16.9	22	-2.3	4.3

4.2.2.1 Spatial Relationship of Percent Silt to Soil Series

The predicted surfaces of TS % Silt in relation to soil series is presented in Figure 29. The spatial distribution of TS % Silt reveals that the lowest predicted silt contents were found in the Cote Blvd. and Dupuis Dr. region. Additionally, within the central region of the Agricultural Reserve lands, the spatial distribution of TS % Silt exhibits a random 'mottled' pattern with localized areas of high and low silt contents. The soils having the greatest predicted TS % Silt generally occurred to the south of the Whitson River within the south-central area.

Additionally, the central region of the Agricultural Reserve lands, both north and south of Whitson River appears to be more spatially variable when compared to the both the Bradley Rd. and, the Cote Blvd. and Dupuis Dr. regions. When comparing both discrete areas of the Bradley FSaL Series, south and north of the Whitson River, considerable textural differences are apparent. On the other hand, discrete areas within the Capreol FSaL Series and the Bradley VFSaL Series, were found to have similar TS % Silt content.

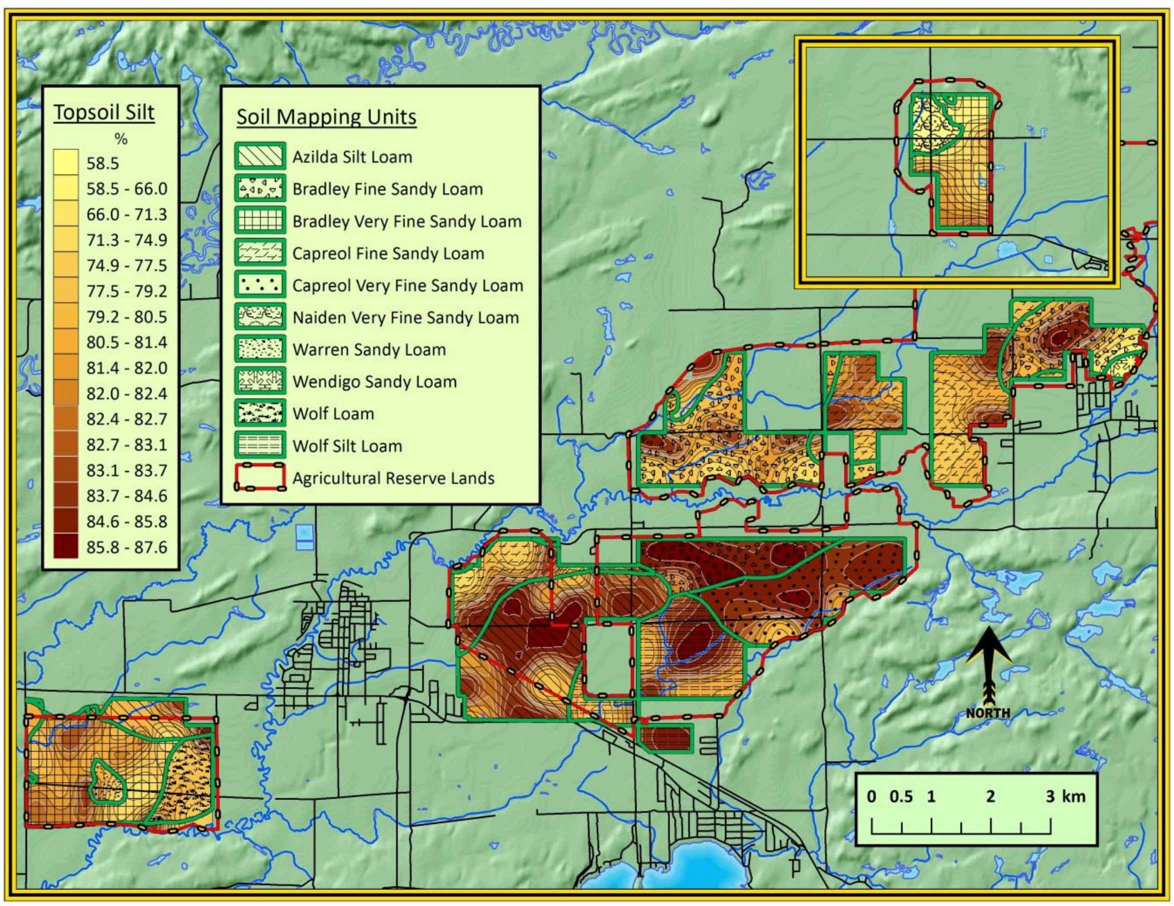


Figure 29. The predicted spatial distribution of Topsoil (0-20 cm) silt content (%) in relation to soil series (Soil Mapping Unit) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

The predicted spatial distribution of SS % Silt in relation to soil series is presented in Figure 30. Throughout the study area, SS % Silt does not seem to reflect levels of the material in the surfaces of the soil series. As was found with TS % Silt, the regions with the greatest predicted SS % Silt were located south of the Whitson River in the south-central region and in the northwest area of the region surrounding Bradley Rd. Areas having lower predicted SS % Silt content were found in Cote Blvd. and Dupuis Dr. region, the south-east portion of Bradley Rd. region and the northern half of the central region of the Agricultural Reserve lands. Generally these areas of low predicted SS % Silt had a uniform spatial distribution.

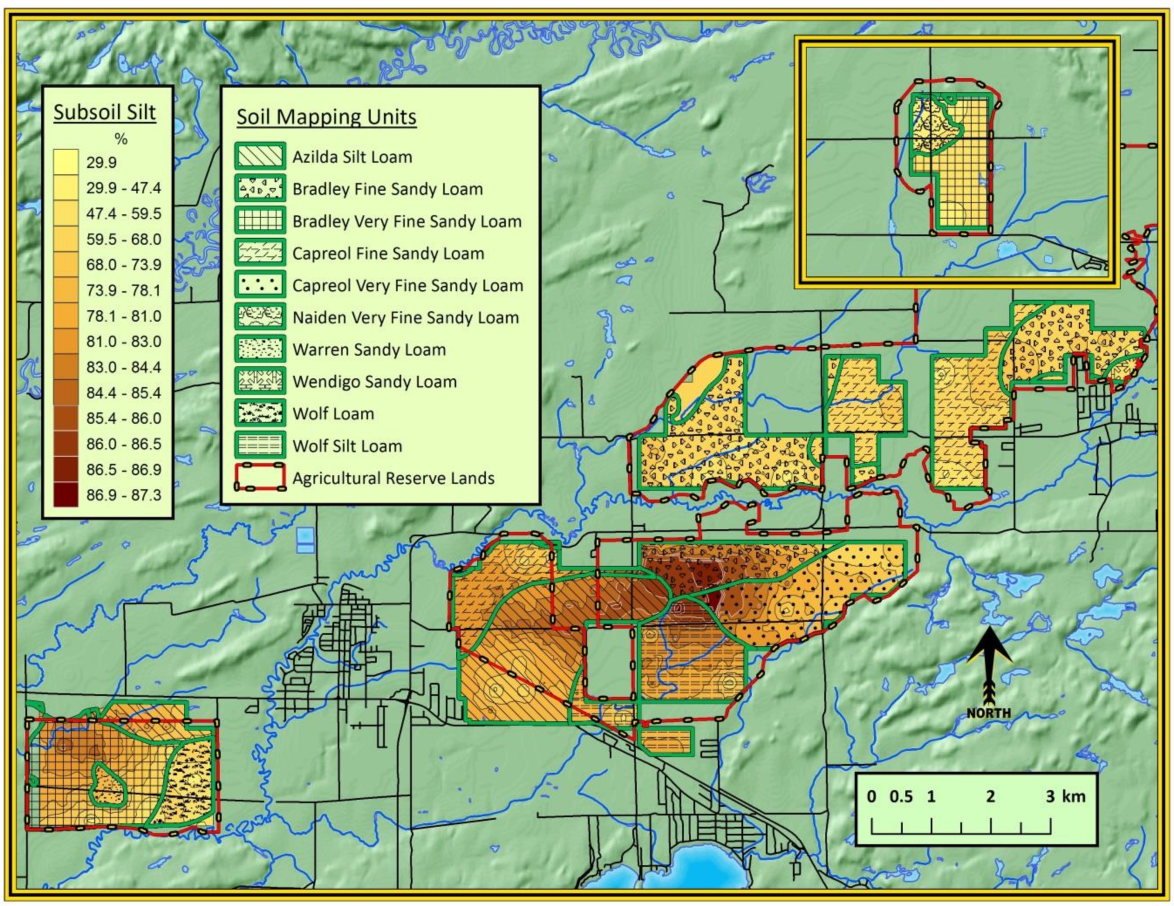


Figure 30. The predicted spatial distribution of subsoil (75-100 cm) silt content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2.3 Clay Content Variability across Soil Series

Over the study area, the median TS % Clay content was 13.7 %. The Wolf SiL Series, with the greatest TS % Clay with a median of 16.7 %, was significantly greater than the Bradley FSaL (*p*=0.000), Bradley VFSaL (*p*=0.028), Capreol FSaL (*p*=0.000) and Capreol VFSaL (*p*=0.003) Series which had median values of 12.0%, 14.5%, 11.6% and 13.5%, respectfully. The Azilda SiL Series was found to have a median TS % Clay content of 14.8 %. Although not significantly different (*p*=0.057), a possible relationship might exist between the Azilda SiL and the Wolf SiL Series. Additionally, the TS % Clay content of the Azilda SiL Series was found to be significantly greater than that of the Bradley FSaL (*p*=0.000), Capreol FSaL (*p*=0.000), Capreol VFSaL (*p*=0.024) Series. Finally, the Capreol VFSaL Series had a median TS % Clay content of 13.5 %. It was found to be significantly greater than the Bradley FSaL (*p*=0.006) and the Capreol FSaL (*p*=0.013) Series.

Over the study area, the median SS % Clay content was 8.91 %. The Azilda SiL Series had the greatest SS % Clay content with a median content of 12.6 %, a content significantly greater than that in the Bradley FSaL (*p*=0.000), Bradley VFSaL (*p*=0.003) and Capreol FSaL (*p*=0.000) Series, which had median SS % Clay contents of 7.75 %, 7.59 % and 7.56 %, respectively. Furthermore, the Wolf SiL Series had a median SS % Clay content of 10.5 %, a content significantly greater than the median of Bradley VFSaL (*p*=0.007) and Capreol FSaL (*p*=0.008) Series, respectfully.

Over the study area, the TS % Clay and SS % Clay estimates had CV values of 21 % and 41 %, respectively. For TS % Clay , the CV values for individual series clay contents were ranked from greatest to lowest as follows: Bradley VFSaL > Capreol FSaL > Wolf SiL > Bradley FSaL >

Azilda SiL >Capreol VFSaL, having values of 25 %, 19 %, 17 %, 16 %, 13 % and 12 %, respectively. Whereas for SS % Clay, the CV values for individual series contents were ranked from greatest to lowest as follows: Bradley VFSaL > Capreol VFSaL > Capreol FSaL >Bradley FSaL >Wolf SiL > Azilda SiL, having CV values of 53 %, 36 %, 34 %, 33 %, 29 % and 23 %, respectively.

Table 19. Table describing the variability of the % Clay content within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		% Clay									
Soil Depth	Soil Series	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	13.7		6.77	22.5	13.9	0.21	2.9	21	0.22	-0.47
	Azilda SiL	14.8	*a*	11.6	20.4	15.2	0.38	2.0	13	0.64	0.64
	Bradley FSaL	12.0	*b*	8.67	16.6	12.4	0.32	1.9	16	0.50	-0.29
	Bradley VFSaL	14.5	*abc*	8.65	20.4	14.1	0.73	3.6	25	-0.052	-1.4
	Capreol FSaL	11.6	*b*	9.12	17.6	12.3	0.47	2.3	19	0.78	-0.21
	Capreol VFSaL	13.5	*c*	11.9	17.2	14.0	0.44	1.65	12	1.1	0.066
	Wolf SiL	16.7	*a*	11.5	22.5	16.7	0.70	2.8	17	0.14	-0.18
75-100 cm	Region	8.91		2.14	22.5	9.36	0.29	3.8	41	0.29	-0.067
	Azilda SiL	12.6	*a*	3.35	15.6	12.0	0.48	2.7	23	-1.6	3.2
	Bradley FSaL	7.75	*bd*	2.50	13.4	8.29	0.49	2.77	33	0.13	-0.64
	Bradley VFSaL	7.59	*bcd*	2.24	20.7	8.86	0.82	4.73	53	0.78	-0.13
	Capreol FSaL	7.56	*b*	3.20	12.9	7.26	0.50	2.47	34	0.59	0.56
	Capreol VFSaL	11.4	*de*	3.35	13.0	9.75	0.87	3.50	36	-0.85	-0.87
	Wolf SiL	10.5	*ace*	4.39	14.8	10.6	0.7	3.1	29	-0.49	-0.52

4.2.3.1 Spatial Relationship of Percent Clay to Soil Series

The predicted surface of TS % Clay in relation to soil series in the study area is presented in Figure 31. The spatial distribution of TS % Clay appears to gradually decrease as distance increases from the Whitson River. In combination with this trend over the entire study area, TS % Clay appears to increase in a south-west direction. At the southernmost extent of the study area, the Azilda SiL, Wolf SiL and Bradley VFSaL Series contain greatest predicted values of TS % Clay. Along Bradley Rd., the TS % Clay content increases in a westerly direction ranging from low to high predicted values. Areas north of the Whitson River and the region surrounding Cote Blvd. and Dupuis Dr. were found to have the lowest predicted TS % Clay content, with a few localized areas of enrichment the along central-northern boundary of the study area. The Bradley VFSaL Series was found to have contrasting TS % Clay contents between the discrete mapped areas in Bradley Rd. region in comparison to the counterpart areas within the Cote Blvd. and Dupuis Dr. region.

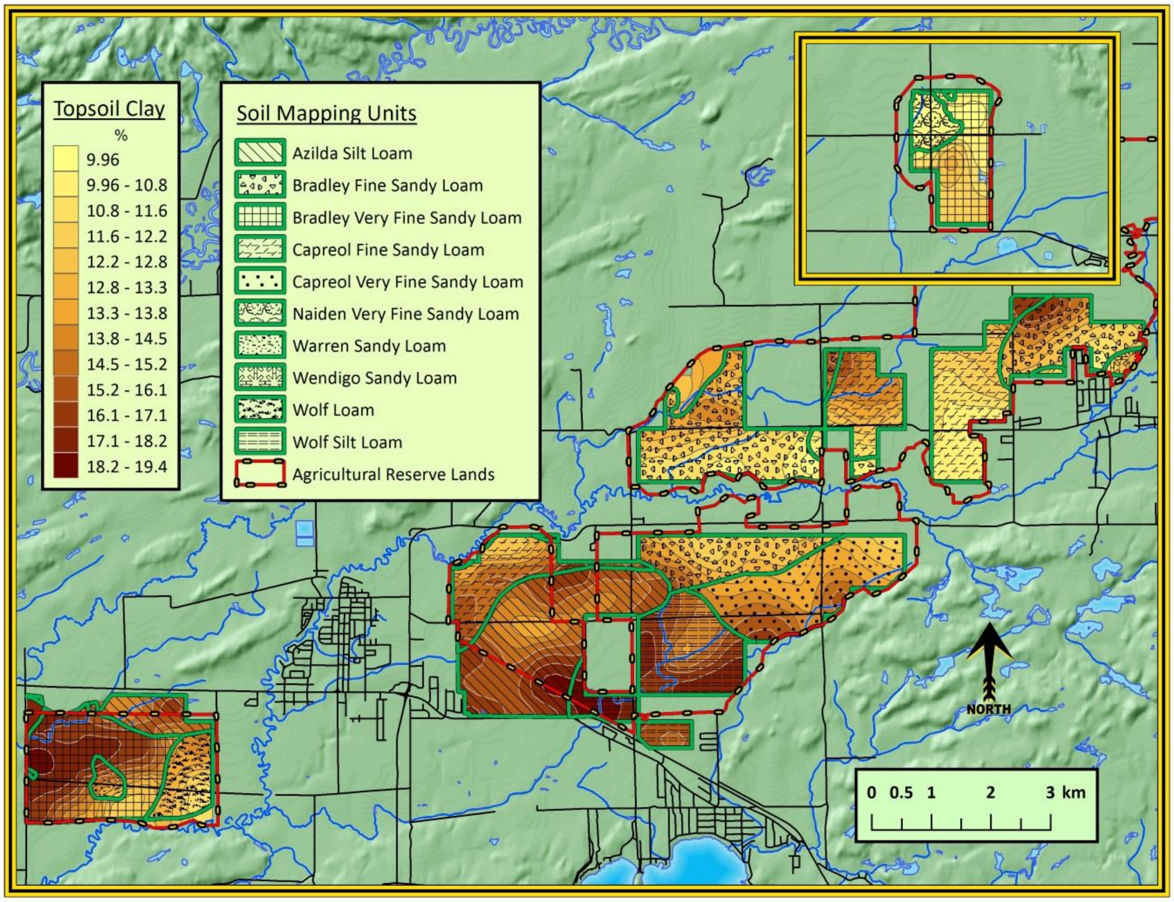


Figure 31. The predicted spatial distribution of Topsoil (0-20 cm) clay content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

The predicted surface of SS % Clay in relation to soil series is presented in Figure 32. The patterns of both the TS % Clay and SS % Clay spatial distributions of seem to resemble one another, reflecting the importance of the soil parent material as a key factor of soil formation. Areas having the greatest SS % Clay are located in the south-central region and within the north-western portion of the Bradley Rd. region. Similar to TS % Clay, soil series containing the highest predicted SS % Clay contents were the Azilda SiL, Wolf SiL and Bradley VFSaL Series. Furthermore, the regions north of the Whitson River and surrounding Cote Blvd. and Dupuis Dr. were both found to have relatively low SS % Clay contents, with only one localized zone of enrichment found north of Whitson River in the central region. Finally, discrete soil series areas, both north and south of the Whitson River were found to have contrasting SS % Clay values. The observed soil textural patterns to the north and south of the Whitson River are similar to those of their parent materials of glaciolacustrine, glaciofluvial and fluvial origin.

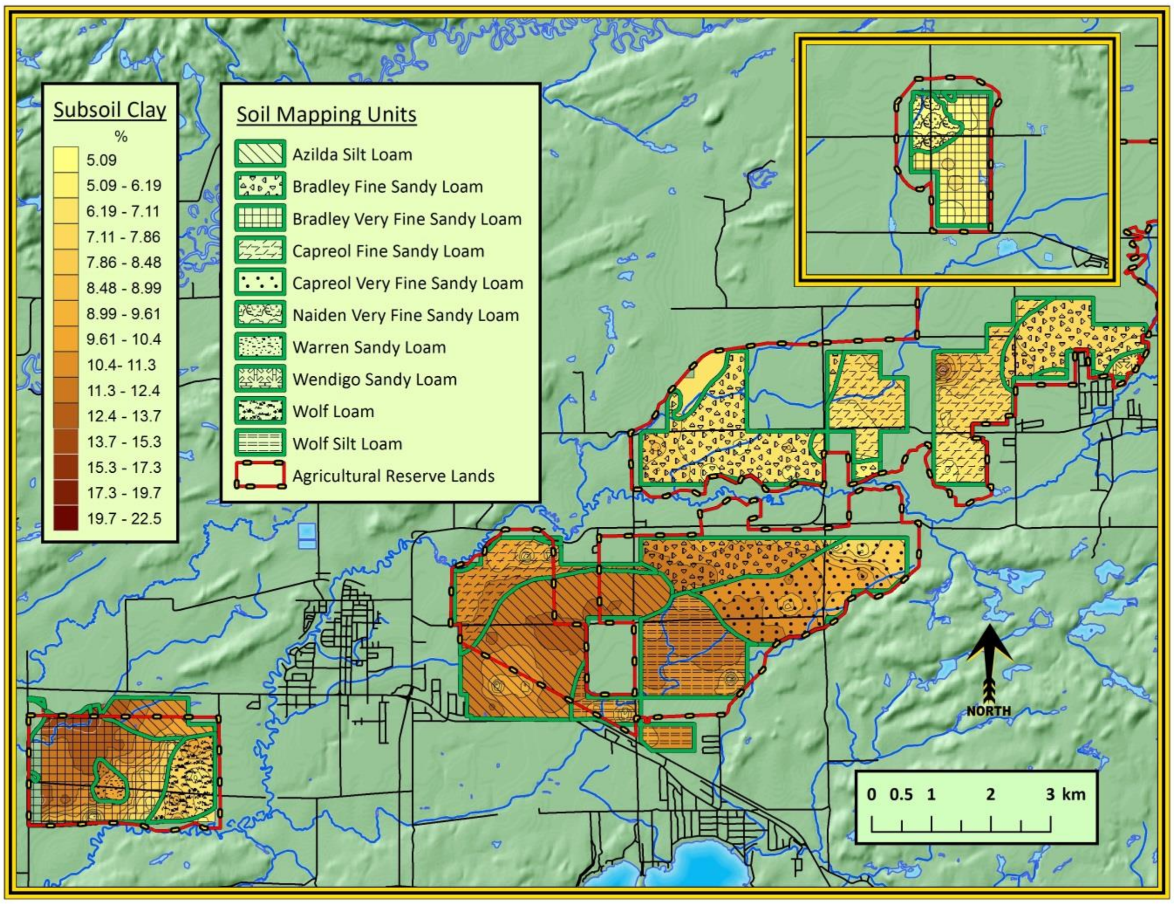


Figure 32. The predicted spatial distribution of subsoil (75-100 cm) clay content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2.4 Topsoil ρ_{bulk} Variability across Soil Series

The median TS ρ_{bulk} of the study area was 1.11 g·cm^3. The Azilda SiL Series had the lowest median TS ρ_{bulk}, with a value of 1.02 g·cm^3, significantly lower than the Bradley FSaL

(p=0.019) and Capreol VFSaL (p=0.001) Series which had median TS ρ_{bulk} values of 1.15 g·cm^3 and 1.22 g·cm^3, respectively. Furthermore, the Capreol VFSaL Series had the overall greatest TS ρ_{bulk} with a median of 1.22 g·cm^3. In addition to being significantly greater than the the Azilda Series, Capreol VFSaL was also found to be significantly greater than Bradley VFSaL (p=0.002), Capreol FSal (p=0.046) and Wolf SiL (p=0.003), with that had median TS ρ_{bulk} values of 1.09 g·cm^3, 1.10 g·cm^3 and 1.08 g·cm^3, respectively.

Over the study area, TS ρ_{bulk} had a CV value of 14 %, with CV values for individual soil series ranked from greatest to lowest as follows: Wolf SiL > Azilda SiL > Bradley FSaL = Bradley VFSaL > Capreol FSaL > Capreol VFSaL, having values of 33 %, 20 %, 12 %, 12 %, 6.9 % and 6.3 %, respectively.

Table 20. Table describing the variability of the topsoil (0- 20 cm) bulk density (ρbulk; g·cm^3) within the City of Greater Sudbury's Agricultural Reserve lands. Soil series median values having similar corresponding letters indicate no significant difference (p=0.050) from one another using Kruskal-Wallis comparison of medians.

		ρbulk									
Soil Depth	Soil Series	Median		Min	Max	Mean			CV	Skewness	Kurtosis
							± SE	± SD	(%)		
0-20 cm	Region	1.11		0.54	1.70	1.11	0.011	0.15	14	0.02	2.2
	Azilda SiL	1.02	*a*	0.54	1.58	1.04	0.038	0.20	20	0.04	1.9
	Bradley FSaL	1.15	*bc*	0.81	1.35	1.13	0.023	0.14	12	-0.66	-0.21
	Bradley VFSaL	1.09	*ac*	0.87	1.43	1.09	0.026	0.13	12	0.47	1.2
	Capreol FSaL	1.10	*ac*	0.93	1.21	1.09	0.015	0.076	6.9	-0.42	-0.31
	Capreol VFSaL	1.22	*b*	1.06	1.32	1.20	0.020	0.076	6.3	-0.49	-0.63
	Wolf SiL	1.08	*ac*	0.84	1.55	1.13	0.045	0.37	33	1.0	1.0

4.2.4.1 Spatial Relationship of Topsoil ρ_{bulk} to Soil Series

The predicted surface of TS ρ_{bulk} for soil series within the study area presented in Figure 33 does not seem to visually conform to the spatial distributions of TS % Sand, TS % Silt or TS %

Clay or to superimposed soil series distributions. The lowest TS ρ_{bulk} values are found along the northern boundary of Bradley Rd. area, along the eastern portion of Bonin Rd. and to the far east of the central area north of the Whitson River. The greatest values of TS ρ_{bulk} are centrally located within the study area. TS ρ_{bulk} values within soil series such as Azilda SiL, Bradley FSaL, Bradley VFSaL and Capreol FSaL vary from high to low across their spatial extents. Overall, the predicted TS ρ_{bulk} values within the Capreol VFSaL appear to be the least variable.

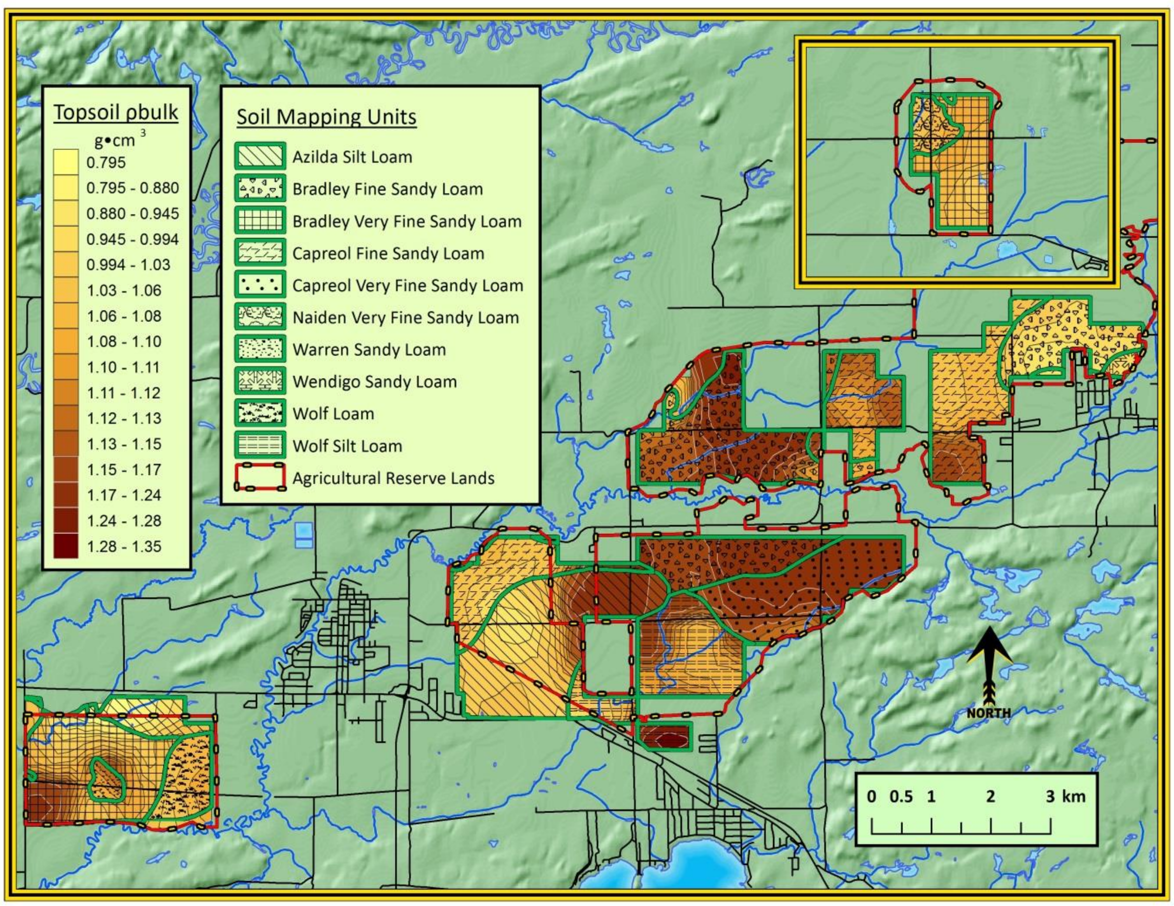


Figure 33. The predicted spatial distribution of topsoil (0-20 cm) bulk density (g·cm^3; ρ_{bulk}) in relation to soil series (soil mapping units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2.5 pH Variability across Soil Series

The median TS $pH_{(H_2O)}$ of the study area was 5.5. Overall, the Azilda SiL and the Wolf SiL Series had the highest TS $pH_{(H_2O)}$ with median values of 6.2. As a result they were both found to be significantly higher than all other soil series. In contrast, the Bradley FSaL Series had the lowest median $pH_{(H_2O)}$ with a value of 5.1, a value significantly less than the Azilda SiL (p=0.000), Bradley VFSaL (p=0.005), Capreol VFSaL (p=0.020) and Wolf SiL (p=0.000) Series. Additionally, Capreol FSaL, with a median TS pH H_2O value of 5.2, was found to be significantly lower than the Bradley VFSaL (p=0.010) and Capreol VFSaL (p=0.027) Series, having TS $pH_{(H_2O)}$ values of 5.5 and 5.4, respectively.

The median SS $pH_{(H_2O)}$ for the entire study area was 7.3. The Azilda SiL Series had the greatest overall SS $pH_{(H_2O)}$, with a median of 8.1, was significantly higher than the Bradley FSaL (p=0.000), Capreol FSaL (p=0.000) and Capreol VFSaL (p=0.006) Series which had median SS $pH_{(H_2O)}$ values of 5.6, 5.9 and 7.0, respectively. The Wolf SiL Series, with a median SS $pH_{(H_2O)}$ value of 7.7, was also found to be significantly higher than the Bradley FSaL (p=0.000), Capreol FSaL (p=0.000) and Capreol VFSaL (p=0.005) Series. On the contrary, the Bradley FSaL Series had the lowest SS pH H_2O with a median of 5.6. As well as being significantly lower than the Azilda SiL and Wolf SiL Series mentioned above, the Bradley FSaL Series was significantly lower than the Bradley VFSaL (p=0.003) and Capreol VFSaL (p=0.034) Series. With a median SS $pH_{(H_2O)}$ of 7.8, the Bradley VFSaL Series was also significantly higher than the Capreol FSaL (p=0.012) Series.

Over the study area, the TS pH$_{(H_2O)}$ and SS pH$_{(H_2O)}$ datasets had CV values were 13 % and 19 %, respectively. For TS pH$_{(H_2O)}$, the CV values of individual soil series were ranked from greatest to lowest as follows: Bradley VFSaL > Capreol VFSaL > Bradley FSaL > Capreol FSaL > Azilda SiL > Wolf SiL, having values of 13 %, 12 %, 11 %, 9.1 %, 8.5 % and 4.0 %, respectively. The pH$_{(H_2O)}$ CV values of individual soil series were ranked from greatest to lowest as follows: Capreol FSaL, Bradley VFSaL = Capreol VFSaL > Bradley FSaL > Azilda SiL > Wolf SiL, having CV values of 21 %, 20 %, 20 %, 18 %, 5.7 % and 5.5 %, respectively.

Table 21. Table describing the variability of pH$_{(H2O)}$ levels within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the region and for the most areally significant soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		pH H_2O									
Soil Depth	Soil Series	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	5.5		3.8	7.1	5.5	0.1	0.7	13	-0.04	-0.52
	Azilda SiL	6.2	*a*	5.3	7.1	6.1	0.1	0.5	8.5	0.26	-0.90
	Bradley FSaL	5.1	*b*	3.8	6.0	5.0	0.1	0.5	11	-0.46	-0.16
	Bradley VFSaL	5.5	*c*	4.4	6.73	5.6	0.2	0.7	13	0.08	-1.4
	Capreol FSaL	5.2	*b*	4.2	6.2	5.1	0.1	0.5	9.1	0.29	0.52
	Capreol VFSaL	5.4	*c*	4.8	6.5	5.6	0.2	0.6	12	0.30	-1.8
	Wolf SiL	6.2	*a*	5.7	7.0	6.3	0.1	0.3	4.0	0.24	-1.1
75-100 cm	Region	7.3		4.0	8.6	6.8	0.1	1.3	19	-0.29	-1.5
	Azilda SiL	8.1	*a*	6.7	8.4	7.9	0.1	0.4	5.7	-1.4	1.6
	Bradley FSaL	5.6	*bc*	4.8	8.6	6.1	0.2	1.1	18	0.87	-0.65
	Bradley VFSaL	7.8	*acd*	4.8	8.5	7.0	0.2	1.4	20	-0.40	-1.7
	Capreol FSaL	5.9	*bd*	4.5	8.4	6.2	0.2	1.3	21	0.50	-1.28
	Capreol VFSaL	7.0	*bd*	4.0	8.3	6.8	0.3	1.3	20	-0.55	-0.80
	Wolf SiL	7.7	*a*	6.8	8.3	7.9	0.1	0.4	5.5	-1.5	1.6

4.2.5.1 Spatial Relationship of pH to Soil Series

The predicted surface for TS pH$_{(H_2O)}$ of soil series within the study area is presented in Figure 34. The areas having the lowest TS pH$_{(H_2O)}$ were found to be east of Martin Rd. and along both banks of the Whitson River. Areas found to have the highest predicted TS pH$_{(H_2O)}$ were located in the south-central region and the Bradley Rd. regions. The majority of these latter areas were found to reflect the distribution of the Azilda SiL, Bradley VSaL and Wolf SiL Series which appear to have a relatively uniform spatial distribution across the area. In the case of the Bradley VFSaL Series, the discrete area along Bradley Rd. was found to have a much higher predicted TS pH$_{(H_2O)}$ values than in the counterpart area in the Cote Blvd. and Dupuis Dr. region. Dissimilar predicted TS pH$_{(H_2O)}$ values were found between discrete areas in the Bradley FSaL Series. As well, the Capreol VFSaL Series was found to range from high and low predicted TS pH$_{(H_2O)}$ across the units spatial extent.

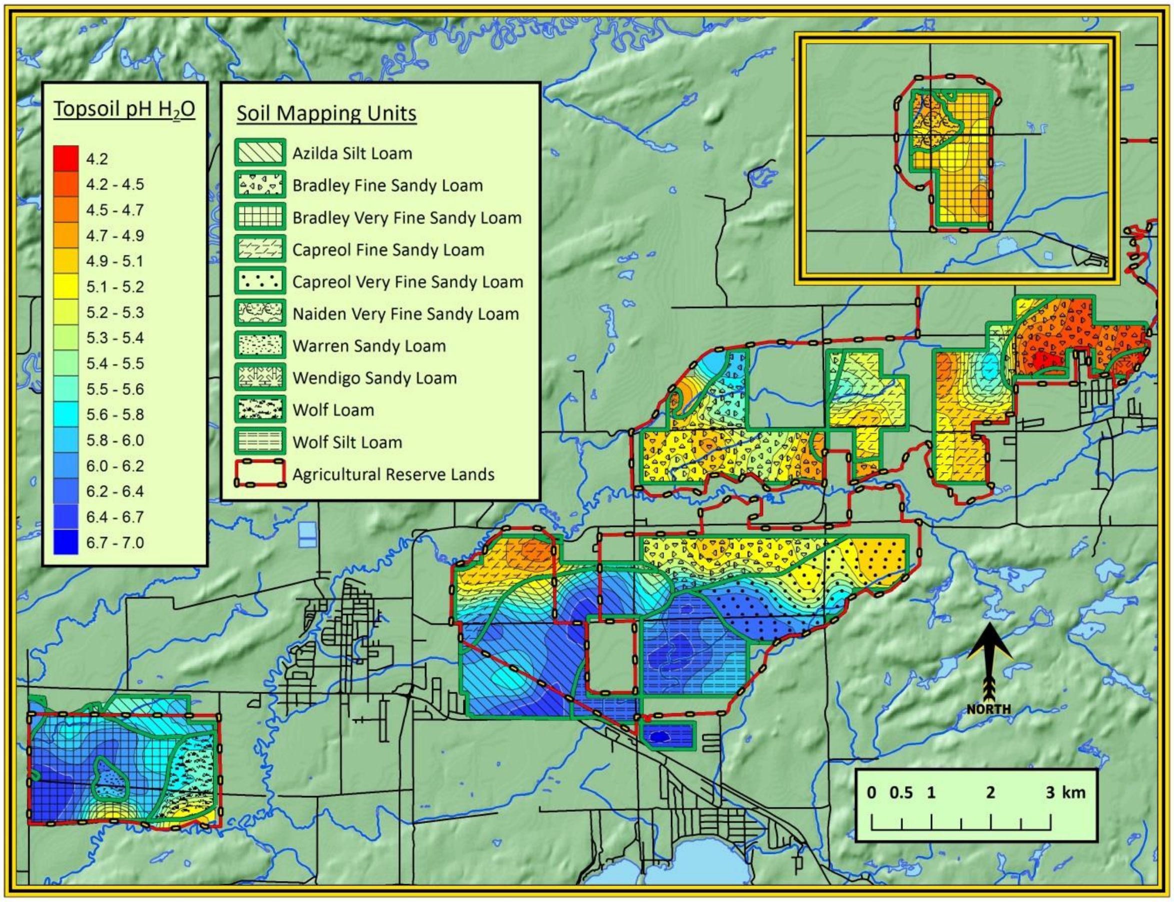


Figure 34. The predicted spatial distribution of Topsoil (0-20 cm) pH in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

The predicted surface of SS pH$_{(H_2O)}$ in relation to soil series within the study area is presented in Figure 35. Further, similar to the spatial distribution of TS pH$_{(H_2O)}$, the Azilda SiL, Bradley VFSaL and Wolf SiL Series were found to host the soils have the highest predicted SS pH$_{(H_2O)}$. In addition, the Bradley VFSaL and Capreol FSaL were also observed to have large differences in predicted SS pH$_{(H_2O)}$ contents between discrete mapped areas. Further similarities to the TS pH$_{(H_2O)}$ spatial distribution were found when comparing the Capreol VFSaL Series, with areas of both high and low SS pH$_{(H_2O)}$ within the soil series boundaries. Finally, for both predicted surfaces, the southern half had predicted circum-neutral to basic soils while the northern part had predicted acidic soils.

SS $pH_{(H_2O)}$ (Figure 35) was also found to have a similar spatial distribution to that of SS % Sand (Figure 28). For the most part, areas having lower SS $pH_{(H_2O)}$ had corresponding greater predicted SS % Sand. The lowest predicted SS $pH_{(H_2O)}$ contents were found in the north-central region and surrounding Cote Blvd. and Dupuis Dr. Further, the SS pH H_2O south of the Whitson River was found to increase as distance from the river increased, an observation similar to that for the area surrounding Bradley Rd.

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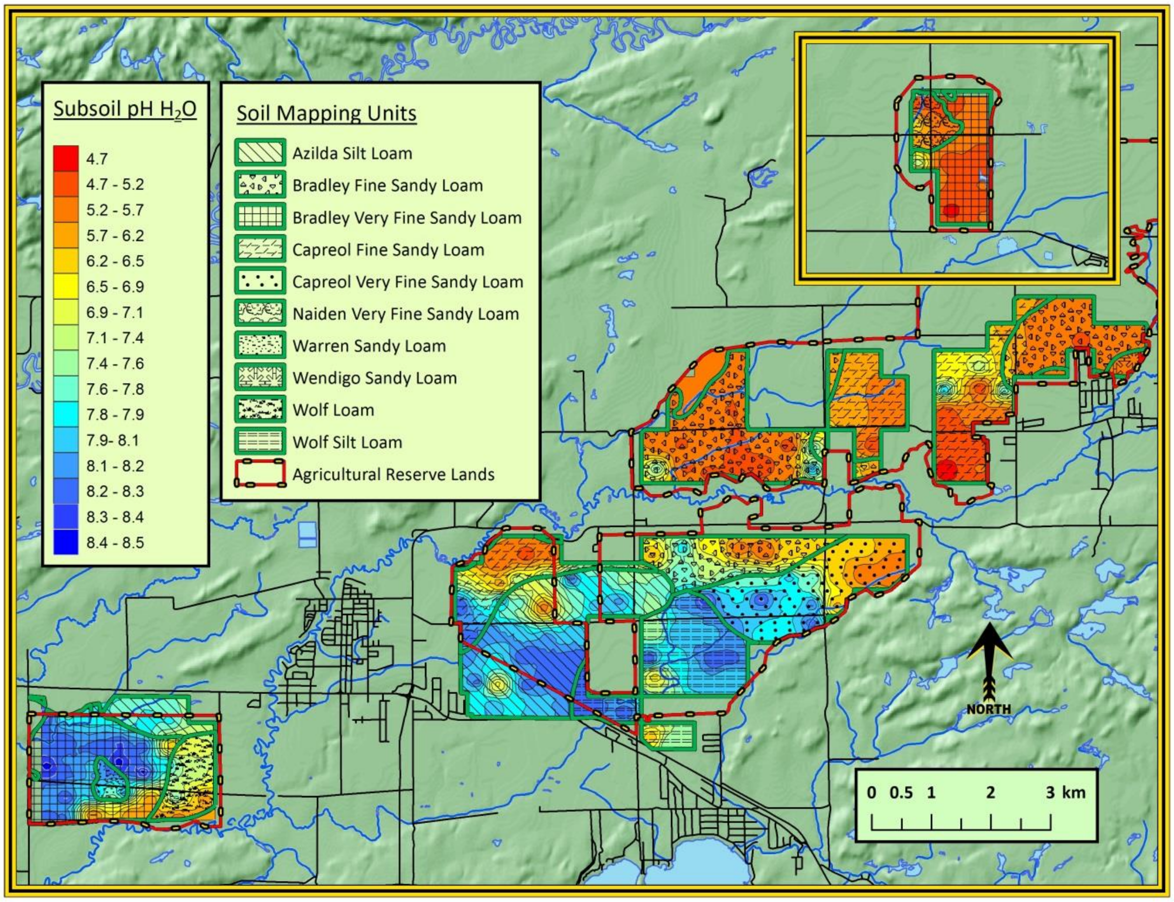


Figure 35. The predicted spatial distribution of subsoil (75-100 cm) pH in relation to soil series (soil mapping units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

4.2.6 Total C Variability across Soil Series

The median TS Total C for the study was 2.42 %. The Wolf SiL Series had the greatest TS Total C with a median content of 3.21 %, a level significantly greater than that for the Bradley FSaL (p=0.000), Capreol FSaL (p=0.006) and Capreol VFSaL (p=0.002) Series which had median TS Total C contents of 1.79 %, 2.46 % and 1.93 %, respectively. Also, the Azilda SiL Series, with a median TS Total C content of 2.72 %, was found to be significantly greater than the Bradley FSaL (p=0.000), Capreol FSaL (p=0.014), Capreol VFSaL (p=0.001) Series. The Bradley VFSaL, with a median of 2.71 %, was only significantly greater median level than the Capreol VFSaL (p=0.019) Series. In contrast, the TS Total C level of the Bradley FSaL Series, having a median of 1.79 %, was found to be significantly less than that of all other soil series.

The median SS Total C of the study was 0.382 %. The Azilda SiL Series had the highest overall SS Total C content, with a median of 1.76%, and was found to be significantly higher than all other soil series with the sole exception of the Wolf SiL (p=0.390) Series which had a median of 1.07 %. No other significant differences were found for the median SS Total C of Bradley VFSaL Series with a value of 1.05 %. Additionally, the Wolf SiL Series Total C was found to be significantly higher than the Bradley FSaL (p=0.000), the Capreol FSaL (p=0.000) and the Capreol VFSaL (p=0.028) Series that had values of 0.147 %, 0.251 % and 0.550 %, respectively. Also, The Bradley FSaL Series was found to have the lowest overall median SS Total C with a median of 0.147 %, a content significantly lower than all other land uses with the sole exception of the Capreol FSaL (p=0.053) Series that had a median of 0.246 %.

Table 22. Table describing the variability of Total % C content within the City of Greater Sudbury Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (p=0.050) from one another using Kruskal-Wallis comparison of medians.

		Total C									
Soil Depth	Soil Series	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	2.42		0.397	13.0	2.64	0.097	1.4	51	3.8	23
	Azilda SiL	2.72	*a*	1.08	13.0	3.50	0.44	2.4	68	2.9	9.2
	Bradley FSaL	1.79	*b*	1.18	3.66	1.95	0.11	0.66	34	1.1	0.56
	Bradley VFSaL	2.71	*ad*	1.61	4.27	2.79	0.14	0.68	25	0.11	-0.48
	Capreol FSaL	2.46	*cd*	1.77	3.69	2.48	0.10	0.50	20	0.43	-0.35
	Capreol VFSaL	1.93	*b*	1.56	3.09	2.09	0.11	0.44	21	1.3	0.87
	Wolf SiL	3.21	*a*	1.31	5.37	3.14	0.28	1.1	36	0.11	-0.47
75-100 cm	Region	0.382		0.065	2.64	0.827	0.060	0.82		0.76	-0.94
	Azilda SiL	1.76	*a*	0.0661	2.64	1.48	0.15	0.84		-0.40	-1.4
	Bradley FSaL	0.147	*b*	0.0657	2.38	0.365	0.085	0.57		2.6	6.0
	Bradley VFSaL	1.05	*cde*	0.0722	2.60	0.994	0.16	0.89		0.40	-1.4
	Capreol FSaL	0.251	*bd*	0.0651	1.85	0.478	0.099	0.53		1.6	1.1
	Capreol VFSaL	0.550	*cd*	0.073	1.94	0.760	0.16	0.66		0.49	-1.4
	Wolf SiL	1.07	*ae*	0.140	2.36	1.34	0.18	0.76		-0.078	-1.4

4.2.6.1 Spatial Relationship of Total C to Soil Series

The predicted surface of TS Total C (%) in relation to soil series within the study area is presented in Figure 36. The spatial distribution of TS Total C (%) has similar patterns to the predicted surface of TS ρ_{bulk} (Figure 33).The lowest predicted TS Total C (%) contents were found to be located within the central region of the Agricultural Reserve along the north and south banks of the Whitson River. A large portion of the extent of this area having low predicted TS Total C (%) is contained within the Bradley FSaL and Capreol VFSaL Series. The soil series with the highest predicted TS Total C (%) were the Azilda SiL, Bradley VFSaL and the Wolf

SiL Series. However, the spatial distribution of TS Total C (%) was not found to be uniform within these soil series. Several localized areas were found to have contrasting high and low predicted TS Total C (%).These complex patterns in the predicted surface of TS Total C (%) were found to poorly conform to the superimposed soil series. Furthermore, the discrete area within the Bradley FSaL Series immediately east of Martin Rd. was found to have higher predicted TS Total C (%) than both the discrete soils series areas to the north and south of the Whitson River.

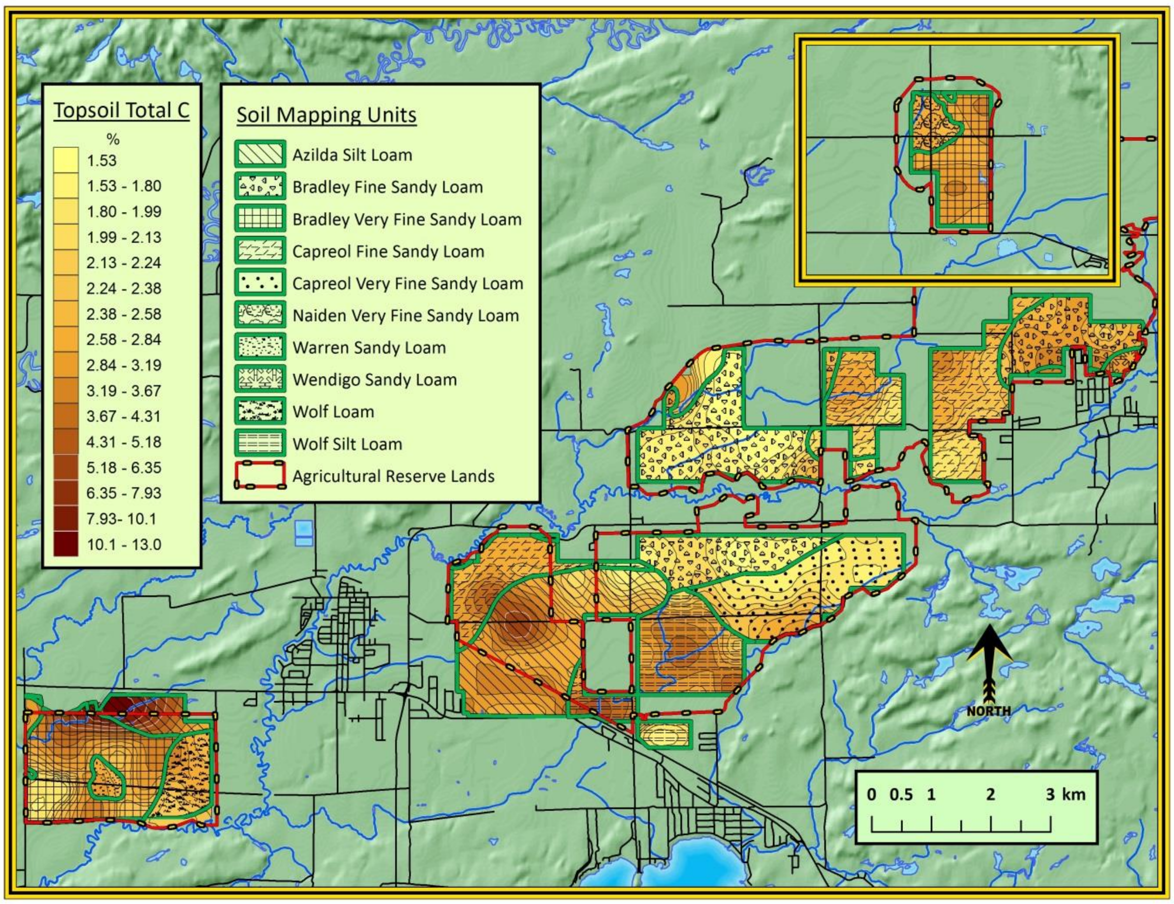


Figure 36. The predicted spatial distribution of Topsoil (0-20 cm) Total C content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

The predicted surface of SS Total C in relation to soil series within the study area is presented in Figure 37. The spatial distribution of SS Total C (%) over the study area appears to increase along south-west gradient, with areas having the highest predicted SS Total C (%) being found within the Bradley Rd. region. As well, to a lesser degree, areas also having greater predicted SS Total C (%) were also found to be situated immediately south of Bonin Rd. The areas were mostly contained within the Azilda SiL, Bradley VFSaL and the Wolf SiL Series. In contrast, the lowest predicted SS Total C (%) was found within the Cote Blvd. and Dupuis Dr. region, and also in the north-central region. Generally, throughout the study area, predicted SS Total C (%) also increased as distance from the Whitson River, although the gradient was found to be less pronounced in the soils north of the Whitson River. In addition, within the Bradley VFSaL Series contrasting SS Total C (%) were found when visually comparing both the discrete areas of Bradley Rd. and Cote Blvd. and Dupuis Dr. regions. The area surrounding Cote Blvd. and Dupuis Dr. was found to have a much lower predicted SS Total C (%) in comparison to the counterpart area in the Bradley Rd. region.

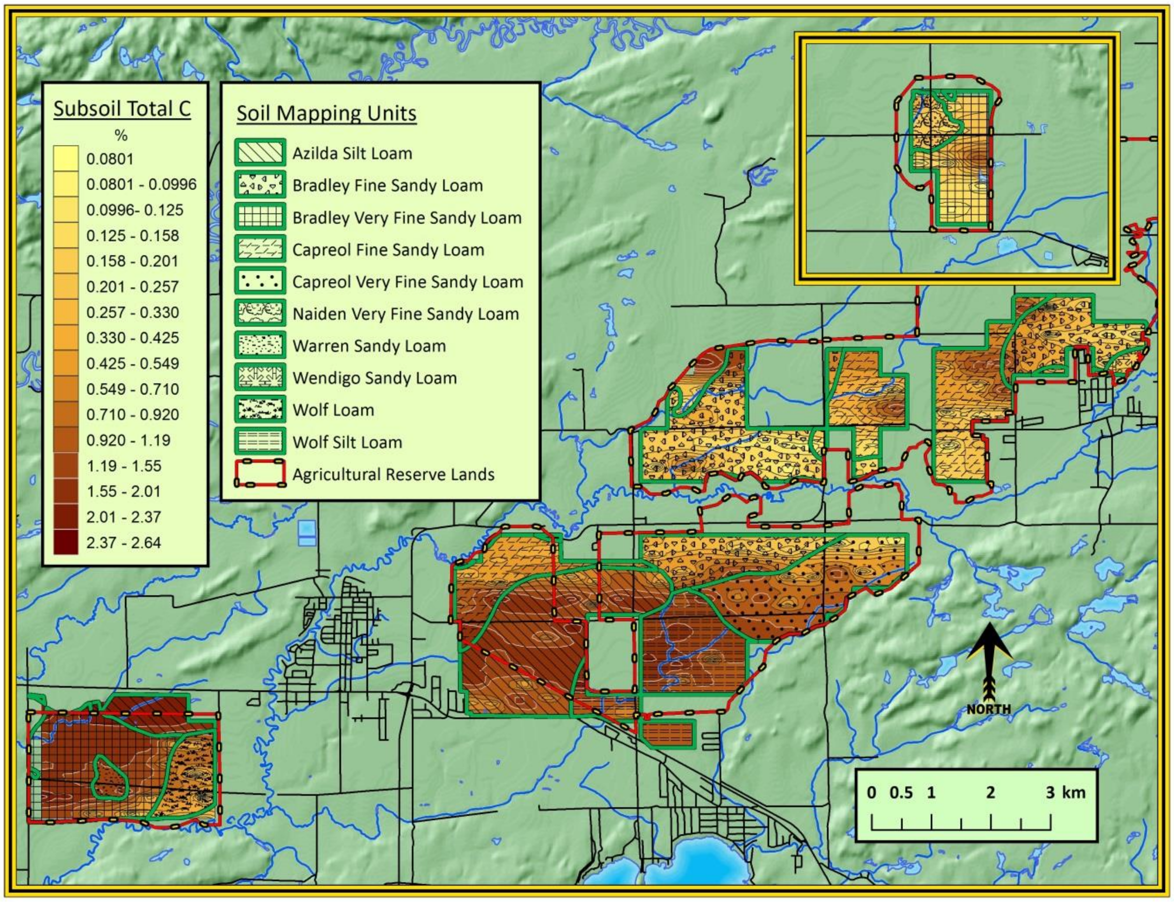


Figure 37. The predicted spatial distribution of subsoil (75-100 cm) Total C content (%) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve lands ( ) of the Greater City of Sudbury, ON (Scale 1:105,750).

Chapter 5

Discussion

In this study, analyzed soil health parameters (*i.e.* TS C, TS bulk density, TS C to N ratio, TS macro and micro nutrients) were found to vary according to the relative land management intensities of Dominant Land Uses in the study area. Results indicate that the studied Dominant Land Uses varied according to their land management intensities as follows: Topsoil Removed > Sod Production > Potato Rotation > Low Intensity = Intensive > Abandoned > Forested. The results from this study suggest that intensive land management practices in the region have led to decreased topsoil total C concentrations, increased bulk density, narrowed the soil C to N ratio, and increased total and available soil major nutrient levels, whilst triggering decreased micronutrient availability. Furthermore, in combination to contrasting soil health differences between Dominant Land Uses, predicted surfaces of soil properties, proved to be useful to highlight spatial patterns within the region of soil health properties influenced by local land use decisions.

5.1 Topsoil Carbon Variability along a Land Management Intensity Gradient

Across the region, cultivated soils were found to have less Total TS C (kg·ha-1) than the uncultivated soils designated in the Forested land use (see Table 2). The Abandoned, Low Intensity, Intensive, Topsoil Removed, Sod Production and Potato Rotation land uses were found to have lower Total TS C (kg·ha-1) than Forested soils by 8.2 %, 11 %, 11 %, 54 %, 42 % and 31 %, respectively. Similar findings are found throughout the literature. In a review of the scientific literature, Murty et al. 2002 found that Soil C loss as a result of cultivation was reported to be on average 30%. In Ontario, Ellert and

Gregorich (1996) examined the impact of cultivation on multiple soil types and found that, on average, soil cultivation decreased soil C by 34 % relative to the uncultivated equivalents. These results are in agreement with those of an earlier study carried out on soils in Ontario. Gregorich et al. (1995) found that Gleysols under cultivation lost 19 % soil C, with the observed differences in losses of topsoil C being associated with management intensity as suggested by the land use cover. Also in this study, a decrease in topsoil C was observed for studied dominant land uses having more intensive land management practices.

The Sod Production and Topsoil Removed land uses were both found to have lowest amount of Topsoil C, a reflection of their intensive management practices. In this study, both the Sod Production and Topsoil Removed land uses were considered the most intensive since they involved the mechanical removal of an unknown and variable quantity of stable organic-rich topsoil material from the impacted landscapes. Studies that have quantified the amount of soil loss under the Sod Production and Topsoil Removal management systems have equated the rate of topsoil loss to be equivalent to extreme erosion rates, and considered these rates to be unsustainable over the long-term (Millar *et al*. 2010; Izurralde *et al*. 2006). The Potato Rotation land use provides a good comparison of the management intensity of Sod Production, especially given that the majority of the sampled sites were in close proximity and on similar soil types. The median Topsoil C difference between Potato Rotation land uses and that for Sod Production, was found to be 16 %. Unlike Potato Rotation, Sod Production does not have detailed research data to suggest the long term sustainably of the management practice. The results of this study indicate, for the first time in Ontario soils, a severe decline in Soil C as a result of Sod Production.

Soils under the Potato Rotation land use were also found to have less Total TS C by 9% in comparison to the average of other active land uses. A range of other studies have also found that Potato Rotation tends to result in a reduction in Soil C contents as a result of a greater frequency of tillage, a deeper incorporation of organic matter, lower inputs of crop residues, all coupled with a heavy reliance on chemical fertilization (Balesder *et al*. 2000; Stark and Porter, 2005). Further, the lower Total TS C of the Potato Rotation found in this study reflect the favored soil texture for the management practice, being common on the sandier soil types of the Agricultural Reserve lands. Land use change on coarser soils under intensive management is more susceptible to soil C loss than those of finer texture (Arevalo *et al*. 2009). Conservation management practices are well studied for the Potato Rotation Land use, and have been shown to be improve soil C levels over the long-term. Land use planning in the area must consider the narrow range of soil types in the region in which Potato Rotation land uses dominates, and protect the limited resources of suitable land. The future protection of this land will allow land managers to adopt lengthier and more sustainable conservation practices (Angers *et al*., 1999; Carter and Sanderson, 2001).

The most intensive land uses, Topsoil Removed, Sod Production and Potato Rotation, (*i.e.* having median topsoil C of 1.31 %, 1.51 % and 1.83 %) were found to all have lower topsoil C than the regional median value of 2.42 % (*or* 5355 $kg \cdot ha^{-1}$). If one only considers active land uses (*i.e.* Low Intensity, Intensive, Sod Production and Potato Rotation) and excludes the Forested and Abandoned land use within the region, the regional mean of Total TS C was approximately 1.94% (*i.e.* 4807 $kg \cdot ha^{-1}$). These results are in agreement with the early study by Ketcheson (1980) which concluded that soils in southern Ontario under cultivation tended equilibrate around 2 % soil C, with variation being related to management practices. Given the long-term Soil C response to land use change, this quantifiable property has been shown to be an accurate indicator of sustainable management practices (Pulleman *et al*. 2000). The complexity in developing critical thresholds for Soil C spanning different land uses and soils types over large regions is important to recognize (Loveland and Webb, 2003). Wilson *et al.* (2008) state that the development of such a critical threshold should take into consideration detailed local data and be based on expected Soil C ranges for an intended land use. Future studies will thus likely benefit from the findings of the current study in developing critical thresholds specific for the Agricultural Reserve.

The Abandoned land use category, when compared to other active land uses currently under cultivation, was found to have higher levels of Total TS C. Further, when Total TS C (%) was corrected for Bulk Density, the Abandoned land use cover was found to not be significantly different than the Forested land use. These findings may possibly be explained by the accumulation of soil C in the surface humus form as a result of natural succession of woody vegetation. With the cessation of cultivation, research has elsewhere documented an increase in soil C content following land abandonment (Knops and Tilman, 2000). In a study of chronosequences of multiple fields of three soil types in Ontario following agricultural abandonment , Foote and Grogan (2010) hypothesised that, from current trends, the majority of C sequestration on these lands will occur within 100 years of abandonment.

5.2 Bulk Density Variability along a Land Management Intensity Gradient

Differences in TS bulk density were also best explained by relative management intensities in the land management units, and coincided to the observed trends found for Total TS C. The more intensive land uses which had less Total TS C were also found to have greater TS bulk densities (see Table 3). Therefore, our data suggests that compaction is occurring as a result of increased land use intensity, observations similar to those of Coote and Ramsay (1983) in their study of soils under different land use intensities in the Ottawa, Ontario region. These increases in TS bulk density are likely a result of management practices such as intensive cultivation, heavy vehicular traffic, livestock trampling and the timing of harvesting for root crops while soil moisture levels are at, or near, field capacity (Batey, 2009). Other studies have highlighted the importance of maintaining soil C to reduce the soil susceptibility to compaction (Thomas *et al*., 1996). When assessing soil health, bulk density can be used as a proxy to estimate soil structure and strength affecting plant growth (Chang, 2005). Soane (1990) stated that improved physical conditions caused by greater amounts of organic matter is a result of the aggregation of primary particles, the resistance of peds to deformation, and the increased ped elasticity which effectively creates a rebound effect under compressional forces.

Spatial patterns found when comparing the predicted surfaces of Total TS C to that of TS bulk density were agreed with the findings of individual land use comparisons, and supported the study hypothesis that land use intensity influences soil properties at the regional scale. Areas which had greater TS bulk density were found to have lower Total TS C. As TS bulk density responds readily to management practices, it has shown to be useful as a short-term indicator of soil health (Pulleman *et al*., 2000). The development of local or land use specific critical thresholds with respect to TS bulk density as an indicator of soil compaction, and therefore soil health, must take into account expected ranges of soil C, water content and texture in the region (Diaz-Zorita and Grosso, 2000).

An analysis of the expected ranges for TS bulk density and Total TS C for individual land uses indicated that Topsoil Removed sites sampled during this study have probably not had sufficient rehabilitation efforts to promote the recovery of agro-ecosystem functions. When describing guidelines to achieve the successful rehabilitation of sites adversely affected by Topsoil Removed, Hart *et al.* 1999 indicated these soils should not have TS bulk density any greater than 1.3 $g \cdot cm^{-3}$. In the current study, the range in TS bulk density values for all sites sampled under the Topsoil Removed land use were well above this threshold, ranging from 1.39 – 1.70 $g \cdot cm^{-3}$.

5.3 C to N Ratio Variability along a Land Management Intensity Gradient

The more intensive land uses in comparison to the least intensive land uses of the region were also found to have narrower C to N ratios (see Table 5). For instance, with a median C to N ratios of 17.0 and 14.7, the Forested and Abandoned land uses were found to have a significantly wider C to N ratio than the Potato Rotation and Sod Production lands with median values of 12.4 and 13.2. A narrowing of C to N ratios previously found in another study in southern Ontario was linked to greater losses of Soil C in comparison to Soil N (Foote and Grogan, 2010). When studying different soils across Ontario, Ellert and Gregorich (1995) suggest that the narrowing of C to N ratio in cultivated soils could be a result of greater losses of C due the preferential maintenance of soil N levels using chemical fertilizers, manure and legumes. When comparing findings for the Forested land use to other land uses, the observed differences between Total TS C and TS Total N were less pronounced, possibly indicating a similar preferential maintenance effect as suggested by Ellert and Gregorich (1995). The only land use found to have significantly less TS Total N than Total TS C was Sod Production, reflective perhaps of a greater loss of stable soil organic matter during the regular harvesting of sod which impacts the soils inherent ability to maintain TS Total N levels.

The spatial distribution of C to N ratio agrees with the expected differences along the land use intensity gradient within the Sudbury region. Areas found to have greater tree litter had greater amounts of soil C in comparison to soil N. When the predicted surface of Total TS C (see Figure 13) is compared to C to N Ratio (see Figure 16), areas having the Forested and Abandoned land uses are found to have both greater Total TS C and wider C to N ratios. Areas having cultivated soils as the active land uses had narrower predicted C to N ratios. The observed wider C to N ratio for the Forested and Abandoned land uses is likely a reflection of reduced litter quality common to coniferous vegetation (Wilson *et al*. 2011). These results might also partially explain the greater amounts of Total TS C for both the Forested and Abandoned land uses, with the wider C to N ratio creating conditions favorable for accumulation of soil C as a result of slower litter decomposition rates. For this reason, C to N ratios has been commonly proposed throughout the literature to be a suitable soil health indicator to predict soil structure and nutrient supply thresholds of soil systems (Allen et al., 2011).

5.4 Soil Major Nutrients Variability along a Land Management Intensity Gradient

The fertilization intensities of the studied land uses are likely reflected in the differences observed for TS Total K and TS Total P. TS Total K (kg·ha^{-1}) values were found to be significantly lower in Forested land uses in comparison to those of Low Intensity, Intensive, Topsoil Removed, Sod Production and Potato Rotation by 19 %, 20 %, 44 %, 31 % and 32 % respectively. Furthermore, both the Sod Production and Potato Rotation land uses were found have significantly greater TS Total K than the Low Intensity, Forested and Abandoned land uses, with similar trends being noted for TS Total P. The Potato Rotation land use was found to have significantly greater TS Total P than all other land uses, perhaps reflective of the high fertilizer applications under this management practice. This observation supports the findings of MacLean (1964) who documented an accumulation of P on Podzolic soils under a Potato Rotation land use. The Intensive land use was found to have significantly greater TS P than the Low Intensity, Forested and Abandoned land uses. Although these findings of accumulation of major nutrients as a result of intensive fertilization are far from novel, they do support the hypothesis that the considerable variability of regional soil properties is controlled by land use intensity. For instance, Soil P accumulates under intensive management practices because 70-90% of applied fertilizer P may react with soil constituents to form insoluble compounds (Fageria, 2009).

The predicted surface of TS Available K (Figure 19) and TS Total K (Figure 20) also supports the observation that models provide enough detail to highlight between-field variation. The area under the Low intensity land use (*i.e.* pasture) in the south-central region of the study area along Bonin Rd. is a visible K-level anomaly. This anomaly is likely the result of nutrients being exported to this local ungulate farming operation through the transportation of culled potatoes for feed for livestock.

5.5 Soil Micro Nutrients Variability along a Land Management Intensity Gradient

The findings in this study suggest that the removal of stable organic matter from the study area is effectively reducing the micronutrient levels in the soils, with the observations relating TS Total and Available Cu levels to those of TS Total C and the reduced soil health caused by the Topsoil Removal land use. With a greater binding affinity to soil organic matter, Cu is commonly more concentrated in the Topsoil than within subsoil (Fageria, 2009). For both observed Cu variables, the Topsoil Removed land use was the only land use to be significantly lower than those measured for the Forested land use which was found to have less Available and Total Cu (41 % and 47 %, respectively). Further, Sod Production was found to have significantly reduced Total Cu in comparison to the Forested soils of the region (by 33%). When compared to the Potato Rotation land use, Sod production was found to have 29 % and 34 % lower TS Available and Total Cu, respectively. Multiple hypotheses could partially explain these differences of soil Cu between the Potato Rotation land use and the Sod Production land use. Either copper is being lost as a result of the removal of soil C and/or the presumed use of copper-based fungicides in Potato Rotations has caused a build-up of Cu in soil. Visible similarities are noted when the predicted surface of Total TS C to those of Total TS Ni and Total TS Cu. The levels of measured TS Total Ni support the Cu results as soil Ni, the divalent ion with the second greatest affinity to organic matter, tends to accumulate in the organic rich layers (Fageria, 2009). The predicted TS Ni surface superimposed by Dominant Land Use Cover can be found in Appendix A.

Soil pH variation in surface soils was found to reflect variability in Topsoil Available Mn. As a direct result of removing the upper horizons and exposing the more alkaline underlying horizons, the Topsoil Removed land use was found to have significantly decreased TS Available Mn in comparison to all other land uses. Both the Dominant Land Use comparisons and observed patterns within the predicted surface of TS Available Mn coincide to those of TS pH_{H20}. This increased availability of Mn has been associated to the increased solubility of Mn compounds under acidic conditions (Fageria, 2009).

5.6 Land Use Decisions as affected by Soil Type and Soil Drainage

The findings of this study suggest that soil type and topography are influencing results obtained for Total TS C and local land use decisions. The inherent soil textures of the Azilda SiL and Wolf SiL Series are significantly finer and have greater amounts of Total TS C in comparison of all other soil types studied. Foote and Grogan, (2010), in their study of Ontario soils, found finer textured soils are less susceptible to soil C loss. In addition, with a visual comparison of Figure 13 depicting the predicted surface of Total TS C (%) superimposed by the Dominant Land Use Cover and Figure 8 depicting the digital elevation model of the study area superimposed with drainage features predict Total TS C is controlled by local topography and soil internal drainage. The greater amounts of Total TS C in close proximity to drainage features and low-lying areas support the accumulation of Soil C because of slower organic matter decomposition rates under wetter soil conditions. Poor internal soil drainage is also probably influencing the spatial distribution of land use decisions, with low-lying areas being either left in the Forested land use or Abandoned land categories. The Azilda SiL and Wolf SiL Series, classified as poorly drained soils (Figure 4; Gillespie *et al*., 1982), were also found to have a good proportion of their land area in the Forested and Abandoned land use classes.

Further improvements to the information provided by this database should include a spatial analysis of land use change across the study area as related to soil properties, landscape drainage features and topography, perhaps using the study by Flinn *et al*. 2005, who examined the geographic distributions of Forested and Abandoned land uses in relation to their soil properties, topography, site drainage and road infrastructure as a guide. Since land managers avoided and abandoned less favorable lands (*i.e*. Forested), this study (Finn et al., 2005) found that topography and soil properties were the leading influences of land use decisions that dictated the spatial distribution of both land use types. Soil drainage was also shown to influence the degree of agricultural abandonment because of the onset of negative effects of forest clearing and ploughing on inherently wet soils (Flinn *et al*. 2005). Development of an information database concerning land avoidance and land abandonment should prove useful for guiding the future expansion of the Agricultural Reverses to include additional prime lands.

Furthermore, expected significant differences between the Low intensity and Intensive land uses were not observed within the Sudbury study area. The lack of observed differences in this study may, in part, be a reflection on the lack of long-term land management history data for analysis and incorporation into the database. The Intensive and Low intensity cropping systems had a median Topsoil C (5600 $kg{\cdot}ha^{-1}$ and 5622 $kg{\cdot}ha^{-1}$, respectively) slightly above that of the regional median (5355 $kg{\cdot}ha^{-1}$). Other studies have provided short questionnaires to property owners and used sequential aerial photographs to develop long-term land management history for individual sites to improve predictive capacities (Fensham and Fairfax, 2003). Further, given that local knowledge is frequently lost with time, the availability of aerial photographs over the last several decades would provide an additional tool to improve historical information in the current study database.

5.7 Land Use Variability

Topsoil Removal was found to have the greatest variability overall in measured and inferred soil properties in this study, having the greatest CV values for all of: TS Total C ($mg{\cdot}kg^{-1}$), TS Total N ($mg{\cdot}kg^{-1}$), TS C to N ratio, TS Available P ($mg{\cdot}kg^{-1}$), TS Total K ($mg{\cdot}kg^{-1}$), TS Total Cu ($mg{\cdot}kg^{-1}$) and TS Total Mn ($mg{\cdot}kg^{-1}$). The degree to which conditions varied is likely reflecting the wide geographic distributions across the study area over different soil types, the depth to which topsoil has been mined, the minimal application of site rehabilitation practices, and the degree of natural site succession over time. A practical application of these results indicates that there is a need for future studies to be carried out to evaluate the success of different reclamation strategies of these lands affected by Topsoil Removal to include a broad range sites.

Overall, the Potato Rotation and Intensive land uses were found to be the least variable for all measured and calculated soil health parameters. These land uses had fewer producers, thus employing similar management practices over a narrow geographic extent containing only a few soil types. These results further highlight the necessity to preserve the critical soil types in the Sudbury region that meet the narrow ‘operating range’ of soil properties needed to produce potatoes and support the viability of the industry.

The Low Intensity land use was the active land use to have the greatest variability between sites, having the highest CV value in comparison to other active land use for the following soil parameters: TS N ($mg \cdot kg^{-1}$), TS C to N Ratio, TS Total P ($mg \cdot kg^{-1}$), TS Available K ($mg \cdot kg^{-1}$), TS Total K ($mg \cdot kg^{-1}$), TS Total K ($mg \cdot kg^{-1}$),TS Total Zn ($mg \cdot kg^{-1}$), TS Available Mn ($mg \cdot kg^{-1}$) and soil pH. The observed results likely varied due to differing management practices (*i.e.* pasture versus forage grassland, differences in fertilization, forage species composition). Further, the Low Intensity land use management practices are able to utilize more marginal lands over all soil types found within the broad study area.

As expected, Forested sites were also found to vary considerably over the study area, perhaps a reflection of the wide geographic distribution and variety of vegetation communities observed. The greater variability of TS Total C for both the Forested and Abandoned land uses also supports the hypothesis that site conditions are found across a greater range of soil moisture regimes in comparison to those found with other land uses.

Conclusion

A better understanding of the variability of regional soil properties on prime agricultural land will improve our ability to manage and protect these finite resources. The findings of this study indicate that land management intensity is an important factor controlling, and perhaps modifying, the variability regional soil properties. The current study is the first in the Sudbury region to demonstrate that soil properties coincide to a land management intensity gradient. Land uses under intensively managed cropping systems in the region tended to reduce TS Total C, increase TS ρbulk, narrow TS C to N ratios and maintain greater major nutrient stocks as result of the application of chemical fertilizers. Also, nutrient content was shown to be negatively affected by removal of topsoil from previously farmed agricultural soils. The usefulness of the data obtained during this study to provide the necessary information to assist in the development of soil rehabilitation guidelines for these severely depleted soils under the Topsoil Removed land use is two-fold. Firstly, the study identifies sites specific soil characteristics that are likely adversely affecting the fertility of these sites and, secondly, the data provides benchmarks for site rehabilitation to other suitable agricultural land uses within these protected lands. Soil nutrient availability and physical property improvement will be required to enable the return of sites under the Topsoil Removed land use to productive agricultural soil uses.

Future analysis of the dataset should aim to improve our understanding to enable sound land management decisions. Preliminary evidence suggests that the fine soil textures of the Azilda SiL and Wolf SiL and local drainage patterns have created unfavorable land management requirements and physical soil conditions resulting in land avoidance and abandonment. Furthermore, contrary to initial predictions, few differences were found between the Intensive and Low Intensity land uses. The incorporation of long-term management history of the subject land-base to the database would improve land use comparisons. Finally, detailed soil profile comparisons will greatly enhance our ability to more precisely predict soil behavior under contrasting land use demands.

To conclude, land use intensification will likely be magnified over time as a result of regional pressures such as increased demand for healthy local produce by an ever expanding local population, rising oil prices and urban sprawl. A better understanding the effects of intensive agricultural practices on soil properties will improve societal ability to sustain these finite resources. At the farm scale, information from this study will hopefully aid in the development of local management strategies and conservation techniques. From a land usplanning perspective, the provided information will help identify other regionally significant soils to protect. The improved protection of these prime agricultural soils would then help alleviate negative effects of land use intensification by increasing land availability, especially important given the predicted improvement in growing degree days with the current climate warming trends.

Reference

Abedin, J. Beckett, P., Spiers, G. 2012. An Evaluation of Extractants for Assessment of Metal Phytoavailability to Guide Reclamation Practices in Acidic Soilscapes in Northern Regions. *Canadian Journal of Soil Science* 92: 253-268.

Acton, D.F., Gregorich, L.J. 1995. Chapter 1 – Understanding Soil Health *In: The Health of Our Soils: Towards Sustainable Agriculture in Canada*. Publication 1906/E. Centre for Land and Biological Research, Research Branch, Agriculture and Agri-Food Canada (Acton, D.F., Gregorich L.J. Eds.).

Akumu, C.E., McLaughlin, J.W. 2013. Regional Variation in Peatand Carbon Stocks Assessments, Northern Ontario, Canada. *Geoderma* 209-210: 161- 167.

Allen D.E., Singh, P.B., Dalal, R. C. 2011. Soil Health Indicators under Climate Change: A Review of Current Knowledge In: *Soil Health and Cimate Change* (Singh, B.P., Cowie, A.L., Chan, K. Y. Eds.) Springer, p. 25-45.

Anderson, D.W., Scott Smith, C.A. 2011. A History of Soil Classification and Soil Survey in Canada: Personal Perspectives. *Canadian Journal of Soil Science* 91: 675-694.

Angers D.A., Edwards, L.M., Sanderson, J.B. Bissonnette, N. 1999 Soil Organic Matter Quality and Aggregate Stability Under Eight Potato Cropping Sequences in a Fine Sandy Loam of Prince Edward Island. *Canadian Journal of Soil Science* 79: 411-417.

Agricultural Economics Research Council of Canada, 1979. Potentials for Agricultural Development in the Sudbury Regional Municipality, Ottawa, ON.

Arevalo, C. B. M., Bhatti, J. S., Chang, S. X., Sidders, D. 2009. Ecosystem Carbon Stocks and Distribution under Different Land-Uses in North Centreal Alberta, Canada. *Forest Ecology and Management* 257: 1776-1785.

Barnett, P.J., Bajc, A.F. 2002. Quaternary Geology In: *The Physical Environment of the Greater City of Sudbury, Ontario Geological Survey Special Volume 6* (Rousell, D.H., Jansons K.J. Eds.), p. 57-85.

Batey, T. 2009. Soil Compaction and Soil Management – a Review. *Soil Use and Management* 25: 335-345.

Balester, J., Chenu, C., Balabane, M. 2000. Relationship of Soil Organic Matter Dynamics to Physical Protection and Tillage. *Soil & Tillage Research* 53: 215-230.

Beckett, P.H. T., Webster R. 1971. Soil Variability: A Review. *Soils and Fertilizers* 34: 1- 15.

Bedard-Haughn, A. 2011. Gleysolic Soils of Canada: Genesis, Distribution and Classification, *Canadian Journal of Soil Science* 91: 763-779.

Bélanger, R. 1949. Région Agricole Sudbury-Nipissing. La Société Historique du Nouvel-Ontario, Collège du Sacré-Cœur, Sudbury, ON.

Bissonette, N., Angers, D.A., Simard, R.R., Lafond, J. 2001. Interactive Effects of Management Practices on Water-Stable Aggregation and Organic Matter of a Humic Gleysol. *Canadian Journal of Soil Science* 81: 545:551.

Bolinder, M.A., Angers, D.A., Dubuc, J.P. 1997. Estimating Shoot to Root Ratios and Annual Carbon Inputs in Soils for Cereal Crops. Agriculture, Ecosystems and Environment 63: 61-66.

Bolinder, M.A., Angers, D.A., Bélanger, G., Michaud, R., Laverdière, M.R. 2002. Root Biomass and Shoot to Root Ratios of Perennial Forage Crops in Eastern Canada. *Canadian Journal of Plant Science* 82: 731-737.

Bolinder, M.A., Janzen, H.H., Gregorich, E.G., Angers, D.A., VandenBygaart, A.J. 2007. An Approach for Estimating Net Primary Productivity and Annual Carbon Inputs to Soil for Common Agriculture Crops in Canada. Agriculture, Ecosystems and Environment 118: 29-42.

Bouma, J. 2001. The Role of Soil Science in the Land Use Negotiation Process. *Soil Use and Management* 17: 1-6.

Bouma, J., van Lanen, H.A.J., Breeuwsma, A., Wosten, H.J.M., Kooistra, M.J. 1986. Soil Survey Data Needs When Studying Modern Land Use Problems. *Soil Use and Management* 2: 125-130.

Bouma, J., Finke, P.A. 1993. Origin and Nature of Soil Resource Variability In: *Soil specific crop management* (Robert, P.C., Rust, R.H., Larson, W.E. Eds.) ASA.CSSA-SSA, Madison, USA

Bradley, B. (2010, 10 October). Azilda Land Owners Win Ontario Municipal Board Ruling. Sudbury Northern Life Available at http://www.northernlife.ca/news/localNews/ 2010/10/ laakso071010.aspx (Verified 6 March 2015)

Brady, N. C.,Weil, R. R. 2008. *The Nature and Properties of Soils*, 14th Ed. Prentice Hall. pp. 372, 840-844

Brannon, G.R., Hajek, B.F. 2000. Update and Recorrelation of Soil Surveys Using GIS and Statistical Analysis. *Soil Science Society of America* 64: 679-680.

Brus, D.J., De Gruijter, J.J., Breeuwsma, A. 1992. Strategies for Updating Soil Survey Information: A Case Study to Estimate Phosphate Sorption Characteristics. *Journal of Soil Science* 43: 567-581.

Bui, E. Soil Survey as a Knowledge System. *Geoderma* 120: 17-26.

Burwasser, G.J. 1979. Quaternary Geology of the Sudbury Basin area, District of Sudbury; Ontario Geological Survey, Report 181, 103p.

Carter, M.R. 1990. Relative Measures of Soil Bulk Density to Characterize Compaction in Tillage Studies on Fine Sandy Loams. *Canadian Journal of Soil Science* 70: 425-433.

Carter, M.R., Gregorich, E.G., Angers, D.A., Donald, R.G., Bolinder, M.A. 1998. Organic C and N Storage, and Organic C Fractions, in Adjacent Cultivated and Forested Soils of Eastern Canada. *Soil & Tillage Research* 47: 253-261.

Carter M.R., Sanderson, J.B. 2001. Influence of Conservation Tillage and Rotation Length on Potato Productivity, Tuber Disease And Soil Quality Parameters on Fine Sandy Loam In Eastern Canada. *Soil & Tillage Research* 63: 1-13.

Carter, M.R. 2002. Soil Quality for Sustainable Land Management Organic Matter and Aggregation Interactions that Maintain Soil Functions. *Agronomy Journal* 94: 38-47.

Carter M.R., Kunelius, H.T., Sanderson, J.B., Kimpinski, J., Platt, H.W., Bolinder, M.A. 2003. Productivity Parameters and Soil Health Dynamics under Long-Term 2 Year Potato Rotations in Atlantic Canada. *Soil & Tillage Research* 72: 153-168.

Carter, M.R., Gregorich, E.G. 2010. Carbon and Nitrogen Storage by Deep-Rooted Tall Fescue (*Lolium arundinaceum*) in the Surface and Subsurface Soil of a Fine Sandy Loam in Eastern Canada. *Agriculture, Ecosystems and Environment* 136: 125-132.

Carter M. R., Sanderson J.B., MacLoed, J. A. 2004. Influence of Compost on the Physical Properties and Organic Matter Fractions of a Fine Sandy Loam throughout the Cycle of a Potato Rotation. *Canadian Journal of Soil Science* 84: 211-218.

Carter, M. R., Peters, R.D.., Noronha, C., Kimpinski, J. 2009. Influence of 10 Years of Conservation Tillage on Some Biological Properties of a Fine Sandy Loam in the Potato Phase of Two Crop Rotations in Atlantic Canada. *Canadian Journal of Soil Science* 89: 391-402.

Canadian Digital Elevation Data, (1:50,000) [computer file]. 2000-2009. Natural Resources Canada, Ottawa, ON. Available FTP: ftp://ftp2.cits.rncan.gc.ca/pub/ geobase/official/cded/ [*Accessed on 5 March 2015*]

Canada Land Inventory, (1:50,000) [computer file]. 1998. Soil Capability for Agriculture, National Soil Database, Agricultural and Agri-Food Canada, Ottawa, ON. Available FTP: http://sis.agr.gc.ca/cansis/nsdb/cli/index.html [*Accessed on 5 March 2015*].

Chang, K. W. 2005. Bulk Density In: *Encyclopedia of Soil Science* 2nd Edition (Lal. R. ed.) CRC Press, Boca Raton, Fl. pp. 191

Chapman, L.J., Thomas, M.K. 1968. The Climate of Northern Ontario. Climatological Studies Number 6. Meteorological Branch, Department of Transport, Toronto, ON.

Charbonneau, P. 2003. Soil Loss during Sod Production In: Sod Production, Available at http://www.omafra.gov.on.ca/english/crops/facts/info_sodprod.htm (*Verified 4 March 2015*) *Ontario Ministry of Agriculture, Food and Rural Affairs*, Ottawa, ON.

Chisholm, P.S., Irwin, R.W., Acton, C.J. 1984. Interpretation of Soil Drainage Groups from Soil Taxonomy – Southern Ontario. *Canadian Journal of Soil Science* 64: 383 – 393.

COGS, 2008. City of Greater Sudbury Agricultural Reserve, Official Plan Designation. Available at http://www.greatersudbury.ca/content/dept_ies/documents/Appendix_Q%E2%80%93Land_Use_Statistics.pdf (Verified 4 March 2015). *Community & Strategic Planning Section*, *City of Greater Sudbury*, ON.

Cook, S.E., Corner, R.J., Grealish, G., Gessler, P.E., Chartres, C.J. 1996. A Rule-based System to Map Soil Properties. *Soil Science Society of America Journal* 60: 1893-1900.

Coote, D.R., Ramsey, J.F. 1983. Quantification of the Effects of Over 35 Years of Intensive Cultivation on Four Soils. *Canadian Journal of Soil Science* 63: 1-14.

Dambrine, E., Dupoey, J.-L., Laut, L., Humbert, L., Thinon, M., Beaufils, T., Richard, H. 2007. Present Forest Biodiversity Patterns in France Related to Former Roman Agriculture. *Ecology* 88: 1430-1439.

Davidson, E.A., Ackerman, L.L., 1993. Changes in Soil Carbon Inventories Following Cultivation of Previously Untilled Soils. *Biogeochemistry* 20: 161-193.

Dewees, D. N., Halewood, M. 1992. The Efficiency of the Common Law: Sulphur Dioxide Emissions in Sudbury. *The University of Toronto Law Journal* 42: 1-21.

Diaz-Zorita, M., Grosso, G. A. 2000. Effect of Soil Texture, Organic Carbon and Water Retention on the Compactability of Soils From Argentinean Pampas. *Soil & Tillage Research* 54: 121-126.

Dolle, M., Schmidt, W. 2009. Impact of Tree Species on Nutrient and Light Availability: Evidence from a Permanent Plot Study of Old-Field Succession. *Plant Ecology* 203: 273-287.

Droogers, P., Fermont, A., Bouma, J. 1996. Effects of Ecological Soil Management on Workability and Trafficability of a Loamy Soil in the Netherlands. *Geoderma* 73: 131-145.

Edwards, L.M., 1988. The Effects of Slop Position and Cropping Sequence on Soil Physical Properties in Prince Edward Island. *Canadian Journal of Soil Science* 68: 763-774.

Ellert, B. H., Bettany, J. R. 1995. Calculating of Organic Matter and Nutrients Stored in Soils Under Contrasting Management Regimes. *Canadian Journal of Soil Science* 75: 529-538.

Ellert, B.H., Gregorich, E.G. 1996. Storage of Carbon, Nitrogen and Phosphorus in Cultivated and Adjacent Forested Soils of Ontario. *Soil Science* 161: 587-603.

Environment Canada, 1972. Soil Capability Classification for Agriculture, Report No. 2, the Canada Land Inventory, Ottawa ON.

Environment Canada, 2012. Canadian Climate Normals 1981-2010 Station Data, Sudbury Station A. Ottawa, Ontario. http://climate.weather.gc.ca/climate_normals/results_e.html?stnID=4132&lang=e&StationName=sudbury&SearchType=Contains&stnNameSubmit=go&dCode=1&dispBack=1 [*Accessed on: 2 March 2015*]

Evans, L.J. 1980. Podzol Development North Of Lake Huron in Relation To Geology and Vegetation. *Canadian Journal of Soil Science* 60: 527-539.

Evans, L. J. 1982*a*. Characteristics of Some Loamy-Textured Podzols in Northeastern Ontario. *Canadian Journal of Soil Science* 62: 281-290.

Evans, L.J. 1982*b*. Cation Exchange Capacites and Surface Areas of Humic Gleysolic Ap Horizons From Southwestern Ontario. *Canadian Journal of Soil Science* 62: 291-296.

Evans, L. J., Cameron, B.H. 1983. The Brookston Series in Southwestern Ontario: Characteristics, Classification and Problems in Defining a Soil Series. *Canadian Journal of Soil Sciences* 63: 339-352.

Fageria, N.K. 2009. The Use of Nutrients in Crops, CRC Press, Boca Raton, Fl. pp. 91, 283, 336.

Fensham, R.J., Fairfax, R.J. 2003. A Land Management History for Central Queensland, Australia as determined from land-holder questionnaire and aerial photography. Journal of Environmental Management 68: 409-420.

Finke, P.A., Wosten, J.H.M. 1996. Effects of Uncertainty in Major Input Variables on Simulated Functional Soil Behavior. *Hydrological Processes* 10: 661-669.

Flinn, K. M., Velland, M., Marks, P. L. 2005. Environmental Causes and Consequences of Forest Clearance and Agriculture Abandonment in Central New York, USA. *Journal of Biogeography* 32: 439-452.

Foote, R.L., Grogan, P. 2010. Soil Carbon Accumulation during Temperate Forest Succession on Abandoned Low Productivity Agricultural Lands. *Ecosystems* 13: 795-812.

Fortin, M.C., Moon, D.E. 1999. Errors Associated with the Use of Soil Survey Data for Estimating Plant-Available Water at a Regional Scale. *Agronomy Journal* 91: 984-990.

Franzluebbers, A.J., Struedemann, J.A. 2009. Soil-Profile Organic Carbon and Total Nitrogen during 12 years of Pasture Management in the Southern Piedmont USA. *Agriculture, Ecosystems and Environment* 129: 28-36.

Gill, D.S., Marks, P.L. 1991. Tree and Shrub Seedling Colonization of Field in Central New York. *Ecological Monographs*: 61: 183-205.

Gillespie, J.E., Acton, C.J, Hoffman, D.W. 1982*a*. Soils of the Sudbury Area; Ontario Institute of Pedology, Soil Survey Report 49.

Gillespie, J.E., Acton, C.J, Hoffman, D.W. 1982*b*. Unpublished Report Soils of the Espanola-Sudbury Region Map Sheet 41I; Ontario Institute of Pedology, Soil Survey Report 49.

Goderya, F.A. 1998. Field Scale Variations in Soil Properties for Spatial Variable Control: A Review. *Journal of Soil Contamination* 7: 243-264.

Gregorich, E.G., Ellert, B.H., Monreal, C.M. 1995. Turnover of Soil Organic Matter and Storage of Corn Residue Carbon Estimated from Natural ^{13}C Abundance. *Canadian Journal of Soil Science* 75: 161-167.

Gregorich, E.G., Drury, C.F., Baldock, J.A. 2001. Changes in Soil Carbon under Long-Term Maize in Monoculture and Legume-Based Rotation. *Canadian Journal of Soil Science* 81: 21-31.

Gregory, A., Watts, C., Griffiths, B., Hallett, P., Kuan, H., Whitmore, A. 2009. The effect of long-term soil management on the physical and biological resilience of a range of arable and grassland soils in England. *Geoderma* 153: 172-185.

Grunzweig, J.M., Sparrow, S.D., Yakir, D., Chapin III, F.S. 2004. Impact of Agriculture Land-Use Change on Carbon Storage in Boreal Alaska. *Global Change Biology* 10:452-472.

Gunn, J. M. 1995. *Restoration and Recovery of an Industrial Region.* Springer-Verlag, New York. NY. pp. 47-67.

Izaurralde, R., Malhi, S., Nyborb, M., Solberg, E., Quiroga Jakas, M. 2006. Crop Performance and Soil Properties in Two Artificially Eroded Soils North-Central Alberta. *Agronomy Journal* 98: 1298-1311.

Harry Cummings and Associates, 2009. Blue Sky Region Agricultural Economic Sector Profile. Available at http://www.hcaconsulting.ca/pdfs/2009%20Blue%20Sky%20Region%20Agri %20 Economic%20Impact.pdf (*Verified 4 March 2015*).

Hart, P.B.S. West, A.W., Kings, J.A., Watts, H.M., Howe, J.C. 1999. Land Restoration Management after Topsoil Mining and Implications for Restoration Policy Guidelines in New Zealand. *Land Degradation & Development* 10: 435-453.

Heuvelink, G.B.M., Webster, R. 2001. Modelling soil variation: Past, Present, and Future. *Geoderma* 100: 269-301.

Hill, R.G.F. 1975. The Retention of Food Land in the Municipality of Sudbury. Economics Branch, Ontario Ministry of Agriculture and Food, Toronto, ON.

Hudson, B.D. 1992. The Soil Survey as Paradigm-based Science. *Soil Science Society of America Journal* 56: 836-841.

Indorante, S.J., McLeese, R.L., Hammer, R.D., Thompson, B.W., Alexander, D.L. 1996. Positioning Soil Survey for the 21st Century. *Journal of Soil and Water Conservation* 51: 21-30.

Izaurralde, R., Malhi, S., Nyborb, M., Solberg, E., Quiroga Jakas, M. 2006. Crop Performance and Soil Properties in Two Artificially Eroded Soils North-Central Alberta. *Agronomy Journal* 98: 1298-1311.

Jenny H. 1941. Factors of soil formation: a system of quantitative pedology. New York: McGraw Hill.

Kenny, E.A., Hall, J.W., Wang, C. 2002. Temporal Trends in Soil Properties at Soil Quality Benchmark Site in Lower Fraser Valley, British Columbia. *Canadian Journal of Soil Science* 83: 499-509.

Ketcheson, J.W. 1980. Long-Range Effects of Intensive Cultivation And Monoculture on Quality of Southern Ontario Soils. *Canadian Journal of Soil Science* 60: 403-410.

Knops, J.M.H., Tilman, D. 2000. Dynamics of Soil Nitrogen and Carbon Accumulation for 61 Years after Agriculture Abandonment. *Ecology*: 88-98.

Laganière, J., Angers, D.A., Paré, D., Bergeron, Y., Chen, H.Y.H., 2011. Black Spruce Soils Accumulate more Uncomplexed Organic Matter than Aspen Soil. *Soil Science Society of America Journal* 75: 1125–1132.

Lalande, R., Gagnon, B., Simard, R.R. 1998. Microbial Biomass C and Alkaline Phophatase Activity in the Two Compost Amended Soils. *Canadian Journal of Soil Science* 78: 581-587.

Lark, R.M., Ander, E.L., Cave, M.R., Knights, K.V., Glennon, M.M., Scanlon, R.P. 2014. Mapping Trace Element Deficiency by Cokriging from Regional Geochemical Soil Data: A Case Study on Colbalt for Grazing Sheep in Ireland. *Geoderma* 226-227: 64-78.

Larney, F., Izaurraulde, R., Janzen, B., Olson, B., Solberg, E., Lindwall, C., Nyborg, M. 1995. Soil Erosion – Crop productivity Relationship for Six Alberta Soils. *Journal of Soil and Water Conservation* 50: 87-91.

Laverdiere, M. R. 1982. Effects of Phosphorus Additions on the Charge Properties of a Podzolic B Horizon. *Canadian Journal of Soil Science* 62: 519 – 525.

Loveland, P., Webb, J. 2003. Is there a Critical Level of Organic Matter in the Agricultural Soils of Temperate Regions: A Review. *Soil & Tillage Research* 70: 1-18.

Lundstrom, U.S., van Breemen, N., Bain, D. 2000. The Podzolization Process: A Review. *Geoderma* 94: 91-107.

MacKay, D.C., Eaves, C.A. 1962. The Influence of Irrigation Treatments on Yields and on Fertilizer Utilization by Sweet Corn and Snap Peas. *Canadian Journal of Plant Science* 42: 219-228.

MacLeod, L.B., Suzuki, M. 1972. Effects of N, P, and K on Chemical Composition of Barley Grown on a Low-Fertility Podzol Soil in the Greenhouse. *Canadian Journal of Soil Science* 52: 169-177.

Malhi. S., Izaurralde, R., Solberg, E. 1994. Influence of Topsoil Removal on Soil Fertility and Barley Growth. *Journal of Soil and Water Conservation* 49: 96-101.

Martel, Y.A., Deschenes, J.M. 1976. Les Effets de la Mise en Culture et de la Prairie Prolongee sur le Carbone, l’Azote et la Structure de quelques Sols du Quebec. *Canadian Journal of Soil Science* 56: 373-383.

Martel, Y.A., MacKenzie, A.F. 1980. Long-Term Effects of Cultivation and Land Use on Soil Quality in Quebec. *Canadian Journal of Soil Science* 60: 411-420.

Mermut, A.R., Eswaran, H. 2001. Some Major Developments in Soil Science since the Mid-1960s *Geoderma* 100: 403-426.

McBratney, A.B., Mendonca, M.L., Minasny, B. 2003. On Digital Soil Mapping. *Geoderma* 117: 3-52.

McKeague, J.A., Wang, C., Topp, G.C., 1982. Estimating Saturated Hydraulic Conductivity from Soil Morphology. *Soil Science Society of America Journal* 46: 1239 – 1244.

McKeague, J.A., Topp, G.C., 1986. Pitfalls in Interpretion of Soil Drainage from Soil Survey Information. *Canadian Journal of Soil Science* 66: 37-44.

Millar, D., Stolt, M., Amador, J.A. 2010. Quantification and Implications of Soil Losses from Commercial Sod Production. *Soil Science Society of America Journal* 74: 892-897.

Miller, M. H. 1986. Soil Degradation in Eastern Canada: Its Extent and Impact. Unpublished Report. Department of Land Resources, University of Guelph.

Millette, G.J.F., Leger, R.G., Bailey, R.E. 1980. A Comparitive Study of Physical and Chemical Properties of Two Cultivated and Forested Orthic Podzols. *Canadian Journal of Soil Science* 60: 707-719.

Moeys, J. 2014. The Soil Texture Wizard: R Functions For Plotting, Classify, Transforming and Exploring Soil Texture Data. Web Page, [Accessed February 14 2014]. http://cran.r-project.org/web/packages/soiltexture/vignettes/soiltexture_vignette.pdf; Data, http://soiltexture.r-forge.r-project.org/

Murty, D., Kirschbaum, M.F., McMurtrie, R.E., McGilvray, H. 2002. Does Conversion of Forest to Agriculture Land Change Carbon and Nitrogen? A review of the Literature. *Global Change Biology* 8: 105-123.

Naeth, M.A., Archibald, H.A., Nemirsky, C.L., Leskiw, L.A., Brierley, J.A., Bock, M.D., VandenBygaart, A. J., Chanasyk, D.S. 2012. Proposed Classification For Human Modified Soils In Canada: Anthroposolic Orger. *Canadian Journal of Soil Science* 92: 7-18.

Oberthur, T. Dobermann, A., Neue, H.U., 1996. How Good is a Reconnaissance Soil Map for Agronomic Purposes? *Soil Use and Management* 12: 33-43.

OCCIAR, 2015. Historical Climate Trends for Sudbury, Ontario Available at http://www.climateontario.ca/doc/publications/datasheet_sudbury.pdf (*Verified 4 March 2015*), *Ontario Centre for Climate Impacts and Adaptation Resources*, Sudbury, ON

Oyedele, D., Aina, P. 2006. Response of Soil Properties and Maize Yield to Simulated Erosion by Artificial Topsoil Removal. *Plant & Soil* 284: 375-384.

Petersen, G.W., Nizeyimana, E., Miller, D.A., Evans, B.M. 2000. The Use of Soil Databases in Resource Assessment and Land Use Planning In *Handbook of Soil Science* (Sumner, M.E. Ed), CRC Press, Boca Raton, FL, pp. H70-H88.

Pulleman, M.M., Bouma, J., van Essan, E. A., Meijles, E.W. 2000. Soil Organic Matter Content as a Function of Different Land Use History. *Soil Science Society of America Journal* 64: 689-693.

Richter, D.D., Markewitz, D., Trumbore, S.E., Wells, C.G. 1999. Rapid Accumulation and Turnover of Soil Carbon in a Re-establishing Forest. *Nature* 400: 56-58.

Roddy, E. 2010. Climate Zones and Planting Dates for Vegetables in Ontario Available at http://www.omafra.gov.on.ca/english/crops/facts/climzoneveg.htm (*Verified 4 March 2015*) *Ontario Ministry of Agriculture, Food and Rural Affairs*, Ottawa, ON.

Rogowski, A.S., Wolf, J.K. 1994. Incorporating Variability into Soil Map Unit Delineations. *Soil Science Society of America* 58: 163-174.

Rousell, D.H., Meyer, W., Pervec, S.A. 2002. Bedrock Geology and Mineral Deposits In: The Physical Environment of the City of Greater Sudbury, Ontario Geological Survey, Special Volume 6, (Rousell, D.H., Jansons K.J. Eds.). pp. 20-55.

Salter, A.P. 1856. The Country Bordering Along the North Shore of Lake Huron, *Crown Lands Department*, Toronto, On

Sanborn, P., Lamontagne, L., Hendershot, W. 2011. Podzolic Soils of Canada: Genesis, Distribution and Classification. *Canadian Journal of Soil Science* 91: 843-880.

Schulp, C.J.E., Verberg, P. H., 2009. Effect of Land Use History and Site Factors on Spatial Variation of Soil Organic Carbon across a Physiographic Region. *Agriculture, Ecosystems and Environment* 133: 86-97.

Simard, R.R., Bates, T.E., Evans, L.J. 1988. Effects of $CaCO_3$ and P Additions on Corn (*Zea mays* L.) Growth and Nutrient Availability of Podzolic Soil. *Canadian Journal of Soil Science* 68: 507-517.

Simonson, R.W. 1959. Outline for Generalized Theory of Soil Genesis. *Soil Science Society of America Proceedings 23*: 152-156.

Simonson, R.W. 1978. A Multiple-Process Model of Soil Genesis. In *Quaternary Soil* (Mahaney, W.C. Ed.), Geo. Abstracts, University of East Aglia, England. pp. 1-25.

Simonson, R.W. 1991. The U.S. Soil Survey - Contributions to Soil Science and its Application. *Geoderma* 48: 1-16.

Soane, B.D. 1990. The Role of Organic Matter in Soil Compactability: A Review of Some Practical Aspects. *Soil Tillage & Research* 16: 179-201.

Soil Classification Working Group, 1998. The Canadian System of Soil Classification. Agriculture and Agri-Food Canada. Publication 1646 (Revised). 187 pp.

Stark, J.C., Porter, G.A., 2005. Potato Nutrient Management in Sustainable Cropping Systems. *American Journal of Potato Research* 82: 329-338.

Tan, X., Chang, S. Kabzems, R. 2005. Effects of Soil Compaction and Forest Floor Removal on Soil Microbial Properties and N Transformations in a Boreal Forest Long-Term Soil Productivity Study. *Forest Ecology and Management* 217: 158-170.

Thomas, G. W., Haszler, G. R., Blevins, R. L. 1996. The Effects of Organic Matter and Tillage on Maximum Compactibility of Soils Using the Proctor Test. *Soil Science* 161: 502-508.

Tiessen, H., Cuevas, E., Chacon, P. 1994. The role of soil organic matter in sustaining soil fertility. *Nature* 371: 783-785.

Tilman, D. 1987. Secondary Succession and the Pattern of Plant Dominance along Experimental Nitrogen Gradients. *Ecological Monographs* 57: 189-214.

Torn, M.S., Trumbore, S.E., Chadwick, O.A., Vitousek, P.M., Hendricks, D.M. 1997. Mineral Control of Soil Organic Carbon Storage and Turnover. *Nature* 389: 170-173.

van Vliet, L.J.P., Padbury, G.A., Rees, H.W., Matin, M.A., 2005. Water erosion. In: Lefebvre, A., Eilers, W.D., Chunn, B. (Eds.), Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series — Report #2. *Agriculture and Agri-Food Canada*, Ottawa, ON. pp. 90–96.

Valentine, K.W.G., Lidstone, A. 1985. Specifications for Soil Survey Intensity (Survey Order) In Canada. *Canadian Journal of Soil Science* 65: 543-553.

Vesterdal, L. Clarke, N., Sigurdsson, B.D., Gundersen, P., 2013. Do Tree Species Influence Soil Carbon Stocks in Temperate and Boreal Forests. *Forest Ecology and Management* 309: 4- 18.

Vogel, H., Vearasilp, T., Hoontrakul, K., Wattana, S., Bolsmann, D. 2001. Rapid Indicator Based Soil Mapping for Regional Planning in Northern Thailand In Sustaining the Global Farm. Selected Papers from the 10th International Soil Conservation Organization Meeting Held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory (Stott, D.E., Mohtar, R.H., Steinhardt, G.C. Eds.), pp. 961-965.

Wang, C., McKeague, J.A. 1986. Short-Range Soil Variability and Classification of Podzolic Pedons Along A Transect in the Laurentian Higlands. *Canadian Journal of Soil Science* 66: 21-30.

Wang, C. Rees, H.W., Daigle, J.L. 1984. Classification of Podzolic Soils Affected by Cultivation. *Canadian Journal of Soil Science* 64: 229-239.

Wang, C., Ross, G.J., Torrance, J.K., Kodama, H. 1991. The Formation of Podzolic B Horizons and Pedogenic Imogolite as Influenced by Microrelief within a Pedon. *Geoderma* 50: 63-77.

Wairiu, M., Lal, R. 2003. Soil Organic Carbon in Relation to Cultivation and Topsoil Removal on Sloping Lands of Kolombangara, Solomon Islands. *Soil & Tillage Research* 70: 19-27.

Webb, T.H., Lilburne, L.R. 2005. Consequences of Soil Map Unit Uncertainty on Environmental Risk Assessments. *Australian Journal of Soil Research* 43: 199-126.

White, E. (2012, 15 July). Sudbury Farmers Frustrated by Agriculture Preserve. *CBC*. Available at http://www.cbc.ca/news/canada/sudbury/sudbury-farmers-frustrated-by-agricultural-preserve-1.1266612 (Verified 6 March 2015)

Whitehouse, M. (2010, 28 September). Ministry backs down from Family. *The Sudbury Star* Available at http://www.thesudburystar.com/2010/09/28/ministry-backs-down-from-family (Verified 6 March 2015)

Wilding, L.P. 1985. Spatial Variability: Its Documentation, Accommodation and Implication to Soil Surveys In: *Soil Spatial Variability* (Nielsen, D.R., Bouma, J. Eds.), ISSS & SSSA, Wageningen, Netherlands

Wilson, B.R., Growns, I., Lemon, J. 2008. Land Use Effects on Soil Properties on the North-Western Slopes of New South Wales: Implications for Soil Condition Assessment. *Australian Journal of Soil Research* 46: 359-367.

Wilson, B.R., Koen, T.B., Barnes, P., Ghosh, S., King, D. 2011. Soil Carbon and Related Soil Properties Along a Soil Type and Land-Use Intensity Gradient, New South Wales, Australia. *Soil Use and Management* 27:437-447.

Wosten, J.H.M., Lilly, A., Nemes, A., Le Bas, C. 1999. Development and Use of a Database of Hydraulic Properties of European Soils. Geoderma 90: 169-185.

Wysocki, D.A., Schoeneberger, P.J., LaGarry, H.E. 2000. Geomorphology of Soil Landscapes In *Handbook of Soil Science* (Sumner, M.E. Ed), CRC Press, Boca Raton, FL, pp. E5-E39.

Appendix A

Additional Predicted Spatial Distribution

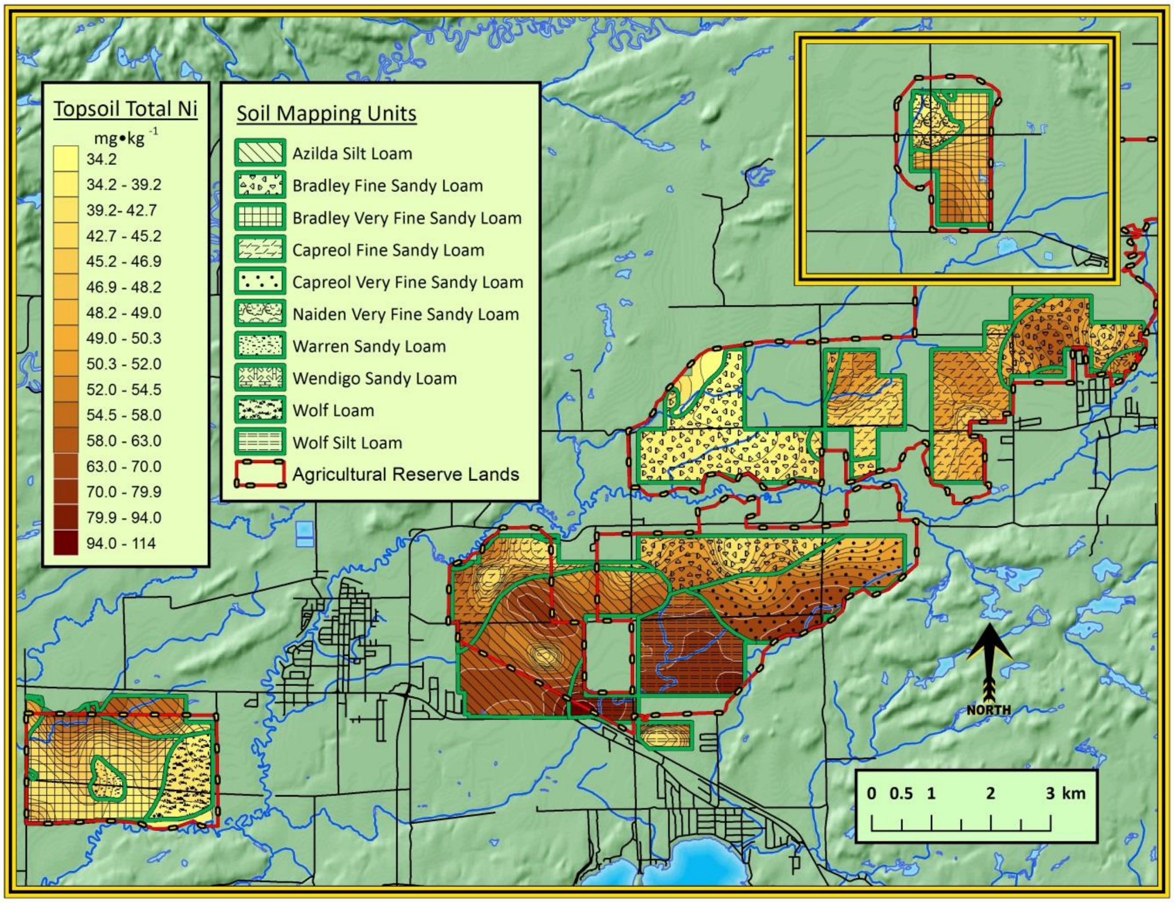


Figure A1. The predicted spatial distribution of Topsoil (0-20 cm) Total Ni (mg·kg^{-1}) in relation to soil series (Soil Mapping Units) within the Agricultural Reserve Lands ( ) of the Greater City of Sudbury, ON.

Appendix B

Method Reports and Prediction Errors

The following is a summary of parameters used to visualize the predicted surfaces of soil properties over the study area. If a parameter is not presented in the below tables then the default setting of the ArcGIS's Geostatistical Wizard was used. The accompanying standard error maps were classified using the Jenks Natural Breaks method with 16 classes.

Table B1. Method report for parameters used to create the predicted surface of Topsoil Total C (%) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total C (%)	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.06701498
Major Range	AUTO; 1194.071
Anisotropy:	FALSE
Partial Sill:	TRUE; 6.029602
Lag Size	213
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	9
Minimum Neighbors	5
Prediction Error	
Root Mean Square:	0.9635205
Mean Standardized	0.004542013
Root Mean Square Standarized:	0.9194414
Average Standard Error:	1.068759

Figure B1. Standard error map for predicted surface of Topsoil Total C (%). Darker reds indicate greater standard error.

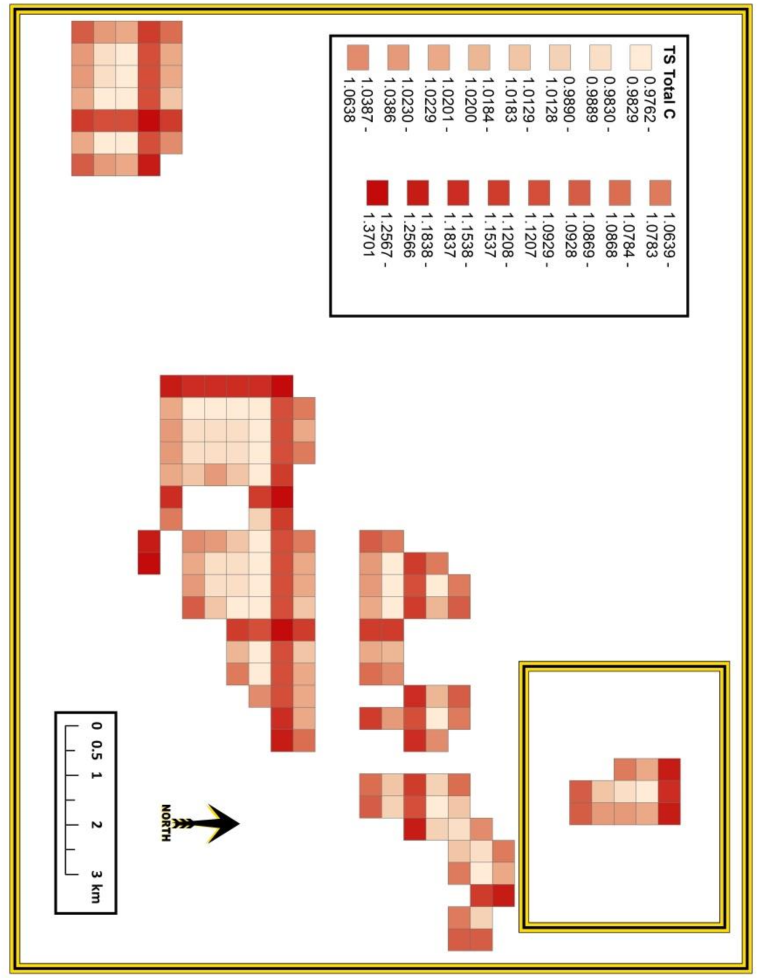


Table B2. Method report for parameters used to create the predicted surface of Topsoil Bulk Density (ρbulk; g·cm^{-3}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS ρbulk (g•cm^{-3})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0230824
Major Range	AUTO; 1216.586
Anisotropy:	FALSE
Partial Sill:	TRUE; 0.085692
Lag Size	213
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	11
Minimum Neighbors	6
Prediction Error	
Root Mean Square:	0.1103072
Mean Standardized	-0.007834544
Root Mean Square Standarized:	0.9457995
Average Standard Error:	0.1169524

Figure B2. Standard error map for the predicted surface of Topsoil Bulk Density (ρbulk; g·cm^{-3}). Darker reds indicate greater standard error.

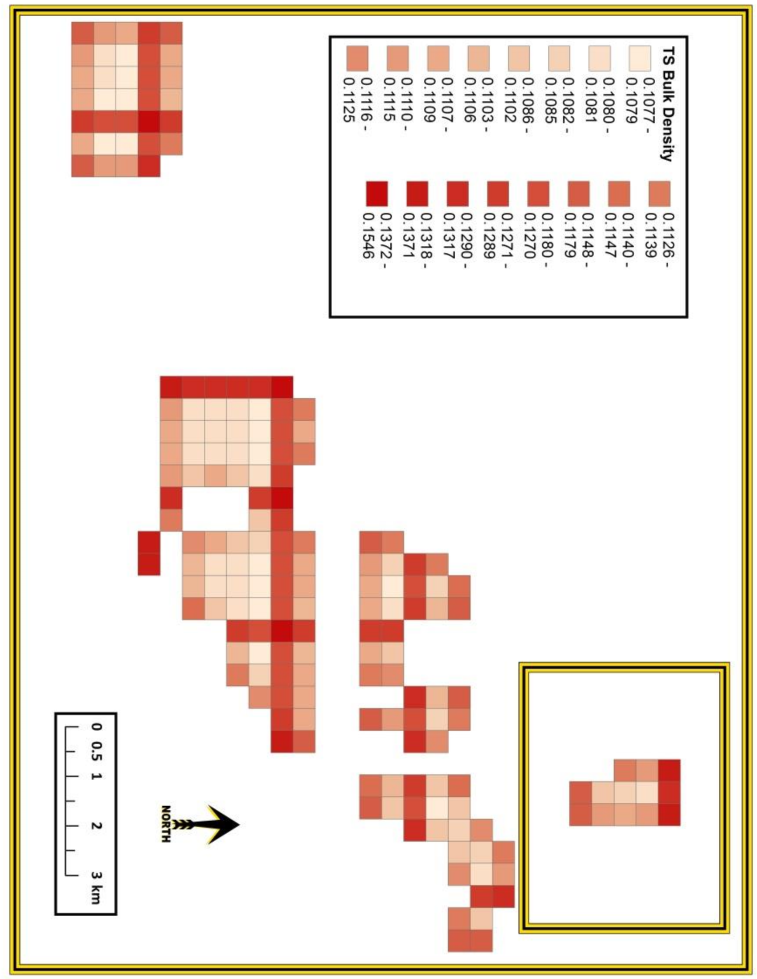


Table B3. Method report for parameters used to create the predicted surface of Topsoil Total N (%) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total N (%)	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.04693242
Major Range	AUTO; 770.356
Anisotropy:	FALSE
Partial Sill:	TRUE; 0.018221
Lag Size	241
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	14
Minimum Neighbors	6
Prediction Error	
Root Mean Square:	0.05270637
Mean Standardized	0.008560803
Root Mean Square Standarized:	0.9567769
Average Standard Error:	0.05469

Figure B3. Standard error map for the predicted surface of Topsoil Total N (%). Darker reds indicate greater standard error.

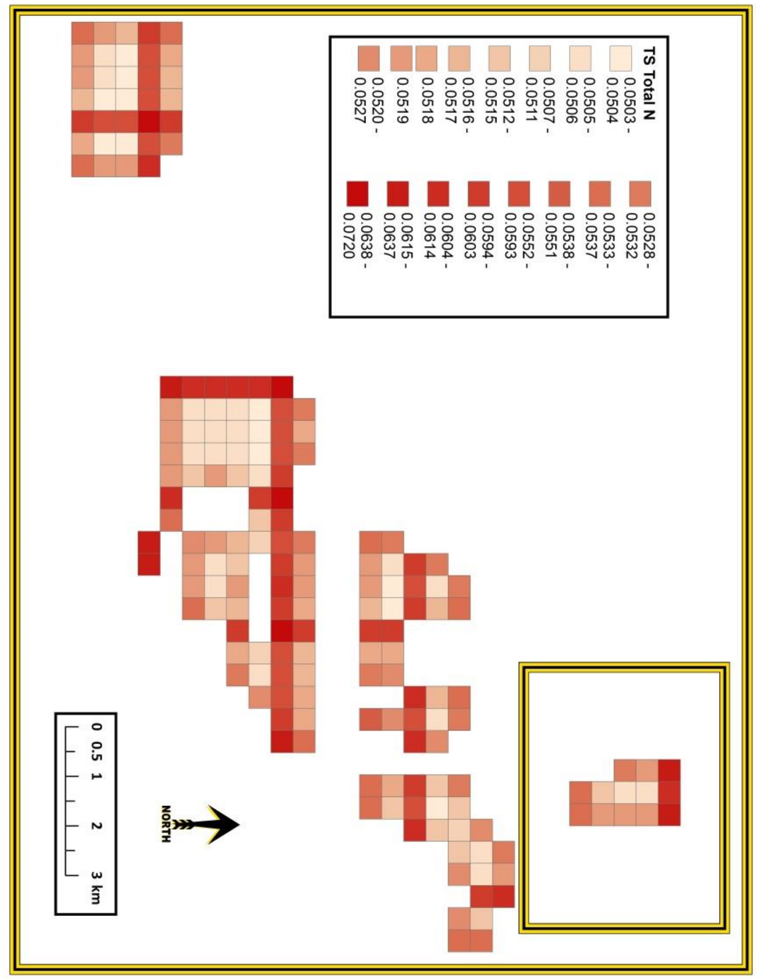


Table B4. Method report for parameters used to create the predicted surface of Topsoil C to N Ratio using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS C to N Ratio	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.2366047
Major Range	AUTO; 1349.658
Anisotropy:	FALSE
Partial Sill:	TRUE; 17.2619976
Lag Size	220
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	2.02424236
Mean Standardized	-0.005284706
Root Mean Square Standarized:	0.9859966
Average Standard Error:	2.026061

Figure B4. Standard error map for the predicted surface of Topsoil C to N Ratio. Darker reds indicate greater standard error.

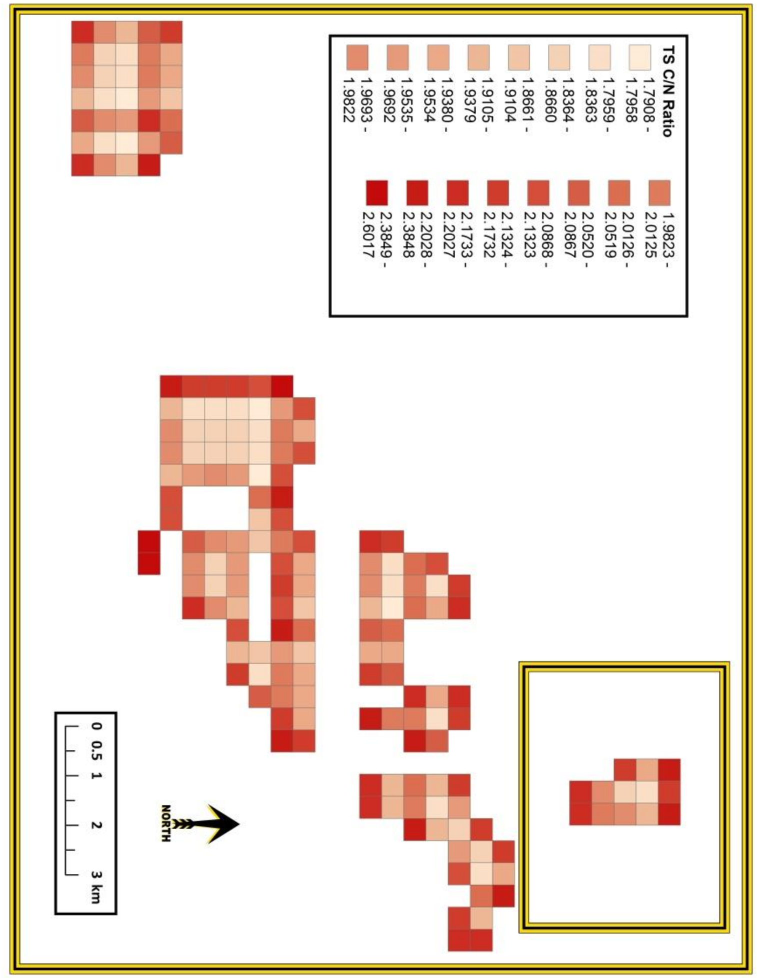


Table B5. Method report for parameters used to create the predicted surface of Topsoil Available P (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Available P (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.1333521
Major Range	AUTO; 918.277
Anisotropy:	FALSE
Partial Sill:	TRUE; 8.0737165
Lag Size	230
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	12
Minimum Neighbors	9
Prediction Error	
Root Mean Square:	1.359846
Mean Standardized	0.005523371
Root Mean Square Standarized:	1.009578
Average Standard Error:	1.342111

Figure B5. Standard error map for the predicted surface of Topsoil Available P (mg·kg^{-1}). Darker reds indicate greater standard error.

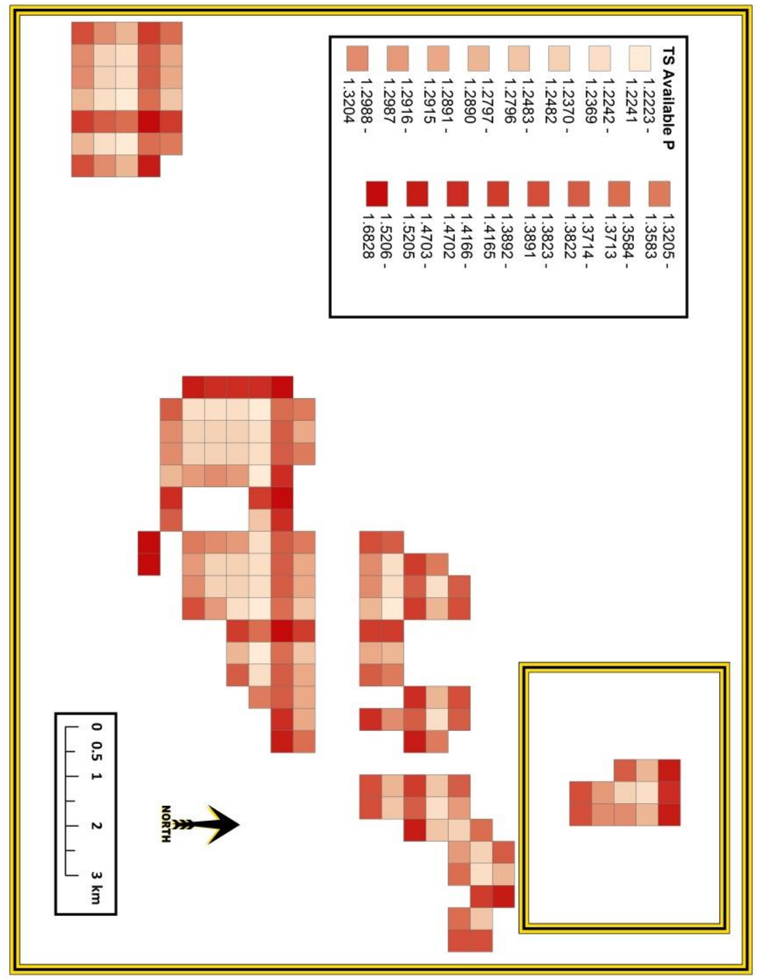


Table B6. Method report for parameters used to create the predicted surface of Topsoil Total P (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total P (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0312692
Major Range	AUTO; 330.9478
Anisotropy:	FALSE
Partial Sill:	TRUE; 31137.4
Lag Size	242
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	66.85125
Mean Standardized	0.00486262
Root Mean Square Standarized:	0.9896793
Average Standard Error:	69.00619

Figure B6. Standard error map for the predicted surface of Topsoil Total P (mg·kg^{-1}). Darker reds indicate greater standard error.

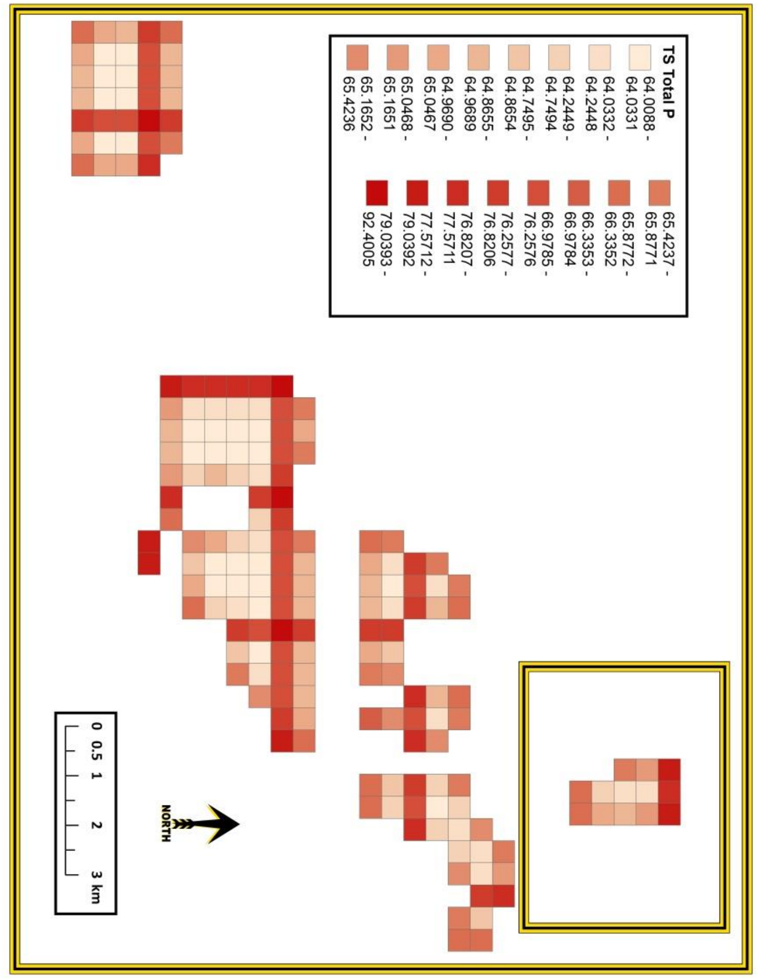


Table B7. Method report for parameters used to create the predicted surface of Topsoil Available K (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Available K (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0218697
Major Range	AUTO; 2516.911
Anisotropy:	FALSE
Partial Sill:	TRUE; 1172.742
Lag Size	232
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	13
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	10.88092
Mean Standardized	-0.01355422
Root Mean Square Standarized:	0.8341102
Average Standard Error:	13.44448

Figure B7. Standard error map for the predicted surface of Topsoil Available K (mg·kg^{-1}). Darker reds indicate greater standard error.

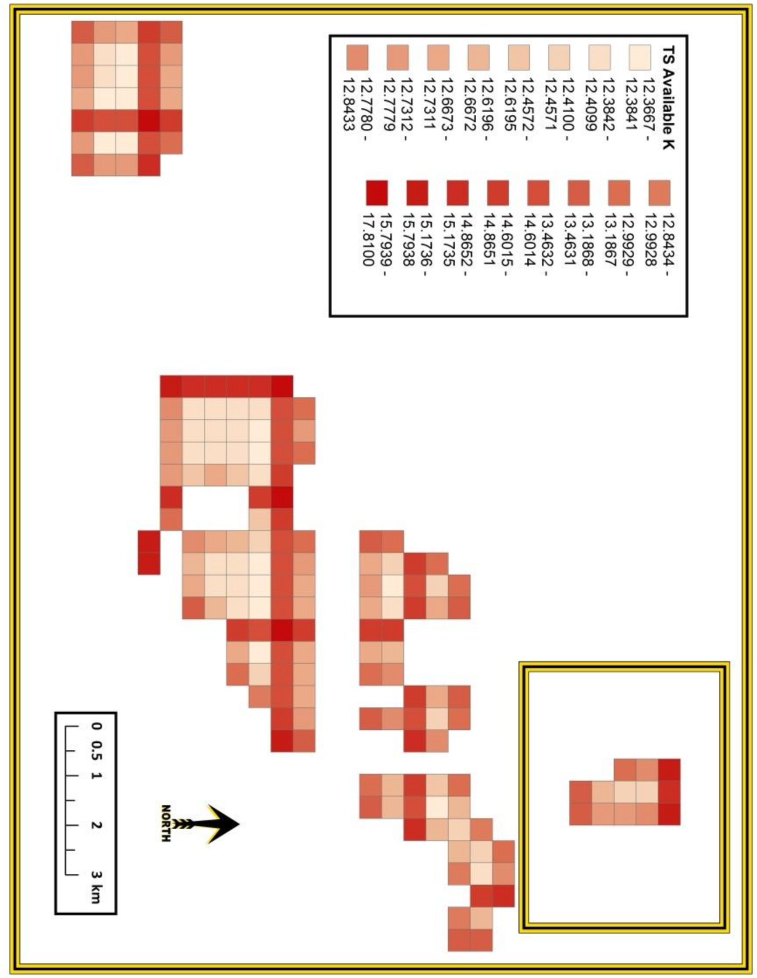


Table B8. Method report for parameters used to create the predicted surface of Topsoil Total K ($mg{\cdot}kg^{-1}$) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total K ($mg{\bullet}kg^{-1}$)	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0312692
Major Range	AUTO; 2516.911
Anisotropy:	FALSE
Partial Sill:	TRUE; 1367.959
Lag Size	245
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	8
Prediction Error	
Root Mean Square:	76.84319
Mean Standardized	0.0166079
Root Mean Square Standarized:	0.9608542
Average Standard Error:	80.29756

Figure B8. Standard error map for the predicted surface of Topsoil Total K ($mg{\cdot}kg^{-1}$). Darker reds indicate greater standard error.

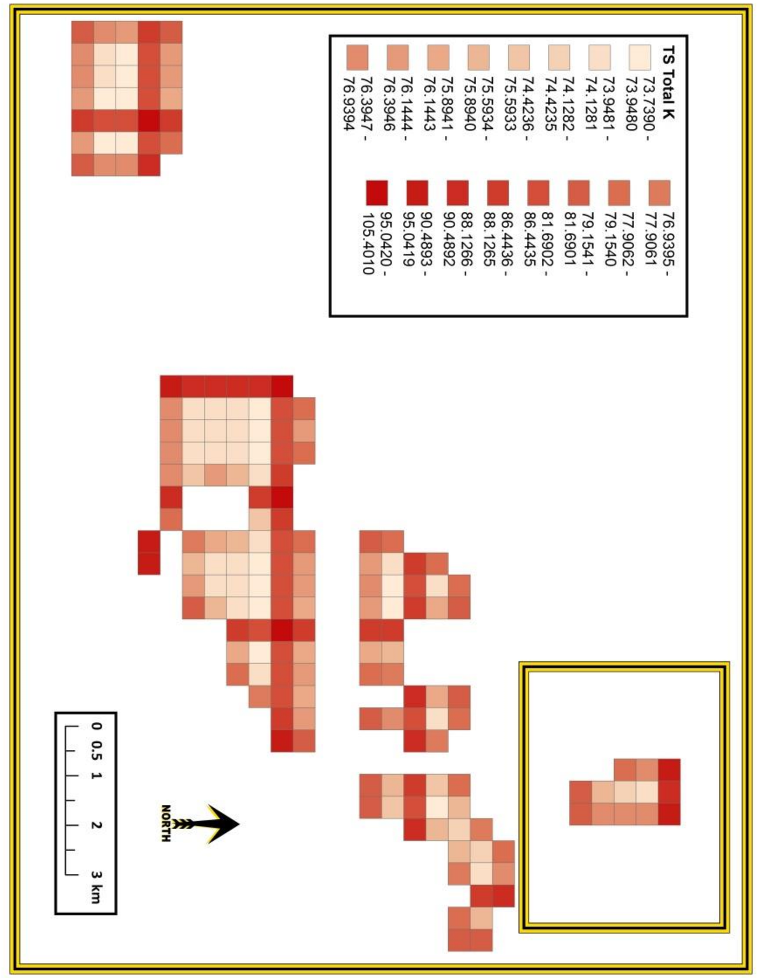


Table B9. Method report for parameters used to create the predicted surface of Topsoil Total Zn (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total Zn (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0312692
Major Range	AUTO; 796.179
Anisotropy:	FALSE
Partial Sill:	TRUE; 325.2657
Lag Size	243
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	12
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	6.917304
Mean Standardized	0.008506525
Root Mean Square Standarized:	0.9932134
Average Standard Error:	7.135385

Figure B9. Standard error map for the predicted surface of Topsoil Total K (mg·kg^{-1}). Darker reds indicate greater standard error.

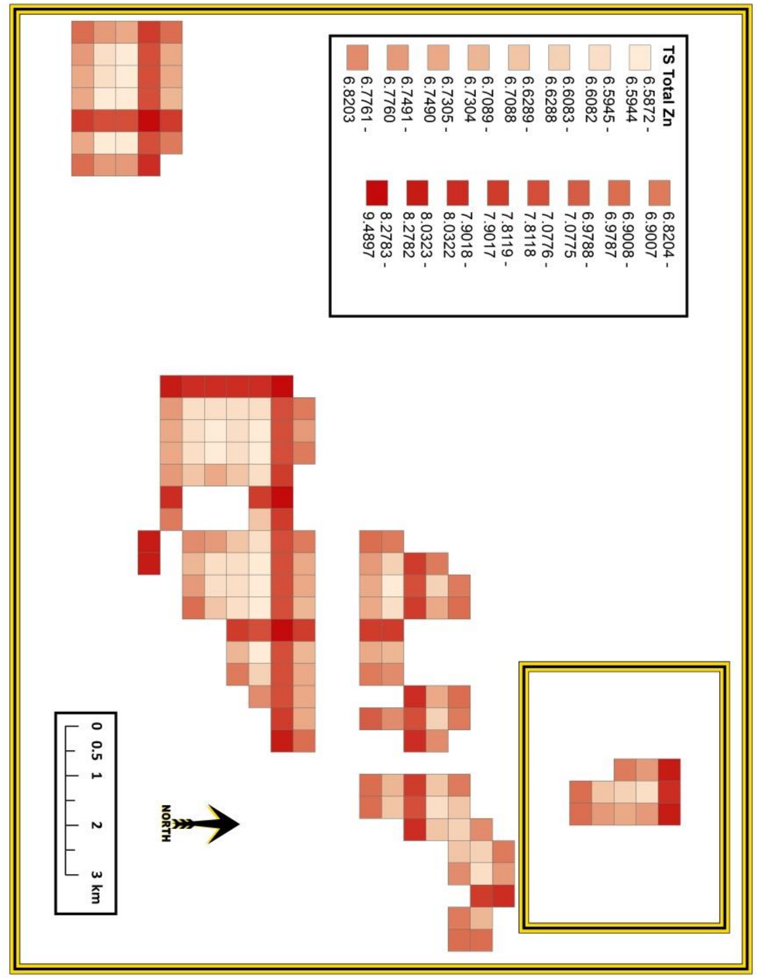


Table B10. Method report for parameters used to create the predicted surface of Topsoil Available Cu ($mg \cdot kg^{-1}$) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Available Cu ($mg \cdot kg^{-1}$)	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0814953
Major Range	AUTO; 2424
Anisotropy:	FALSE
Partial Sill:	TRUE; 0.0941235
Lag Size	202
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	7.527549
Mean Standardized	0.003208712
Root Mean Square Standarized:	0.8073201
Average Standard Error:	9.449689

Figure B10. Standard error map for the predicted surface of Topsoil Available Cu ($mg \cdot kg^{-1}$). Darker reds indicate greater standard error.

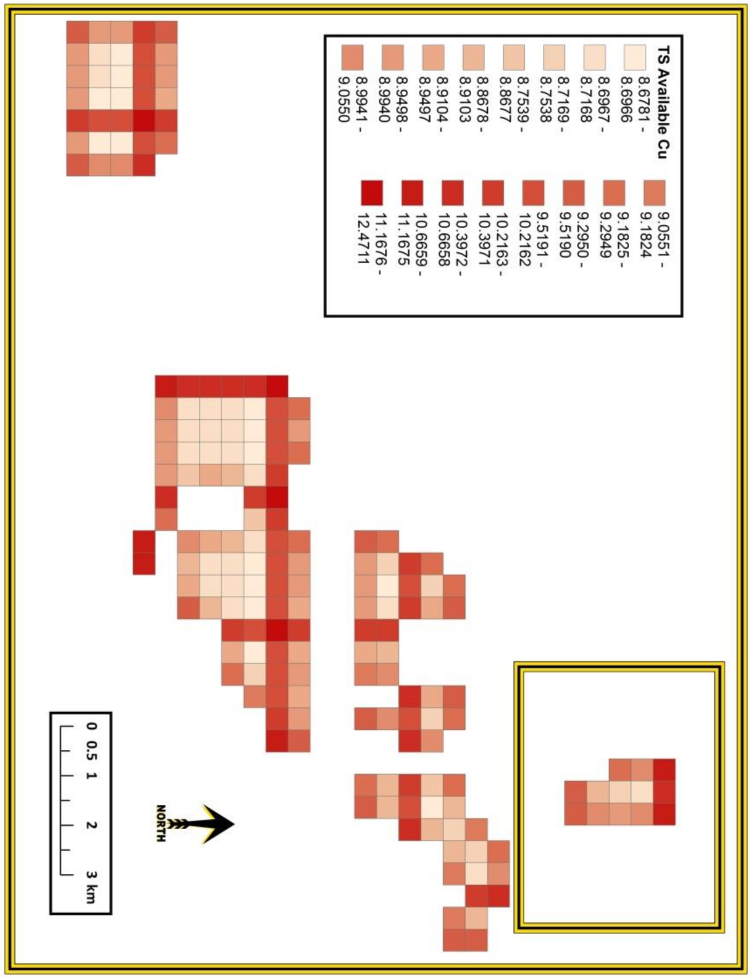


Table B11. Method report for parameters used to create the predicted surface of Topsoil Total Cu (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total Cu (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.088367
Major Range	AUTO; 3012
Anisotropy:	FALSE
Partial Sill:	TRUE; 290.5622
Lag Size	251
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	14
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	7.185151
Mean Standardized	-0.003265395
Root Mean Square Standarized:	1.002866
Average Standard Error:	7.161673

Figure B11. Standard error map for study areas predicted Topsoil Total Cu (mg·kg^{-1}). Darker reds indicate greater standard error.

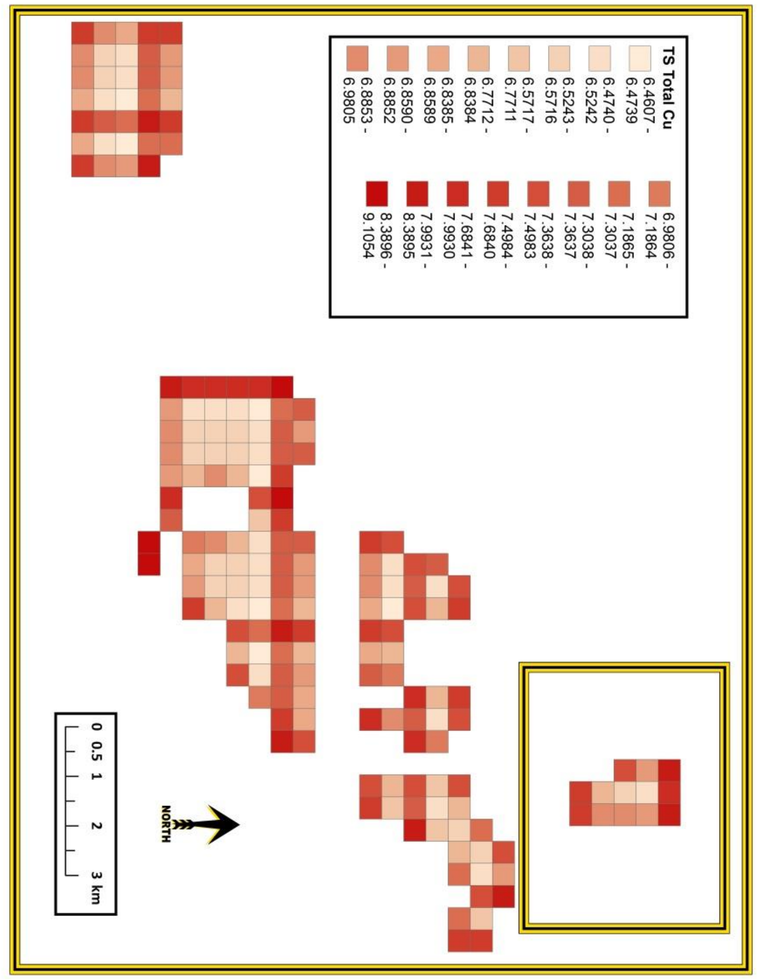


Table B12. Method report for parameters used to create the predicted surface of Topsoil Available Mn (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Available Mn (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0432257
Major Range	AUTO; 2516.911
Anisotropy:	FALSE
Partial Sill:	TRUE; 86.25217
Lag Size	245
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	21
Minimum Neighbors	9
Prediction Error	
Root Mean Square:	3.658773
Mean Standardized	-0.03208059
Root Mean Square Standarized:	0.9421996
Average Standard Error:	3.9091

Figure B12. Standard error map for the predicted surface of Topsoil Available Mn (mg·kg^{-1}). Darker reds indicate greater standard error.

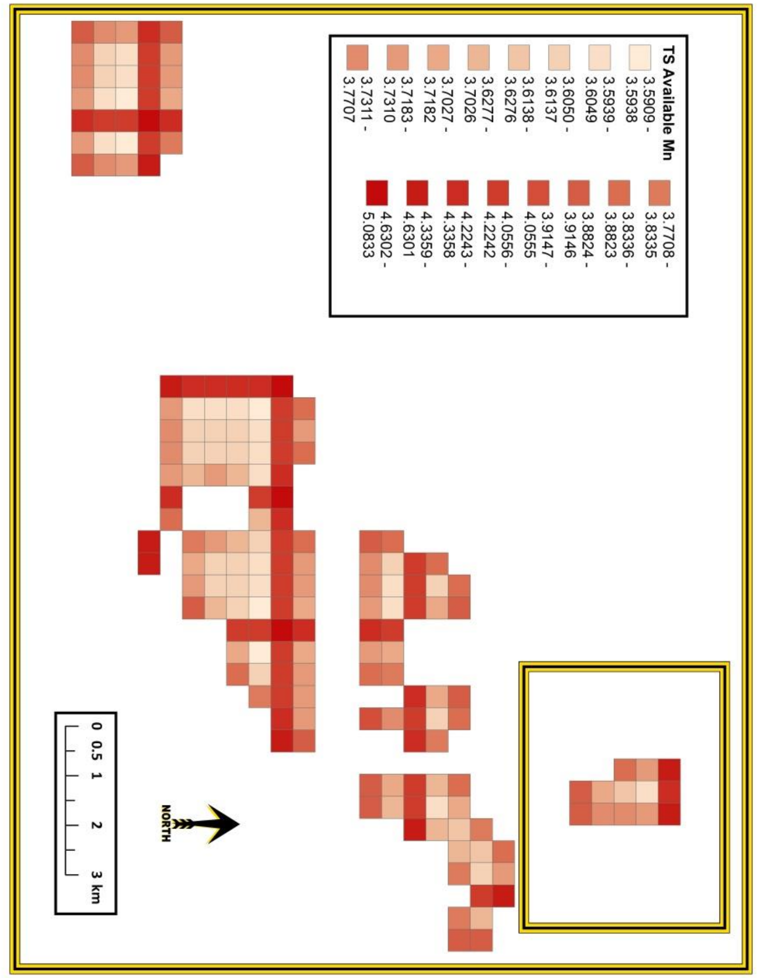


Table B13. Method report for parameters used to create the predicted surface of Topsoil Total Mn ($mg \cdot kg^{-1}$) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total Mn ($mg \cdot kg^{-1}$)	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0147884
Major Range	AUTO; 1640.652
Anisotropy:	FALSE
Partial Sill:	TRUE; 35671.075
Lag Size	233
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	16
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	3.659307
Mean Standardized	-0.03244444
Root Mean Square Standarized:	0.9396366
Average Standard Error:	3.923577

Figure B13. Standard error map for the predicted surface of Topsoil Total Mn ($mg \cdot kg^{-1}$). Darker reds indicate greater standard error.

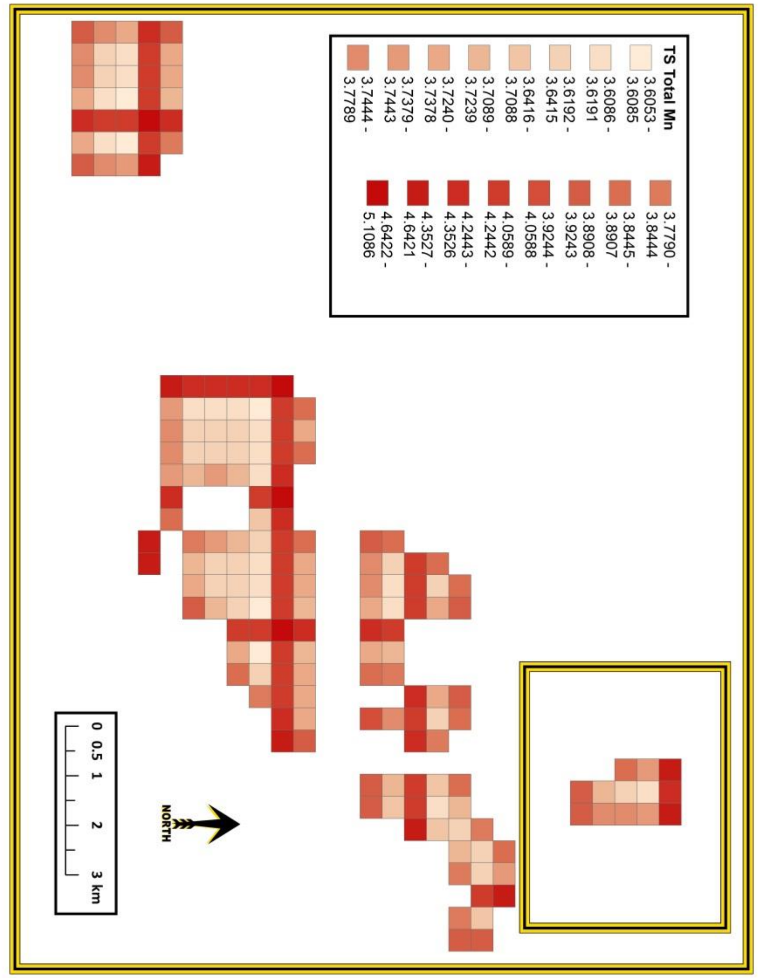


Table B14. Method report for parameters used to create the predicted surface of Topsoil pH H_2O using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS pH H_2O	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0432257
Major Range	AUTO; 2880
Anisotropy:	FALSE
Partial Sill:	TRUE; 86.25217
Lag Size	240
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	14
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	0.4210408
Mean Standardized	0.2238049
Root Mean Square Standarized:	0.8210414
Average Standard Error:	0.5167525

Figure B14. Standard error map for the predicted surface of Topsoil Total pH H_2O. Darker reds indicate greater standard error.

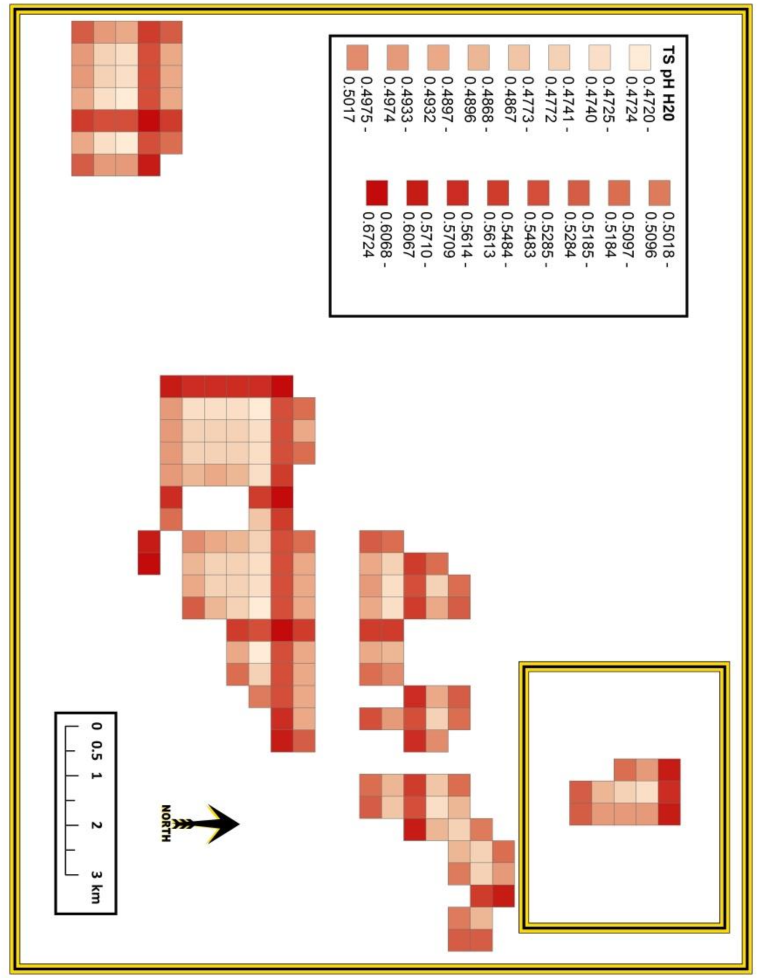


Table B15. Method report for parameters used to create the predicted surface of Topsoil % Sand using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS % Sand	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.2996143
Major Range	AUTO; 2263.236
Anisotropy:	FALSE
Partial Sill:	TRUE; 76.3331
Lag Size	220
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	3.731544
Mean Standardized	-0.01904646
Root Mean Square Standarized:	0.8660615
Average Standard Error:	4.20687

Figure B15. Standard error map for the predicted surface of Topsoil % Sand. Darker reds indicate greater standard error.

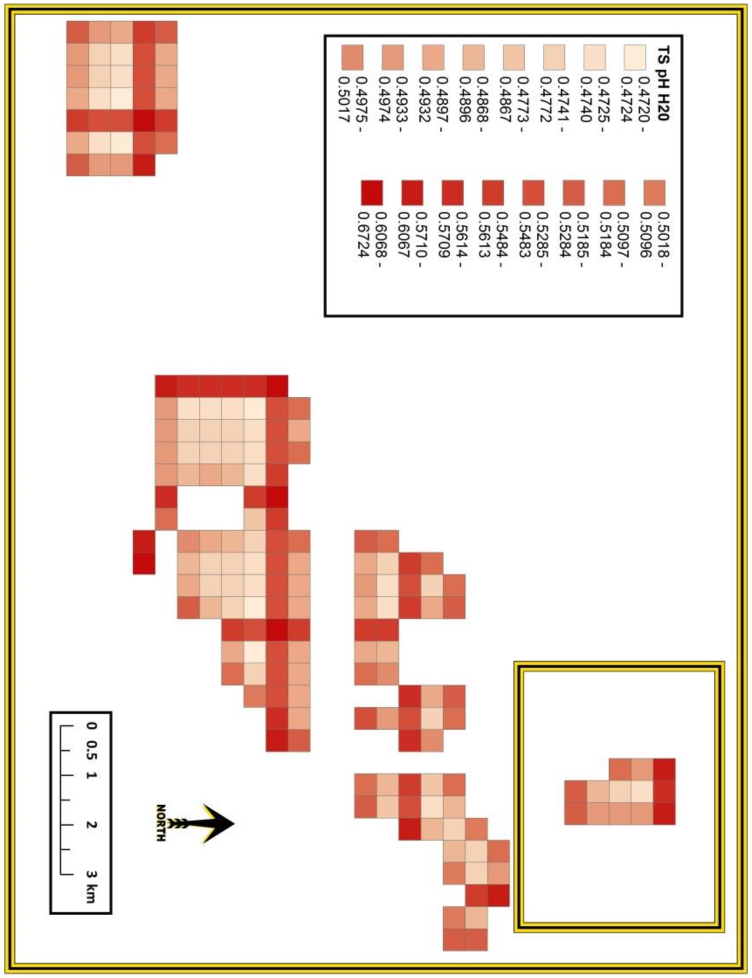


Table B16. Method report for parameters used to create the predicted surface of Topsoil % Silt using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS % Silt	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.3768529
Major Range	AUTO; 1776.813
Anisotropy:	FALSE
Partial Sill:	TRUE; 48.0357
Lag Size	220
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	15
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	3.161275
Mean Standardized	0.01988962
Root Mean Square Standarized:	0.94227
Average Standard Error:	3.251633

Figure B16. Standard error map for the predicted surface of Topsoil % Silt. Darker reds indicate greater standard error.

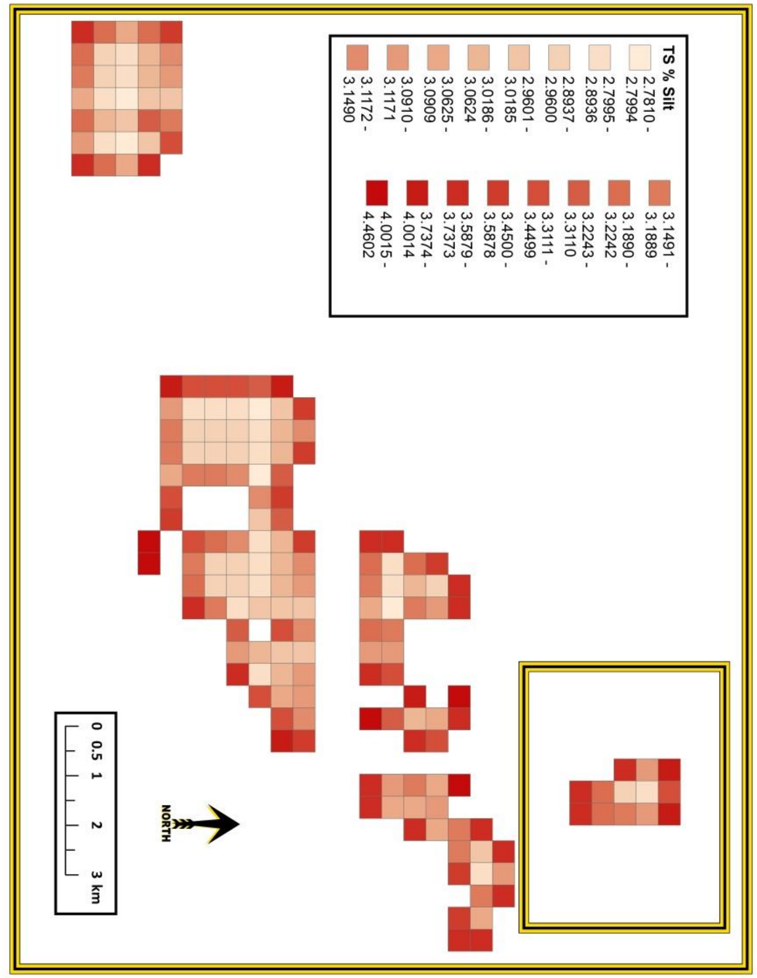


Table B17. Method report for parameters used to create the predicted surface of Topsoil % Clay using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS % Clay	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0334514
Major Range	AUTO; 2201.853
Anisotropy:	FALSE
Partial Sill:	TRUE; 30.234
Lag Size	228
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	14
Minimum Neighbors	10
Prediction Error	
Root Mean Square:	2.045619
Mean Standardized	0.002636318
Root Mean Square Standarized:	0.9231033
Average Standard Error:	2.220568

Figure B17. Standard error map for the predicted surface of Topsoil % Clay. Darker reds indicate greater standard error.

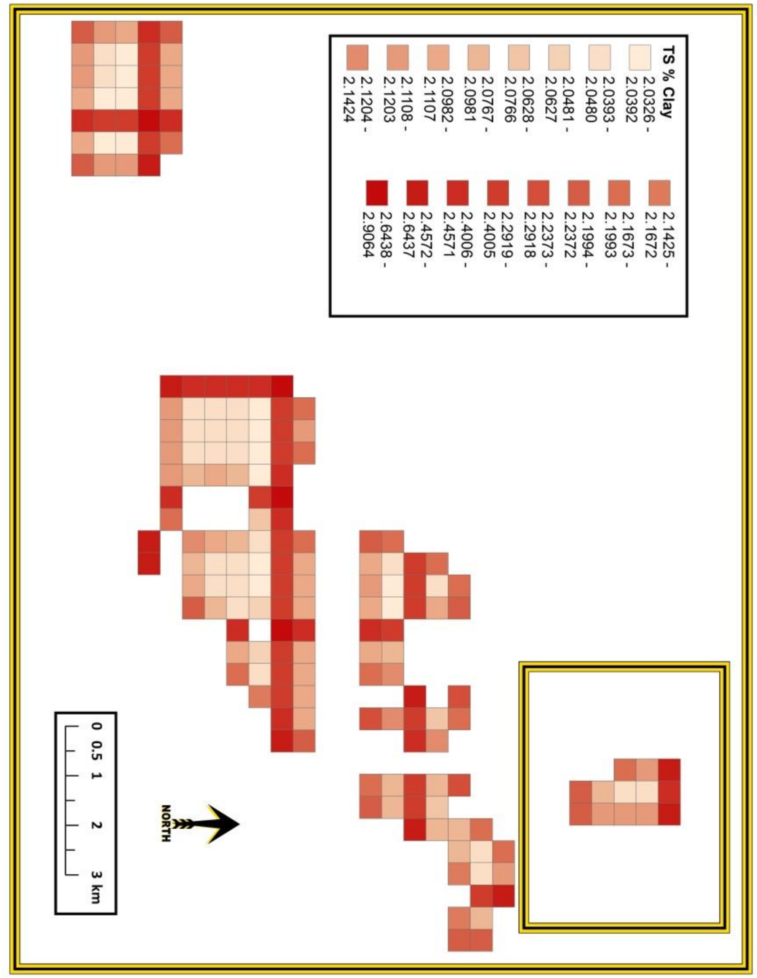
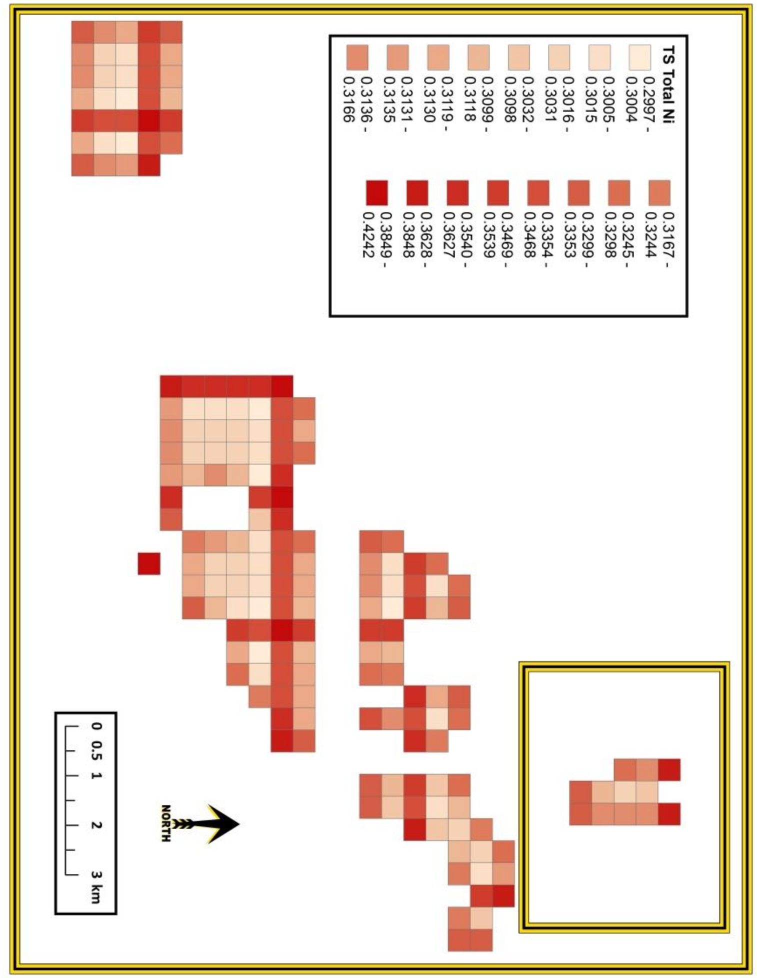


Table B18. Method report for parameters used to create the predicted surface of Topsoil Total Ni (mg·kg^{-1}) using ArcGIS 10.1 Geostatistical Wizard. All other parameters were set to default.

TS Total Ni (mg•kg^{-1})	
General Properities	
Data Set Type:	Gaussian
Lattice Spacing:	158.038
Variable :	Covariance
Confidence Level	90
Model	
Type:	K-Bessel
Parameter:	AUTO; 0.0712096
Major Range	AUTO; 3204
Anisotropy:	FALSE
Partial Sill:	TRUE; 504.7003
Lag Size	267
Number of Lags:	12
Search Neighborhood	
Neighborhood Type:	Standard
Maximum Neighbors	12
Minimum Neighbors	9
Prediction Error	
Root Mean Square:	0.3212592
Mean Standardized	-0.02703072
Root Mean Square Standarized:	0.9835157
Average Standard Error:	0.3276792

Figure B18. Standard error map for the predicted surface of Topsoil Total Ni (mg·kg^{-1}). Darker reds indicate greater standard error.



Appendix C

Supplementary Soil Descriptive Statistics and Significance Tables

Table C1. Table describing the variability of Total Al (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		Total Al									
Soil Depth	Soil Map Unit	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	11950		6250	18500	12074	118	1657	14	0.58	1.67
	Azilda SiL	13000	*a*	10500	15400	13038	220	1185	9.085	-0.12	0.028
	Bradley FSaL	11400	*b*	8740	12900	11296	153	917	8.1	-0.73	0.76
	Bradley VFSaL	12550	*ad*	9180	16600	12900	470	2302	18	-0.07	-1.4
	Capreol FSaL	10800	*b*	9410	13000	11026	211	1057	9.6	0.61	-0.57
	Capreol VFSaL	12000	*cd*	10700	13100	11920	211	817.8	6.9	-0.15	-1.0
	Wolf SiL	12400	*ad*	10000	13900	12313	251	1005	8.2	-0.59	0.41
75-100 cm	Region	7740		2260	12500	7819	152	2100	27	0.031	-0.47
	Azilda SiL	9010	*a*	3380	12300	8816	374	2080	24	-0.82	0.84
	Bradley FSaL	7110	*bc*	3000	11000	7527	276	1853	25	0.14	-0.34
	Bradley VFSaL	7720	*bd*	4280	12500	7702	341	1960	25	0.55	-0.27
	Capreol FSaL	6740	*be*	2260	12000	6843	393	2189	32	0.35	1.0
	Capreol VFSaL	8265	*acde*	5210	11400	8208	511	2042	25	-0.04	-1.2
	Wolf SiL	8950	*acd*	4390	12100	8274	507	2212	27	-0.47	-0.75

Table C2. Table describing the variability of Total Ca (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

Total Ca												
Soil Depth	Soil Map Unit	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	5290		2010	33600	6117	241	3398	56	3.3	21
	Azilda SiL	7480	a	5030	33600	9661	1022	5501	57	3.2	13
	Bradley FSaL	3735	*b*	2900	7850	3972	168	1008	25	2.1	5.4
	Bradley VFSaL	5370	*c*	2770	8960	5647	458	2244	40	0.14	-1.8
	Capreol FSaL	4280	*bc*	2920	11000	4616	335	1674	36	2.4	8.3
	Capreol VFSaL	5240	*c*	3500	12300	5771	617	2389	41	1.6	2.9
	Wolf SiL	9300	*a*	6270	14900	9724	614	2478	25	0.64	-0.35
75-100 cm	Region	7170		265	59500	18309	1309	18096	99	0.82	-0.81
	Azilda SiL	38800	*a*	3550	59500	33094	3199	17813	54	-0.37	-1.3
	Bradley FSaL	3870	*b*	265	55500	8575	1807	12122	141	2.6	6.4
	Bradley VFSaL	19100	*bc*	2480	56500	21207	3318	19063	90	0.46	-1.3
	Capreol FSaL	3830	*d*	282	42800	10108	2310	12863	127	1.7	1.5
	Capreol VFSaL	13400	*c*	3070	33700	14473	2663	10653	74	0.50	-1.1
	Wolf SiL	37400	*a*	4620	58900	33015	4165	18154	55	-0.10	-1.4

Table C3. Table describing the variability of Total Fe (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

Total Fe											
Soil Depth	Soil Map Unit	Median		Min	Max	Mean	± SE	± SD	CV (%)	Skewness	Kurtosis
0-20 cm	Region	12900		7930	18800	12904	164	2308	18	0.17	-0.64
	Azilda SiL	14800	*a*	11600	16900	14803	255	1374	9.3	-0.37	0.075
	Bradley FSaL	11750	*b*	9010	13500	11535	206	1238	11	-0.47	-0.48
	Bradley VFSaL	12600	*acd*	7930	18800	13175	664	3253	25	0.027	-1.3
	Capreol FSaL	10400	*b*	9300	14600	11220	362	1811	16	0.95	-0.47
	Capreol VFSaL	13400	*c*	10700	14900	12987	384	1488	11	-0.29	-1.4
	Wolf SiL	14350	*ad*	13400	16500	14594	258	1034	7.1	0.57	-0.98
75-100 cm	Region	9790		1830	15400	9955	178	2459	25	-0.46	0.85
	Azilda SiL	10900	*a*	5740	15300	11129	396	2206	20	-0.25	0.29
	Bradley FSaL	9420	*bc*	2420	13900	9528	359	2409	25	-0.40	0.88
	Bradley VFSaL	9490	*bc*	6780	13800	9700	311	1786	18	0.63	-0.25
	Capreol FSaL	9190	*b*	1830	14100	8717	497	2769	32	-0.91	1.3
	Capreol VFSaL	11000	*ac*	7710	14100	10741	517	2069	19	0.07	-1.1
	Wolf SiL	11700	*a*	6920	15400	11269	537	2341	21	-0.52	-0.45

Table C4. Table describing the variability of Total Mg (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil seres. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		Total Mg									
Soil Depth	Soil Map Unit	Median		Min	Max	Mean			CV	Skewness	Kurtosis
							± SE	± SD	(%)		
0-20 cm	Region	3570		1440	15900	3772	119	1668	44	2.4	14
	Azilda SiL	4570	*a*	3780	15900	5341	447	2409	45	3.5	14
	Bradley FSaL	2665	*b*	1690	5210	2768	115	692	25	1.2	3.1
	Bradley VFSaL	3230	*bd*	1690	6170	3668	321	1573	43	0.28	-1.6
	Capreol FSaL	2660	*b*	1820	5830	2868	195	974	34	1.4	2.2
	Capreol VFSaL	3720	*cd*	2570	6160	3731	255	987	26	1.0	1.1
	Wolf SiL	5320	*e*	4230	8150	5543	263	1053	19	1.0	0.96
75-100 cm	Region	4770		572	19400	7092	336	4642	65	0.40	-1.4
	Azilda SiL	12400	*a*	2280	14300	10591	658	3661	35	-0.96	-0.61
	Bradley FSaL	3140	*b*	1090	15000	4568	532	3571	78	1.9	2.5
	Bradley VFSaL	9680	*bc*	2320	13400	7480	808	4641	62	0.007	-1.9
	Capreol FSaL	2980	*b*	572	13300	4871	692	3852	79	1.3	0.41
	Capreol VFSaL	7500	*c*	2290	13400	7156	933	3732	52	0.18	-1.3
	Wolf SiL	12600	*a*	2940	19400	11271	978	4262	38	-0.46	-0.24

Table C5. Table describing the variability of Total Na (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		Total Na									
Soil Depth	Soil Map Unit	Median		Min	Max	Mean			CV	Skewness	Kurtosis
							± SE	± SD	(%)		
0-20 cm	Region	653		291	1010	621	11	149	24	-0.16	-0.59
	Azilda SiL	727	*a*	622	1010	743	17	90	12	1.5	2.9
	Bradley FSaL	487	*b*	347	773	511	18	107	21	0.62	-0.49
	Bradley VFSaL	627	*ac*	349	877	626	39	194	31	-0.010	-1.6
	Capreol FSaL	540	*bc*	391	768	537	20	101	19	0.68	-0.20
	Capreol VFSaL	688	*a*	549	812	688	19	75	11	-0.041	-0.78
	Wolf SiL	737	*a*	666	808	733	11	43	5.8	0.24	-0.38
75-100 cm	Region	704		196	1440	702	15	213		0.31	0.15
	Azilda SiL	875	*a*	473	1440	840	35	197		0.52	1.7
	Bradley FSaL	651	*b*	196	1090	675	27	182		0.04	0.35
	Bradley VFSaL	750	*bc*	356	1240	707	41	237		0.29	-0.91
	Capreol FSaL	606	*b*	201	1110	611	39	214		0.14	-0.38
	Capreol VFSaL	668	*b*	443	736	642	23	91		-1.1	0.18
	Wolf SiL	794	*ac*	460	1270	806	50	218		0.40	0.24

Table C6. Table describing the variability of Total K (mg·kg^{-1}) within the City of Greater Sudbury's Agricultural Reserve lands. The topsoil (TS; 0- 20 cm) and the subsoil (SS;75-100 cm) summaries are shown for the regional and the most expansive soil series. Soil series median values having similar corresponding letters indicate no significant difference (*p*=0.050) from one another using Kruskal-Wallis comparison of medians.

		Total K									
Soil Depth	Soil Map Unit	Median		Min	Max	Mean			CV	Skewness	Kurtosis
							± SE	± SD	(%)		
0-20 cm	Region	580		382	963	573	7.2	101	18	0.47	1.1
	Azilda SiL	601	*ad*	499	961	621	17	92	15	1.9	5.6
	Bradley FSaL	570	*ac*	417	733	575	13	78	14	0.12	-0.23
	Bradley VFSaL	551	*bce*	400	785	557	25	125	22	0.43	-1.0
	Capreol FSaL	492	*b*	396	963	523	25	127	24	2.2	5.8
	Capreol VFSaL	627	*d*	579	745	638	11	44	6.9	0.90	1.1
	Wolf SiL	619	*de*	574	691	618	8	31	5.1	0.59	0.55
75-100 cm	Region	534		162	1460	563	13	175	31	1.2	3.6
	Azilda SiL	689	*a*	334	1460	695	35	193	28	1.8	7.9
	Bradley FSaL	516	*b*	266	785	514	14	96	19	0.51	2.0
	Bradley VFSaL	490	*bc*	330	1140	571	38	216	38	0.87	-0.15
	Capreol FSaL	456	*b*	162	733	466	24	134	29	-0.061	-0.038
	Capreol VFSaL	571	*b*	312	635	530	25	98	19	-1.1	0.50
	Wolf SiL	685	*ac*	338	1070	647	39	170	26	0.28	1.3

Table C6. Table listing the *p*-values used to determine the statistical significant differences of topsoil properties for Dominant Land Use comparisons using Kruskal-Wallis comparison of medians (SPSS 19).

Dominant Land Use Comparisons	Total C	Total N	Total P	Total K	Total Cu	Total Mn	Total Zn	Total N	Total P	Total K	Total Cu	Total Mn	Total Zn
	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	$kg \cdot ha^{-1}$	%	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$
Abandoned & Forested	0.060	0.246	0.450	0.058	0.821	0.290	0.117	0.874	0.806	0.780	0.097	0.741	0.650
Abandoned & Low Intensity	0.345	0.494	0.059	0.196	0.335	0.597	0.186	0.206	0.436	0.542	0.464	0.647	0.549
Abandoned & Intensive	0.594	0.778	0.001	0.031	0.161	0.129	0.012	0.125	0.004	0.256	0.020	0.502	0.217
Abandoned & Topsoil Removed	0.034	0.418	0.003	0.002	0.021	0.083	0.976	0.008	0.823	0.354	0.000	0.570	0.003
Abandoned & Sod	0.000	0.000	0.000	0.000	0.022	0.339	0.083	0.000	0.019	0.061	0.000	0.528	0.163
Abandoned & Potato Rotation	0.000	0.003	0.000	0.000	0.232	0.237	0.009	0.000	0.000	0.004	0.208	0.019	0.562
Forested & Low Intensity	0.002	0.091	0.020	0.001	0.643	0.156	0.008	0.470	0.603	0.670	0.006	0.498	0.978
Forested & Intensive	0.039	0.582	0.002	0.001	0.129	0.026	0.002	0.262	0.011	0.164	0.001	0.643	0.107
Forested & Topsoil Removed	0.004	0.589	0.004	0.000	0.008	0.049	0.357	0.016	0.919	0.314	0.000	0.693	0.004
Forested & Sod	0.000	0.000	0.000	0.000	0.014	0.050	0.003	0.000	0.089	0.029	0.000	0.501	0.295
Forested & Potato Rotation	0.000	0.122	0.000	0.000	0.484	0.977	0.000	0.000	0.000	0.001	0.001	0.013	0.946
Low Intensity & Intensive	0.817	0.386	0.041	0.324	0.035	0.231	0.147	0.505	0.011	0.084	0.042	0.288	0.099
Low Intensity & Topsoil Removed	0.056	0.320	0.060	0.014	0.011	0.118	0.405	0.033	0.919	0.293	0.000	0.492	0.001
Low Intensity & Sod	0.000	0.000	0.008	0.000	0.002	0.683	0.744	0.000	0.085	0.014	0.000	0.978	0.204
Low Intensity & Potato Rotation	0.000	0.001	0.000	0.000	0.754	0.126	0.283	0.000	0.000	0.001	0.477	0.043	0.860
Intensive & Topsoil Removed	0.073	0.551	0.823	0.073	0.062	0.371	0.062	0.135	0.052	0.881	0.009	0.709	0.001
Intensive & Sod	0.000	0.000	0.639	0.063	0.372	0.618	0.325	0.000	0.164	0.832	0.020	0.250	0.010
Intensive & Potato Rotation	0.000	0.052	0.095	0.062	0.037	0.019	0.281	0.002	0.239	0.371	0.108	0.006	0.042
Topsoil Removed & Sod	0.508	0.741	0.705	0.395	0.131	0.369	0.257	0.777	0.288	0.723	0.069	0.395	0.002
Topsoil Removed & Potato Rotation	0.559	0.877	0.356	0.236	0.010	0.080	0.110	0.535	0.005	0.970	0.001	0.147	0.000
Sod & Potato Rotation	0.000	0.002	0.006	0.852	0.002	0.013	0.333	0.001	0.003	0.317	0.000	0.033	0.122

Table C7. *p*-values used to determine the statistical significant differences of topsoil properties for Dominant Land Use comparisons using Kruskal-Wallis comparison of medians (SPSS 19).

Dominant Land Use Comparisons	Total C %	C:N Ratio	pH H_2O	ρbulk $g\cdot cm^3$	Av P $kg\cdot ha^{-1}$	Av K $kg\cdot ha^{-1}$	Av Cu $kg\cdot ha^{-1}$	Av_Mn $kg\cdot ha^{-1}$	Av Zn $kg\cdot ha^{-1}$	Av P $mg\cdot kg^{-1}$	Av K $mg\cdot kg^{-1}$	Av Cu $mg\cdot kg^{-1}$	Av_Mn $mg\cdot kg^{-1}$	Av Zn $mg\cdot kg^{-1}$
Abandoned & Forested	0.012	0.000	0.018	0.002	0.799	0.022	0.627	0.110	0.108	0.163	0.002	0.159	0.011	0.146
Abandoned & Low Intensity	0.008	0.002	0.766	0.000	0.310	0.023	0.411	0.777	0.806	0.916	0.265	0.941	0.647	0.536
Abandoned & Intensive	0.129	0.211	0.048	0.024	0.234	0.622	0.179	0.046	0.468	0.579	0.515	0.056	0.042	0.208
Abandoned & Topsoil Removed	0.000	0.418	0.013	0.000	0.001	0.189	0.029	0.020	0.138	0.000	0.022	0.001	0.005	0.272
Abandoned & Sod	0.000	0.000	0.851	0.000	0.777	0.000	0.250	0.488	0.971	0.188	0.000	0.009	0.912	0.850
Abandoned & Potato Rotation	0.000	0.000	0.001	0.000	0.191	0.000	0.089	0.012	0.012	0.967	0.000	0.668	0.040	0.037
Forested & Low Intensity	0.000	0.000	0.028	0.000	0.308	0.904	0.709	0.064	0.151	0.244	0.079	0.149	0.002	0.041
Forested & Intensive	0.001	0.000	0.000	0.001	0.235	0.150	0.066	0.005	0.092	0.714	0.097	0.007	0.000	0.068
Forested & Topsoil Removed	0.000	0.072	0.003	0.000	0.000	0.045	0.017	0.003	0.419	0.000	0.002	0.000	0.000	0.822
Forested & Sod	0.000	0.000	0.051	0.000	0.935	0.000	0.157	0.605	0.205	0.038	0.015	0.000	0.058	0.231
Forested & Potato Rotation	0.000	0.000	0.443	0.000	0.213	0.000	0.187	0.317	0.459	0.209	0.000	0.400	0.742	0.738
Low Intensity & Intensive	0.699	0.141	0.028	0.364	0.772	0.182	0.032	0.142	0.500	0.536	0.765	0.068	0.080	0.469
Low Intensity & Topsoil Removed	0.000	0.593	0.012	0.000	0.000	0.042	0.009	0.016	0.142	0.000	0.011	0.000	0.004	0.156
Low Intensity & Sod	0.000	0.203	0.796	0.000	0.471	0.000	0.095	0.274	0.932	0.289	0.000	0.010	0.654	0.664
Low Intensity & Potato Rotation	0.000	0.018	0.001	0.003	0.798	0.000	0.276	0.004	0.022	0.860	0.000	0.632	0.006	0.004
Intensive & Topsoil Removed	0.002	0.502	0.062	0.000	0.001	0.136	0.191	0.156	0.076	0.000	0.025	0.016	0.037	0.126
Intensive & Sod	0.000	0.025	0.059	0.000	0.372	0.000	0.762	0.018	0.479	0.178	0.001	0.399	0.051	0.245
Intensive & Potato Rotation	0.000	0.003	0.000	0.008	0.845	0.000	0.013	0.000	0.006	0.564	0.000	0.025	0.000	0.003
Topsoil Removed & Sod	0.202	0.777	0.014	0.000	0.002	0.001	0.143	0.008	0.156	0.001	0.000	0.042	0.005	0.317
Topsoil Removed & Potato Rotation	0.009	0.846	0.004	0.000	0.000	0.000	0.006	0.001	0.630	0.000	0.000	0.001	0.000	0.873
Sod & Potato Rotation	0.000	0.394	0.000	0.015	0.406	0.001	0.018	0.159	0.015	0.228	0.001	0.007	0.079	0.032

Table C8. *p*-values used to determine the statistical significant differences of subsoil properties for soil series comparisons using Kruskal-Wallis comparison of medians (SPSS 19).

Soil Series Comparisons	Total C	Sand	Silt	Clay	pH	pH	Total Al	Total Ca	Total Fe	Total K	Total Mg	Total Na
	%	%	%	%	H_2O	$CaCl_2$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$
Azilda SiL & Bradley FSaL	0.000	0.000	0.003	0.000	0.000	0.000	0.002	0.000	0.001	0.000	0.000	0.001
Azilda SiL & Bradley VFSaL	0.014	0.003	0.000	0.003	0.166	0.010	0.014	0.005	0.004	0.017	0.002	0.024
Azilda SiL & Capreol FSaL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Azilda SiL & Capreol VFSaL	0.002	0.018	0.171	0.035	0.006	0.001	0.302	0.001	0.582	0.000	0.006	0.001
Azilda SiL & Wolf SiL	0.390	0.181	0.206	0.120	0.603	0.764	0.522	0.889	0.522	0.374	0.318	0.390
Bradley FSaL & Bradley VFSaL	0.002	0.990	0.232	0.969	0.003	0.003	0.840	0.057	0.952	0.980	0.078	0.660
Bradley FSaL & Capreol FSaL	0.053	0.371	0.371	0.214	0.903	0.796	0.149	0.996	0.318	0.062	0.866	0.197
Bradley FSaL & Capreol VFSaL	0.009	0.168	0.394	0.110	0.034	0.036	0.231	0.010	0.105	0.329	0.012	0.718
Bradley FSaL & Wolf SiL	0.000	0.014	0.115	0.012	0.000	0.000	0.199	0.000	0.016	0.001	0.000	0.021
Bradley VFSaL & Capreol FSaL	0.086	0.674	0.897	0.410	0.012	0.006	0.138	0.047	0.317	0.132	0.108	0.108
Bradley VFSaL & Capreol VFSaL	0.579	0.455	0.064	0.348	0.382	0.296	0.382	0.765	0.107	0.873	0.839	0.430
Bradley VFSaL & Wolf SiL	0.132	0.095	0.007	0.070	0.131	0.037	0.300	0.016	0.017	0.157	0.002	0.193
Capreol FSaL & Capreol VFSaL	0.240	0.057	0.087	0.027	0.143	0.115	0.059	0.036	0.019	0.071	0.032	0.645
Capreol FSaL & Wolf SiL	0.000	0.002	0.008	0.001	0.000	0.000	0.025	0.000	0.002	0.000	0.000	0.006
Capreol VFSaL & Wolf SiL	0.028	0.270	0.809	0.512	0.005	0.001	0.921	0.002	0.417	0.007	0.003	0.004

Table C9. *p*-values used to determine the statistical significant differences of subsoil properties for soil series comparisons using Kruskal-Wallis comparison of medians (SPSS 19).

Soil Series Comparisons	Total C	Sand	Silt	Clay	pH	ρbulk	Total C	Total K	Total Ca	Total Mg	Total Fe
	%	%	%	%	H_2O	$g{\cdot}cm^3$	$kg{\cdot}ha^{-1}$	$kg{\cdot}ha^{-1}$	$kg{\cdot}ha^{-1}$	$kg{\cdot}ha^{-1}$	$kg{\cdot}ha^{-1}$
Azilda SiL & Bradley FSaL	0.000	0.000	0.010	0.000	0.000	0.019	0.000	0.384	0.000	0.000	0.000
Azilda SiL & Bradley VFSaL	0.416	0.000	0.000	0.368	0.020	0.231	0.438	0.192	0.007	0.028	0.120
Azilda SiL & Capreol FSaL	0.030	0.000	0.000	0.000	0.000	0.101	0.014	0.031	0.000	0.000	0.000
Azilda SiL & Capreol VFSaL	0.001	0.001	0.496	0.024	0.011	0.001	0.001	0.002	0.023	0.085	0.951
Azilda SiL & Wolf SiL	0.758	0.272	0.232	0.057	0.236	0.177	0.367	0.092	0.014	0.035	0.492
Bradley FSaL & Bradley VFSaL	0.000	0.729	0.026	0.070	0.005	0.100	0.000	0.113	0.045	0.222	0.398
Bradley FSaL & Capreol FSaL	0.000	0.342	0.305	0.684	0.758	0.063	0.000	0.008	0.207	0.649	0.061
Bradley FSaL & Capreol VFSaL	0.134	0.001	0.014	0.006	0.020	0.116	0.004	0.010	0.000	0.000	0.001
Bradley FSaL & Wolf SiL	0.001	0.000	0.171	0.000	0.000	0.526	0.000	0.937	0.000	0.000	0.000
Bradley VFSaL & Capreol FSaL	0.095	0.564	0.138	0.073	0.010	0.795	0.078	0.562	0.368	0.124	0.069
Bradley VFSaL & Capreol VFSaL	0.002	0.074	0.000	0.928	0.988	0.002	0.019	0.001	0.204	0.149	0.112
Bradley VFSaL & Wolf SiL	0.307	0.000	0.001	0.028	0.010	0.782	0.123	0.038	0.000	0.001	0.053
Capreol FSaL & Capreol VFSaL	0.014	0.000	0.000	0.013	0.027	0.000	0.150	0.000	0.006	0.001	0.000
Capreol FSaL & Wolf SiL	0.041	0.000	0.011	0.000	0.000	0.936	0.006	0.001	0.000	0.000	0.000
Capreol VFSaL & Wolf SiL	0.007	0.000	0.146	0.003	0.005	0.044	0.002	0.004	0.001	0.001	0.502

Appendix D

Soil Series Particle Size Distribution Curves and Textural Classes

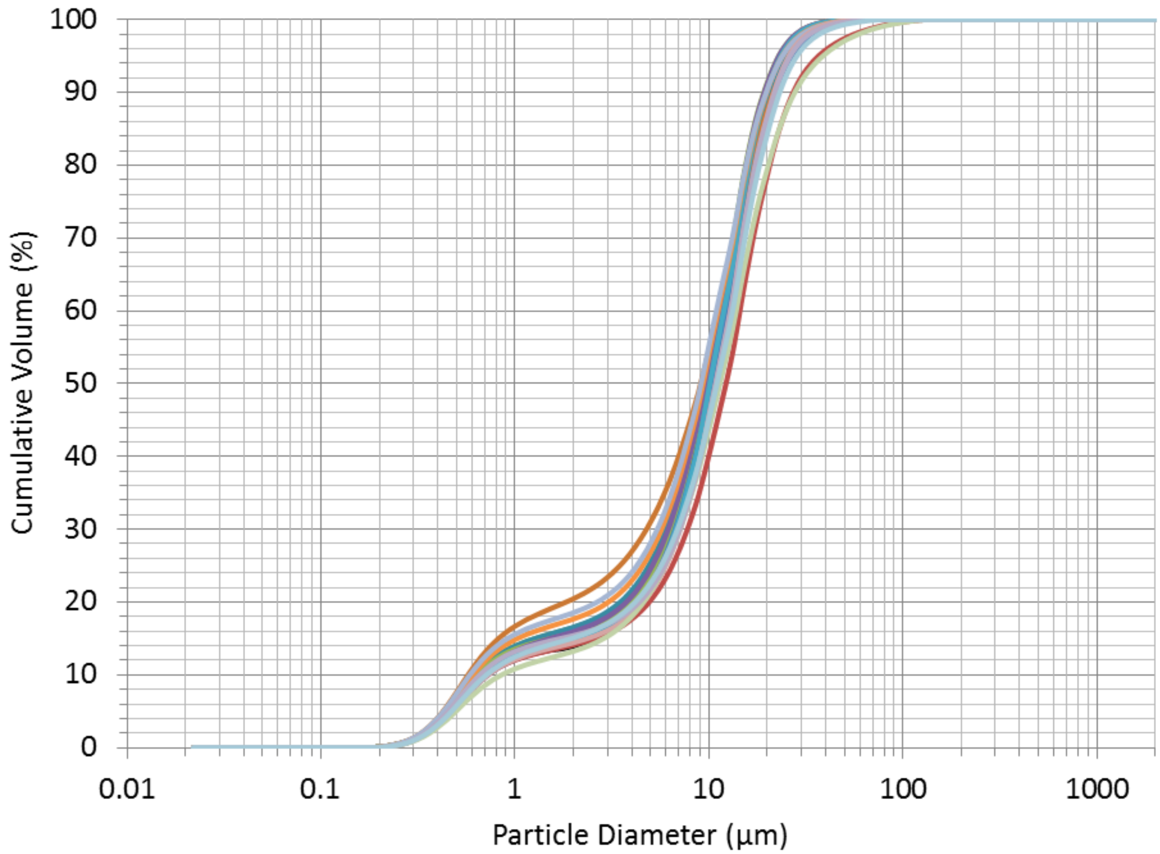


Figure D1. The particle size distribution curves of Topsoil (0-20cm) samples (N=16; each sample represented by a different colour line) taken from within the Azilda Silt Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

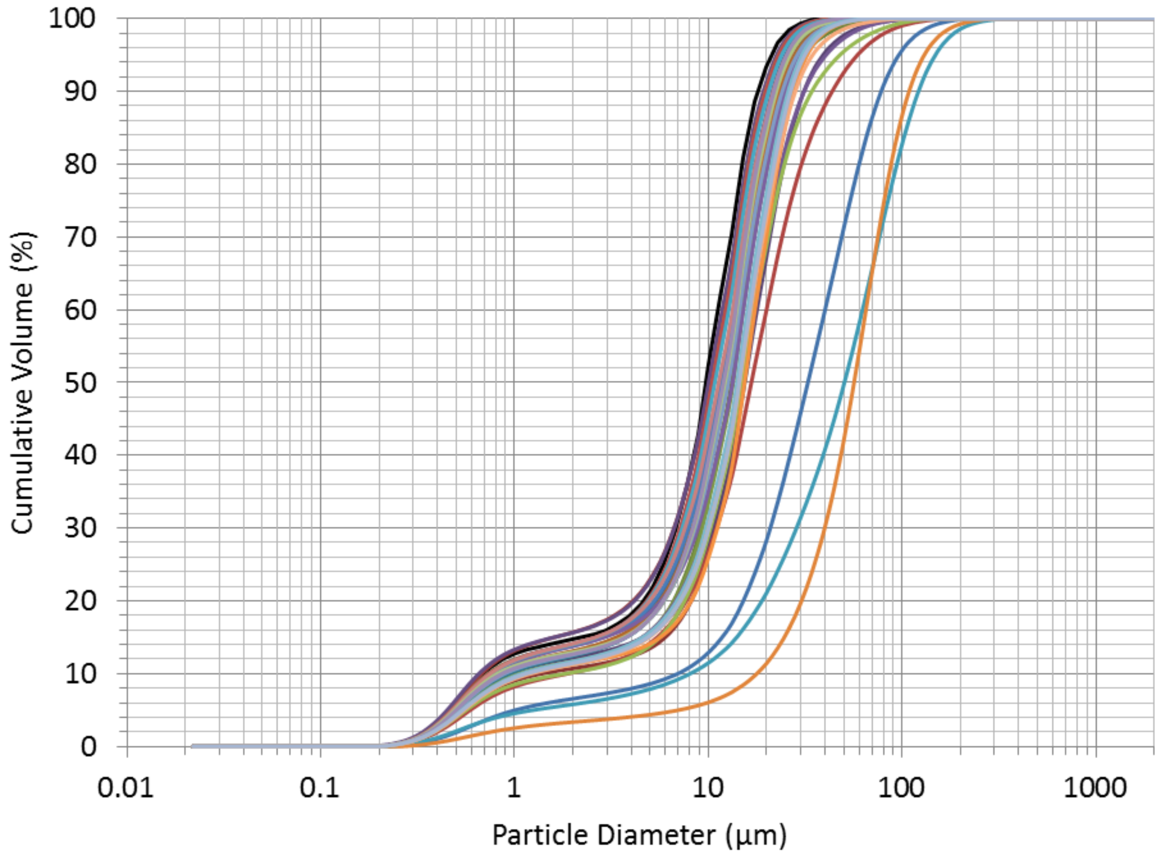


Figure D2. The particle size distribution curves of Subsoil (75-100cm) samples (N=31; each sample represented by a different colour line) taken from within the Azilda Silt Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

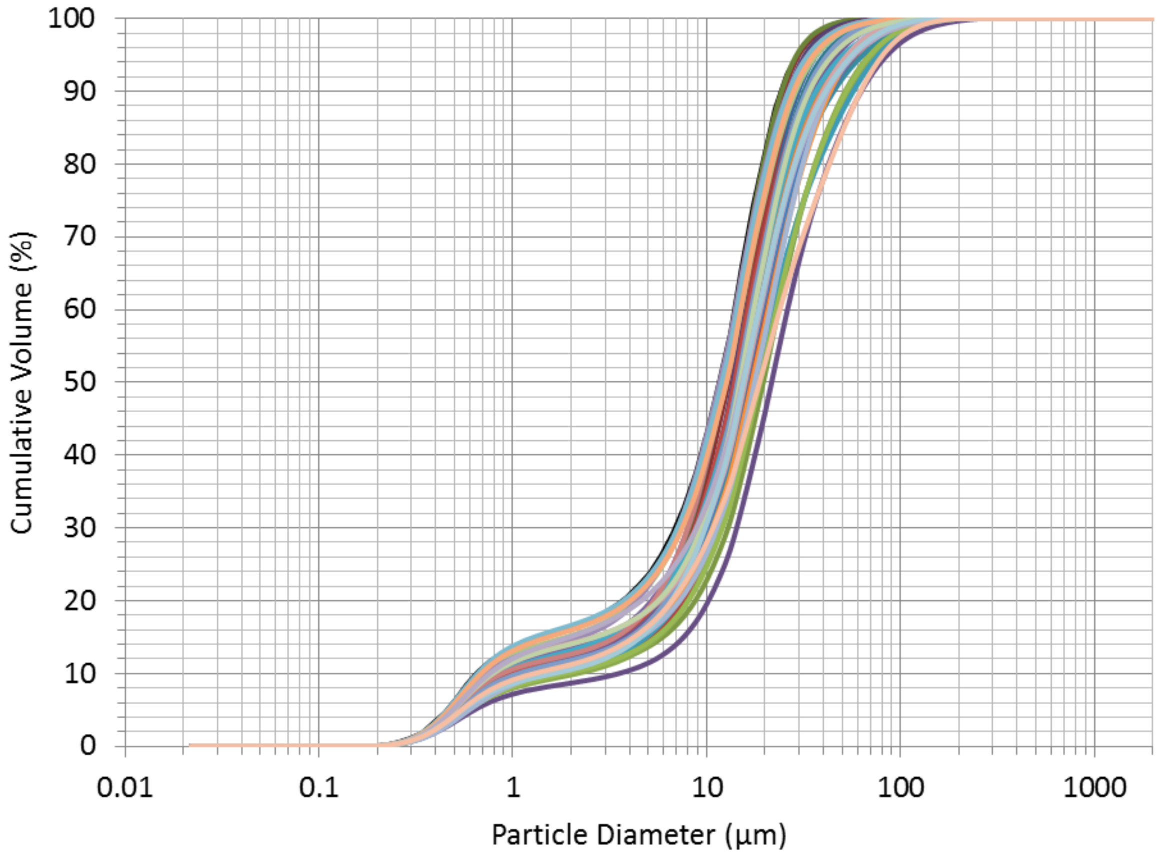


Figure D3. The particle size distribution curves of Topsoil (0-20cm) samples (N=36; each sample represented by a different colour line) taken from within the Bradley Fine Sandy Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

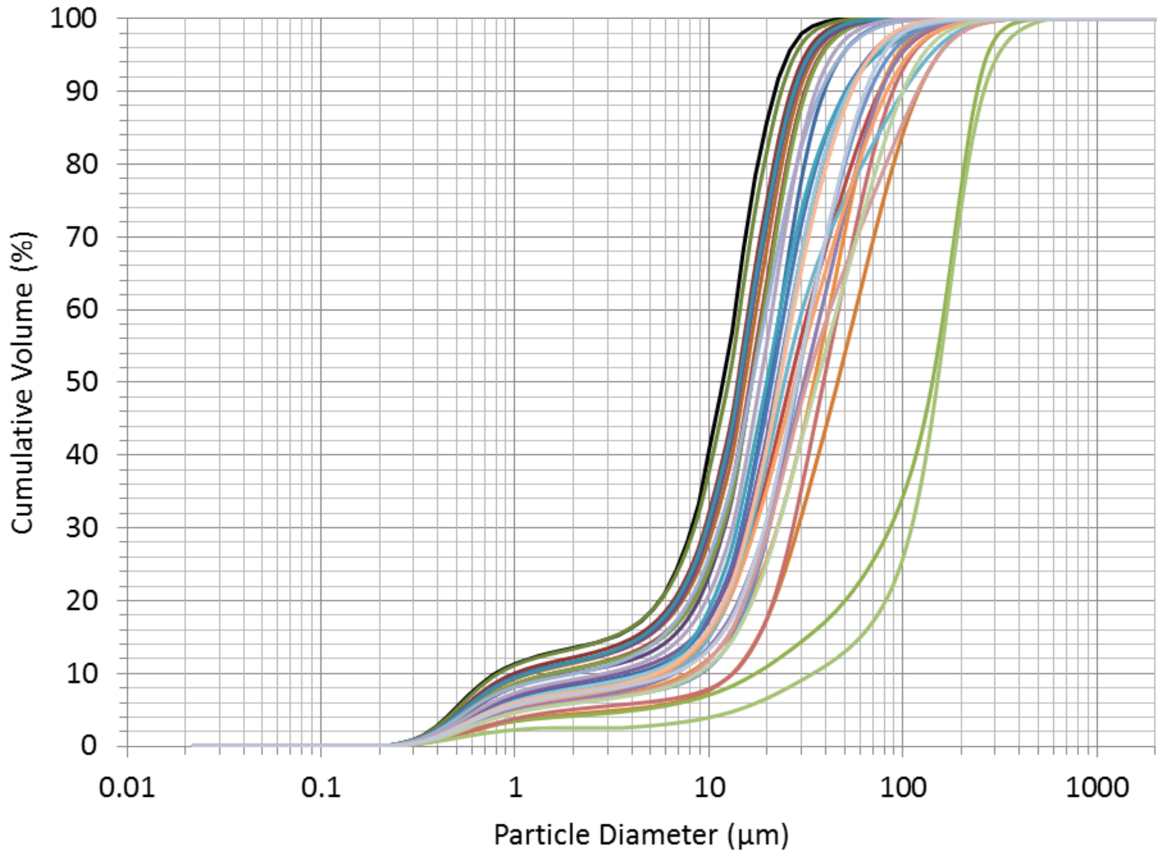


Figure D4. The particle size distribution curves of Subsoil (75-100cm) samples (N=46; each sample represented by a different colour line) taken from within the Bradley Fine Sandy Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

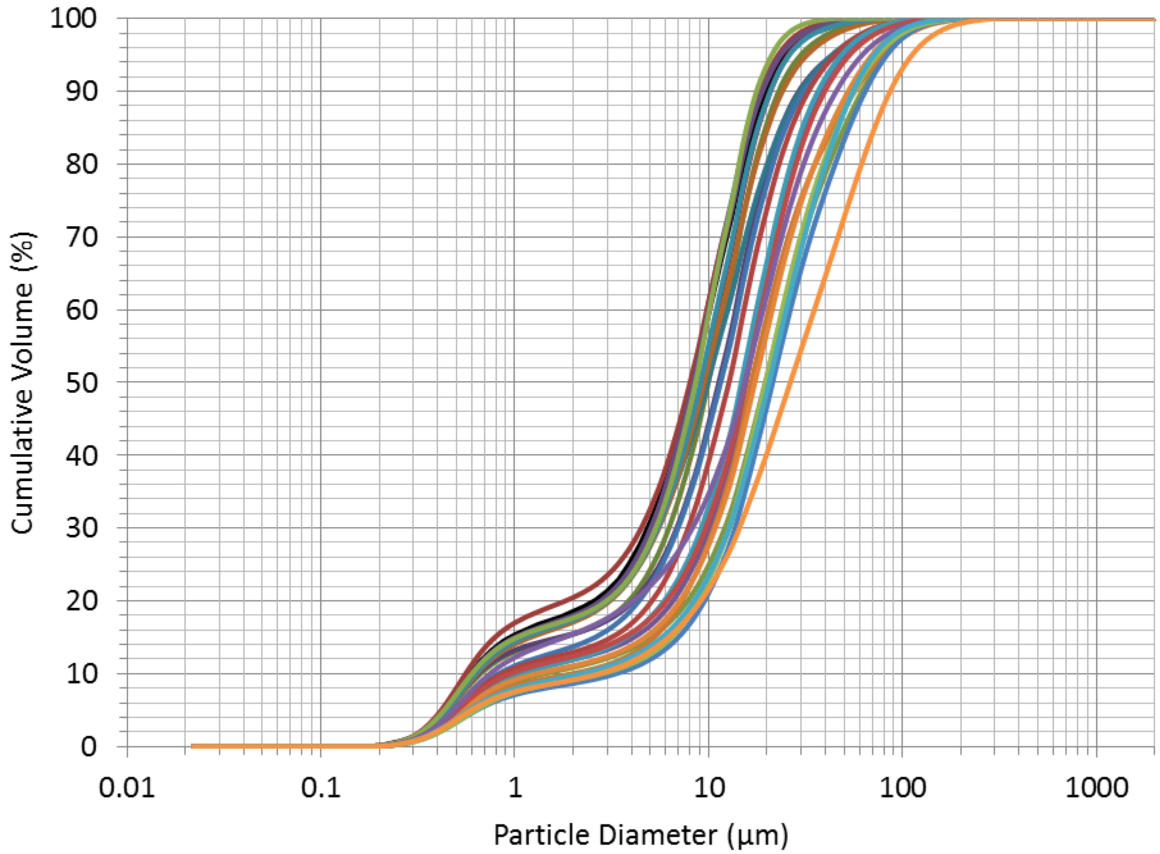


Figure D5. The particle size distribution curves of Topsoil (0-20cm) samples (N=23; each sample represented by a different colour line) taken from within the Bradley Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

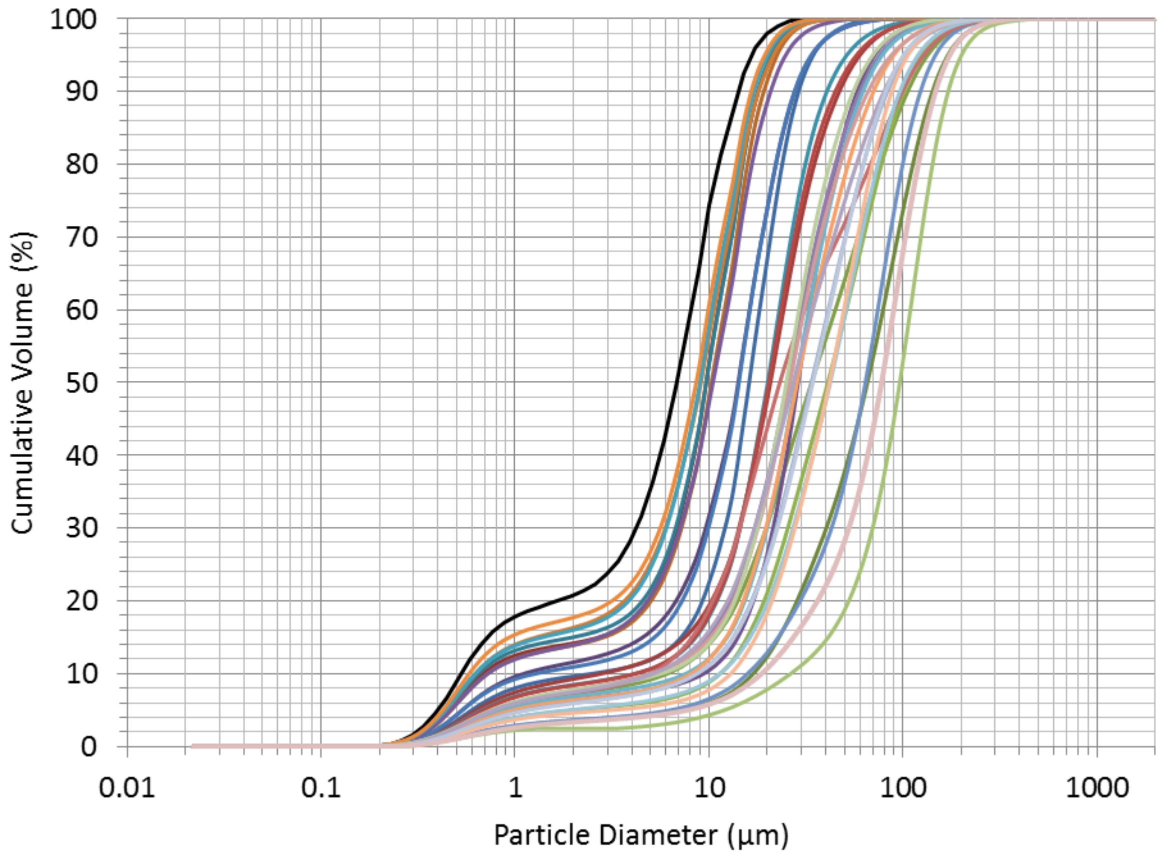


Figure D6. The particle size distribution curves of Subsoil (75-100cm) samples (N=33; each sample represented by a different colour line) taken from within the Bradley Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 μm) is depicted along the cumulative volume (0-100%) of particles measured.

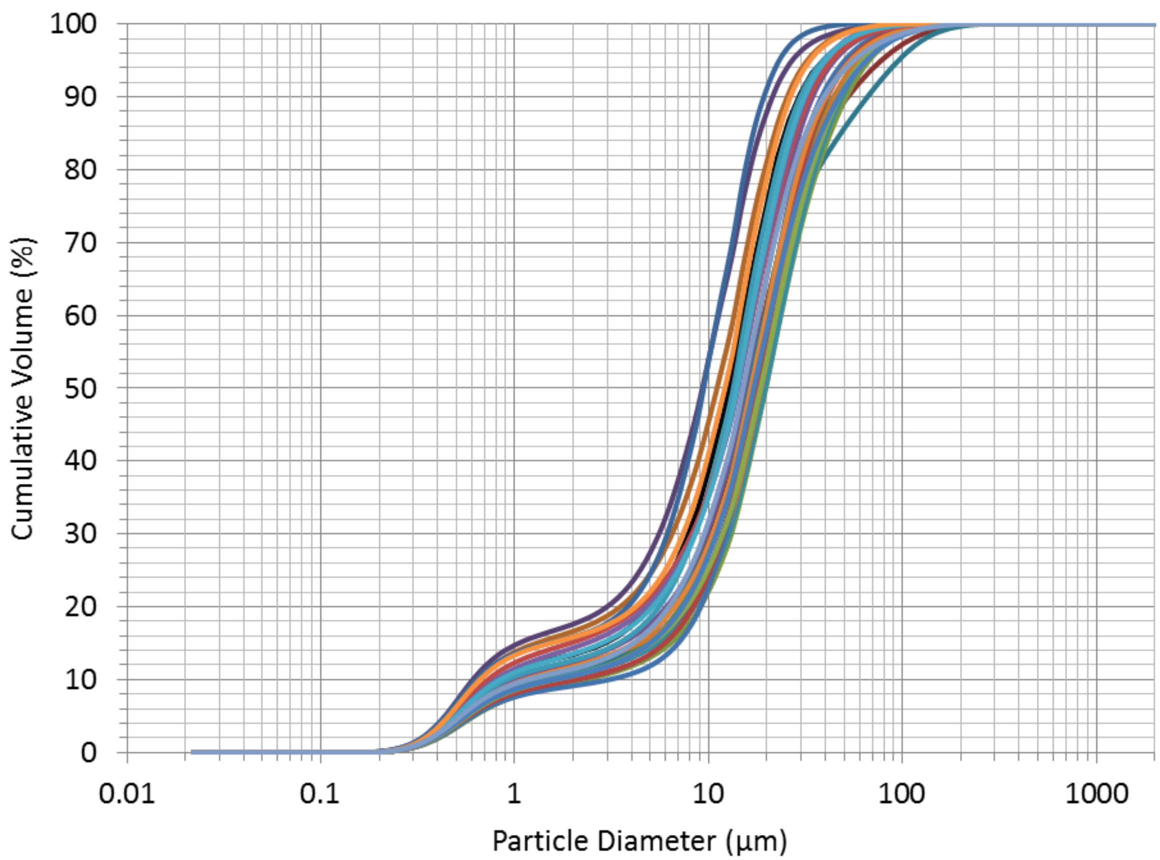


Figure D7. The particle size distribution curves of Topsoil (0-20cm) samples (N=25; each sample represented by a different colour line) taken from within the Capreol Fine Sandy Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

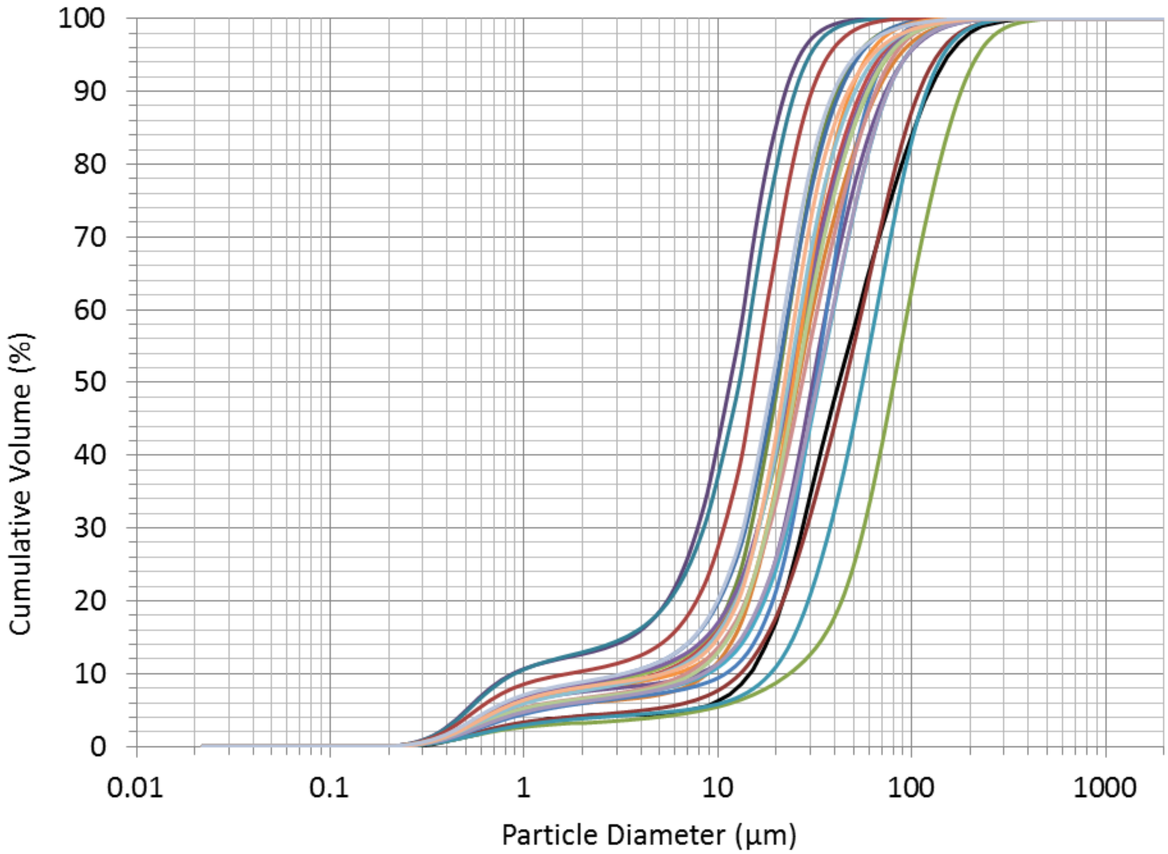


Figure D8. The particle size distribution curves of Subsoil (75-100cm) samples (N=32; each sample represented by a different colour line) taken from within the Capreol Fine Sandy Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

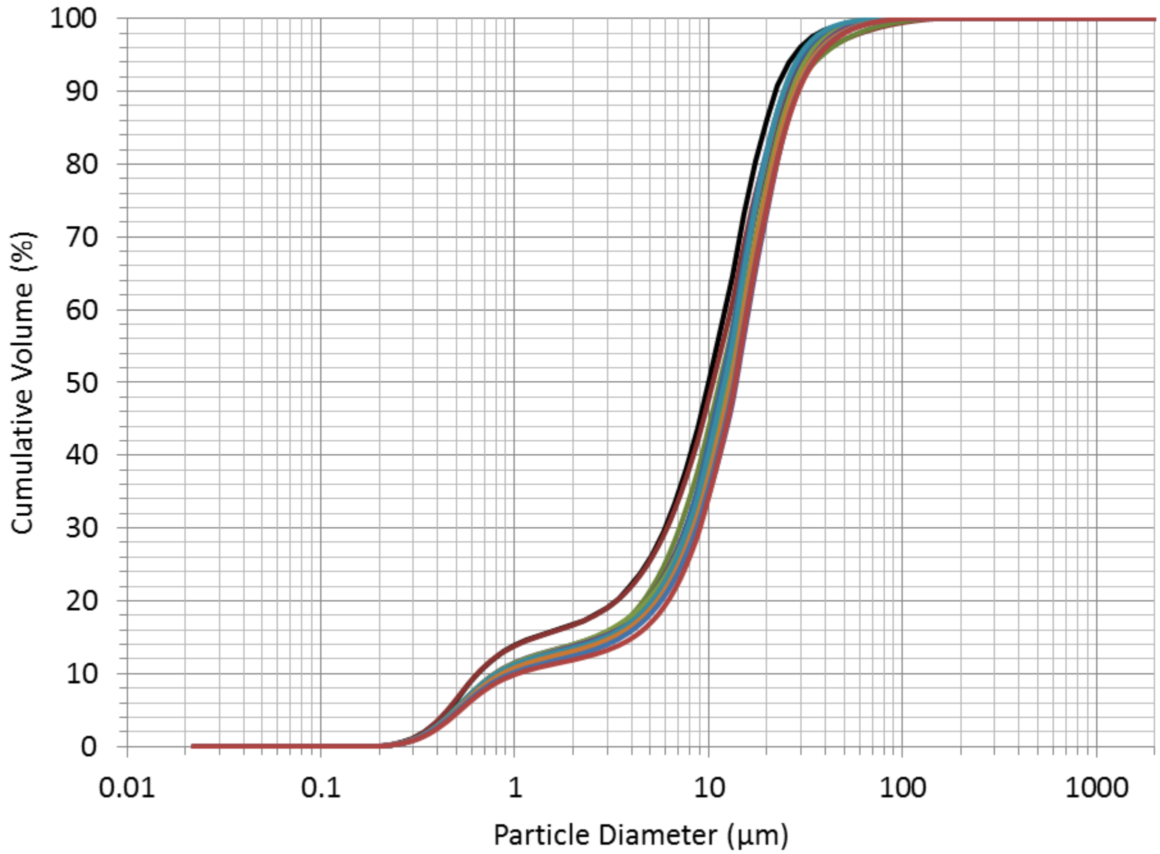


Figure D9. The particle size distribution curves of Topsoil (0-20cm) samples (N=15; each sample represented by a different colour line) taken from within the Capreol Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

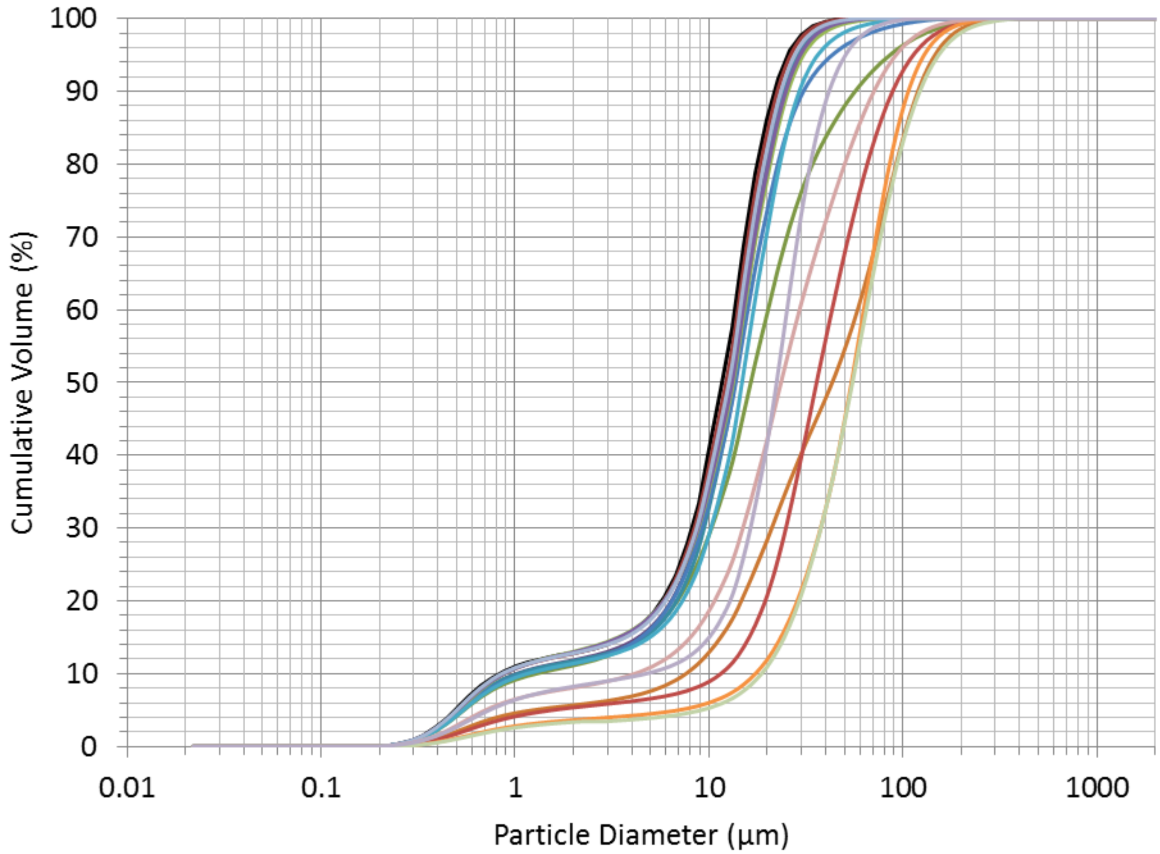


Figure D10. The particle size distribution curves of Subsoil (75-100cm) samples (N=16; each sample represented by a different colour line) taken from within the Capreol Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

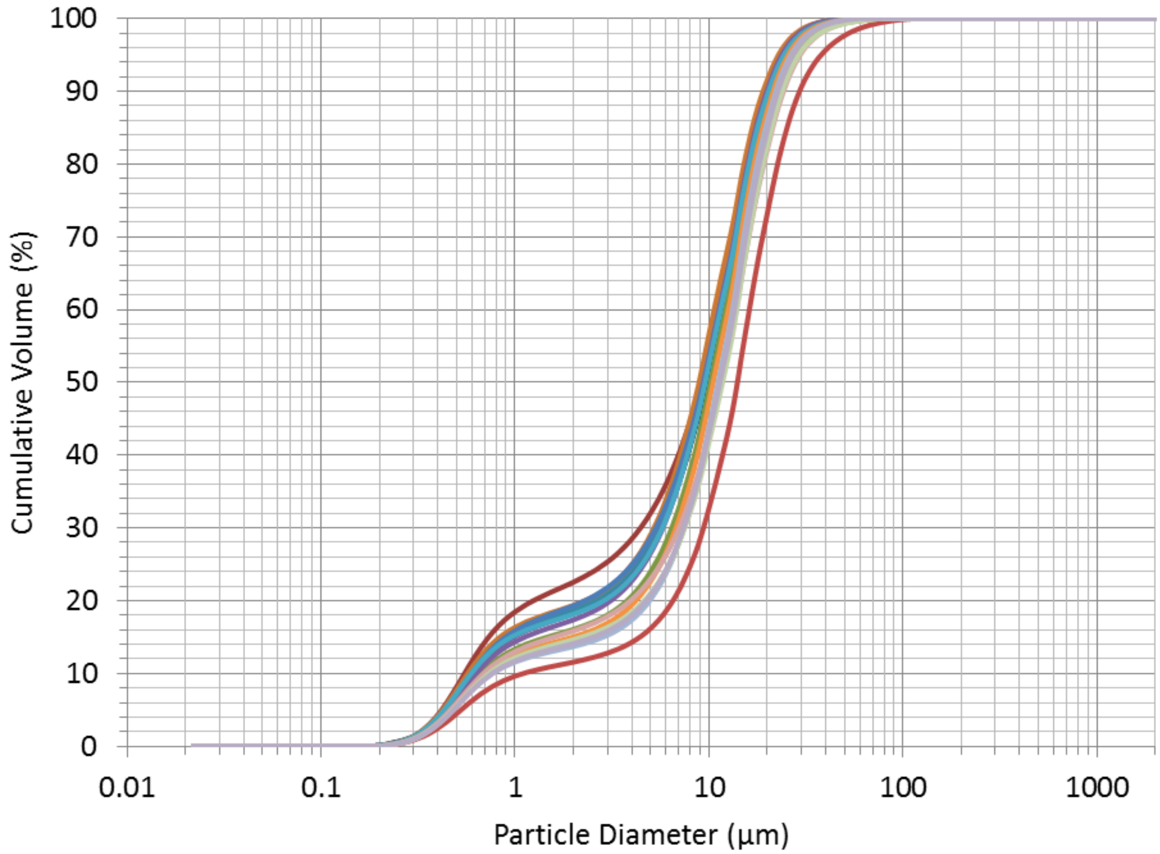


Figure D11. The particle size distribution curves of Topsoil (0-20cm) samples (N=16; each sample represented by a different colour line) taken from within the Wolf Silt Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 μm) is depicted along the cumulative volume (0-100%) of particles measured.

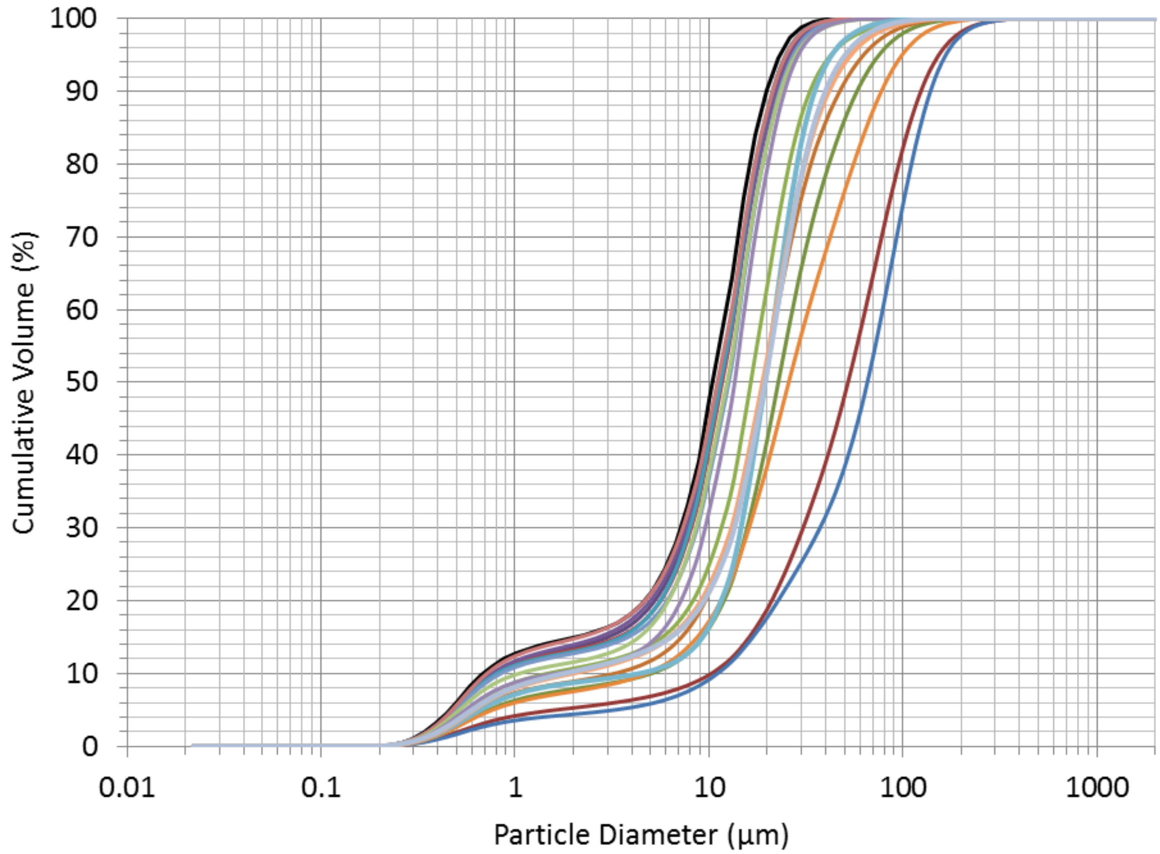


Figure D12. The particle size distribution curves of Subsoil (75-100cm) samples (N=19; each sample represented by a different colour line) taken from within the Wolf Silt Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

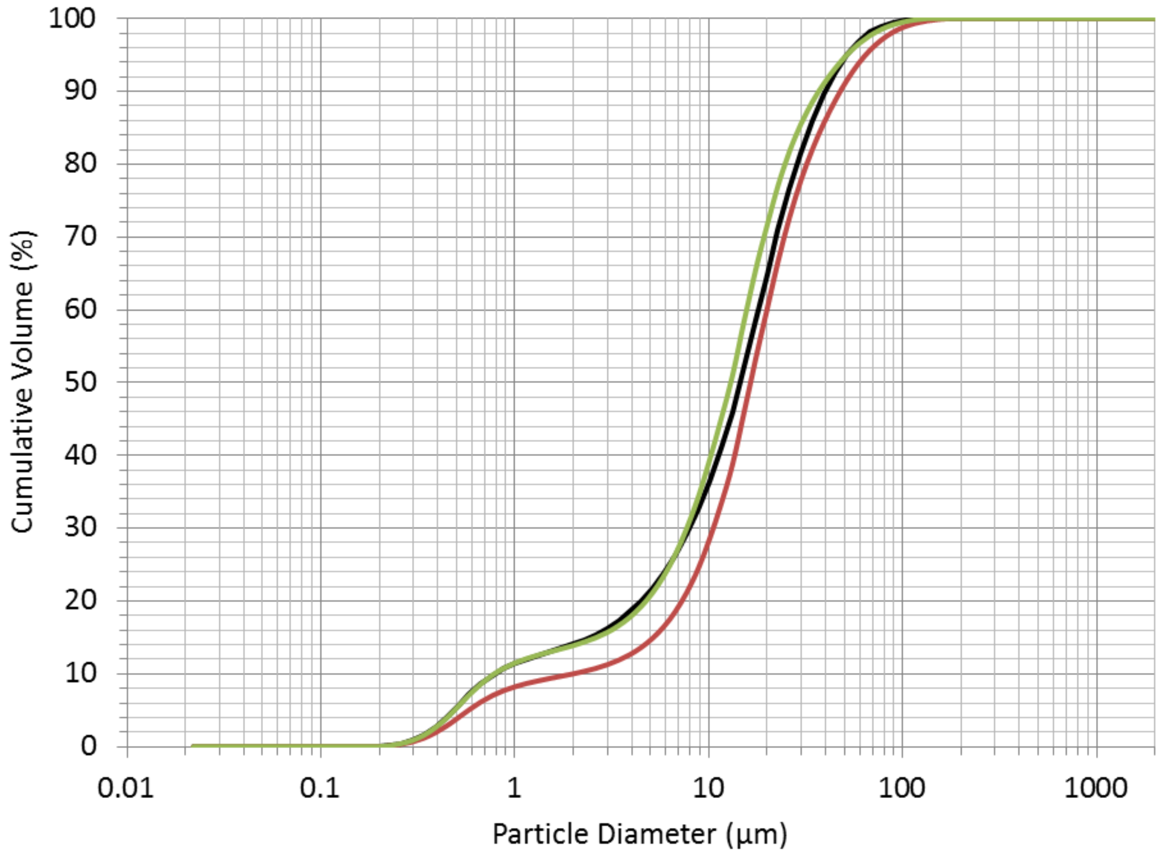


Figure D13. The particle size distribution curves of Topsoil (0-20cm) samples (N=3; each sample represented by a different colour line) taken from within the Wolf Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

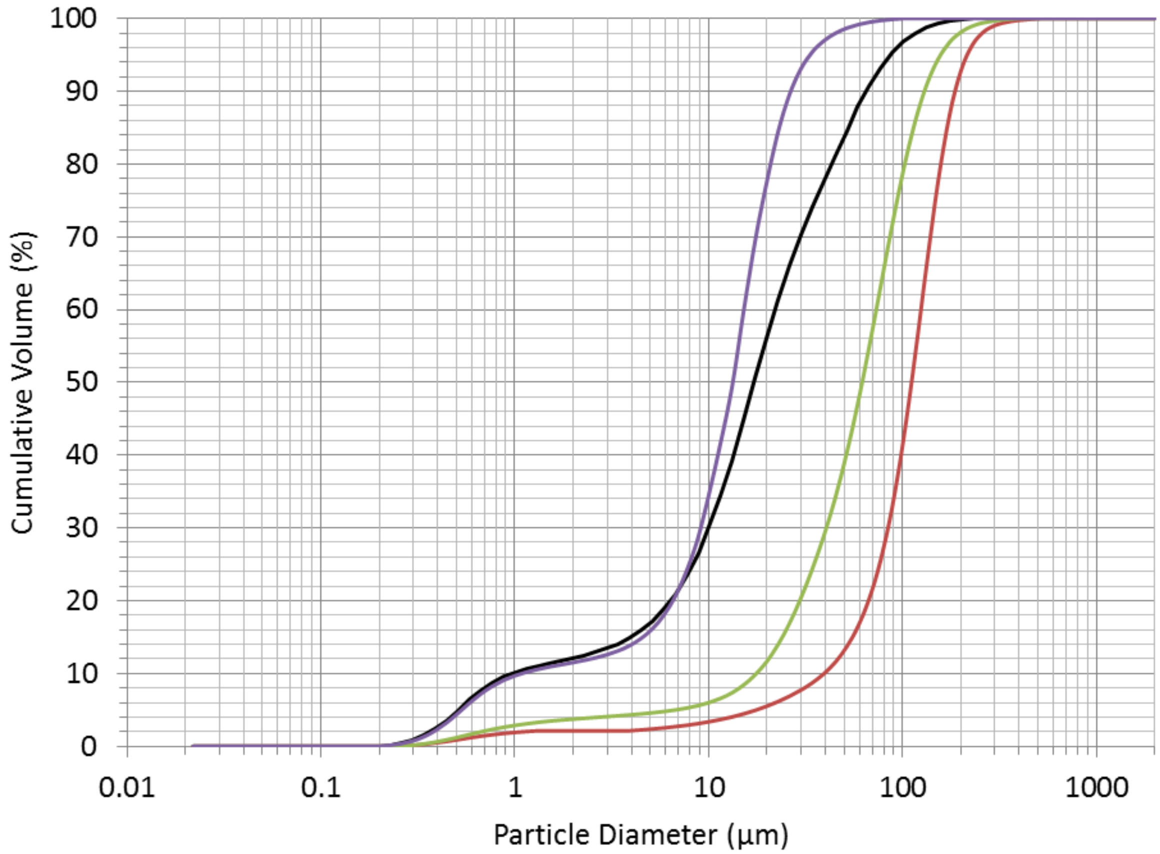


Figure D14. The particle size distribution curves of Subsoil (75-100cm) samples (N=4; each sample represented by a different colour line) taken from within the Wolf Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

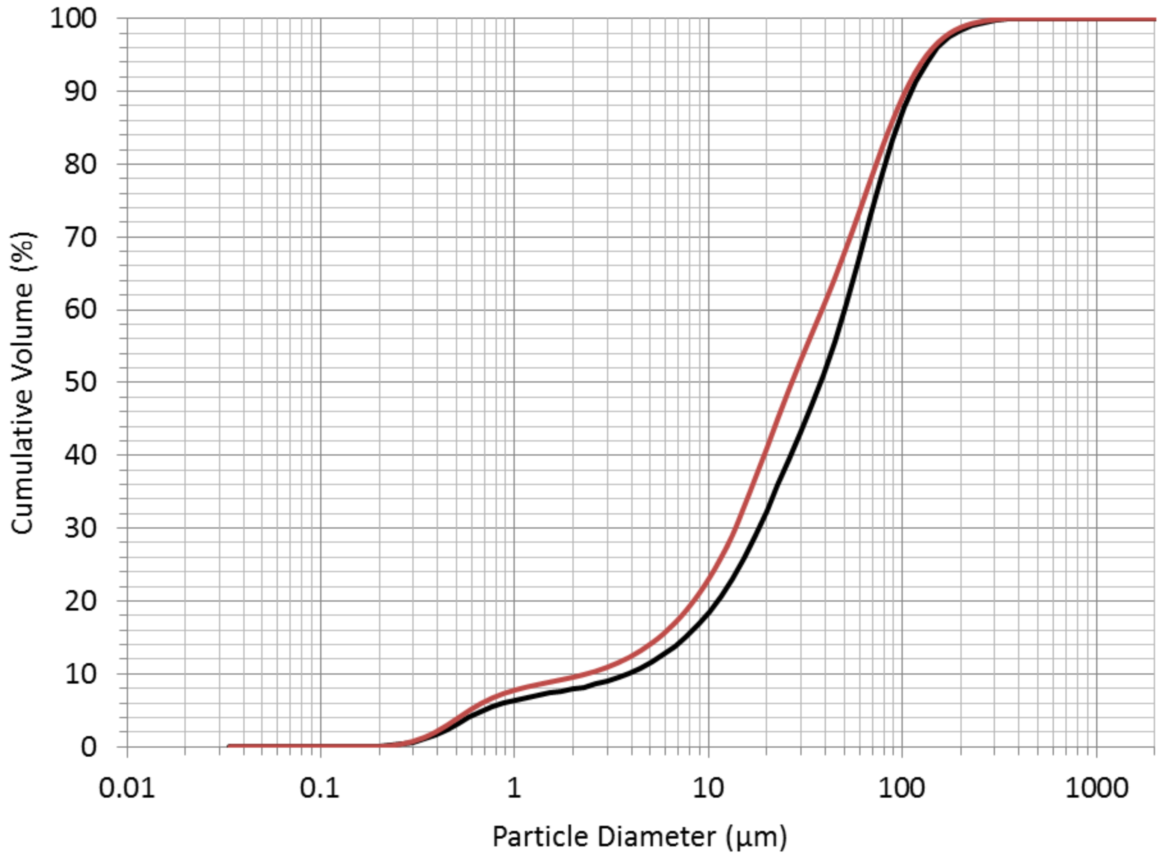


Figure D15. The particle size distribution curves of Topsoil (0-20cm) samples (N=2; each sample represented by a different colour line) taken from within the Naiden Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Topsoil particles size (0.01- 2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

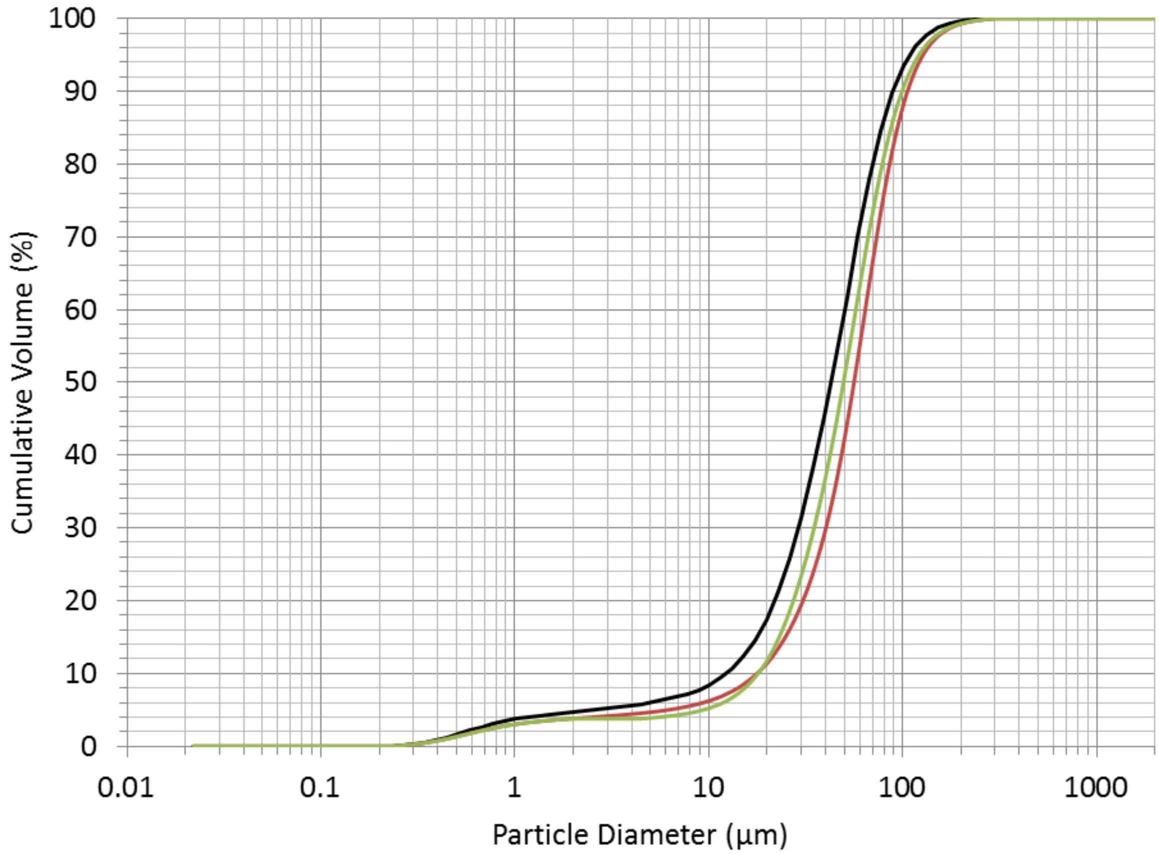


Figure D16. The particle size distribution curves of Subsoil (75-100cm) samples (N=3; each sample represented by a different colour line) taken from within the Naiden Very Fine Sandy Loam Series (Gillespie *et al*. 1982). Subsoil particles size (0.01-2000 µm) is depicted along the cumulative volume (0-100%) of particles measured.

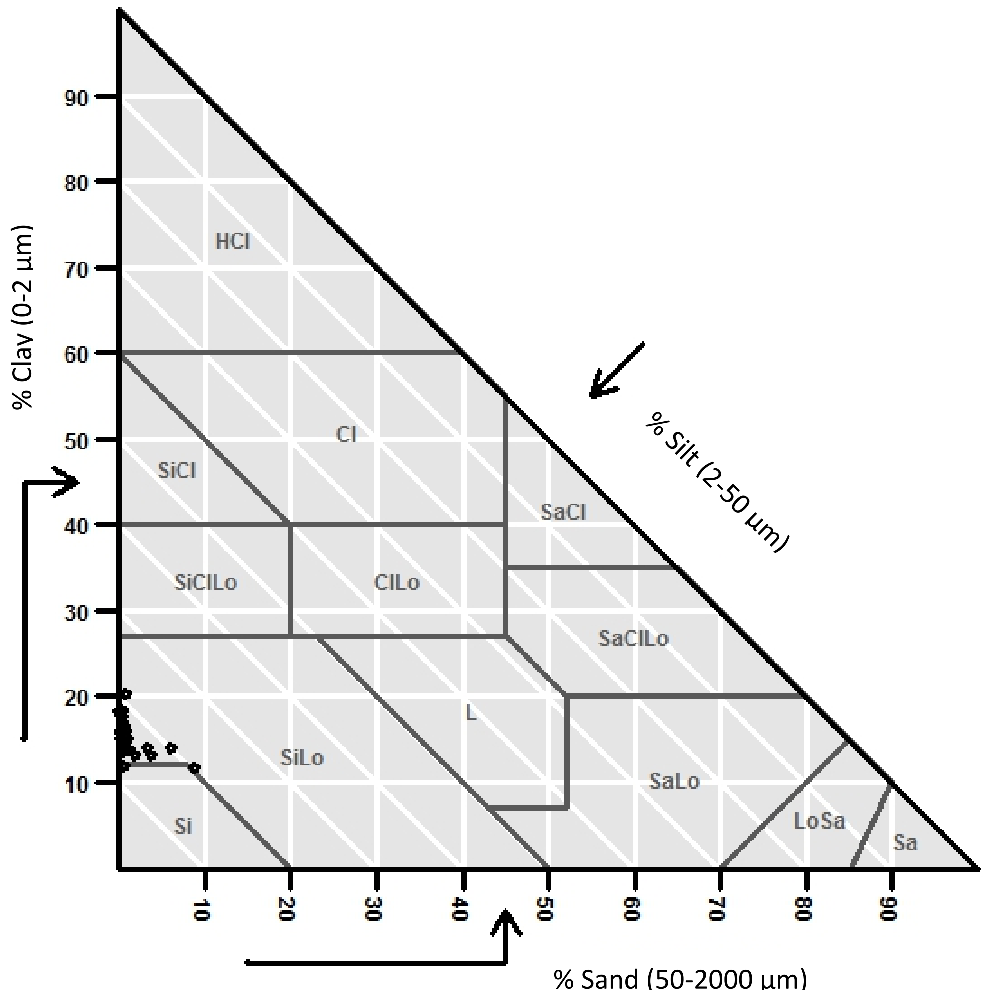


Figure D17. Topsoil (0-20cm) particle size data of samples (n=16; each sample represented by a black dot) taken within the Azilda Silt Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

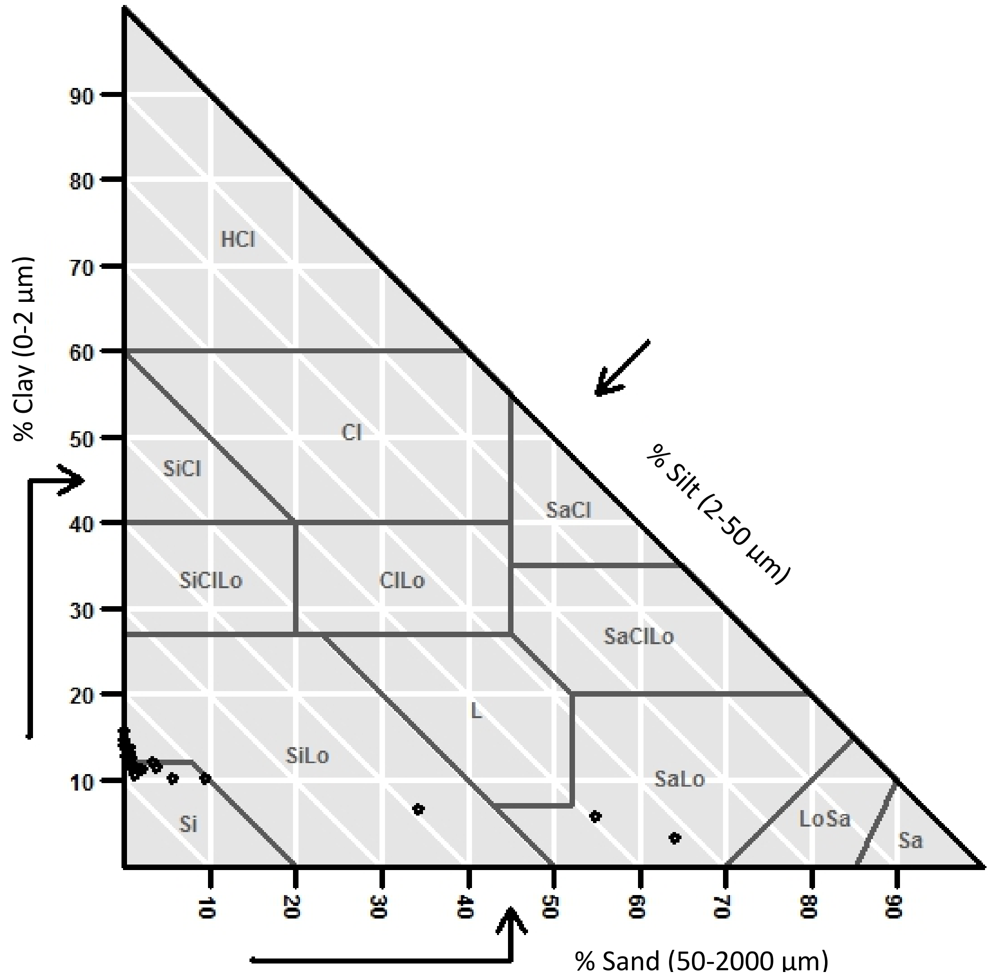


Figure D18. Subsoil (75-100cm) particle size data of samples (n=31; each sample represented by a black dot) taken within the Azilda Silt Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

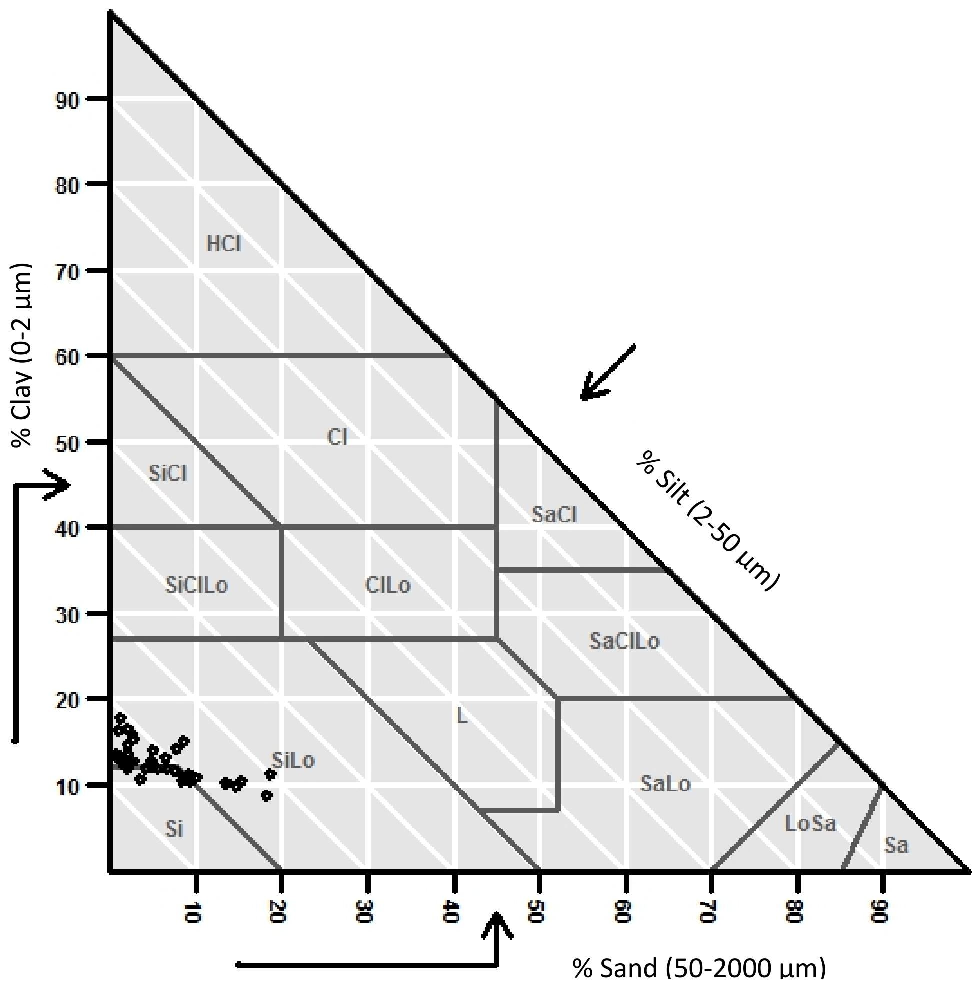


Figure D19. Topsoil (0-20cm) particle size data of samples (n=36; each sample represented by a black dot) taken within the Bradley Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

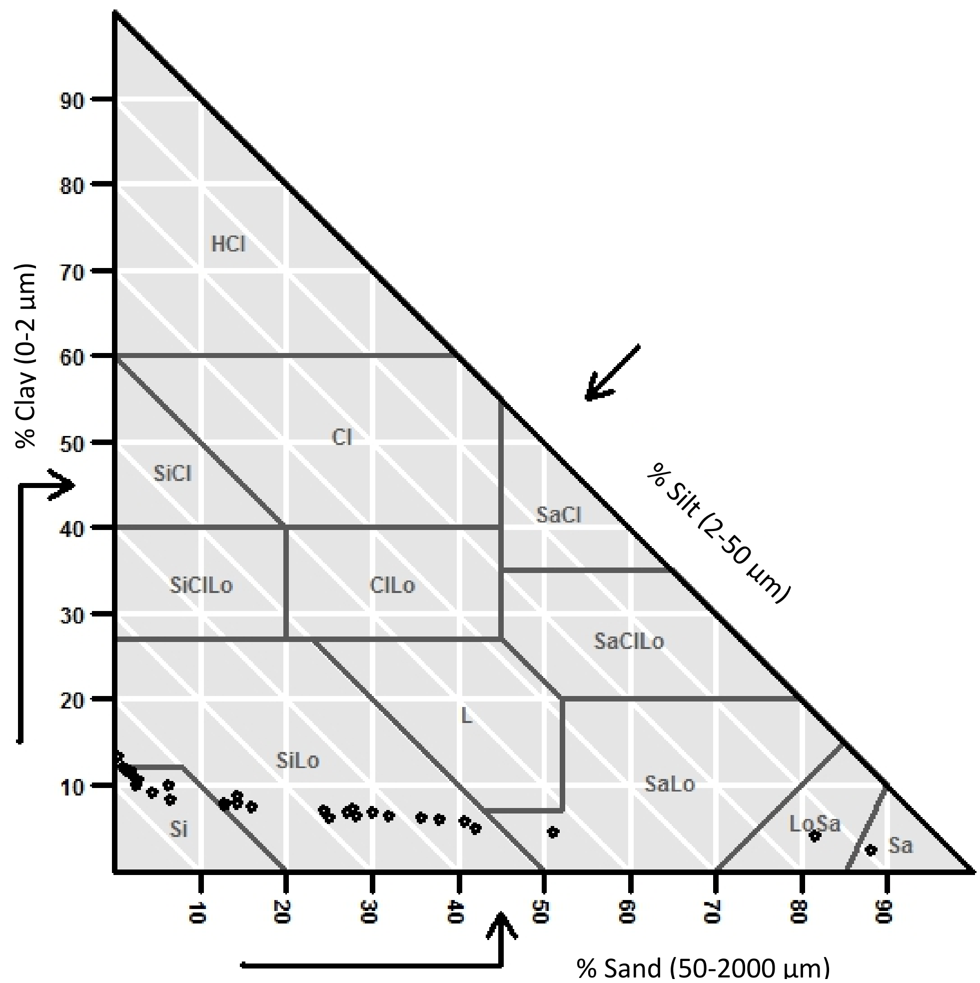


Figure D20. Subsoil (75-100cm) particle size data of samples (n=46; each sample represented by a black dot) taken within the Bradley Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

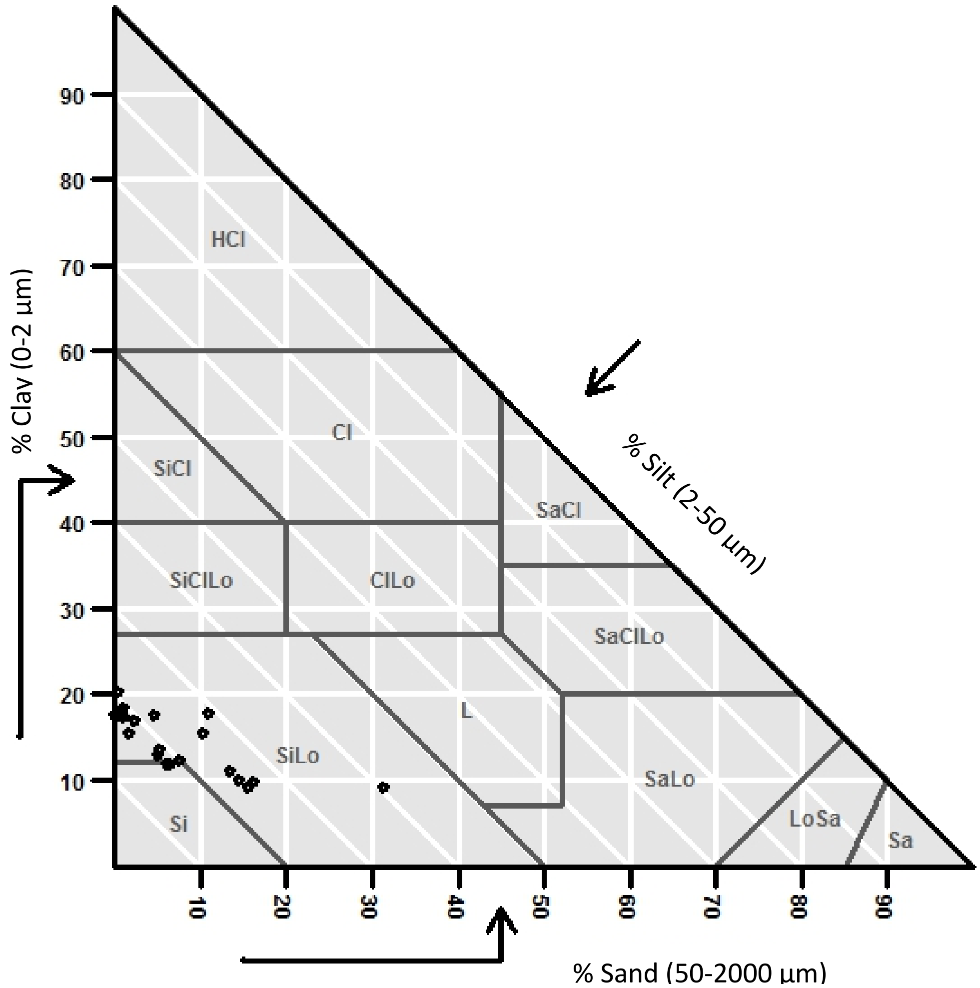


Figure D21. Topsoil (0-20cm) particle size data of samples (n=23; each sample represented by a black dot) taken from for the Bradley Very Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

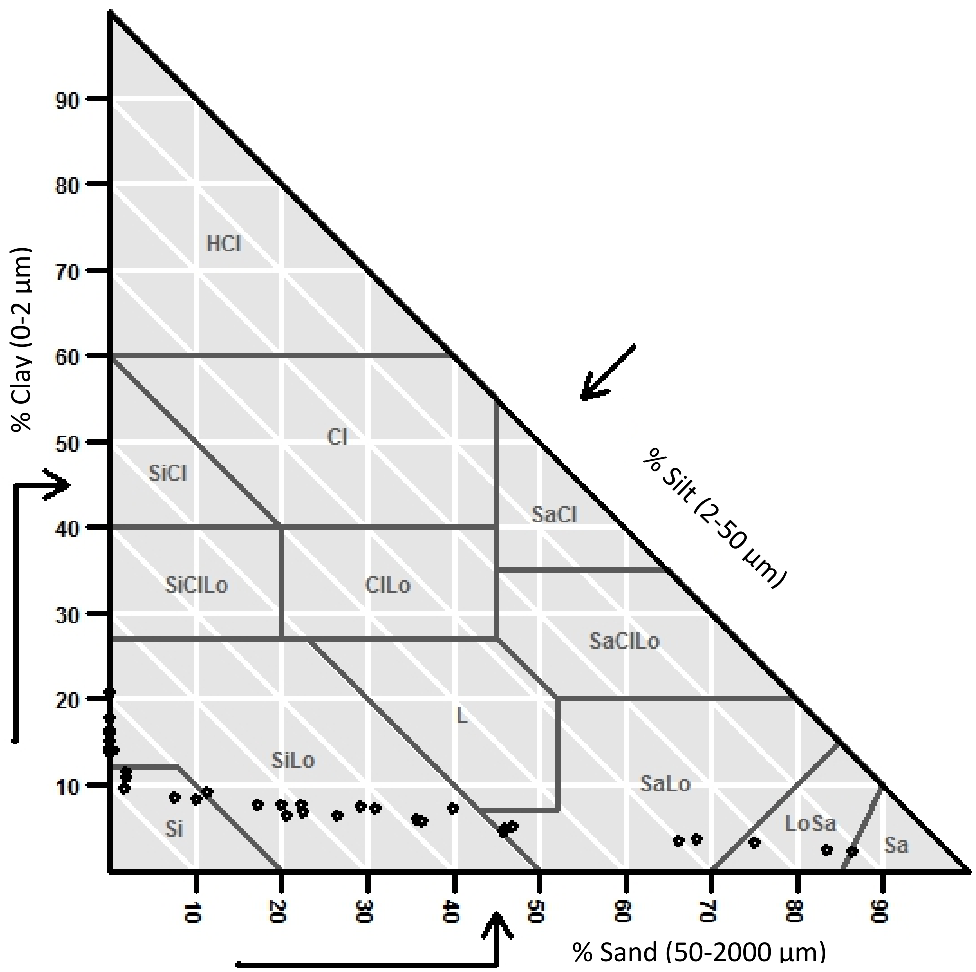


Figure D22. Subsoil (75-100cm) particle size data of samples (n=33; ; each sample represented by a black dot) taken within the Bradley Very Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

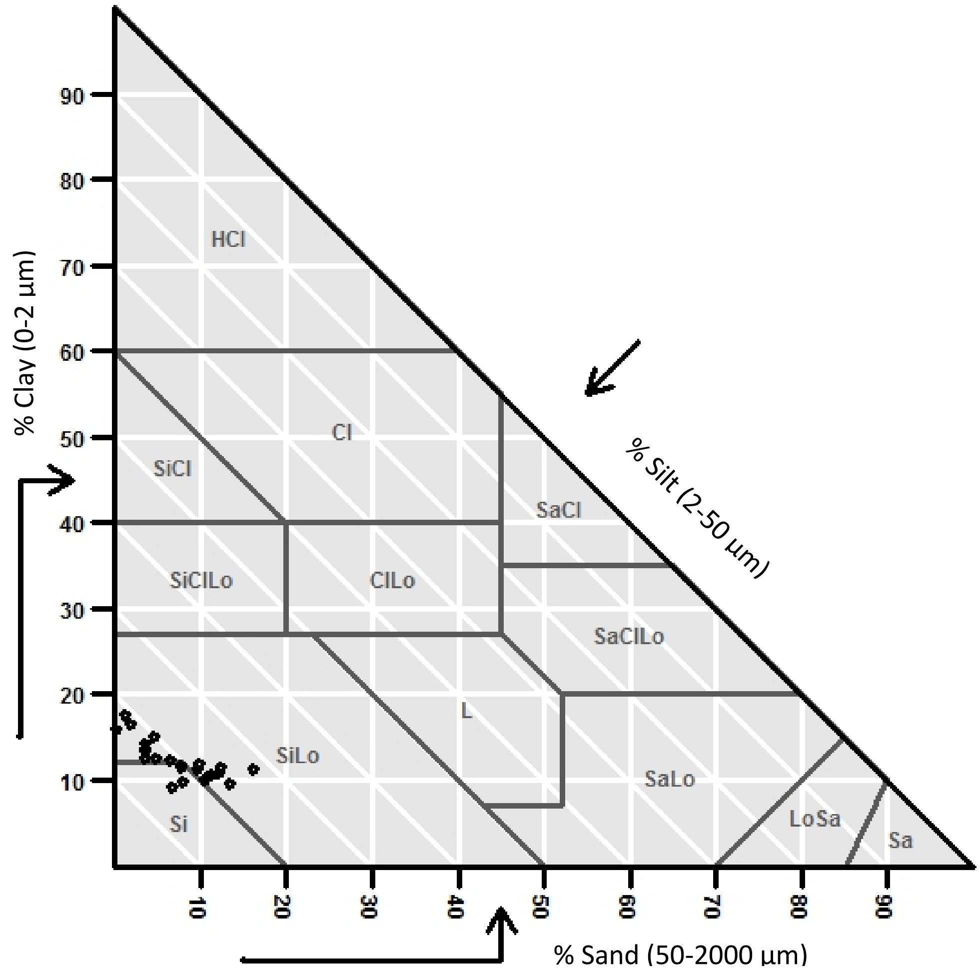


Figure D23. Topsoil (0-20cm) particle size data of samples (n=25; ; each sample represented by a black dot) taken within the Capreol Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

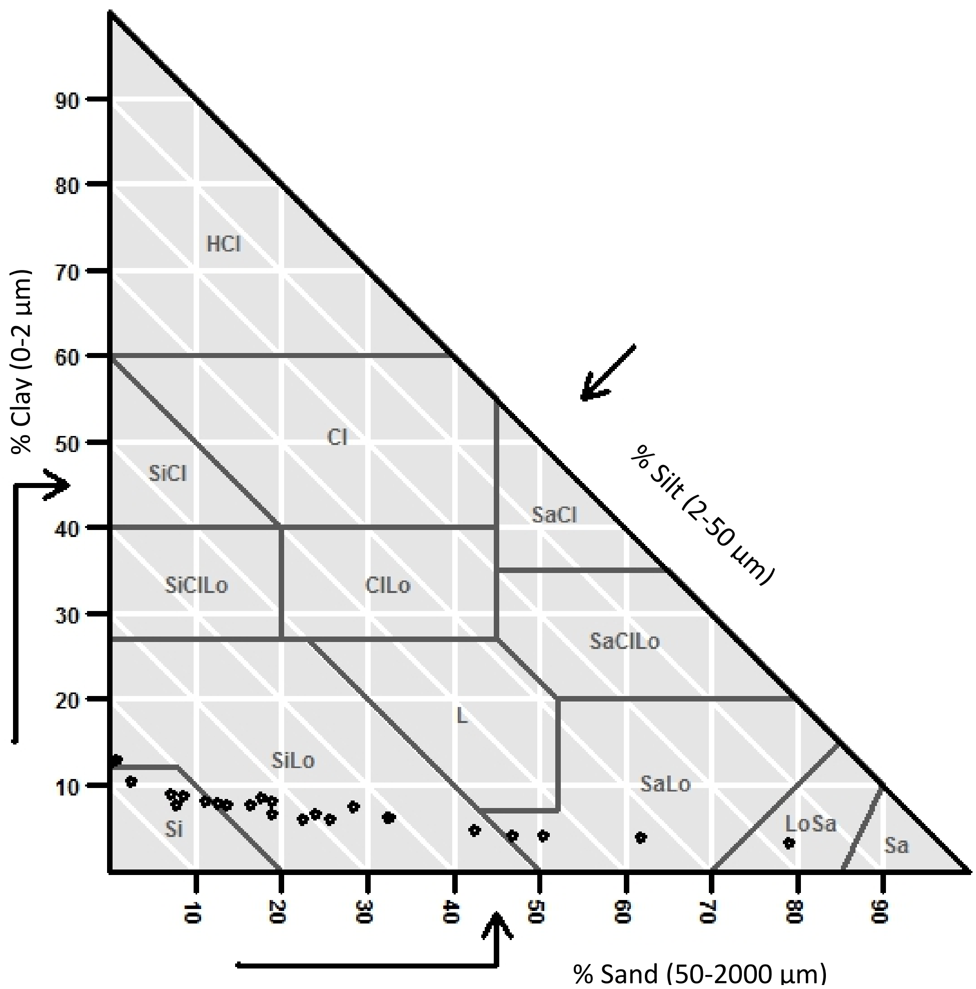


Figure D24. Subsoil (75-100cm) particle size data of samples (n=32; each sample represented by a black dot) taken within the Capreol Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

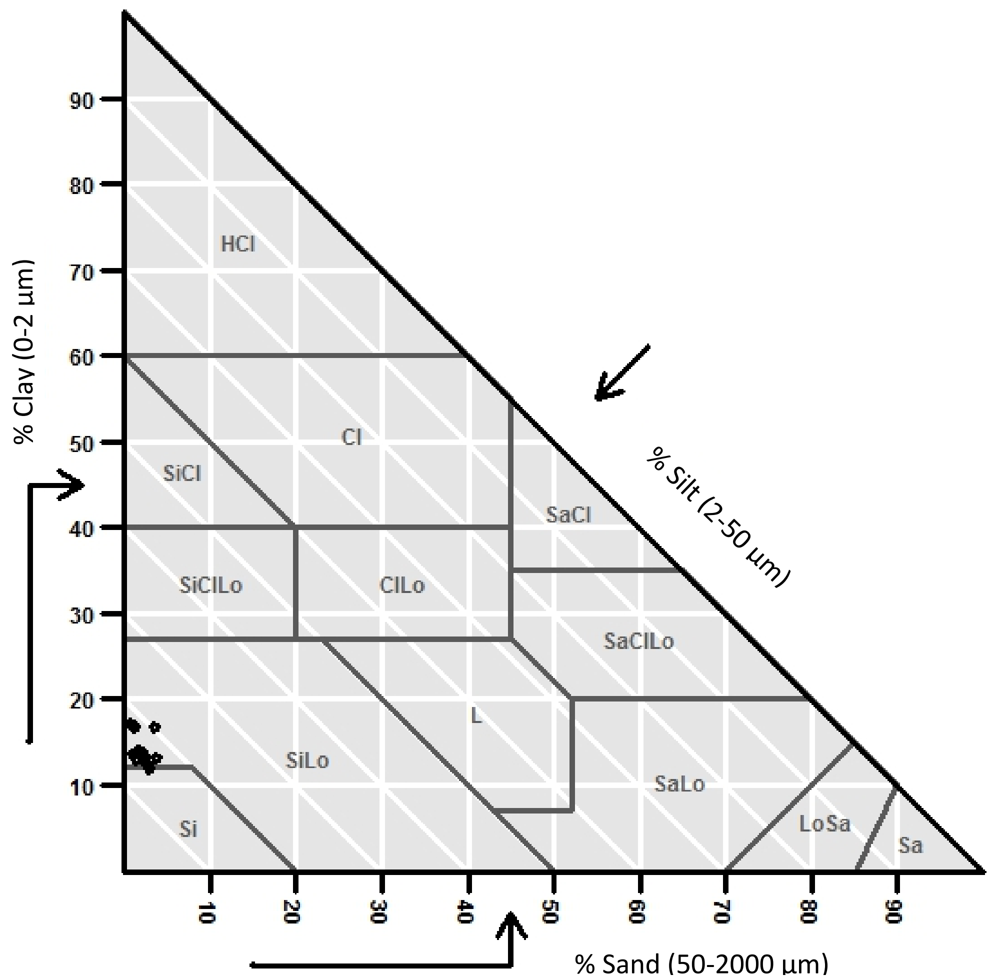


Figure D25. Topsoil (0-20cm) particle size data of samples (n=15; each sample represented by a black dot) taken within the Capreol Very Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

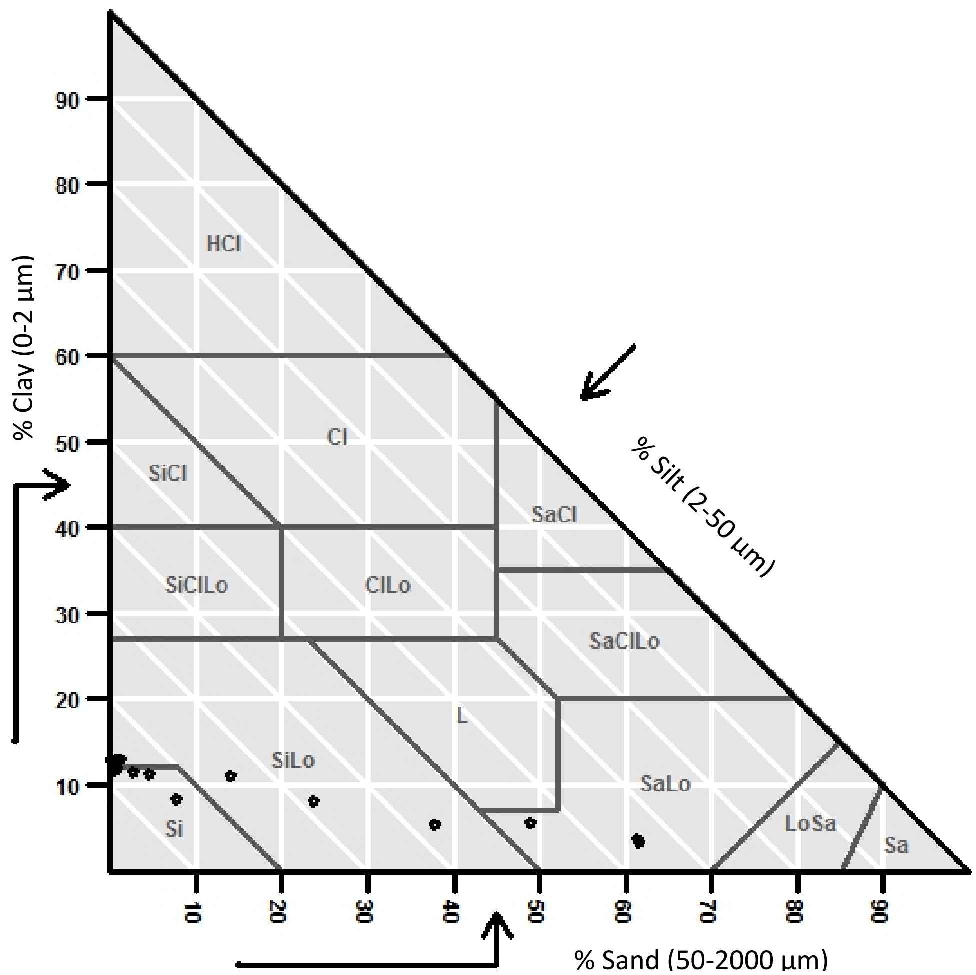


Figure D26. Subsoil (75-100cm) particle size data of samples (n=16; each sample represented by a black dot) taken within the Capreol Very Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

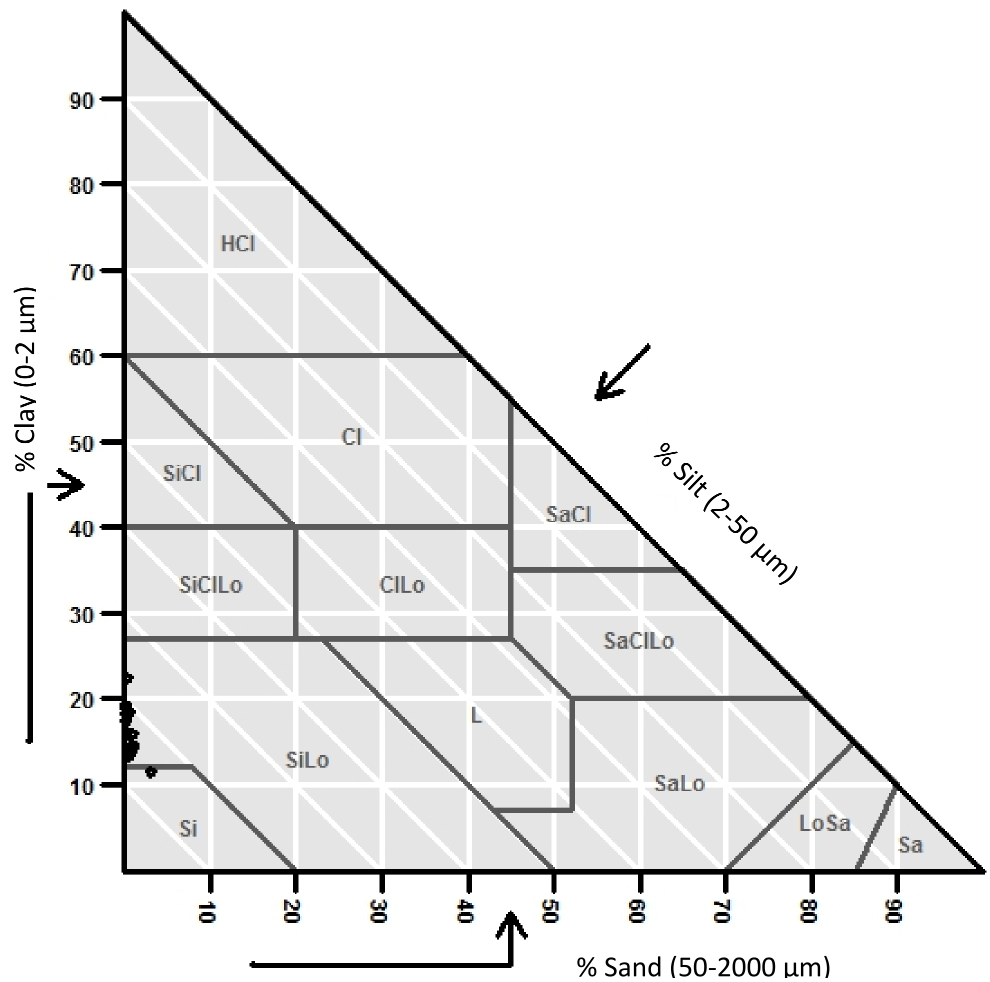


Figure D27. Topsoil (0-20cm) particle size data of samples (n=16; each sample represented by a black dot) taken within the Wolf Silt Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

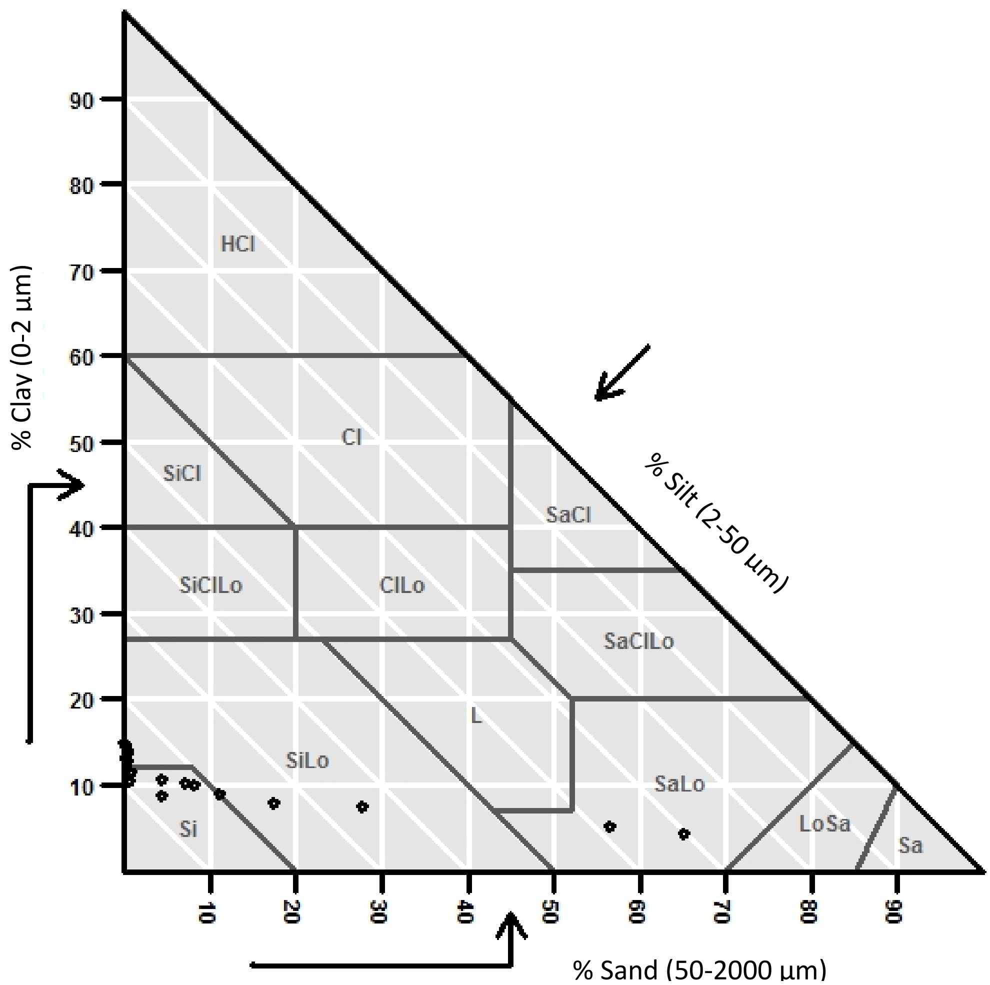


Figure D28. Subsoil (75-100cm) particle size data of samples (n=19; each sample represented by a black dot) taken within the Wolf Silt Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

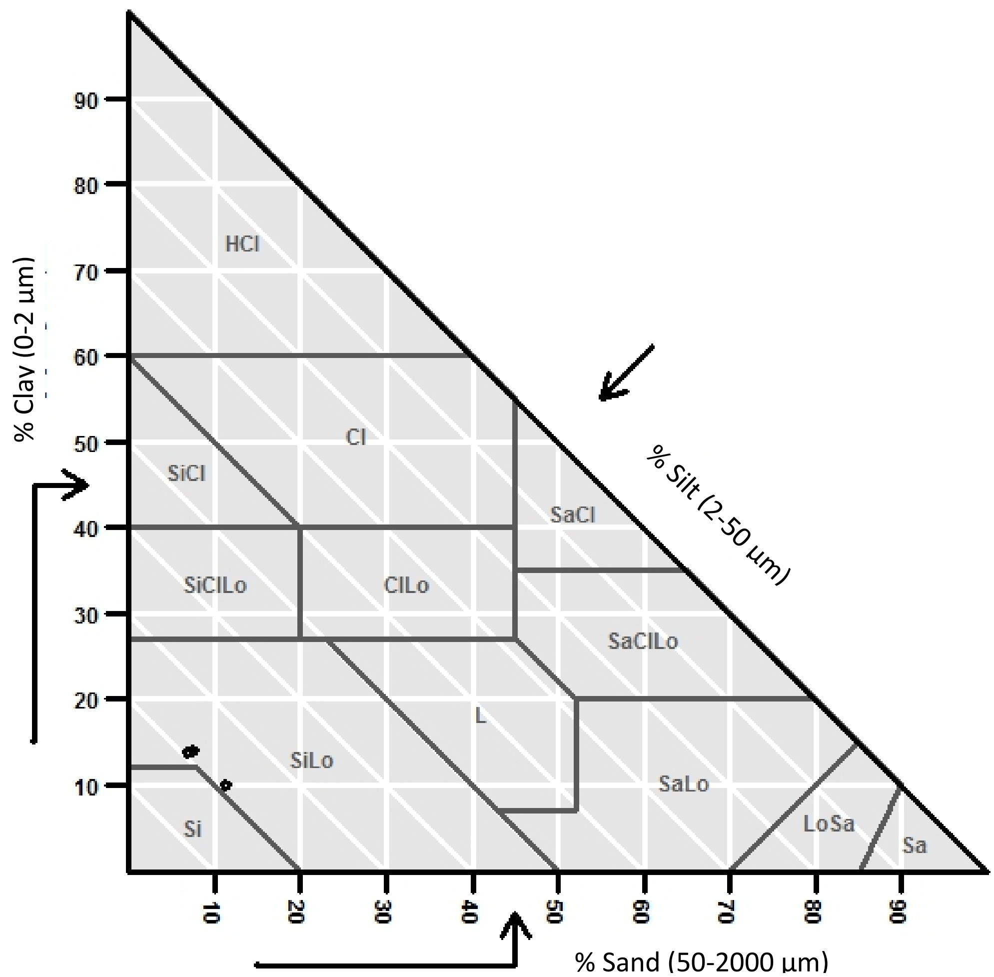


Figure D29. Topsoil (0-20cm) particle size data of samples (n=3; each sample represented by a black dot) taken within the Wolf Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

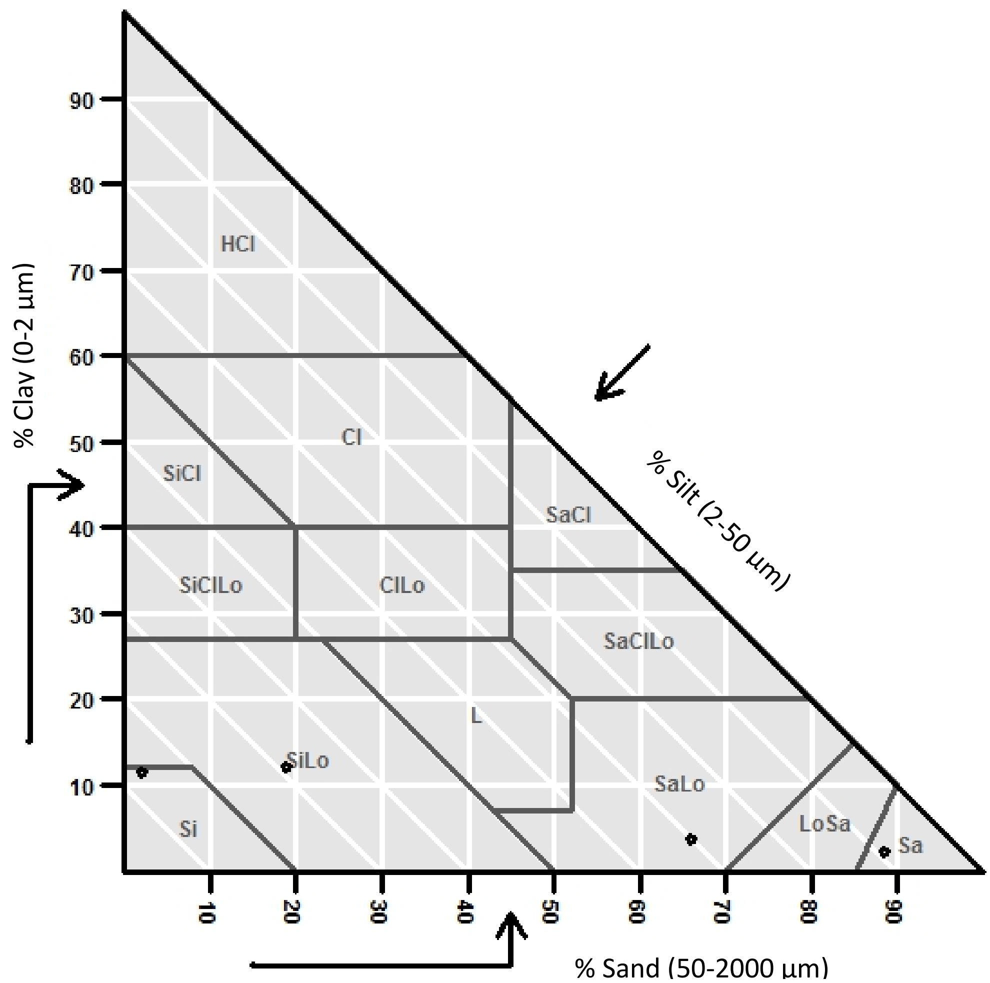


Figure D30. Subsoil (75-100cm) particle size data of samples (n=4; each sample represented by a black dot) taken within the Wolf Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

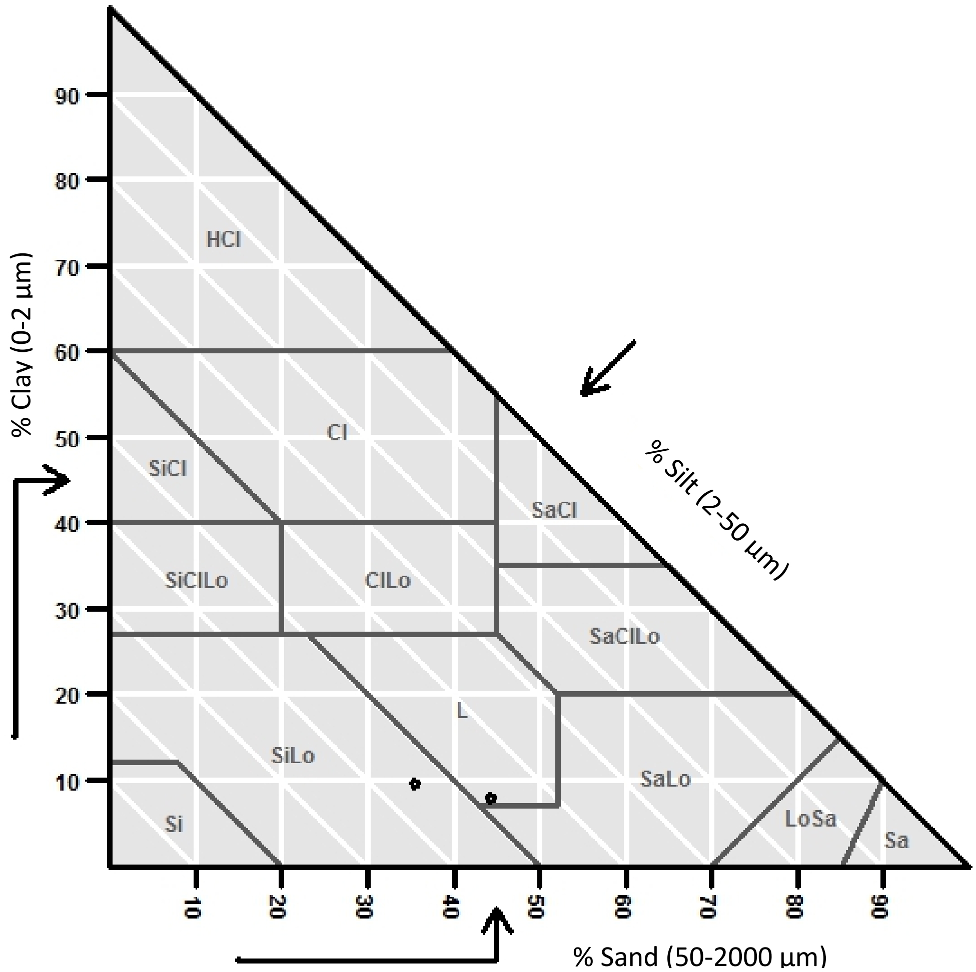


Figure D31. Topsoil (0-20cm) particle size data of samples (n=2; each sample represented by a black dot) taken within the Naiden Very Fine Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

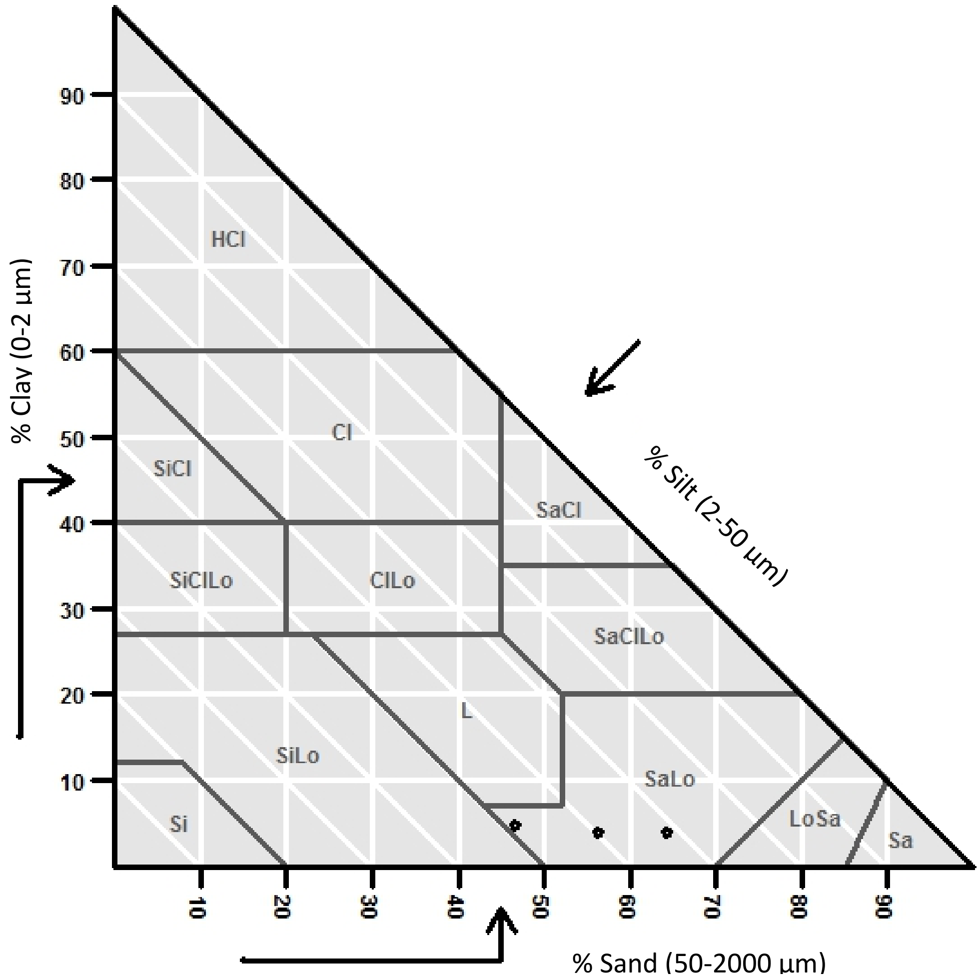


Figure D32. Subsoil (75-100cm) particle size data of samples (n=3; each sample represented by a black dot) taken within the Naiden Very Fine Sandy Loam ser (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to the measure % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

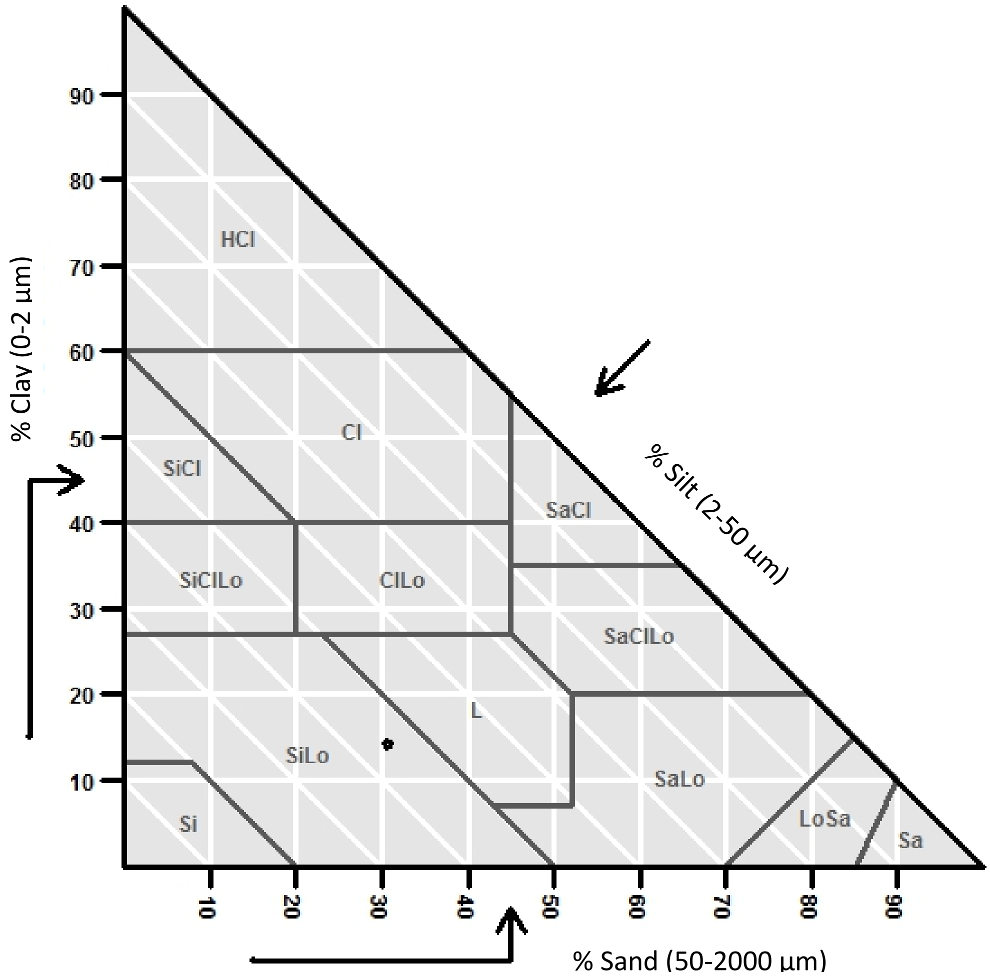


Figure D33. Topsoil (0-20cm) particle size data of samples (n=1; each sample represented by a black dot) taken within Wendigo Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

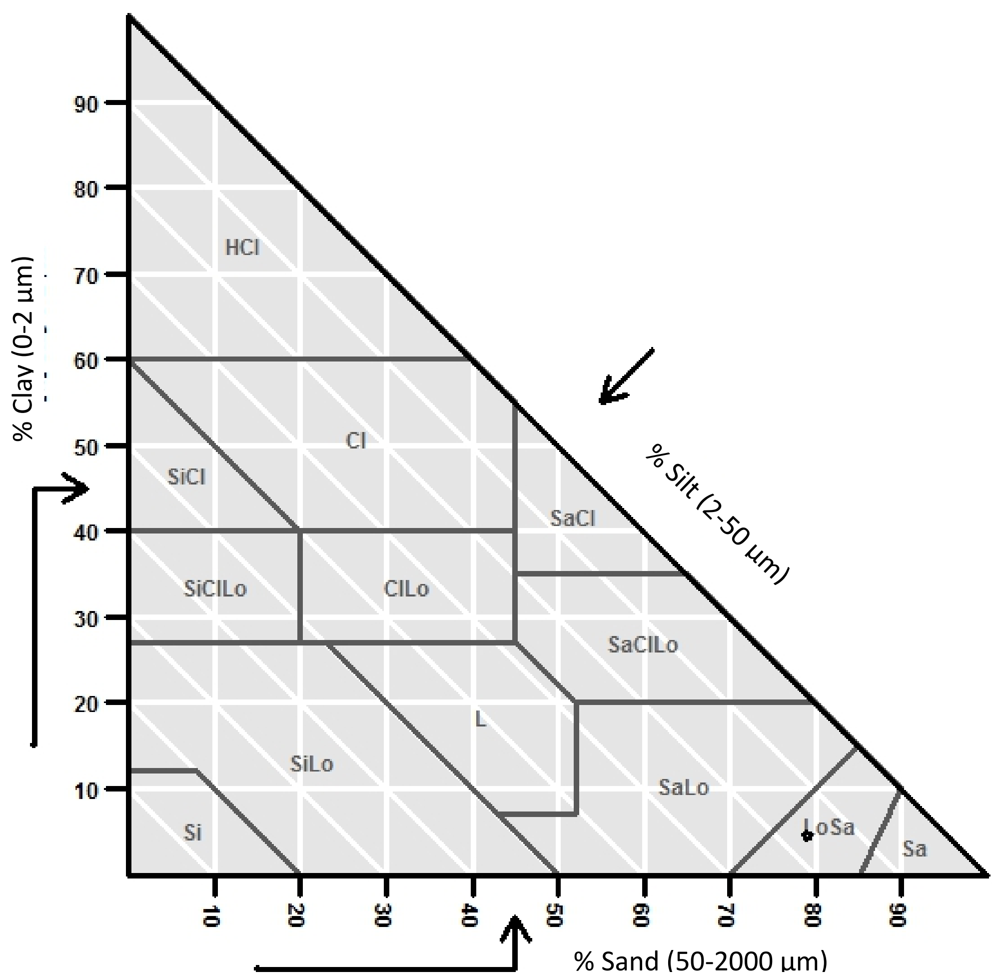


Figure D34. Subsoil (75-100cm) particle size data of samples (n=1; each sample represented by a black dot) taken within the Wendigo Sandy Loam Series (Gillespie *et al*. 1982) plotted over the Canadian soil textural class triangle (Moeys, 2014) according to their % of Clay (0-2 µm), % of Silt (0-50 µm) and % of Sand (50-2000 µm) particles. Abbreviations for the textural classes are HCl, heavy clay; Cl, clay; SiCl, silty clay; SiClLo, silty clay loam; ClLo, clay loam; SaCl, sandy clay; SiLo, silt loam; L, loam; SaClLo, sandy clay loam; SaLo, sandy loam; Si, silt; LoSa, loamy sand; Sa, sand (Soil Classification Working Group, 1998).

Appendix E

Site Replicates and Site Identification Numbers

Table E1. Mean values (n=2) of field site replicates with their associated ± standard deviations (SD). Soil variables include topsoil (TS) bulk density (ρbulk; g·cm^3) and, subsoil (SS) and topsoil pH using both the $CaCl_2$ and H_20 methods of analysis.

Site	TS ρbulk		SS pH H_2O		SS pH $CaCl_2$		TS pH H_2O		TS pH $CaCl_2$	
	(g·cm^3)	± SD		± SD		± SD		± SD		± SD
14	1.2	0.09	8.3	0.06	7.6	0.02	5.9	0.02	5.6	0.24
21	1.0	0.01	8.4	0.03	7.6	0.07	6.1	0.54	5.8	0.67
22	1.2	0.04	7.1	1.46	6.3	1.60	5.5	0.28	5.5	0.13
29	1.3	0.11	7.1	1.64	6.3	1.68	5.0	0.03	4.7	0.01
30	1.2	0.19	5.9	0.70	5.5	0.23	5.5	0.25	5.3	0.26
35	1.3	0.12	7.1	1.62	6.7	1.33	6.7	0.01	6.3	0.08
43	1.0	0.02	7.9	0.23	7.4	0.09	5.2	0.17	4.8	0.29
47	1.2	0.01	8.2	0.00	7.7	0.17	6.4	0.30	6.2	0.35
52	1.2	0.03	8.0	0.23	7.5	0.19	6.3	0.04	6.1	0.11
81	1.2	0.004	7.9	0.28	7.3	0.13	5.8	0.06	5.6	0.07
98	1.0	0.10	7.8	0.03	7.1	0.06	5.1	0.10	4.8	0.23
109	1.2	0.01	7.9	0.09	7.2	0.27	5.5	0.18	5.2	0.16
118	1.2	0.03	5.2	0.14	4.4	0.11	5.4	0.11	5.1	0.12
130	1.1	0.02	5.2	0.43	4.7	0.02	5.2	0.25	4.9	0.38
131	1.1	0.03	5.7	0.58	4.9	0.65	4.9	0.12	4.5	0.01
141	1.2	0.003	4.9	0.003	4.5	0.15	4.8	0.06	4.5	0.17
161	1.1	0.02	8.3	0.08	7.4	0.17	5.9	0.13	5.6	0.21
167	1.2	0.06	5.0	0.24	4.5	0.29	4.7	0.03	4.4	0.16
169	1.2	0.03	5.6	0.21	4.8	0.04	5.5	0.04	5.2	0.16
182	0.8	0.04	5.5	0.57	4.8	0.45	3.9	0.04	3.5	0.01

Table E2. Mean values (n=2) of field site replicates with their associated ± standard deviations (SD). Variables include total soil nutrient concentrations ($mg \cdot kg^{-1}$) of P, K, Zn, Cu and Mn.

Site	TS Total P		TS Total K		TS Total Zn		TS Total Cu		TS Total Mn	
	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD
14	279	112	505	60	30.2	7.5	22.5	6.4	185	1
21	230	20	585	30	32.8	4.8	21.8	1.8	277	63
22	343	42	450	16	28.1	0.9	27.2	1.2	221	65
29	299	37	450	33	25.5	2.1	25.9	1.6	145	11
30	276	47	581	25	28.0	2.5	24.6	2.1	207	6
35	225	10	573	157	29.1	2.1	25.4	13.8	238	105
43	199	56	571	19	35.0	3.0	43.3	5.4	282	5
47	313	54	652	122	35.0	1.5	40.6	4.2	219	23
52	296	13	1011	70	36.0	2.5	37.5	2.6	402	203
81	209	1	552	32	31.6	1.7	42.8	0.2	324	105
98	286	28	611	8	33.6	1.7	48.0	0.4	235	49
109	401	45	638	23	30.8	0.8	43.2	3.0	147	24
118	425	37	655	30	25.8	0.6	31.1	1.6	177	34
130	223	6	422	6	22.4	0.3	36.0	0.2	103	4
131	211	13	373	22	22.8	0.1	33.7	2.8	126	16
141	421	63	563	71	28.3	3.5	35.9	6.8	131	13
161	192	14	419	23	22.5	1.9	32.8	3.5	133	12
167	428	6	601	38	28.7	2.3	29.0	3.5	152	21
169	241	11	537	30	27.1	2.8	18.9	0.9	389	309
182	164	2	449	33	19.5	0.4	49.2	7.3	142	57

Table E3. Mean values (n=2) of field site replicates with their associated ± standard deviations (SD). Variables include available (Av) soil nutrient concentrations ($mg \cdot kg^{-1}$) of P, K, Zn, Cu and Mn. Sites with no data for TS Av Zn were below the minimum detection limit.

Site	TS Av P		TS Av K		TS Av Zn		TS Av Cu		TS Av Mn	
	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD	$mg \cdot kg^{-1}$	± SD
14	6.08	1.12	7.50	5.66			0.245	0.042	2.72	0.042
21	4.44	0.06	3.50	0.68			0.263	0.025	1.11	0.025
22	7.65	3.61	8.93	0.87	0.0139	0.0134	0.358	0.148	5.13	0.148
29	4.41	0.93	10.5	0.93	0.0772	0.0303	0.303	0.028	5.30	0.028
30	4.54	1.09	20.1	2.12			0.299	0.056	4.83	0.056
35	3.33	2.21	8.07	6.97			0.183	0.078	0.663	0.078
43	3.72	2.50	8.74	5.89	0.0922	0.0021	0.454	0.148	6.09	0.148
47	7.53	4.62	25.4	2.05			0.421	0.204	1.59	0.204
52	7.37	4.01	91.2	11.3			0.523	0.204	2.26	0.204
81	6.31	0.79	3.61	0.08			0.624	0.085	3.58	0.085
98	7.18	0.04	15.1	5.80	0.0741	0.0194	0.717	0.150	7.10	0.150
109	6.95	1.65	29.8	7.21			0.524	0.071	1.92	0.071
118	4.02	0.51	44.6	1.34			0.416	0.071	1.64	0.071
130	3.38	0.12	6.45	0.61	0.0360	0.0238	0.391	0.064	1.90	0.064
131	4.81	0.37	8.45	2.91	0.0975	0.0940	0.521	0.067	7.47	0.067
141	4.05	0.73	60.1	12.9	0.295	0.093	0.403	0.088	5.74	0.088
161	4.82	0.22	6.89	1.60			0.496	0.016	1.71	0.016
167	3.21	0.64	59.6	10.7	0.342	0.074	0.300	0.117	8.81	0.117
169	1.75	0.46	33.8	1.48			0.204	0.050	2.23	0.050
182	4.23	1.77	32.4	8.91	0.436	0.324	0.790	0.510	12.0	0.510

Table E4. Mean values (n=2) of field site replicates with their associated ± standard deviations (SD). Variables include the concentration (%) of topsoil (TS) and subsoil (SS) particle size fractions for sand, silt and clay. Missing data were left blank.

Site	TS Sand		TS Silt		TS Clay		SS Sand		SS Silt		SS Clay	
	%	± SD	%	± SD	%	± SD	%	± SD	%	± SD	%	± SD
14	3.19	2.17	79.7	0.2	17.1	2.4						
21	0.304	0.029	79.9	0.9	19.8	0.9						
22	10.3	1.3	76.8	2.8	12.9	4.1						
29	10.3	1.7	77.6	0.4	12.1	1.2						
30	10.7	2.7	74.9	1.8	14.4	0.9						
35	0	0	79.9	3.5	20.1	3.5						
43	0.241	0.144	82.3	0.5	17.5	0.6						
47	0.340	0.039	81.8	5.1	18.0	4.9						
52	0.233	0.150	82.7	2.0	17.1	1.9						
81	0.261	0.148	82.0	0.7	17.7	0.5						
98	1.10	0.51	84.1	2.1	14.8	2.6						
109	1.68	0.08	84.6	0.4	13.7	0.3						
118	1.67	0.25	85.7	0.3	12.7	0.5						
130	10.4	0.2	77.6	4.5	12.0	4.8						
131	12.9	3.7	76.8	3.6	10.4	0.1	31.4	21.6	60.7	17.6	7.87	3.98
141	9.19	2.39	79.7	1.6	11.1	0.8						
161	2.88	0.78	82.3	2.0	14.8	2.8	7.57	7.41	80.0	1.2	12.4	6.2
167	9.25	1.37	80.6	1.8	10.1	0.4	41.5	14.0	52.8	12.8	5.74	1.17
169	4.75	0.36	84.0	1.5	11.2	1.2	16.9	3.7	74.9	3.0	8.27	0.69
182	5.56	1.29	82.9	3.6	11.5	2.3						

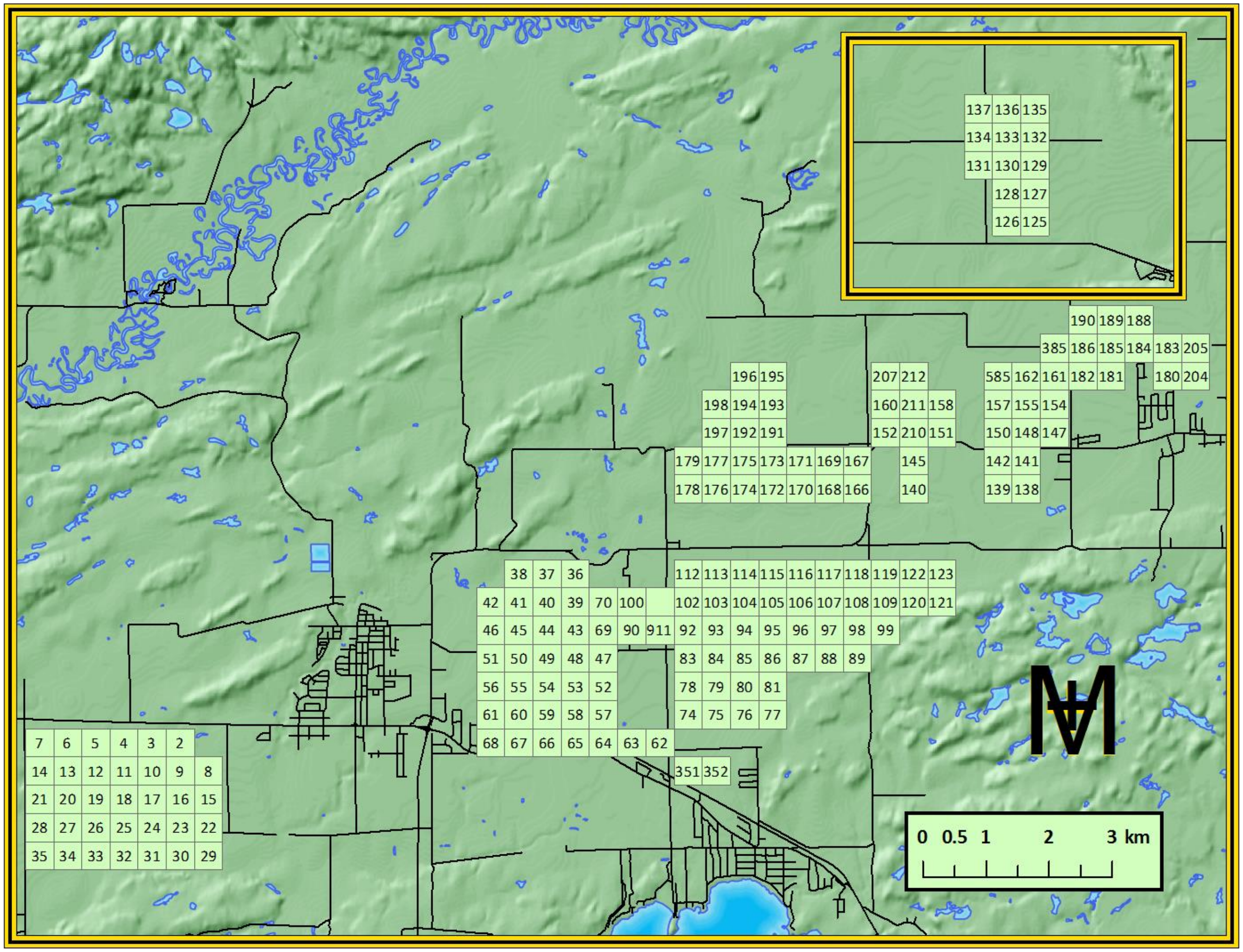


Figure E1. Site and sample identification number given to each cell of the 20 ha grid superimposed over the study area (grid origin: 17 T 479595 m East, 5155885 m North). Data courtesy of Natural Resources Canada and City of Greater Sudbury.

SID	X_COORD	Y_COORD	TS_SMU	L_U_Cat	%Sand	%Silt	%Clay	pHH2O	pHCaCl2	BulkDensitygc	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn
2	482021	5156908	Azilda SiL	Forested	0.372	81.319	18.308	5.92	5.74	0.875530	0.785	2.331	58.372	15.912	0.060	0.968	0.580
3	481634	5156948	Azilda SiL	Forested	5.993	79.932	14.075	5.54	5.30	0.662710	0.578	1.987	55.360	14.453	0.027	0.386	0.379
4	481205	5157015	Azilda SiL	Forested	8.715	79.661	11.624	5.51	5.44	0.535550	0.811	1.874	59.276	12.808	0.028	0.435	0.360
5	480729	5156920		Abandoned	3.094	82.229	14.680	5.55	5.29	0.665119	0.583	1.370	29.930	8.899	0.037	1.129	0.396
6	480253	5156891		Forested	0.114	81.715	18.169	5.75	5.53	0.814068	0.760	0.854	49.363	14.120	0.050	1.244	0.444
7	479750	5156975		Low Intensity	0.000	81.158	18.839	6.08	5.59	1.116448	0.916	3.227	76.102	21.806	0.066	0.846	0.635
8	482496	5156542		Abandoned	1.544	83.207	15.251	6.05	5.74	1.097898	1.120	1.825	55.554	12.209	0.056	1.006	0.509
9	482013	5156515		Forested	16.145	73.168	10.686	5.49	5.21	1.270663	0.987	2.364	63.883	19.687	0.052	0.848	0.210
10	481567	5156512		Intensive	0.000	81.510	18.490	5.91	5.67	1.099439	0.756	0.692	46.598	13.152	0.052	0.814	0.547
11	481154	5156525	BradleyVFSaL	Intensive	0.919	80.607	18.470	6.37	5.99	1.062410	1.037	1.957	62.555	15.083	0.060	0.866	0.233
12	480721	5156532	BradleyVFSaL	Low Intensity	0.662	81.686	17.654	6.25	6.10	1.170830	0.405	0.774	73.326	19.516	0.049	0.700	0.389
13	480272	5156542	BradleyVFSaL	Abandoned	1.663	82.961	15.375	5.51	5.26	0.947020	0.653	2.354	54.981	15.044	0.047	1.032	0.721
14	479819	5156475	BradleyVFSaL	Intensive	4.728	79.814	15.456	5.91	5.80	1.085840	1.124	2.447	66.614	16.196	0.046	1.828	0.258
15	482479	5156108		Low Intensity	7.440	78.494	14.064	5.44	5.21	1.077189	0.833	2.325	43.350	12.942	0.084	1.633	1.506
16	482039	5156100	Wolf Loam	Abandoned	8.668	77.388	13.946	5.70	5.47	0.969182	0.441	1.662	30.094	8.626	0.055	1.020	0.828
17	481689	5156090	BradleyVFSaL	Forested	4.595	77.838	17.568	5.44	5.09	0.897110	0.663	2.067	52.827	11.272	0.046	0.919	0.770
18	481177	5156122	BradleyVFSaL	Low Intensity	2.144	80.822	17.034	6.09	5.94	1.176000	1.077	2.175	71.419	16.696	0.062	0.988	0.412
19	480738	5156099		Low Intensity	0.138	80.620	19.242	6.32	6.22	1.195896	0.418	2.042	65.040	16.197	0.039	0.448	0.296
20	480273	5156136	BradleyVFSaL	Forested	0.576	81.705	17.718	6.00	5.81	0.965720	0.792	2.792	65.828	18.862	0.057	0.732	0.549
21	479808	5156115	BradleyVFSaL	Intensive	0.324	79.272	20.404	6.46	6.26	1.040470	0.916	0.814	66.038	14.496	0.057	0.501	0.235
22	482566	5155679	Wolf Loam	Low Intensity	11.203	78.806	9.991	5.71	5.41	1.126712	1.149	1.873	57.012	12.529	0.057	1.032	0.523
23	482099	5155741	Wolf Loam	Abandoned	6.792	79.344	13.865	5.80	5.61	1.078935	0.756	3.162	57.894	13.074	0.057	1.062	0.517
24	481676	5155604	BradleyVFSaL	Intensive	17.867	71.281	10.850	6.10	5.94	1.067100	1.193	2.199	74.432	20.025	0.056	0.765	0.598
25	481198	5155620		Intensive	14.128	73.464	12.411	6.28	6.06	1.196210	0.929	2.225	60.140	18.533	0.049	0.798	0.198
26	480695	5155551		Forested	4.097	82.340	13.563	5.90	5.53	1.032592	0.710	0.650	43.765	12.352	0.049	0.765	0.513
27	480211	5155601	BradleyVFSaL	Sod	0.580	81.495	17.927	6.73	6.52	1.236430	0.442	1.252	30.885	7.649	0.031	0.895	0.097
28	479780	5155580	BradleyVFSaL	Sod	0.948	81.707	17.343	6.70	6.50	1.222530	0.895	2.381	66.817	13.757	0.050	1.015	0.145
29	482552	5155279		Low Intensity	14.500	75.501	10.001	4.85	4.49	1.105520	0.824	6.594	37.185	7.178	0.062	1.660	2.508
30	482153	5155279		Intensive	5.090	81.229	13.680	4.95	4.57	0.886360	0.657	4.775	46.030	12.826	0.062	1.965	1.141
31	481617	5155258		Intensive	4.931	82.139	12.931	6.33	6.16	1.139830	0.789	2.182	64.059	15.798	0.040	0.600	0.299
32	481191	5155300	BradleyVFSaL	Forested	14.500	75.501	10.001	4.85	4.49	1.105520	0.824	6.594	37.185	7.178	0.062	1.660	2.508
33	480707	5155238	BradleyVFSaL	Forested	5.090	81.229	13.680	4.95	4.57	0.886360	0.657	4.775	46.030	12.826	0.062	1.965	1.141
34	480193	5155255	BradleyVFSaL	Sod	4.931	82.139	12.931	6.33	6.16	1.139830	0.789	2.182	64.059	15.798	0.040	0.600	0.299
35	479823	5155234	BradleyVFSaL	Sod	0.000	82.393	17.610	6.69	6.35	1.241610	1.123	2.986	66.383	14.149	0.055	0.430	0.197
36	488312	5159590	CapreolFSaL	Abandoned	3.562	82.985	13.456	4.37	4.04	0.974280	0.826	4.326	32.931	7.970	0.087	2.143	3.020
37	487889	5159553	CapreolFSaL	Forested	12.436	76.188	11.378	4.55	4.08	1.020500	0.680	3.960	32.166	4.503	0.066	1.990	1.176
38	487479	5159577	CapreolFSaL	Low Intensity	9.583	79.139	11.278	5.18	4.83	1.125020	1.281	4.544	52.935	10.366	0.086	2.250	1.281
39	488278	5159228		Abandoned	0.811	82.640	16.551	5.03	4.73	1.089354	0.843	2.351	43.839	13.088	0.085	1.652	1.523
40	487871	5159217		Low Intensity	0.628	82.543	16.830	5.05	4.62	1.036989	0.472	1.778	32.200	9.229	0.059	1.091	0.886
41	487484	5159138	CapreolFSaL	Low Intensity	1.169	81.263	17.570	4.68	4.51	1.072720	0.723	6.210	29.922	9.673	0.074	1.398	1.351
42	486935	5159223	CapreolFSaL	Low Intensity	16.129	72.550	11.321	4.58	4.28	1.023130	0.507	2.534	19.046	5.027	0.050	3.985	1.792
43	488285	5158756	Azilda SiL	Forested	0.343	82.615	17.044	5.31	5.04	1.011220	0.388	0.910	42.432	15.997	0.070	1.303	0.468
44	487907	5158833	Azilda SiL	Forested	0.454	85.568	13.977	5.48	5.32	0.978980	0.578	0.932	44.084	15.081	0.067	1.584	0.541
45	487471	5158835		Forested	0.978	84.179	14.843	5.70	5.42	0.863673	0.768	0.973	44.038	15.072	0.055	1.702	0.393
46	486913	5158796	CapreolFSaL	Intensive	1.768	81.636	16.593	5.30	5.07	1.096600	0.735	1.286	44.021	16.828	0.066	1.741	0.542
47	488730	5158429	Azilda SiL	Low Intensity	0.367	85.350	14.511	6.64	6.46	1.169090	0.996	6.266	84.876	18.589	0.065	0.699	0.197
48	488378	5158249	Azilda SiL	Forested	0.589	87.597	11.814	6.22	5.99	0.968660	0.473	0.804	73.066	16.151	0.053	0.585	0.225
49	487875	5158294	Azilda SiL	Forested	1.756	85.186	13.060	6.10	5.91	0.733280	0.727	0.736	68.234	16.267	0.048	0.705	0.174
50	487423	5158201	Azilda SiL	Abandoned	0.516	85.491	13.995	6.42	6.08	1.015080	0.561	0.678	50.543	14.965	0.046	0.783	0.301
51	487040	5158220	CapreolFSaL	Abandoned	0.162	84.022	15.815	6.24	6.00	1.084600	0.590	0.835	56.212	14.990	0.044	1.693	0.330

SID	X_COORD	Y_COORD	TS_SMU	L_U_Cat	%Sand	%Silt	%Clay	pHH2O	pHCaCl2	BulkDensitygc	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn
52	488762	5157865	Azilda SiL	Low Intensity	0.127	84.130	15.742	6.33	6.17	1.219710	1.105	20.296	79.037	20.345	0.092	1.398	0.378
53	488357	5157865	Azilda SiL	Abandoned	0.295	83.222	16.480	6.15	5.88	0.989820	0.471	0.756	44.938	13.303	0.064	0.974	0.339
54	487891	5157828	Azilda SiL	Abandoned	0.309	85.404	14.287	5.86	5.46	1.010820	0.439	0.602	48.317	17.750	0.060	0.981	0.390
55	487448	5157902	Azilda SiL	Abandoned	0.521	82.949	16.525	5.91	5.52	0.968150	0.565	0.661	46.681	14.023	0.053	1.030	0.361
56	486990	5157879		Abandoned	0.000	81.733	18.267	6.11	5.86	1.017666	0.687	1.201	41.120	15.719	0.061	1.627	0.506
57	488741	5157392		Forested	0.135	80.879	18.988	6.19	5.98	1.147291	0.466	1.209	81.458	16.406	0.078	0.631	0.360
58	488344	5157495	Azilda SiL	Abandoned	0.717	78.881	20.403	6.57	6.41	0.947350	0.790	0.989	78.061	14.987	0.087	0.326	0.261
59	487923	5157405	Azilda SiL	Abandoned	0.679	83.385	15.934	5.36	5.05	1.085850	0.848	1.166	57.573	19.241	0.111	1.691	0.826
60	487424	5157466	Azilda SiL	Abandoned	3.252	82.667	14.081	5.72	5.40	0.980860	0.796	1.152	56.536	13.694	0.070	1.107	0.329
61	487048	5157466	Azilda SiL	Abandoned	0.135	84.154	15.712	5.72	5.41	1.071130	0.583	0.844	46.273	14.653	0.060	0.754	0.446
62	489622	5156953	Wolf SiL	Abandoned	0.514	81.074	18.412	6.15	5.92	0.997160	0.669	0.769	65.498	16.896	0.056	0.297	0.315
63	489199	5157018	Wolf SiL	Forested	0.382	77.121	22.497	6.22	6.09	0.843440	0.630	0.926	76.128	17.516	0.073	0.421	0.359
64	488774	5156981		Forested	1.251	80.913	17.833	6.27	5.87	0.901337	0.745	0.946	60.990	17.035	0.103	0.477	0.349
651			Azilda SiL	Topsoil Removed				7.07	6.70	1.386220	0.215	0.779	52.560	12.290	0.044	0.706	0.058
65	488359	5157111	Azilda SiL	Abandoned	0.130	83.981	15.888	6.62	6.35	0.999750		0.786	39.190	9.498	0.031	0.045	0.042
66	487942	5157031	Azilda SiL	Abandoned	0.142	84.860	14.999	6.81	6.53	1.072880	0.594	1.034	69.636	14.389	0.079	0.348	0.196
67	487444	5157060	Azilda SiL	Intensive	0.317	82.045	17.636	6.28	6.14	1.079170	1.340	1.386	73.384	17.504		1.017	0.296
68	487088	5157058	Azilda SiL	Abandoned	0.364	81.131	18.504	6.15	5.91	0.929080	0.688	0.815	50.404	15.268	0.065	0.866	0.451
69	488717	5158799	Azilda SiL	Intensive	0.380	85.232	14.392	6.68	6.53	1.288420	1.253	1.058	90.077	16.214	0.107	0.396	0.184
70	488721	5159236		Low Intensity	0.514	79.640	19.847	5.48	5.36	1.147851	0.900	3.880	57.163	13.958	0.093	1.093	0.882
74	490114	5157469	Wolf SiL	Forested	0.334	83.644	16.024	6.22	6.09	1.022950	1.088	1.403	95.748	21.482	0.129	0.362	0.526
75	490577	5157403	Wolf SiL	Abandoned	0.156	81.636	18.210	6.13	5.86	1.063770	0.808	1.130	73.826	18.318	0.123	0.594	0.519
76	490934	5157442	Wolf SiL	Forested	0.155	81.085	18.756	5.72	5.41	1.085870	0.975	1.045	73.188	21.565	0.134	0.791	0.884
77	491424	5157482	Wolf SiL	Abandoned	0.131	80.534	19.334	5.78	5.53	0.989440	1.233	1.482	64.710	17.315	0.119	0.687	0.239
78	490068	5157872	Wolf SiL	Intensive	0.158	80.582	19.264	6.60	6.41	1.235980	0.606	0.848	82.811	17.798	0.110	0.457	0.292
79	490574	5157889	Wolf SiL	Abandoned	3.146	85.313	11.540	6.73	6.51	1.111390	1.114	1.105	90.022	16.693	0.107	0.302	0.333
80	491024	5157859	Wolf SiL	Abandoned	0.957	84.915	14.129	6.31	6.12	1.033210	0.794	0.711	63.439	18.474	0.099	0.810	0.337
81	491447	5157869	Wolf SiL	Low Intensity	0.156	82.504	17.343	5.77	5.56	1.170010	1.346	0.831	72.774	19.141	0.132	0.931	0.695
83	490081	5158306	Wolf SiL	Forested	0.305	81.585	18.107	5.79	5.51	1.179190	0.958	1.441	70.280	21.438	0.120	1.363	1.059
84	490546	5158276	Wolf SiL	Forested	0.354	84.644	15.002	6.49	6.30	1.067000	1.105	1.498	84.507	17.670	0.116	0.444	0.230
85	490994	5158299	Wolf SiL	Forested	0.440	85.874	13.322	5.76	5.60	0.951490	0.866	1.859	68.507	18.021	0.115	0.834	0.615
86	491416	5158276		Low Intensity	0.994	83.694	15.313	6.44	6.31	1.191905	0.999	0.684	82.480	17.950	0.117	0.539	0.221
87	491945	5158334	CapreolVFSaL	Low Intensity	1.129	82.169	16.701	6.23	6.00	1.128520	1.282	4.243	75.385	20.088	0.141	0.668	0.506
88	492362	5158358	CapreolVFSaL	Low Intensity	3.553	79.803	16.644	6.41	6.25	1.085360	0.951	0.794	65.556	14.804	0.096	0.571	0.205
89	492695	5158455	CapreolVFSaL	Low Intensity	3.670	83.120	13.211	6.10	5.92	1.058770	0.918	1.791	53.172	14.607	0.148	1.242	0.393
90	489228	5158661	Azilda SiL	Low Intensity	3.670	83.120	13.211	6.40	6.20	1.081520	0.686	1.681	66.189	13.065	0.068	0.971	0.205
911	489670	5158811	Azilda SiL	Low Intensity	1.258	84.995	13.746	6.20	5.40	1.250450	1.171	3.927	51.615	14.966	0.071	0.771	0.188
912	489835	5158831	Azilda SiL	Sod	0.419	84.955	14.626	5.62	5.80	1.038570	0.906	4.445	44.866	15.495	0.096	1.292	0.604
913	489494	5158897	Azilda SiL	Forested	0.559	84.057	15.385	5.50	5.17	1.154800	0.737	2.656	40.187	13.673	0.070	1.263	0.617
921			Azilda SiL	Topsoil Removed	0.662	85.803	13.533	7.10	6.45	1.582400	0.163	1.071	46.454	9.354	0.034	0.803	0.032
92	490037	5158761	Azilda SiL	Patatoe	1.023	83.930	15.051	5.50	5.17	1.135960	0.693	0.977	49.528	14.586	0.065	0.602	0.343
93	490554	5158750	Wolf SiL	Patatoe	1.015	83.168	15.820	6.67	6.35	1.265190	0.868	2.657	80.213	17.890	0.105	0.762	0.218
94	490962	5158805		Low Intensity	1.012	84.940	14.050	6.46	6.02	1.186381	1.239	1.193	67.861	16.586	0.115	1.272	0.349
95	491409	5158824	CapreolVFSaL	Low Intensity	1.512	84.516	13.973	6.49	6.11	1.232040	0.959	1.496	65.544	14.834	0.087	0.946	0.214
96	491858	5158805	CapreolVFSaL	Abandoned				6.41	6.02	1.155630	1.210	1.079	65.937	15.239	0.098	0.387	0.339
97	492320	5158799	CapreolVFSaL	Sod	1.118	85.321	13.562	5.50	5.29	1.316970	1.371	4.212	70.365	19.954	0.128	1.369	1.109
98	492726	5158750	CapreolVFSaL	Forested	1.460	85.509	13.032	5.12	4.93	1.118160	1.610	2.460	53.001	18.740	0.137	0.818	1.239
99	493164	5158814	CapreolVFSaL	Patatoe	0.863	81.962	17.174	6.08	5.79	1.267230	2.040	3.117	61.334	19.363	0.141	1.262	0.469
100	489089	5159177		Low Intensity	0.880	83.594	15.526	6.05	5.82	1.203765	1.895	0.833	84.504	18.249	0.115	1.399	1.117
1011	489673	5159190		Sod	0.956	82.749	16.295	6.00	5.73	1.356323	2.110	5.669	69.172	19.585	0.148	2.696	0.898

SID	X_COORD	Y_COORD	TS_SMU	L_U_Cat	%Sand	%Silt	%Clay	pHH2O	pHCaCl2	BulkDensitygc	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn
1012	489834	5159217		Patatoe	1.792	83.639	14.569	5.49	5.25	1.249249	1.354	1.659	59.214	21.862	0.110	1.721	1.234
1013	489502	5159222		Low Intensity	1.182	83.599	15.219	5.51	5.55	1.278977	2.609	2.220	79.297	21.487	0.154	2.075	1.673
1021				Topsoil Removed	0.953	82.648	16.397	6.75	6.05	1.704899	0.225	0.668	50.465	17.560	0.044	3.785	0.177
102	490094	5159247		Patatoe	0.902	83.292	15.810	5.24	5.10	1.106332	1.117	5.310	57.529	14.736	0.105	1.724	1.582
103	490587	5159245	BradleyFSaL	Abandoned	0.953	82.648	16.397	5.59	5.20	1.150710	1.731	5.109	75.026	21.380	0.157	1.814	1.245
104	490965	5159219	BradleyFSaL	Patato	0.854	85.849	13.297	5.05	4.88	1.052530	1.143	0.766	53.679	13.346	0.120	1.652	1.579
105	491495	5159209		Sod	1.296	86.185	12.517	5.71	5.38	1.235781	1.782	3.954	81.067	18.561	0.120	1.671	1.038
106	491915	5159205		Sod	0.870	85.358	13.769	5.05	4.73	1.223354	1.338	4.453	55.051	13.163	0.125	2.219	1.605
107	492365	5159202		Sod	1.933	84.905	13.161	5.22	4.85	1.237452	1.492	4.191	60.558	14.873	0.136	2.168	1.800
108	492806	5159200	CapreolVFSaL	Sod	1.960	84.969	13.073	4.97	4.59	1.227340	1.587	9.525	51.563	18.071	0.169	2.888	1.471
109	493172	5159215	CapreolVFSaL	Low Intensity	1.738	84.292	13.971	5.40	5.10	1.223510	1.987	8.540	57.260	18.206	0.140	0.993	0.570
112	490077	5159657	BradleyFSaL	Patato	0.734	85.627	13.638	5.14	4.81	1.183780	1.023	12.217	46.878	12.832	0.079	1.068	1.288
113	490562	5159663	BradleyFSaL	Patato	1.355	86.170	12.476	5.30	5.05	1.159740	0.997	12.015	49.405	15.633	0.098	1.211	1.039
114	490985	5159710	BradleyFSaL	Sod	3.602	85.860	10.538	4.81	4.55	1.119940	1.091	6.160	43.006	10.908	0.108	1.557	2.643
115	491526	5159633	BradleyFSaL	Sod	2.273	85.280	12.446	5.09	4.80	1.352360	0.679	7.318	42.687	6.575	0.077	1.784	1.331
116	491930	5159642	BradleyFSaL	Patato	2.563	84.768	12.669	5.07	4.78	1.271410	1.994	8.693	59.635	15.212	0.169	2.158	1.294
117	492339	5159619	BradleyFSaL	Patato	1.938	86.219	11.844	5.13	4.78	1.235650	1.426	9.861	47.943	13.370	0.120	2.034	0.939
118	492783	5159663		Patato	1.490	85.466	13.045	5.36	5.01	1.257449	1.096	11.386	44.541	13.963	0.117	2.132	0.453
119	493163	5159700	CapreolVFSaL	Patato	2.076	84.197	13.728	5.22	4.86	1.261830	1.921	14.587	37.603	14.133	0.139	2.332	0.472
120	493621	5159262	CapreolVFSaL	Patato	0.990	85.513	13.497	4.81	4.38	1.212510	1.489	8.463	49.955	12.780	0.164	1.695	1.339
121	494160	5159357	CapreolVFSaL	Patato	2.464	84.476	13.062	4.89	4.49	1.232270	0.754	9.710	45.101	14.935	0.105	1.291	0.614
122	493612	5159649	CapreolVFSaL	Patato	2.728	84.882	12.389	4.92	4.57	1.203570	1.527	9.869	55.946	15.703	0.148	1.955	0.713
123	494166	5159706	CapreolVFSaL	Patato	2.835	85.287	11.878	4.93	4.60	1.290400	1.053	13.678	57.552	13.936	0.141	1.548	1.025
125	509775	5164987	BradleyVFSaL	Forested	6.414	81.651	11.933	4.79	4.33	1.057460	0.637	2.369	31.301	9.433	0.103	1.692	0.681
126	509336	5165041	BradleyVFSaL	Low Intensity	6.084	82.032	11.883	5.13	4.73	1.046540	0.661	2.114	40.815	12.307	0.088	1.122	1.384
127	509755	5165504	BradleyVFSaL	Abandoned	13.467	75.469	11.062	4.86	4.31	0.866820	0.433	1.429	19.417	9.258	0.055	1.064	0.144
1271			BradleyVFSaL	Topsoil Removed	19.968	71.387	8.648	4.36	3.84	1.433880	0.347	4.474	16.920	2.658	0.068	4.273	0.769
128	509340	5165553	BradleyVFSaL	Low Intensity	7.568	80.057	12.375	4.91	4.46	1.084520	0.967	1.440	42.079	20.888	0.109	1.874	0.249
129	509787	5165954	BradleyVFSaL	Abandoned	15.566	75.308	9.125	4.90	4.58	1.101380	1.280	2.908	57.712	15.596	0.133	2.060	1.969
130	509277	5165918	BradleyVFSaL	Low Intensity	10.219	74.383	15.398	5.39	5.12	1.121520	0.738	1.350	41.048	23.552	0.077	1.189	0.231
131	508841	5165856		Abandoned	15.505	74.192	10.303	4.77	4.46	1.073220	1.088	2.254	44.217	12.728	0.122	1.801	1.958
132	509729	5166454	BradleyVFSaL	Low Intensity	16.070	74.203	9.726	5.25	4.73	1.039170	0.555	2.827	39.073	11.098	0.070	1.062	0.526
133	509326	5166488		Low Intensity	31.196	59.673	9.131	4.76	4.71	1.129800	0.619	3.118	35.024	17.196	0.046	1.640	0.359
134	508805	5166470	Naiden	Abandoned	44.352	47.758	7.888	5.27	4.91	1.024849	0.637	2.644	29.311	13.200	0.080	2.419	0.607
135	509806	5166827	BradleyVFSaL	Low Intensity	31.196	59.673	9.131	4.76	4.71	1.129803	0.619	3.118	35.024	17.196	0.046	1.640	0.359
136	509314	5166793		Low Intensity	24.569	65.238	10.194	5.19	4.89	1.090733	0.176	0.692	18.739	12.413		1.010	0.127
1361				Topsoil Removed	35.580	57.644	6.774	5.79	5.36	1.479941	0.639	1.027	37.590	24.952	0.067	2.634	0.577
137	508776	5166843	Naiden	Abandoned	35.508	54.970	9.522	4.32	3.95	0.991444	0.252	4.204	11.045	2.717	0.079	2.578	1.467
138	495571	5161047	CapreolFSaL	Patato	10.485	79.555	9.962	4.81	4.89	1.149710	0.690	13.038	39.320	7.703	0.088	0.915	0.825
139	495014	5161004	CapreolFSaL	Patato	13.329	77.072	9.598	5.17	4.75	1.209250	0.622	14.414	38.938	8.392	0.074	1.250	0.430
140	493670	5161100	BradleyFSaL	Forested	13.432	76.439	10.127	4.75	4.34	1.048410	0.560	8.052	25.581	4.634	0.073	1.027	2.558
141	495531	5161384	CapreolFSaL	Patato	10.881	78.599	10.522	4.89	4.64	1.148670	0.811	15.898	37.906	6.961	0.078	0.972	1.068
142	495076	5161350	CapreolFSaL	Patato	12.036	77.168	10.796	5.22	4.93	1.154830	0.788	13.973	41.574	10.925	0.083	0.922	0.617
145	493774	5161429	CapreolFSaL	Patato	9.710	78.369	11.920	5.35	5.08	1.067740	0.715	5.979	36.517	17.895	0.081	1.251	0.606
147	495930	5161920	CapreolFSaL	Low Intensity	6.695	84.185	9.118	4.94	4.51	1.095600	0.622	2.870	32.430	9.751	0.087	0.990	0.789
148	495470	5161957	CapreolFSaL	Abandoned	7.879	82.237	9.887	4.72	4.38	1.100640	0.792	2.994	41.384	10.808	0.108	1.142	1.512
150	495017	5161958	CapreolFSaL	Forested	11.190	78.276	10.537	5.15	4.89	0.929580	1.010	2.008	51.499	10.802	0.082	0.757	1.630
151	494157	5161984	CapreolFSaL	Patato	4.833	82.700	12.468	5.37	5.06	1.210240	0.973	4.623	39.696	13.530	0.088	1.053	0.547
152	493258	5161968	CapreolFSaL	Low Intensity	3.427	83.958	12.614	5.09	4.64	1.120400	0.975	4.370	37.645	13.534	0.095	1.288	0.652
154	495970	5162395		Low Intensity	6.475	81.217	12.304	5.57	5.25	1.048309	0.721	2.914	43.190	10.609	0.084	1.013	0.560

SID	X_COORD	Y_COORD	TS_SMU	L_U_Cat	%Sand	%Silt	%Clay	pHH2O	pHCaCl2	BulkDensitygc	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn
155	495459	5162347	CapreolFSaL	Intensive	7.747	80.557	11.697	5.58	5.42	1.047880	0.891	1.689	60.567	19.134	0.107	0.526	0.704
157	494987	5162363	CapreolFSaL	Forested	10.966	78.516	10.517	4.73	4.39	1.014070	0.860	1.659	50.298	11.986	0.124	2.231	1.371
158	494092	5162361	CapreolFSaL	Low Intensity	4.487	80.407	15.105	5.36	5.04	1.197280	1.113	2.466	49.088	17.600	0.115	0.917	0.800
160	493267	5162337		Low Intensity				5.79	5.57	1.058953	1.233	0.779	65.655	15.079	0.079	0.534	0.608
161	495976	5162809		Low Intensity	3.439	83.707	12.854	5.97	5.72	1.164836	1.086	1.342	66.396	11.951	0.118	0.930	0.380
162	495500	5162822	CapreolFSaL	Intensive				5.63	5.38	1.133310	1.215	2.652	54.172	16.818	0.114	0.766	0.850
166	492754	5161023	BradleyFSaL	Patato	18.311	73.017	8.672	4.61	4.20	1.021240	1.042	14.052	28.799	6.577	0.089	1.897	1.373
167	492746	5161475		Patato	8.283	81.854	9.861	4.69	4.48	1.268681	0.700	17.051	39.837	7.714	0.055	1.073	1.880
168	492381	5161004	BradleyFSaL	Sod	10.088	79.101	10.808	5.11	4.80	1.137890	0.630	10.446	43.923	6.941	0.053	1.507	1.538
169	492365	5161420	BradleyFSaL	Sod	5.012	82.931	12.056	5.51	5.27	1.246910	0.354	8.678	42.894	8.878	0.042	0.950	0.406
170	491968	5161039	BradleyFSaL	Sod	6.662	81.418	11.923	5.66	4.91	1.256660	0.452	8.319	38.705	7.439	0.047	1.164	0.968
171	491958	5161457	BradleyFSaL	Sod	9.359	80.167	10.477	5.24	4.72	1.265040	0.455	9.311	36.180	7.312	0.056	0.633	0.807
172	491489	5161065	BradleyFSaL	Patato	14.713	75.497	9.791	5.24	4.86	1.225060	0.605	10.119	36.997	8.698	0.058	3.357	0.735
173	491497	5161496	BradleyFSaL	Sod	5.645	82.455	11.902	5.27	4.62	1.220070	0.476	6.003	40.506	14.348	0.051	1.054	0.630
174	490981	5161036	BradleyFSaL	Patato	15.302	74.309	10.386	4.98	4.23	1.134100	0.724	16.444	34.930	9.141	0.067	0.935	1.921
175	490986	5161443	BradleyFSaL	Patato	7.540	80.842	11.622	4.55	4.52	1.128880	0.806	10.950	46.058	9.347	0.072	1.167	1.678
176	490567	5161024	BradleyFSaL	Sod	9.389	79.494	11.116	5.35	5.04	1.140340	0.527	13.274	45.614	8.849	0.052	0.543	1.033
177	490555	5161414	BradleyFSaL	Patato	4.672	82.659	12.671	5.30	5.01	1.150140	0.591	14.262	44.626	6.809	0.063	0.821	0.925
178	490156	5161089	BradleyFSaL	Patato	13.690	76.156	10.154	5.10	4.66	1.169500	0.351	14.432	34.383	5.005	0.024	0.585	1.895
179	490148	5161425	BradleyFSaL	Patato	2.039	84.481	13.481	4.91	4.60	1.133130	0.431	14.345	42.379	8.159	0.053	0.841	1.702
180	497674	5162847		Forested	24.523	66.619	8.857	4.61	4.30	0.891217	1.276	6.399	43.491	9.572	0.150	2.781	0.738
181	496834	5162804		Forested	6.646	81.328	12.025	3.97	3.54	0.812098	0.645	4.954	11.694	2.907	0.109	4.044	1.475
182	496391	5162774	BradleyFSaL	Forested	6.474	80.393	13.130	3.84	3.52	0.813650	0.483	6.298	21.480	3.889	0.070	0.599	2.343
183	497724	5163237	BradleyFSaL	Patato	9.143	79.513	11.342	4.65	4.29	1.059410	1.023	5.339	15.065	3.814	0.239	7.034	3.793
184	497264	5163239	BradleyFSaL	Forested	4.067	84.138	11.795	3.95	3.56	0.897940	0.844	5.011	15.714	4.131	0.116	5.082	2.353
185	496821	5163285	BradleyFSaL	Low Intensity	1.922	85.441	12.639	4.56	4.21	0.975100	1.162	3.744	36.859	12.559	0.139	2.009	2.340
186	496388	5163275	BradleyFSaL	Forested	2.670	82.152	15.179	4.26	4.02	0.939780	1.348	3.214	41.914	15.036	0.161	3.515	1.735
188	497261	5163685	BradleyFSaL	Forested	1.986	83.454	14.563	3.82	3.45	0.898030	0.939	4.544	21.912	5.496	0.128	6.735	1.277
189	496746	5163731		Abandoned	1.180	81.124	17.695	4.79	4.52	1.069351	1.407	1.566	48.121	17.965	0.149	2.139	1.181
190	496358	5163702		Abandoned	2.518	78.273	19.207	5.19	5.04	1.066262	1.486	2.096	54.806	18.318	0.122	1.418	1.280
191	491438	5161895	BradleyFSaL	Sod	1.934	81.483	16.582	5.71	5.50	1.294550	0.854	4.971	54.889	9.916	0.060	1.396	0.482
192	491011	5161921	BradleyFSaL	Sod	2.479	81.575	15.946	5.85	5.78	1.300100	0.848	3.735	52.133	17.637	0.071	1.842	0.329
193	491441	5162360	BradleyFSaL	Sod	8.355	80.690	10.957	5.61	5.19	1.212940	0.621	7.860	40.512	8.830	0.058	0.691	1.007
194	491023	5162361	BradleyFSaL	Abandoned	7.611	78.281	14.109	5.25	4.94	1.226130	1.195	4.702	53.148	12.907	0.070	1.372	0.767
195	491476	5162817		Sod	4.938	81.042	14.018	6.02	5.81	1.316320	0.738	4.385	61.179	15.255	0.054	1.113	0.320
196	491033	5162814		Sod	2.411	84.101	13.488	6.13	6.05	1.296591	0.775	0.812	81.685	18.852	0.064	0.591	0.565
197	490610	5161901	BradleyFSaL	Forested	8.636	76.320	15.045	4.88	4.62	1.086150	1.514	3.563	43.012	12.013	0.085	2.131	1.510
198	490620	5162374	BradleyFSaL	Forested	8.329	81.146	10.525	4.34	4.02	0.833210	1.563	2.966	47.326	8.749	0.074	2.050	0.873
204	498114	5162876		Forested	30.735	55.093	14.173	3.95	3.66	0.904724	1.484	3.329	32.932	4.270	0.204	5.121	7.907
205	498213	5163203	BradleyFSaL	Forested	18.654	70.129	11.213	4.26	3.90	0.992570	1.151	3.732	38.909	4.903	0.129	3.295	6.194
207	493292	5162786		Low Intensity	0.778	81.129	18.092	5.36	5.20	1.158690	1.087	0.721	74.620	21.042	0.116	0.806	1.754
210	493749	5161962	CapreolFSaL	Abandoned	3.448	82.244	14.307	4.56	4.35	1.127020	1.837	3.223	48.913	14.358	0.165	2.322	1.875
211	493721	5162373	CapreolFSaL	Abandoned	3.448	82.244	14.307	5.48	5.25	1.061960	1.491	2.081	67.965	18.499	0.104	0.962	1.761
212	493742	5162786	CapreolFSaL	abandoned	3.502	83.013	13.484	5.27	4.93	1.155310	1.282	1.174	61.232	18.370	0.119	1.680	2.773
351	490065	5156614	Wolf SiL	Topsoil Removed	1.029	84.339	14.629	7.04	6.26	1.448180	0.224	0.497	37.140	10.834	0.038	0.475	0.049
352	490478	5156598	Wolf SiL	Topsoil Removed	0.455	85.460	14.084	6.86	6.29	1.546130	0.704	2.160	85.675	24.055	0.103	0.512	0.333
385	495952	5163294		Abandoned	4.872	83.553	11.578	5.59	5.21	1.066313	0.817	2.197	42.226	15.099	0.078	1.109	0.397
585	494991	5162832	CapreolFSaL	Forested	7.730	80.830	11.442	4.15	3.76	0.951640	1.745	3.997	42.634	11.039	0.177	6.757	1.410

SID	Av_Zn	Av_Ni	T_P	T_K	T_Mg	T_Ca	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	PER_C	PER_N	PER_S	T_P
2	0.0635	0.0621	36.419	109.43	869.6	1533	6.314	2859	52.2	5.97	9.87	0.0587	1.441	8.92	2.08	0.703	4.63	0.262	0.380	214
3	0.0822	0.0417	26.970	64.39	499.4	1484	4.684	1536	28.8	3.73	6.72	0.0489	0.782	4.92	1.52	0.485	8.52	0.331	0.135	209
4	0.0148	0.0330	34.189	55.89	402.2	1630	4.763	1228	28.8	3.21	6.20	0.0617	0.662	4.27	1.33	0.499	12.95	0.515	0.123	323
5	0.0432	0.0434	34.852	66.38	586.6	404	3.166	1583	24.2	3.57	5.19	0.0310	0.717	4.24	1.15	0.404	10.34	0.554	0.115	539
6		0.0428	56.575	82.54	1053.0	571	4.488	2003	25.2	4.23	6.70	0.0482	0.952	6.25	1.39	0.482	5.91	0.354	0.070	326
7	0.0754	0.0683	32.272	136.94	1875.3	1173	5.888	3554	61.1	7.92	10.62	0.0539	1.670	10.90	2.29	0.802	2.82	0.185	0.047	255
8	0.0010	0.0224	81.684	101.23	1185.7	635	6.148	2481	38.4	6.30	9.09	0.0628	1.151	7.44	1.94	0.619	2.20	0.146	0.031	320
9	0.0087	0.0440	90.481	138.70	1516.3	892	6.040	3157	38.8	8.03	8.72	0.0679	1.367	8.35	2.03	0.823	3.31	0.192	0.034	218
10	0.0054	0.1065	72.728	121.94	1528.6	901	7.012	3179	82.3	7.43	10.56	0.0773	1.712	8.82	2.29	0.878	2.92	0.162	0.030	233
11	0.0118	0.0263	76.547	159.27	1269.6	1844	6.338	3704	62.3	8.50	10.25	0.0591	1.860	13.05	2.06	0.626	2.19	0.146	0.029	372
12		0.0248	41.805	145.09	1267.6	1978	5.097	3689	56.3	7.18	9.84	0.0429	1.701	12.43	1.95	0.642	2.42	0.123	0.025	187
13	0.0040	0.0595	35.022	104.50	828.5	1363	5.818	2862	47.8	6.31	9.87	0.0616	1.418	9.13	2.09	0.670	4.27	0.208	0.032	186
14	0.0260	0.0343	76.191	116.42	942.8	1579	5.746	3022	39.6	7.56	9.70	0.0653	1.652	10.30	2.12	0.626	3.37	0.215	0.035	358
15	0.0685	0.1024	41.674	108.69	971.7	800	6.659	3037	52.1	6.60	10.72	0.0549	1.474	8.36	2.00	0.781	2.54	0.185	0.030	262
16	0.0121	0.0604	39.487	97.95	889.4	740	6.153	2875	46.6	6.00	9.97	0.0521	1.338	7.71	1.94	0.749	3.80	0.231	0.040	353
17	0.0014	0.0449	54.594	97.88	666.1	1023	5.159	2703	69.8	5.78	8.37	0.0565	1.419	7.79	1.87	0.728	3.38	0.215	0.037	309
18		0.0202	77.976	149.63	1131.0	1620	5.807	3583	61.1	7.68	9.58	0.0564	1.674	10.84	1.97	0.710	2.15	0.162	0.029	333
19		0.0218	38.433	144.86	1283.9	1941	4.920	3653	69.7	7.26	9.29	0.0496	1.734	11.09	1.90	0.663	2.66	0.131	0.021	182
20	0.0653	0.0590	27.915	118.45	1014.8	1622	5.093	3074	52.8	6.85	9.19	0.0466	1.445	9.43	1.98	0.694	3.43	0.177	0.022	148
21		0.0217	49.886	123.90	1100.0	1654	4.723	3333	65.6	7.40	8.67	0.0517	1.632	10.08	2.09	0.611	2.35	0.177	0.029	244
22	0.0010	0.0230	83.827	103.88	651.2	1217	6.310	2546	39.4	6.47	9.33	0.0644	1.181	7.64	1.99	0.635	2.94	0.200	0.035	372
23	0.0033	0.0284	52.980	113.65	754.1	1216	5.426	2777	47.2	8.29	8.57	0.0555	1.312	7.61	2.03	0.714	2.17	0.162	0.033	248
24	0.0018	0.0512	87.754	121.59	727.4	1457	6.217	2728	55.0	7.19	9.09	0.0704	1.288	7.70	1.94	0.888	3.24	0.231	0.046	415
25	0.0081	0.0414	85.179	130.58	840.1	1427	5.686	2972	36.5	7.56	8.21	0.0639	1.287	7.86	1.91	0.775	2.37	0.169	0.037	364
26	0.0051	0.1000	68.307	114.53	846.7	1436	6.585	2986	77.3	6.97	9.92	0.0726	1.607	8.28	2.15	0.824	3.28	0.200	0.033	334
27		0.0147	68.525	189.41	1428.4	1839	5.236	4536	83.2	8.95	10.21	0.0627	2.090	13.54	2.29	0.750	1.61	0.131	0.022	284
28	0.0142	0.0178	65.199	173.63	1243.9	1803	4.647	3722	65.0	8.74	8.67	0.0467	1.704	10.84	2.06	0.620	1.84	0.138	0.023	282
29	0.0858	0.0878	69.181	109.18	544.8	707	5.988	2659	51.5	6.68	7.31	0.0586	1.103	6.20	2.02	0.843	2.17	0.154	0.024	325
30	0.0412	0.0831	31.893	90.85	520.6	853	4.637	2034	31.7	4.40	7.00	0.0460	0.936	5.36	1.81	0.602	2.14	0.154	0.026	309
31		0.0349	61.779	156.16	1345.0	1906	4.423	3898	80.7	7.68	8.89	0.0454	1.844	11.72	1.91	0.618	2.22	0.146	0.023	264
32	0.0858	0.0878	69.181	109.18	544.8	707	5.988	2659	51.5	6.68	7.31	0.0586	1.103	6.20	2.02	0.843	2.13	0.146	0.020	320
33	0.0412	0.0831	31.893	90.85	520.6	853	4.637	2034	31.7	4.40	7.00	0.0460	0.936	5.36	1.81	0.602	3.75	0.185	0.027	185
34		0.0349	61.779	156.16	1345.0	1906	4.423	3898	80.7	7.68	8.89	0.0454	1.844	11.72	1.91	0.618	2.61	0.162	0.026	271
35	0.0333	0.0262	53.290	106.12	578.8	717	8.062	2756	37.7	6.34	11.42	0.0643	1.151	7.17	2.41	0.928	1.66	0.115	0.019	232
36	0.0758	0.2475	35.659	77.16	381.9	569	6.002	1921	18.4	4.23	7.52	0.0411	0.783	4.89	2.32	0.799	2.93	0.185	0.027	183
37	0.0587	0.1546	105.345	92.28	484.5	967	6.855	2835	61.3	6.33	9.03	0.0661	1.110	5.99	2.13	1.242	2.76	0.162	0.023	524
38	0.0218	0.0792	46.318	110.50	831.5	1068	7.940	3220	88.2	7.43	12.66	0.0735	1.943	9.04	2.36	1.026	2.91	0.192	0.035	210
39	0.0693	0.1036	42.145	109.92	809.0	983	6.735	3071	52.7	6.67	10.84	0.0555	1.491	8.45	2.03	0.790	2.36	0.169	0.026	199
40	0.0129	0.0646	42.249	104.80	791.7	952	6.583	3076	49.8	6.42	10.66	0.0558	1.432	8.24	2.07	0.802	2.14	0.154	0.023	206
41	0.0203	0.0945	55.745	89.15	493.9	613	5.001	2316	35.0	4.82	7.26	0.0398	1.027	5.33	1.59	0.730	2.83	0.200	0.030	272
42	0.0245	0.0944	37.602	112.19	862.4	1177	8.481	2902	46.6	6.95	12.87	0.0615	1.488	8.75	2.15	0.836	1.77	0.123	0.021	184
43	0.0181	0.0769	47.412	116.34	894.5	1377	9.383	3167	55.4	7.39	13.96	0.0821	1.657	9.60	2.43	0.990	2.93	0.177	0.025	238
44	0.0046	0.0764	66.319	114.66	846.9	1535	10.383	2900	47.6	7.77	14.60	0.0980	1.558	9.63	2.59	0.998	3.82	0.208	0.029	343
45	0.0089	0.0650	44.891	88.08	617.9	859	5.360	2168	32.4	4.93	8.09	0.0507	1.045	6.43	1.58	0.606	5.02	0.292	0.041	263
46		0.0779	81.754	173.92	1264.3	2385	7.915	3144	52.7	7.92	12.08	0.0735	1.607	9.61	2.04	0.800	3.07	0.200	0.028	377
47	0.0054	0.0493	64.066	132.34	1269.6	2455	10.194	3320	47.5	8.42	15.10	0.0844	1.662	10.48	2.57	0.912	2.72	0.200	0.033	274
48		0.0611	66.913	102.10	878.7	2500	11.210	2538	35.2	6.25	14.56	0.1038	1.338	8.98	2.33	0.896	3.80	0.215	0.031	348
49	0.0011	0.0406	38.148	84.64	712.6	1077	4.549	2231	36.3	4.58	7.31	0.0402	1.070	7.08	1.29	0.482	7.29	0.385	0.065	265
50		0.0369	56.687	120.71	967.3	1427	7.215	3350	54.9	7.19	11.63	0.0618	1.657	10.21	2.02	0.793	2.68	0.185	0.031	286
51	0.0157	0.0430	63.238	205.05	939.0	1363	8.219	3109	59.2	7.58	12.63	0.0730	1.616	8.99	2.24	1.014	2.90	0.200	0.034	297

SID	Av_Zn	Av_Ni	T_P	T_K	T_Mg	T_Ca	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	PER_C	PER_N	PER_S	T_P
52	0.0053	0.0761	74.402	234.43	1058.7	1556	9.587	3806	132.9	9.20	14.54	0.0998	2.120	10.15	2.63	1.395	2.66	0.215	0.036	305
53		0.0558	61.963	107.89	898.8	1637	4.296	2673	42.6	5.15	7.34	0.0455	1.225	8.31	1.62	0.588	2.49	0.177	0.031	313
54		0.0615	39.422	107.96	974.4	1415	7.500	2810	47.7	6.49	11.30	0.0582	1.460	8.37	1.91	0.756	2.26	0.154	0.023	195
55	0.0014	0.0563	49.562	105.66	820.3	1295	7.511	2766	48.2	6.17	11.16	0.0569	1.395	8.64	1.79	0.707	3.18	0.208	0.032	258
56		0.0727	38.690	122.96	1087.8	1651	8.163	3322	56.1	7.47	12.52	0.0626	1.657	9.99	2.13	0.873	3.14	0.192	0.029	191
57		0.0537	45.892	134.00	1073.9	1657	10.234	3488	67.0	8.03	15.21	0.0847	1.916	9.75	2.41	1.090	2.37	0.169	0.026	200
58		0.0508	59.114	127.32	1233.4	2406	9.473	2880	49.1	6.54	13.02	0.0802	1.484	9.76	2.08	0.894	3.55	0.215	0.035	312
59	0.0231	0.1494	44.732	114.08	881.8	1331	11.836	3168	60.6	9.25	15.60	0.0822	1.712	9.01	2.55	0.985	3.43	0.208	0.034	209
60	0.0027	0.0710	62.600	119.92	802.1	1420	8.803	2778	46.6	7.02	13.17	0.0743	1.454	10.27	2.93	0.784	3.53	0.238	0.038	320
61		0.0540	41.988	142.89	1051.8	1397	8.441	3599	75.2	8.35	13.92	0.0722	1.842	11.42	2.76	0.913	2.74	0.192	0.026	196
62		0.0712	55.860	135.91	1048.4	1890	11.664	3088	76.1	7.49	16.54	0.0879	1.768	10.39	2.40	1.037	4.06	0.231	0.038	284
63	0.0086	0.0721	65.685	108.80	837.1	1819	12.160	2779	71.9	7.81	15.87	0.1051	1.492	9.03	2.36	1.139	5.37	0.292	0.047	390
64	0.0029	0.1334	52.753	120.75	1084.9	1945	12.461	2892	53.1	8.41	19.98	0.0773	1.980	9.36	2.35	1.078	4.54	0.238	0.040	301
651	0.0260		79.493	203.44	2578.3	4236	4.576	4341	93.9	6.93	8.79	0.0207	2.100	14.70	1.32	0.437	1.08	0.062	0.009	304
65	0.0298	0.1644	47.188	130.77	1199.7	1924	9.258	3379	80.0	7.38	14.02	0.0726	1.830	10.30	2.32	0.912	2.62	0.185	0.031	236
66	0.0206	0.0369	55.164	145.98	1699.0	3062	7.215	3251	62.1	6.40	11.35	0.0547	1.567	11.12	1.77	0.648	2.59	0.154	0.021	263
67	0.0237	0.0896	70.362	129.72	951.8	1489	8.936	3065	57.2	7.55	13.34	0.0727	1.610	9.78	2.53	0.986	2.64	0.208	0.034	326
68	0.0112	0.0605	46.909	117.73	860.9	1356	8.370	2925	69.7	7.14	12.51	0.0710	1.556	9.33	2.17	0.866	3.70	0.231	0.039	255
69		0.0299	80.554	165.48	1420.6	2625	9.085	3809	69.2	8.21	14.08	0.0782	1.848	12.40	2.37	1.053	2.13	0.162	0.028	313
70	0.0040	0.1235	63.591	146.92	867.8	1129	7.369	3214	62.4	8.22	11.43	0.0643	1.543	9.32	2.21	1.015	1.88	0.162	0.028	277
74	0.0069	0.0960	53.193	131.96	1374.8	2598	11.109	3335	105.8	6.79	15.71	0.0827	1.843	10.00	2.35	1.232	3.49	0.192	0.029	260
75		0.1021	41.274	132.12	1153.1	1913	11.446	3298	74.3	7.43	16.45	0.0789	1.740	9.83	2.38	1.289	3.06	0.185	0.026	194
76		0.1605	44.738	133.78	1153.2	1705	10.859	3366	68.4	7.38	16.51	0.0830	1.833	11.03	2.32	1.029	2.69	0.162	0.024	206
77	0.0039	0.1136	47.889	113.59	862.8	1538	12.823	2810	38.0	6.81	18.09	0.0790	1.583	9.62	2.45	1.120	4.59	0.285	0.044	242
78		0.0497	55.619	146.83	1374.4	2437	10.061	3634	71.2	8.31	14.98	0.0737	1.839	11.45	2.40	1.031	2.41	0.162	0.023	225
79		0.0540	104.692	144.70	1398.1	3312	12.470	3023	64.5	7.69	15.25	0.1316	1.527	10.60	2.38	1.160	4.23	0.246	0.047	471
80		0.0785	54.347	126.05	1039.4	1796	11.448	3079	57.2	6.70	16.06	0.0806	1.630	10.31	2.44	1.029	3.71	0.231	0.036	263
81	0.0023	0.1210	48.672	134.32	1064.7	1467	10.039	3393	58.3	7.68	14.98	0.0695	1.746	10.62	2.33	0.929	1.97	0.154	0.023	208
83	0.0055	0.1215	45.281	136.79	997.6	1597	10.353	3349	62.0	8.84	16.08	0.0719	1.740	10.87	2.55	1.024	3.34	0.200	0.027	192
84		0.0651	64.020	134.66	1350.8	2732	10.329	2924	46.1	6.83	14.64	0.0796	1.468	10.20	2.22	0.980	3.48	0.192	0.031	300
85		0.1332	38.060	115.13	890.6	1460	9.229	2569	42.2	5.75	13.23	0.0554	1.366	8.24	2.06	0.839	3.07	0.185	0.025	200
86	0.0594	0.0570	55.781	134.21	1268.2	2241	10.441	3409	69.8	7.20	15.54	0.0808	1.878	10.46	2.35	0.987	2.31	0.169	0.023	234
87		0.0995	59.135	152.35	1060.8	1688	10.586	3363	61.6	8.04	15.53	0.0783	1.724	9.68	2.32	0.984	2.54	0.200	0.036	262
88	0.0084	0.0612	72.068	132.41	1018.1	1836	11.440	3169	53.4	7.84	15.63	0.1031	1.589	9.92	2.65	1.066	2.91	0.208	0.034	332
89	0.0385	0.0731	75.239	124.42	809.1	1412	20.470	2942	56.7	22.49	15.30	0.1480	1.660	9.27	6.33	1.215	3.09	0.223	0.039	358
90	0.0061	0.0320	64.675	128.48	960.4	1620	8.046	3266	67.7	7.33	12.37	0.0712	1.648	10.19	2.51	0.785	2.64	0.208	0.033	299
911		0.0417	85.696	165.96	1178.0	1714	7.903	3630	69.6	7.26	10.99	0.0563	1.721	10.92	2.35	1.059	2.13	0.169	0.025	221
912	0.0050	0.1273	51.513	142.49	899.4	1294	9.866	3116	54.6	6.98	14.33	0.0648	1.577	9.97	2.45	1.045	1.60	0.131	0.021	347
913		0.0691	51.042	130.26	873.0	1162	8.176	3187	63.7	6.72	12.38	0.0610	1.693	9.38	2.28	0.935	3.14	0.192	0.027	248
921	0.1330		96.069	220.89	5024.6	10618	4.077	4266	91.3	6.57	7.55	0.0179	1.978	13.53	1.75	0.465	1.74	0.046	0.007	304
92	0.0190	0.0345	51.345	125.86	913.3	1356	9.247	3158	56.1	7.41	13.65	0.0743	1.577	9.00	2.36	1.020	2.42	0.185	0.028	226
93	0.0176	0.0461	61.741	157.64	1267.7	2108	8.856	3391	58.5	7.26	13.34	0.0666	1.665	9.92	2.35	0.891	1.90		0.004	244
94	0.0030	0.0717	67.386	126.71	932.5	1604	9.989	3227	53.6	7.14	14.38	0.0778	1.640	9.40	2.37	0.989	2.36		0.012	284
95	0.0027	0.0436	68.255	142.67	1017.7	1708	9.240	3400	61.4	7.81	14.09	0.0712	1.693	9.95	2.51	0.951	1.93		0.004	277
96	0.0025	0.0487	65.015	144.55	1420.2	2836	7.585	3228	55.8	6.80	11.62	0.0551	1.570	10.07	7.68	0.779	2.11		0.003	282
97	0.0022	0.1187	74.731	150.23	955.3	1371	9.913	3441	57.8	7.94	14.61	0.0768	1.751	10.35	2.32	1.040	1.80	0.163	0.008	291
98	0.0135	0.1841	68.431	137.76	854.3	1172	10.667	3131	60.4	7.78	15.68	0.0751	1.756	9.62	2.37	1.114	2.32	0.174	0.007	306
99	0.0073	0.1067	85.918	171.84	1138.0	1642	11.506	3776	83.4	10.29	17.56	0.0994	2.078	11.63	2.64	1.247	1.89	0.166	0.002	339
100	0.0032	0.0799	78.726	144.93	1068.9	1680	9.245	3635	75.6	9.05	14.23	0.0862	1.914	11.36	2.60	0.987	2.38	0.445	0.005	327
1011		0.0770	101.995	187.72	1142.0	1628	9.467	4259	96.8	8.44	12.26	0.0708	2.124	11.75	2.71	1.918	1.35	0.175	0.003	376

SID	Av_Zn	Av_Ni	T_P	T_K	T_Mg	T_Ca	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	PER_C	PER_N	PER_S	T_P
1012		0.0857	61.963	140.42	944.4	1289	8.870	3348	58.0	7.37	13.32	0.0692	1.622	9.72	2.52	1.114	2.03	0.306	0.011	248
1013	0.0043	0.1322	98.993	158.85	989.9	1453	9.516	3607	70.9	8.85	13.71	0.0790	1.926	10.56	2.58	1.811	2.09	0.325	0.008	387
1021		0.0006	103.999	217.89	1844.7	2448	4.024	5081	123.4	7.47	8.63		2.346	16.91	1.38	0.505	0.40	0.224	0.004	305
102	0.0110	0.1128	52.883	142.27	781.1	1049	7.789	2921	52.7	7.19	11.37	0.0555	1.429	8.43	3.25	1.031	1.79	0.246	0.007	239
103		0.1473	67.662	155.58	904.5	1376	9.183	3061	54.1	7.66	13.19	0.0690	1.556	9.07	2.95	0.925	2.05	0.213	0.004	294
104	0.0027	0.1238	54.732	108.62	709.4	1017	7.873	2737	50.7	6.08	11.68	0.0608	1.381	7.77	2.21	0.800	2.20	0.199	0.008	260
105		0.0927	81.809	147.31	889.8	1399	7.736	3312	53.9	6.55	11.64	0.0613	1.550	9.52	2.19	1.013	1.71	0.143	0.002	331
106	0.0103	0.1365	75.114	149.98	812.3	1101	8.637	3083	45.3	6.90	12.09	0.0573	1.488	8.56	2.20	1.106	1.46	0.131	0.008	307
107	0.0076	0.1405	69.278	148.25	867.2	1165	9.447	3222	49.9	7.95	13.61	0.0678	1.584	9.08	2.18	1.090	1.48	0.134	0.004	286
108	0.0224	0.2010	72.331	158.03	763.9	962	9.429	2888	40.1	6.83	12.56	0.0554	1.408	8.14	2.13	1.148	1.84	0.136	0.006	303
109	0.1383	0.1047	105.956	160.03	763.5	1099	11.085	2936	31.8	7.39	14.22	0.0719	1.402	8.37	2.50	1.549	2.04	0.174	0.011	433
112	0.1279	0.0713	91.625	173.54	783.7	952	7.624	3196	50.0	8.05	10.80	0.0509	1.444	8.57	2.13	1.141	1.65	0.153	0.012	387
113	0.0466	0.0564	69.817	161.44	714.4	942	8.211	3039	66.1	7.56	11.83	0.0585	1.464	7.91	2.48	1.039	2.00	0.181	0.012	301
114	0.0573	0.1324	72.796	122.97	589.1	806	7.884	2822	38.1	6.05	11.47	0.0571	1.223	7.08	2.16	0.885	2.02	0.175	0.013	325
115	0.1890	0.0583	77.949	158.82	819.3	1045	6.204	3314	49.0	6.05	9.97	0.0424	1.522	9.20	1.76	0.846	1.24	0.107	0.009	294
116	0.0607	0.1304	114.975	154.65	705.0	1001	9.400	2956	37.4	7.48	11.80	0.0594	1.329	7.96	2.31	1.506	1.65	0.136	0.010	455
117	0.0391	0.1028	103.053	159.40	694.4	942	8.600	2916	37.1	7.91	11.94	0.0554	1.312	7.96	2.20	0.998	1.69	0.147	0.007	417
118	0.0244	0.0535	112.855	169.16	718.2	976	8.057	3178	50.3	6.56	10.56	0.0513	1.326	7.93	2.10	1.674	1.57	0.131	0.009	451
119	0.0530	0.1047	128.202	188.01	706.6	967	10.221	2776	31.0	6.66	12.11	0.0535	1.264	7.75	2.46	1.855	1.67	0.143	0.012	508
120	0.0834	0.2008	70.325	162.48	793.0	992	10.864	3104	39.3	7.78	13.99	0.0589	1.436	8.88	2.36	1.086	1.56	0.141	0.009	290
121	0.0377	0.1018	71.718	156.50	697.5	978	10.745	2908	35.0	7.02	13.53	0.0611	1.250	8.03	2.44	1.109	1.88	0.159	0.010	291
122	0.0627	0.1467	76.116	148.87	629.1	891	9.605	2593	25.9	8.98	11.57	0.0536	1.112	7.37	2.16	1.013	1.97	0.156	0.008	317
123	0.0583	0.1097	81.295	159.75	663.3	903	10.685	2761	33.8	7.90	13.19	0.0588	1.226	7.54	2.46	1.174	1.77	0.148	0.012	315
125	0.0209	0.1743	34.050	91.15	427.2	730	8.037	1836	19.8	4.04	10.55	0.0368	0.846	6.13	2.09	0.958	2.63	0.161	0.010	161
126	0.0144	0.1101	45.629	95.03	504.4	787	8.414	2198	45.2	5.38	11.91	0.0592	1.168	6.84	2.20	1.134	2.90	0.215	0.017	218
127	0.0664	0.1054	28.085	72.81	294.7	556	6.727	1375	13.8	2.88	8.36	0.0362	0.551	4.14	1.80	0.832	3.17	0.198	0.020	162
1271	0.0774	0.3929	53.627	118.73	556.3	794	10.209	2954	24.9	5.36	11.18	0.0511	1.124	7.89	2.54	1.270	2.47	0.147	0.018	187
128	0.0252	0.1119	43.381	157.47	583.5	959	9.218	2277	23.2	4.51	11.37	0.0588	0.887	7.11	2.43	1.137	3.38	0.220	0.016	200
129	0.0306	0.1538	57.272	100.01	495.6	771	8.348	2577	47.1	4.98	10.66	0.0515	1.115	6.54	2.73	1.115	2.72	0.187	0.008	260
130	0.0118	0.0520	50.917	95.55	623.6	870	8.097	2400	22.4	4.98	10.90	0.0543	0.965	6.42	2.29	1.164	2.70	0.215	0.014	227
131	0.0352	0.1754	47.222	83.28	427.1	678	7.663	2340	29.4	4.87	10.47	0.0498	0.977	5.86	2.17	1.080	2.79	0.230	0.022	220
132	0.0210	0.0831	46.970	83.13	380.3	702	7.337	1945	19.1	4.39	9.54	0.0509	0.802	5.13	2.10	1.029	2.99	0.206	0.018	226
133	0.0608	0.0766	43.610	91.74	381.9	739	7.841	1905	17.9	3.43	9.87	0.0488	0.761	4.95	2.15	1.062	2.42	0.197	0.012	296
134	0.0054	0.0463	49.193	80.76	356.6	644	7.133	1941	27.1	5.33	8.28	0.0418	0.773	4.28	2.09	1.140	2.63	0.192	0.014	240
135	0.0608	0.0766	43.610	91.74	381.9	739	7.841	1905	17.9	3.43	9.87	0.0488	0.761	4.95	2.15	1.062	3.51	0.216	0.016	193
136	0.0128		45.811	84.42	447.2	692	7.308	2312	27.7	4.73	9.55	0.0532	1.158	5.74	2.18	1.161	2.75	0.190	0.019	210
1361	0.0093	0.0743	58.014	120.76	713.3	983	3.049	2747	33.2	4.26	6.01	0.0281	1.341	7.37	1.11	0.447	0.79	0.071	0.006	196
137	0.0644	0.1681	40.253	80.11	285.5	399	7.654	2003	19.0	3.45	6.74	0.0375	0.688	4.42	2.06	1.083	2.78	0.149	0.019	203
138	0.0287	0.0989	90.367	129.69	418.5	766	9.106	2171	24.4	6.14	11.57	0.0550	0.945	5.38	2.08	1.118	2.05	0.169	0.014	393
139	0.0665	0.0578	82.229	138.58	454.7	825	8.876	2358	24.7	6.80	11.44	0.0549	1.018	5.64	2.23	0.972	1.80	0.138	0.011	340
140	0.0841	0.1231	84.712	105.05	404.7	614	7.758	2390	40.3	5.07	9.35	0.0463	1.011	5.16	1.99	1.141	1.81	0.137	0.018	404
141	0.0829	0.1181	106.826	140.83	438.8	788	9.350	2272	27.8	7.08	11.26	0.0561	0.976	5.56	2.46	1.139	2.05	0.159	0.018	465
142	0.0275	0.0651	77.835	134.42	466.6	820	8.707	2166	32.6	6.58	10.79	0.0594	1.023	5.47	2.14	1.120	2.13	0.167	0.013	337
145	0.0139	0.0446	78.158	105.07	882.0	1347	7.004	2499	94.8	5.38	9.57	0.0534	1.397	5.40	2.05	1.066	2.18	0.149	0.005	366
147	0.0281	0.0863	49.740	96.85	484.3	747	8.217	2279	30.9	4.67	10.89	0.0476	1.001	5.96	2.21	1.030	2.15	0.163	0.016	227
148	0.0253	0.1129	56.793	97.08	462.3	737	8.057	2289	29.3	4.89	9.42	0.0502	0.977	5.50	2.82	1.153	2.15	0.158	0.017	258
150	0.0124	0.1030	65.070	78.46	470.4	892	7.678	1859	44.4	6.77	10.30	0.0666	1.002	5.87	1.75	0.970	3.17	0.239	0.013	350
151	0.0194	0.0712	77.213	126.35	660.8	1000	7.625	2905	37.8	6.73	11.04	0.0622	1.278	7.55	2.32	1.116	1.78	0.144	0.010	319
152	0.0178	0.0861	58.709	117.87	634.1	887	7.417	2308	28.5	6.16	10.37	0.0576	1.087	7.08	2.07	1.071	2.45	0.184	0.012	262
154	0.0046	0.0547	51.157	94.35	520.0	1304	7.841	2327	32.7	5.93	10.92	0.0562	1.069	6.16	2.04	0.868	2.39	0.181	0.011	244

SID	Av_Zn	Av_Ni	T_P	T_K	T_Mg	T_Ca	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	PER_C	PER_N	PER_S	T_P
155	0.0057	0.0736	63.082	98.50	679.0	1207	8.006	2305	39.4	5.49	11.36	0.0608	1.199	6.41	1.87	0.807	2.52	0.200	0.013	301
157	0.0284	0.1779	37.521	82.34	419.8	730	7.829	1886	21.7	3.83	9.74	0.0442	0.821	5.56	1.84	0.815	2.46	0.135	0.011	185
158		0.0666	63.216	108.23	658.5	1025	7.351	2339	33.3	6.25	10.63	0.0587	1.125	7.16	2.01	0.812	1.86	0.143	0.008	264
160	0.0955	0.0519	75.609	95.73	703.1	1391	8.260	2330	51.7	6.86	11.42	0.0894	1.165	7.96	1.98	0.777	3.27	0.254	0.011	357
161		0.0436	47.059	101.34	657.0	1132	8.224	2469	32.8	5.54	11.46	0.0538	1.181	6.99	2.09	0.846	1.94	0.141	0.006	202
162	0.0144	0.0936	63.465	103.58	684.5	1086	8.001	2539	42.2	5.98	12.08	0.0635	1.312	7.73	2.06	0.775	2.64	0.196	0.013	280
166	0.0598	0.1364	75.776	118.67	345.2	635	7.210	1855	21.9	4.82	8.27	0.0498	0.795	4.39	1.84	1.025	2.49	0.154	0.019	371
167	0.0736	0.1106	109.614	159.35	548.1	860	7.967	2816	42.4	7.69	10.61	0.0525	1.220	6.93	2.31	1.109	1.83	0.131	0.025	432
168	0.0086	0.0403	81.701	134.73	539.4	753	6.008	2731	46.2	6.53	8.76	0.0414	1.129	6.37	1.82	0.935	1.82	0.121	0.006	359
169	0.0095	0.0048	62.096	139.16	698.3	910	4.863	2968	151.4	7.23	8.55	0.0481	1.499	7.63	1.67	0.731	1.18	0.085	0.007	249
170	0.0082	0.0230	62.833	141.75	666.0	870	5.554	3041	45.2	6.66	8.75	0.0407	1.322	7.46	1.77	0.973	1.36	0.095	0.010	250
171	0.0412	0.0261	64.517	129.54	597.1	840	5.263	2502	30.6	5.90	7.79	0.0359	1.070	6.76	1.71	0.754	1.44	0.100	0.010	255
172	0.0222	0.0331	59.293	127.41	470.4	777	5.831	2573	34.5	6.30	8.62	0.0429	0.992	5.71	1.76	0.730	1.61	0.108	0.017	242
173	0.0591	0.0264	66.372	140.31	712.5	971	4.880	2757	41.0	6.10	7.93	0.0373	1.232	7.71	1.55	0.591	1.52	0.109	0.011	272
174	0.0526	0.0767	78.707	143.12	467.2	705	6.056	2382	37.7	7.35	8.14	0.0411	0.964	5.60	1.75	0.832	1.82	0.128	0.019	347
175	0.1129	0.1255	79.022	152.62	591.5	842	6.751	2371	37.7	7.99	8.62	0.0485	1.163	6.71	1.94	1.052	1.90	0.141	0.014	350
176	0.0071	0.0129	72.297	145.96	545.1	801	5.040	2714	45.6	6.89	7.91	0.0395	1.131	6.27	1.74	0.634	1.50	0.108	0.011	317
177	0.0084	0.0144	80.970	156.42	609.6	837	5.682	2898	45.1	7.48	8.44	0.0449	1.261	7.11	1.87	0.883	1.66	0.117	0.011	352
178	0.0204	0.0283	73.912	138.47	486.5	774	5.520	2596	44.2	6.71	7.95	0.0426	1.095	5.94	1.67	0.699	1.52	0.108	0.018	316
179	0.0147	0.0388	70.481	165.44	707.1	848	5.643	3014	51.7	7.23	8.79	0.0451	1.294	7.80	1.82	0.748	1.76	0.107	0.018	311
180	0.0467	0.2192	52.225	81.28	256.7	569	8.449	1556	15.9	3.65	8.77	0.0551	0.597	3.81	1.82	0.939	3.56	0.129	0.021	293
181	0.1218	0.4320	30.210	83.32	337.8	513	9.453	1689	17.1	3.54	9.66	0.0439	0.703	4.47	2.16	0.992	3.80	0.202	0.024	186
182	0.0337	0.0664	26.362	76.81	317.3	472	8.836	1676	29.6	3.22	7.89	0.0378	0.737	4.44	2.29	0.949	2.91	0.154	0.021	162
183	0.1411	0.4344	78.608	116.54	457.7	686	7.246	2437	40.0	5.87	8.98	0.0441	1.006	5.78	2.00	0.968	1.96	0.136	0.017	371
184	0.1376	0.3574	42.742	91.41	414.8	569	8.153	2065	27.3	4.42	9.37	0.0445	0.875	5.32	2.03	0.975	3.07	0.181	0.024	238
185	0.0400	0.1989	42.514	102.00	606.5	759	8.776	2535	42.9	5.73	11.90	0.0599	1.236	7.49	2.30	1.086	2.75	0.184	0.015	218
186	0.0624	0.2349	39.283	96.05	524.4	720	8.195	2312	28.2	5.09	10.77	0.0479	0.985	6.54	2.29	0.960	3.11	0.201	0.019	209
188	0.1173	0.3933	35.742	99.32	481.3	627	8.190	1994	22.6	4.47	9.75	0.0413	0.880	6.05	2.12	0.848	3.51	0.173	0.023	199
189	0.0306	0.1294	40.635	109.93	678.0	860	7.678	2588	31.4	5.50	10.52	0.0471	1.095	7.72	2.20	0.918	2.39	0.174	0.007	190
190	0.0134	0.1194	44.356	106.84	708.0	992	7.144	2666	39.7	6.16	10.83	0.0565	1.224	7.81	2.07	0.842	2.21	0.174	0.010	208
191		0.0087	64.728	156.64	914.0	1295	4.427	3210	54.1	6.76	8.05	0.0386	1.440	9.27	1.64	0.621	1.21	0.093	0.005	250
192		0.0159	70.548	150.43	1351.3	2036	4.902	3112	50.6	5.94	7.96	0.0329	1.390	9.49	1.55	0.597	1.37	0.093	0.005	272
193	0.0146	0.0769	62.102	133.91	638.0	910	3.420	2766	48.0	6.06	6.60	0.0315	1.276	7.28	1.47	0.638	1.25	0.103	0.006	256
194	0.0022	0.0568	63.189	149.65	778.8	1332	4.556	2498	35.8	5.61	8.25	0.0424	1.230	8.50	1.57	0.500	1.73	0.133	0.011	258
195		0.0038	60.391	146.51	974.1	1497	3.860	3151	47.8	5.65	7.40	0.0331	1.365	8.98	1.39	0.554	1.21	0.094	0.005	230
196		0.0412	50.567	125.77	1083.9	1693	4.564	2982	45.1	8.71	8.27	0.0340	1.390	9.36	1.62	0.558	1.66	0.111	0.006	195
197	0.0107	0.1108	58.000	101.23	756.0	1101	4.779	2161	33.9	5.54	7.45	0.0424	1.058	6.47	1.66	0.608	2.12	0.160	0.013	267
198	0.0245	0.1750	50.992	69.49	396.6	668	5.316	1501	17.7	3.93	7.55	0.0488	0.788	4.85	1.55	0.567	3.66	0.259	0.025	306
204	0.1305	0.4288	36.008	74.01	269.6	501	9.391	1692	50.7	3.91	9.90	0.0575	0.650	3.17	1.86	1.205	2.83	0.152	0.018	199
205	0.0991	0.3414	43.871	84.17	389.1	689	8.119	1791	51.8	4.67	9.99	0.0566	0.850	4.80	1.96	0.828	2.59	0.154	0.015	221
207		0.1379	60.947	126.07	1432.1	904	7.555	3221	60.7	6.65	11.66	0.0637	1.497	9.22	2.11	0.772	2.44	0.176	0.008	263
210	0.0462	0.2056	55.675	98.28	545.5	848	6.897	2119	30.2	5.61	9.71	0.0485	1.014	6.13	2.03	0.884	2.17	0.165	0.017	247
211	0.0435	0.1045	66.479	97.49	652.0	1153	7.158	2315	47.8	6.46	10.28	0.0639	1.113	7.12	1.81	0.737	2.98	0.224	0.011	313
212	0.0138	0.1389	51.758	114.38	764.8	1167	8.249	2819	75.1	6.84	12.34	0.0675	1.419	8.23	2.21	0.834	2.55	0.190	0.011	224
351			59.116	136.91	1791.1	2769	4.285	3011	52.7	5.10	7.10	0.0205	1.341	9.78	1.12	0.413	1.31	0.164	0.018	269
352		0.0563	68.899	178.54	2019.1	2990	7.968	4074	79.7	7.82	12.73	0.0467	2.013	13.12	1.89	0.722	1.49	0.179	0.020	230
385		0.0612	51.823	97.67	680.3	1094	6.760	2154	28.6	5.16	9.64	0.0495	1.060	6.21	1.89	0.661	2.60	0.256	0.037	243
585	0.0944	0.4911	41.682	116.48	506.3	822	7.823	1960	22.8	4.72	10.32	0.0552	0.917	6.00	2.02	0.797	3.69	0.295	0.038	219

SID	T_K	T_Ca	T_Mg	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	T_Al	T_Na	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn	Av_Zn	Av_Ni
2	643	9010	5110	37.1	16800	307	35.1	58.0	0.345	8.47	52.4	12.20	4.13	15400	784	4.61	13.70	343	93.5	0.355	5.69	3.41	0.3730	0.365
3	499	11500	3870	36.3	11900	223	28.9	52.1	0.379	6.06	38.1	11.80	3.76	10900	622	4.48	15.40	429	112.0	0.207	2.99	2.94	0.6370	0.323
4	528	15400	3800	45.0	11600	272	30.3	58.6	0.583	6.25	40.3	12.60	4.71	10900	648	7.66	17.70	560	121.0	0.263	4.11	3.40	0.1400	0.312
5	585	10300	3890	45.8	12500	210	44.0	60.5	0.678	7.27	52.4	12.70	4.08	15100	494	6.67	15.70	415	88.3	0.237	3.99	2.04	0.0765	0.208
6	667	10100	5800	42.7	16800	302	39.5	68.0	0.434	9.15	68.1	12.30	3.62	18500	614	4.93	12.00	390	96.0	0.248	2.68	1.64	0.0542	0.162
7	701	7340	5580	26.7	18500	325	48.9	49.4	0.306	8.77	63.3	11.70	3.62	17200	757	4.40	3.66	290	73.5	0.224	4.19	2.02	0.0515	0.178
8	544	6100	4040	18.0	13100	184	23.0	32.1	0.172	5.91	43.2	6.41	2.12	11800	655	4.27	9.02	236	66.7	0.164	5.59	1.52		0.111
9	730	6410	4350	27.6	14500	217	27.7	46.8	0.258	6.80	49.3	9.60	3.35	13200	695	3.97	4.19	244	88.1	0.257	7.60	3.43	0.0097	0.318
10	759	7830	5680	28.0	18200	328	37.3	51.3	0.258	8.54	62.2	10.40	3.69	16400	791	3.80	6.88	278	80.1	0.252	2.47	2.53	0.0213	0.143
11	774	8960	6170	30.8	18000	303	41.3	49.8	0.287	9.04	63.4	10.00	3.04	16000	873	5.04	9.51	304	73.3	0.291	4.21	1.13	0.0571	0.128
12	649	8850	5670	22.8	16500	252	32.1	44.0	0.192	7.61	55.6	8.71	2.87	15300	835	1.81	3.46	328	87.3	0.219	3.13	1.74		0.111
13	555	7240	4400	30.9	15200	254	33.5	52.4	0.327	7.53	48.5	11.10	3.56	14600	731	3.47	12.50	292	79.9	0.249	5.48	3.83	0.0214	0.316
14	547	7420	4430	27.0	14200	186	35.5	45.6	0.307	7.76	48.4	9.97	2.94	15400	653	5.28	11.50	313	76.1	0.215	8.59	1.21	0.1220	0.161
15	499	4410	3040	23.8	11900	182	26.8	39.0	0.233	5.39	31.9	8.68	3.04	12500	645	4.38	10.30	225	66.9	0.277	8.49	2.98	0.3250	0.326
16	515	6570	3560	28.0	12500	157	26.4	41.8	0.301	5.94	39.0	8.66	3.01	13000	706	4.74	5.33	308	88.1	0.313	7.76	2.77		0.267
17	554	5790	3770	29.2	15300	395	32.7	47.4	0.320	8.03	44.1	10.60	4.12	14700	731	3.75	11.70	299	63.8	0.260	5.20	4.36	0.0080	0.254
18	639	6920	4830	24.8	15300	261	32.8	40.9	0.241	7.15	46.3	8.41	3.03	14000	877	4.60	9.29	305	71.3	0.266	4.22	1.76		0.086
19	686	9190	6080	23.3	17300	330	34.4	44.0	0.235	8.21	52.5	8.99	3.14	15800	942	1.98	9.67	308	76.7	0.184	2.12	1.40		0.103
20	628	8600	5380	27.0	16300	280	36.3	48.7	0.247	7.66	50.0	10.50	3.68	15300	859	4.20	14.80	349	100.0	0.302	3.88	2.91	0.3460	0.313
21	606	8090	5380	23.1	16300	321	36.2	42.4	0.253	7.98	49.3	10.20	2.99	15100	868	4.48	3.98	323	70.9	0.281	2.45	1.15		0.106
22	461	5400	2890	28.0	11300	175	28.7	41.4	0.286	5.24	33.9	8.83	2.82	11400	664	5.10	8.31	253	55.6	0.253	4.58	2.32	0.0044	0.224
23	532	5690	3530	25.4	13000	221	38.8	40.1	0.260	6.14	35.6	9.50	3.34	12600	684	3.54	14.80	271	61.2	0.267	4.97	2.42	0.0155	0.133
24	575	6890	3440	29.4	12900	260	34.0	43.0	0.333	6.09	36.4	9.16	4.20	12700	664	5.64	10.40	352	94.7	0.267	3.62	2.83	0.0083	0.242
25	558	6100	3590	24.3	12700	156	32.3	35.1	0.273	5.50	33.6	8.15	3.31	11200	740	3.97	9.51	257	79.2	0.209	3.41	0.85	0.0348	0.102
26	560	7020	4140	32.2	14600	378	34.1	48.5	0.355	7.86	40.5	10.50	4.03	13300	764	3.47	3.18	214	60.4	0.241	3.74	2.51	0.0250	0.177
27	785	7620	5920	21.7	18800	345	37.1	42.3	0.260	8.66	56.1	9.48	3.11	16600	824	1.83	5.19	128	31.7	0.130	3.71	0.40		0.061
28	751	7800	5380	20.1	16100	281	37.8	37.5	0.202	7.37	46.9	8.90	2.68	14700	820	3.87	10.30	289	59.5	0.216	4.39	0.63	0.0612	0.077
29	473	3440	2260	27.0	10700	153	26.9	36.8	0.246	4.37	24.8	9.58	4.20	10500	532	3.75	11.20	160	29.6	0.283	8.06	4.71	0.0986	0.366
30	599	4140	3030	26.1	12900	202	29.7	38.9	0.257	5.63	33.3	9.21	3.18	12600	535	3.77	21.60	240	38.0	0.259	8.43	2.61		0.177
31	459	3840	2260	23.2	10300	187	26.5	34.3	0.237	4.74	25.1	9.21	3.03	9920	547	2.76	19.70	207	50.2	0.212	7.18	1.63		0.113
32	505	3270	2520	27.7	12300	238	30.9	33.8	0.271	5.10	28.7	9.36	3.90	10800	547	3.81	30.50	172	33.2	0.285	7.68	11.60	0.3970	0.406
33	527	4950	3020	26.9	11800	184	25.5	40.6	0.267	5.43	31.1	10.50	3.49	10600	600	3.81	27.70	267	74.4	0.358	11.40	6.62	0.2390	0.482
34	685	8360	5900	19.4	17100	354	33.7	39.0	0.199	8.09	51.4	8.38	2.71	14800	821	3.46	9.57	281	69.3	0.175	2.63	1.31		0.153
35	462	3120	2520	35.1	12000	164	27.6	49.7	0.280	5.01	31.2	10.50	4.04	12400	465	4.89	13.00	289	61.6	0.238	1.87	0.86	0.1450	0.114
36	396	2920	1960	30.8	9860	95	21.7	38.6	0.211	4.02	25.1	11.90	4.10	10200	461	4.24	22.20	169	40.9	0.449	11.00	15.50	0.3890	1.270
37	459	4810	2410	34.1	14100	305	31.5	44.9	0.329	5.52	29.8	10.60	6.18	12500	424	3.38	19.70	160	22.4	0.329	9.90	5.85	0.2920	0.769
38	501	4840	3770	36.0	14600	400	33.7	57.4	0.333	8.81	41.0	10.70	4.65	12800	660	5.81	20.60	240	47.0	0.388	10.20	5.81	0.0990	0.359
39	519	4640	3820	31.8	14500	249	31.5	51.2	0.262	7.04	39.9	9.57	3.73	13000	667	3.98	11.10	207	61.8	0.399	7.80	7.19	0.3270	0.489
40	511	4640	3860	32.1	15000	243	31.3	52.0	0.272	6.98	40.2	10.10	3.91	13200	677	2.30	8.67	157	45.0	0.289	5.32	4.32	0.0630	0.315
41	435	2990	2410	24.4	11300	171	23.5	35.4	0.194	5.01	26.0	7.78	3.56	10200	559	3.53	30.30	146	47.2	0.361	6.82	6.59	0.0992	0.461
42	549	5760	4220	41.5	14200	228	34.0	63.0	0.301	7.28	42.8	10.50	4.09	12600	716	2.48	12.40	93	24.6	0.244	19.50	8.77	0.1200	0.462
43	584	6910	4490	47.1	15900	278	37.1	70.1	0.412	8.32	48.2	12.20	4.97	14100	704	1.95	4.57	213	80.3	0.349	6.54	2.35	0.0907	0.386
44	593	7940	4380	53.7	15000	246	40.2	75.5	0.507	8.06	49.8	13.40	5.16	14500	634	2.99	4.82	228	78.0	0.344	8.19	2.80	0.0239	0.395
45	516	5030	3620	31.4	12700	190	28.9	47.4	0.297	6.12	37.7	9.27	3.55	12100	629	4.50	5.70	258	88.3	0.324	9.97	2.30	0.0519	0.381
46	802	11000	5830	36.5	14500	243	36.5	55.7	0.339	7.41	44.3	9.42	3.69	12900	768	3.39	5.93	203	77.6	0.303	8.03	2.50		0.359
47	566	10500	5430	43.6	14200	203	36.0	64.6	0.361	7.11	44.8	11.00	3.90	12700	721	4.26	26.80	363	79.5	0.276	2.99	0.84	0.0230	0.211
48	531	13000	4570	58.3	13200	183	32.5	75.7	0.540	6.96	46.7	12.10	4.66	12200	694	2.46	4.18	380	84.0	0.274	3.04	1.17		0.318
49	588	7480	4950	31.6	15500	252	31.8	50.8	0.279	7.43	49.2	8.96	3.35	13600	786	5.05	5.11	474	113.0	0.334	4.90	1.21	0.0079	0.282
50	609	7200	4880	36.4	16900	277	36.3	58.7	0.312	8.36	51.5	10.20	4.00	14900	729	2.83	3.42	255	75.5	0.231	3.95	1.52		0.186
51	963	6400	4410	38.6	14600	278	35.6	59.3	0.343	7.59	42.2	10.50	4.76	13000	694	2.77	3.92	264	70.4	0.206	7.95	1.55	0.0737	0.202

SID	T_K	T_Ca	T_Mg	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	T_Al	T_Na	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn	Av_Zn	Av_Ni
52	961	6380	4340	39.3	15600	545	37.7	59.6	0.409	8.69	41.6	10.80	5.72	13100	732	4.53	83.20	324	83.4	0.378	5.73	1.51	0.0219	0.312
53	545	8270	4540	21.7	13500	215	26.0	37.1	0.230	6.19	42.0	8.16	2.97	11900	666	2.38	3.82	227	67.2	0.325	4.92	1.71		0.282
54	534	7000	4820	37.1	13900	236	32.1	55.9	0.288	7.22	41.4	9.47	3.74	12500	716	2.17	2.98	239	87.8	0.298	4.85	1.93		0.304
55	550	6740	4270	39.1	14400	251	32.1	58.1	0.296	7.26	45.0	9.30	3.68	13000	707	2.94	3.44	243	73.0	0.277	5.36	1.88	0.0074	0.293
56	607	8150	5370	40.3	16400	277	36.9	61.8	0.309	8.18	49.3	10.50	4.31	14000	782	2.08	2.74	282	76.3	0.283	3.37	1.56		0.209
57	584	7220	4680	44.6	15200	292	35.0	66.3	0.369	8.35	42.5	10.50	4.75	13100	655	2.03	5.27	355	71.5	0.342	2.75	1.57		0.234
58	672	12700	6510	50.0	15200	259	34.5	68.7	0.423	7.83	51.5	11.00	4.72	12500	725	4.17	5.22	412	79.1	0.460	1.72	1.38		0.268
59	533	6220	4120	55.3	14800	283	43.2	72.9	0.384	8.00	42.1	11.90	4.60	12500	662	3.96	5.45	269	89.9	0.518	7.90	3.86	0.1080	0.698
60	613	7260	4100	45.0	14200	238	35.9	67.3	0.380	7.43	52.5	15.00	4.01	13600	761	4.07	5.89	289	70.0	0.359	5.66	1.68	0.0140	0.363
61	667	6520	4910	39.4	16800	351	39.0	65.0	0.337	8.60	53.3	12.90	4.26	14800	780	2.72	3.94	216	68.4	0.282	3.52	2.08		0.252
62	691	9610	5330	59.3	15700	387	38.1	84.1	0.447	8.99	52.8	12.20	5.27	13500	743	3.40	3.91	333	85.9	0.285	1.51	1.60		0.362
63	646	10800	4970	72.2	16500	427	46.4	94.2	0.624	8.86	53.6	14.00	6.76	12700	696	3.74	5.50	452	104.0	0.435	2.50	2.13	0.0509	0.428
64	689	11100	6190	71.1	16500	303	48.0	114.0	0.441	11.30	53.4	13.40	6.15	13000	855	4.25	5.40	348	97.2	0.589	2.72	1.99	0.0163	0.761
651	778	16200	9860	17.5	16600	359	26.5	33.6	0.079	8.03	56.2	5.06	1.67	13300	983	0.82	2.98	201	47.0	0.167	2.70	0.22	0.0995	
65	654	9620	6000	46.3	16900	400	36.9	70.1	0.363	9.15	51.5	11.60	4.56	14500	765	3.34	3.93	196	47.5	0.156	0.23	0.21	0.1490	0.822
66	696	14600	8100	34.4	15500	296	30.5	54.1	0.261	7.47	53.0	8.46	3.09	13100	847	2.83	4.93	332	68.6	0.377	1.66	0.93	0.0984	0.176
67	601	6900	4410	41.4	14200	265	35.0	61.8	0.337	7.46	45.3	11.70	4.57	12700	650	6.21	6.42	340	81.1		4.71	1.37	0.1100	0.415
68	640	7370	4680	45.5	15900	379	38.8	68.0	0.386	8.46	50.7	11.80	4.71	13900	696		4.43	274	83.0	0.352	4.71	2.45	0.0609	0.329
69	643	10200	5520	35.3	14800	269	31.9	54.7	0.304	7.18	48.2	9.19	4.09	12500	843	4.87	4.11	350	63.0	0.414	1.54	0.72		0.116
70	640	4920	3780	32.1	14000	272	35.8	49.8	0.280	6.72	40.6	9.61	4.42	12900	656	3.92	16.90	249	60.8	0.405	4.76	3.84	0.0173	0.538
74	645	12700	6720	54.3	16300	517	33.2	76.8	0.404	9.01	48.9	11.50	6.02	12100	703	5.32	6.86	468	105.0	0.630	1.77	2.57	0.0336	0.469
75	621	8990	5420	53.8	15500	349	34.9	77.3	0.371	8.18	46.2	11.20	6.06	12900	666	3.80	5.31	347	86.1	0.579	2.79	2.44		0.480
76	616	7850	5310	50.0	15500	315	34.0	76.0	0.382	8.44	50.8	10.70	4.74	13300	734	4.49	4.81	337	99.3	0.615	3.64	4.07		0.739
77	574	7770	4360	64.8	14200	192	34.4	91.4	0.399	8.00	48.6	12.40	5.66	13900	740	6.23	7.49	327	87.5	0.600	3.47	1.21	0.0196	0.574
78	594	9860	5560	40.7	14700	288	33.6	60.6	0.298	7.44	46.3	9.70	4.17	12000	749	2.45	3.43	335	72.0	0.444	1.85	1.18		0.201
79	651	14900	6290	56.1	13600	290	34.6	68.6	0.592	6.87	47.7	10.70	5.22	11600	738	5.01	4.97	405	75.1	0.481	1.36	1.50		0.243
80	610	8690	5030	55.4	14900	277	32.4	77.7	0.390	7.89	49.9	11.80	4.98	13100	735	3.84	3.44	307	89.4	0.477	3.92	1.63		0.380
81	574	6270	4550	42.9	14500	249	32.8	64.0	0.297	7.46	45.4	9.95	3.97	12900	722	5.75	3.55	311	81.8	0.564	3.98	2.97	0.0098	0.517
83	580	6770	4230	43.9	14200	263	37.5	68.2	0.305	7.38	46.1	10.80	4.34	12700	684	4.06	6.11	298	90.9	0.510	5.78	4.49	0.0234	0.515
84	631	12800	6330	48.4	13700	216	32.0	68.6	0.373	6.88	47.8	10.40	4.59	11800	807	5.18	7.02	396	82.8	0.543	2.08	1.08		0.305
85	605	7670	4680	48.5	13500	222	30.2	69.5	0.291	7.18	43.3	10.80	4.41	11700	747	4.55	9.77	360	94.7	0.603	4.38	3.23		0.700
86	563	9400	5320	43.8	14300	293	30.2	65.2	0.339	7.88	43.9	9.86	4.14	12200	762	4.19	2.87	346	75.3	0.489	2.26	0.93	0.2490	0.239
87	675	7480	4700	46.9	14900	273	35.6	68.8	0.347	7.64	42.9	10.30	4.36	12500	778	5.68	18.80	334	89.0	0.625	2.96	2.24		0.441
88	610	8460	4690	52.7	14600	246	36.1	72.0	0.475	7.32	45.7	12.20	4.91	13000	765	4.38	3.66	302	68.2	0.443	2.63	0.95	0.0388	0.282
89	592	6720	3850	97.4	14000	270	107.0	72.8	0.704	7.90	44.1	30.10	5.78	13100	718	4.37	8.52	253	69.5	0.706	5.91	1.87	0.1830	0.348
90	594	7490	4440	37.2	15100	313	33.9	57.2	0.329	7.62	47.1	11.60	3.63	13700	761	3.17	7.77	306	60.4	0.315	4.49	0.95	0.0280	0.148
911	564	5030	3780	35.4	13800	276	29.1	53.6	0.264	7.33	40.6	9.89	4.05	12300	773	3.19	11.50	174	59.2	0.304	5.47	2.67		0.299
912	672	6940	4770	32.0	14700	282	29.4	44.5	0.228	6.97	44.2	9.53	4.29	12600	729	4.74	15.90	209	60.6	0.286	3.12	0.76		0.169
913	686	6230	4330	47.5	15000	263	33.6	69.0	0.312	7.59	48.0	11.80	5.03	13200	727	4.36	21.40	216	74.6	0.464	6.22	2.91	0.0241	0.613
921	699	33600	15900	12.9	13500	289	20.8	23.9	0.057	6.26	42.8	5.55	1.47	10500	1010	0.52	3.39	147	29.6	0.108	2.54	0.10	0.4210	
92	554	5970	4020	40.7	13900	247	32.6	60.1	0.327	6.94	39.6	10.40	4.49	12700	689	3.05	4.30	218	64.2	0.288	2.65	1.51	0.0837	0.152
93	623	8330	5010	35.0	13400	231	28.7	52.7	0.263	6.58	39.2	9.30	3.52	11800	808	3.43	10.50	317	70.7	0.414	3.01	0.86	0.0694	0.182
94	534	6760	3930	42.1	13600	226	30.1	60.6	0.328	6.91	39.6	9.98	4.17	11900	677	5.22	5.03	286	69.9	0.486	5.36	1.47	0.0125	0.302
95	579	6930	4130	37.5	13800	249	31.7	57.2	0.289	6.87	40.4	10.20	3.86	12300	693	3.89	6.07	266	60.2	0.355	3.84	0.87	0.0110	0.177
96	627	12300	6160	32.9	14000	242	29.5	50.4	0.239	6.81	43.7	33.30	3.38	12100	765	5.25	4.68	286	66.1	0.427	1.68	1.47	0.0109	0.211
97	585	5340	3720	38.6	13400	225	30.9	56.9	0.299	6.82	40.3	9.02	4.05	11900	645	5.34	16.40	274	77.7	0.497	5.33	4.32	0.0085	0.462
98	616	5240	3820	47.7	14000	270	34.8	70.1	0.336	7.85	43.0	10.60	4.98	12300	747	7.20	11.00	237	83.8	0.611	3.66	5.54	0.0603	0.823
99	678	6480	4490	45.4	14900	329	40.6	69.3	0.392	8.20	45.9	10.40	4.92	13000	812	8.05	12.30	242	76.4	0.555	4.98	1.85	0.0288	0.421
100	602	6980	4440	38.4	15100	314	37.6	59.1	0.358	7.95	47.2	10.80	4.10	13600	688	7.87	3.46	351	75.8	0.478	5.81	4.64	0.0131	0.332
1011	692	6000	4210	34.9	15700	357	31.1	45.2	0.261	7.83	43.3	10.00	7.07	12700	737	7.78	20.90	255	72.2	0.546	9.94	3.31		0.284

SID	T_K	T_Ca	T_Mg	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	T_Al	T_Na	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn	Av_Zn	Av_Ni
1012	562	5160	3780	35.5	13400	232	29.5	53.3	0.277	6.49	38.9	10.10	4.46	12400	644	5.42	6.64	237	87.5	0.440	6.89	4.94		0.343
1013	621	5680	3870	37.2	14100	277	34.6	53.6	0.309	7.53	41.3	10.10	7.08	13000	670	10.20	8.68	310	84.0	0.602	8.11	6.54	0.0168	0.517
1021	639	7180	5410	11.8	14900	362	21.9	25.3		6.88	49.6	4.05	1.48	12000	927	0.66	1.96	148	51.5	0.130	11.10	0.52		0.002
102	643	4740	3530	35.2	13200	238	32.5	51.4	0.251	6.46	38.1	14.70	4.66	12000	712	5.05	24.00	260	66.6	0.474	7.79	7.15	0.0499	0.510
103	676	5980	3930	39.9	13300	235	33.3	57.3	0.300	6.76	39.4	12.80	4.02	12000	688	7.52	22.20	326	92.9	0.680	7.88	5.41		0.640
104	516	4830	3370	37.4	13000	241	28.9	55.5	0.289	6.56	36.9	10.50	3.80	11900	630	5.43	3.64	255	63.4	0.570	7.85	7.50	0.0127	0.588
105	596	5660	3600	31.3	13400	218	26.5	47.1	0.248	6.27	38.5	8.88	4.10	12100	653	7.21	16.00	328	75.1	0.487	6.76	4.20		0.375
106	613	4500	3320	35.3	12600	185	28.2	49.4	0.234	6.08	35.0	8.99	4.52	12000	705	5.47	18.20	225	53.8	0.510	9.07	6.56	0.0423	0.558
107	612	4810	3580	39.0	13300	206	32.8	56.2	0.280	6.54	37.5	9.01	4.50	12400	667	6.16	17.30	250	61.4	0.563	8.95	7.43	0.0315	0.580
108	662	4030	3200	39.5	12100	168	28.6	52.6	0.232	5.90	34.1	8.94	4.81	11200	688	6.65	39.90	216	75.7	0.710	12.10	6.16	0.0937	0.842
109	654	4490	3120	45.3	12000	130	30.2	58.1	0.294	5.73	34.2	10.20	6.33	11700	606	8.12	34.90	234	74.4	0.574	4.06	2.33	0.5650	0.428
112	733	4020	3310	32.2	13500	211	34.0	45.6	0.215	6.10	36.2	9.01	4.82	12700	623	4.32	51.60	198	54.2	0.334	4.51	5.44	0.5400	0.301
113	696	4060	3080	35.4	13100	285	32.6	51.0	0.252	6.31	34.1	10.70	4.48	12200	553	4.30	51.80	213	67.4	0.421	5.22	4.48	0.2010	0.243
114	549	3600	2630	35.2	12600	170	27.0	51.2	0.255	5.46	31.6	9.66	3.95	12500	458	4.87	27.50	192	48.7	0.480	6.95	11.80	0.2560	0.591
115	599	3940	3090	23.4	12500	185	22.8	37.6	0.160	5.74	34.7	6.65	3.19	11600	651	2.56	27.60	161	24.8	0.290	6.73	5.02	0.7130	0.220
116	612	3960	2790	37.2	11700	148	29.6	46.7	0.235	5.26	31.5	9.14	5.96	11200	608	7.89	34.40	236	60.2	0.667	8.54	5.12	0.2400	0.516
117	645	3810	2810	34.8	11800	150	32.0	48.3	0.224	5.31	32.2	8.90	4.04	11500	705	5.77	39.90	194	54.1	0.486	8.23	3.80	0.1580	0.416
118	676	3900	2870	32.2	12700	201	26.2	42.2	0.205	5.30	31.7	8.40	6.69	11500	657	4.38	45.50	178	55.8	0.466	8.52	1.81	0.0976	0.214
119	745	3830	2800	40.5	11000	123	26.4	48.0	0.212	5.01	30.7	9.76	7.35	10700	645	7.61	57.80	149	56.0	0.550	9.24	1.87	0.2100	0.415
120	670	4090	3270	44.8	12800	162	32.1	57.7	0.243	5.92	36.6	9.72	4.48	12000	662	6.14	34.90	206	52.7	0.677	6.99	5.52	0.3440	0.828
121	635	3970	2830	43.6	11800	142	28.5	54.9	0.248	5.07	32.6	9.89	4.50	11500	633	3.06	39.40	183	60.6	0.428	5.24	2.49	0.1530	0.413
122	620	3710	2620	40.0	10800	108	37.4	48.2	0.223	4.63	30.7	9.00	4.22	10700	619	6.36	41.10	233	65.4	0.617	8.14	2.97	0.2610	0.611
123	619	3500	2570	41.4	10700	131	30.6	51.1	0.228	4.75	29.2	9.54	4.55	10800	549	4.08	53.00	223	54.0	0.548	6.00	3.97	0.2260	0.425
125	431	3450	2020	38.0	8680	94	19.1	49.9	0.174	4.00	29.0	9.88	4.53	9500	513	3.01	11.20	148	44.6	0.487	8.00	3.22	0.0989	0.824
126	454	3760	2410	40.2	10500	216	25.7	56.9	0.283	5.58	32.7	10.50	5.42	10900	518	3.16	10.10	195	58.8	0.421	5.36	6.61	0.0686	0.526
127	420	3210	1700	38.8	7930	80	16.6	48.2	0.209	3.18	23.9	10.40	4.80	9180	431	2.50	8.24	112	53.4	0.317	6.14	0.83	0.3830	0.608
1271	414	2770	1940	35.6	10300	87	18.7	39.0	0.178	3.92	27.5	8.85	4.43	11600	424	1.21	15.60	59	9.3	0.238	14.90	2.68	0.2700	1.370
128	726	4420	2690	42.5	10500	107	20.8	52.4	0.271	4.09	32.8	11.20	5.24	12300	395	4.46	6.64	194	96.3	0.504	8.64	1.15	0.1160	0.516
129	454	3500	2250	37.9	11700	214	22.6	48.4	0.234	5.06	29.7	12.40	5.06	11300	483	5.81	13.20	262	70.8	0.603	9.35	8.94	0.1390	0.698
130	426	3880	2780	36.1	10700	100	22.2	48.6	0.242	4.30	28.6	10.20	5.19	11700	357	3.29	6.02	183	105.0	0.345	5.30	1.03	0.0528	0.232
131	388	3160	1990	35.7	10900	137	22.7	48.8	0.232	4.55	27.3	10.10	5.03	11400	354	5.07	10.50	206	59.3	0.568	8.39	9.12	0.1640	0.817
132	400	3380	1830	35.3	9360	92	21.1	45.9	0.245	3.86	24.7	10.10	4.95	10400	349	2.67	13.60	188	53.4	0.335	5.11	2.53	0.1010	0.400
133	382	3100	1910	35.0	11300	173	27.1	43.9	0.249	4.55	23.9	9.83	4.97	11900	291	2.47	4.38	120	79.2		7.44	3.43	0.0300	0.245
134	394	3140	1740	34.8	9470	132	26.0	40.4	0.204	3.77	20.9	10.20	5.56	9870	336	3.11	12.90	143	64.4	0.390	11.80	2.96	0.0265	0.226
135	406	3270	1690	34.7	8430	79	15.2	43.7	0.216	3.37	21.9	9.52	4.70	9730	382	2.74	13.80	155	76.1	0.204	7.26	1.59	0.2690	0.339
136	387	3170	2050	33.5	10600	127	21.7	43.8	0.244	5.31	26.3	10.00	5.32	11900	293	0.81	3.17	86	56.9		4.63	0.58	0.0585	
1361	408	3320	2410	10.3	9280	112	14.4	20.3	0.095	4.53	24.9	3.74	1.51	9730	417	2.16	3.47	127	84.3	0.226	8.90	1.95	0.0314	0.251
137	404	2010	1440	38.6	10100	96	17.4	34.0	0.189	3.47	22.3	10.40	5.46	10500	312	1.27	21.20	56	13.7	0.397	13.00	7.40	0.3250	0.848
138	564	3330	1820	39.6	9440	106	26.7	50.3	0.239	4.11	23.4	9.04	4.86	10300	433	3.00	56.70	171	33.5	0.383	3.98	3.59	0.1250	0.430
139	573	3410	1880	36.7	9750	102	28.1	47.3	0.227	4.21	23.3	9.20	4.02	10300	443	2.57	59.60	161	34.7	0.306	5.17	1.78	0.2750	0.239
140	501	2930	1930	37.0	11400	192	24.2	44.6	0.221	4.82	24.6	9.48	5.44	11100	390	2.67	38.40	122	22.1	0.348	4.90	12.20	0.4010	0.587
141	613	3430	1910	40.7	9890	121	30.8	49.0	0.244	4.25	24.2	10.70	4.96	10800	428	3.53	69.20	165	30.3	0.341	4.23	4.65	0.3610	0.514
142	582	3550	2020	37.7	9380	141	28.5	46.7	0.257	4.43	23.7	9.28	4.85	10100	422	3.41	60.50	180	47.3	0.361	3.99	2.67	0.1190	0.282
145	492	6310	4130	32.8	11700	444	25.2	44.8	0.250	6.54	25.3	9.59	4.99	11500	391	3.35	28.00	171	83.8	0.378	5.86	2.84	0.0649	0.209
147	442	3410	2210	37.5	10400	141	21.3	49.7	0.217	4.57	27.2	10.10	4.70	10900	458	2.84	13.10	148	44.5	0.398	4.52	3.60	0.1280	0.394
148	441	3350	2100	36.6	10400	133	22.2	42.8	0.228	4.44	25.0	12.80	5.24	10400	499	3.60	13.60	188	49.1	0.489	5.19	6.87	0.1150	0.513
150	422	4800	2530	41.3	10000	239	36.4	55.4	0.358	5.39	31.6	9.40	5.22	11100	496	5.43	10.80	277	58.1	0.440	4.07	8.77	0.0667	0.554
151	522	4130	2730	31.5	12000	156	27.8	45.6	0.257	5.28	31.2	9.59	4.61	10800	559	4.02	19.10	164	55.9	0.364	4.35	2.26	0.0801	0.294
152	526	3960	2830	33.1	10300	127	27.5	46.3	0.257	4.85	31.6	9.26	4.78	10700	557	4.35	19.50	168	60.4	0.425	5.75	2.91	0.0795	0.384
154	450	6220	2480	37.4	11100	156	28.3	52.1	0.268	5.10	29.4	9.74	4.14	11000	469	3.44	13.90	206	50.6	0.400	4.83	2.67	0.0221	0.261

SID	T_K	T_Ca	T_Mg	T_Cu	T_Fe	T_Mn	T_Zn	T_Ni	T_Cd	T_Co	T_Cr	T_Pb	T_As	T_Al	T_Na	Av_P	Av_K	Av_Ca	Av_Mg	Av_Cu	Av_Fe	Av_Mn	Av_Zn	Av_Ni
155	470	5760	3240	38.2	11000	188	26.2	54.2	0.290	5.72	30.6	8.92	3.85	10900	543	4.25	8.06	289	91.3	0.510	2.51	3.36	0.0274	0.351
157	406	3600	2070	38.6	9300	107	18.9	48.0	0.218	4.05	27.4	9.09	4.02	9410	477	4.24	8.18	248	59.1	0.611	11.00	6.76	0.1400	0.877
158	452	4280	2750	30.7	9770	139	26.1	44.4	0.245	4.70	29.9	8.41	3.39	10000	521	4.65	10.30	205	73.5	0.482	3.83	3.34		0.278
160	452	6570	3320	39.0	11000	244	32.4	53.9	0.422	5.50	37.6	9.35	3.67	11400	573	5.82	3.68	310	71.2	0.375	2.52	2.87	0.4510	0.245
161	435	4860	2820	35.3	10600	141	23.8	49.2	0.231	5.07	30.0	8.99	3.63	10200	579	4.66	5.76	285	51.3	0.507	3.99	1.63		0.187
162	457	4790	3020	35.3	11200	186	26.4	53.3	0.280	5.79	34.1	9.10	3.42	10900	558	5.36	11.70	239	74.2	0.501	3.38	3.75	0.0635	0.413
166	581	3110	1690	35.3	9080	107	23.6	40.5	0.244	3.89	21.5	9.02	5.02	9290	420	5.10	68.80	141	32.2	0.438	9.29	6.72	0.2930	0.668
167	628	3390	2160	31.4	11100	167	30.3	41.8	0.207	4.81	27.3	9.09	4.37	11000	438	2.76	67.20	157	30.4	0.217	4.23	7.41	0.2900	0.436
168	592	3310	2370	26.4	12000	203	28.7	38.5	0.182	4.96	28.0	8.00	4.11	12300	426	2.77	45.90	193	30.5	0.235	6.62	6.76	0.0379	0.177
169	558	3650	2800	19.5	11900	607	29.0	34.3	0.193	6.01	30.6	6.68	2.93	11600	472	1.42	34.80	172	35.6	0.168	3.81	1.63	0.0379	0.019
170	564	3460	2650	22.1	12100	180	26.5	34.8	0.162	5.26	29.7	7.06	3.87	12200	430	1.80	33.10	154	29.6	0.188	4.63	3.85	0.0327	0.092
171	512	3320	2360	20.8	9890	121	23.3	30.8	0.142	4.23	26.7	6.74	2.98	10600	492	1.80	36.80	143	28.9	0.221	2.50	3.19	0.1630	0.103
172	520	3170	1920	23.8	10500	141	25.7	35.2	0.175	4.05	23.3	7.17	2.98	10400	383	2.47	41.30	151	35.5	0.238	13.70	3.00	0.0905	0.135
173	575	3980	2920	20.0	11300	168	25.0	32.5	0.153	5.05	31.6	6.36	2.42	11000	528	1.95	24.60	166	58.8	0.211	4.32	2.58	0.2420	0.108
174	631	3110	2060	26.7	10500	166	32.4	35.9	0.181	4.25	24.7	7.73	3.67	10800	396	3.19	72.50	154	40.3	0.294	4.12	8.47	0.2320	0.338
175	676	3730	2620	29.9	10500	167	35.4	38.2	0.215	5.15	29.7	8.60	4.66	10500	551	3.57	48.50	204	41.4	0.320	5.17	7.43	0.5000	0.556
176	640	3510	2390	22.1	11900	200	30.2	34.7	0.173	4.96	27.5	7.63	2.78	11900	455	2.31	58.20	200	38.8	0.226	2.38	4.53	0.0311	0.056
177	680	3640	2650	24.7	12600	196	32.5	36.7	0.195	5.48	30.9	8.13	3.84	12300	412	2.57	62.00	194	29.6	0.272	3.57	4.02	0.0363	0.063
178	592	3310	2080	23.6	11100	189	28.7	34.0	0.182	4.68	25.4	7.16	2.99	11300	347	1.50	61.70	147	21.4	0.102	2.50	8.10	0.0870	0.121
179	730	3740	3120	24.9	13300	228	31.9	38.8	0.199	5.71	34.4	8.04	3.30	12900	447	1.90	63.30	187	36.0	0.234	3.71	7.51	0.0649	0.171
180	456	3190	1440	47.4	8730	89	20.5	49.2	0.309	3.35	21.4	10.20	5.27	8650	347	7.16	35.90	244	53.7	0.841	15.60	4.14	0.2620	1.230
181	513	3160	2080	58.2	10400	105	21.8	59.5	0.270	4.33	27.5	13.30	6.11	11100	405	3.97	30.50	72	17.9	0.670	24.90	9.08	0.7500	2.660
182	472	2900	1950	54.3	10300	182	19.8	48.5	0.232	4.53	27.3	14.10	5.83	10100	383	2.97	38.70	132	23.9	0.429	3.68	14.40	0.2070	0.408
183	550	3240	2160	34.2	11500	189	27.7	42.4	0.208	4.75	27.3	9.42	4.57	11900	451	4.83	25.20	71	18.0	1.130	33.20	17.90	0.6660	2.050
184	509	3170	2310	45.4	11500	152	24.6	52.2	0.248	4.87	29.6	11.30	5.43	11500	408	4.70	27.90	88	23.0	0.645	28.30	13.10	0.7660	1.990
185	523	3890	3110	45.0	13000	220	29.4	61.0	0.307	6.34	38.4	11.80	5.57	11900	505	5.96	19.20	189	64.4	0.711	10.30	12.00	0.2050	1.020
186	511	3830	2790	43.6	12300	150	27.1	57.3	0.255	5.24	34.8	12.20	5.11	11200	507	7.17	17.10	223	80.0	0.855	18.70	9.23	0.3320	1.250
188	553	3490	2680	45.6	11100	126	24.9	54.3	0.230	4.90	33.7	11.80	4.72	11100	523	5.23	25.30	122	30.6	0.712	37.50	7.11	0.6530	2.190
189	514	4020	3170	35.9	12100	147	25.7	49.2	0.220	5.12	36.1	10.30	4.29	11400	629	6.58	7.32	225	84.0	0.699	10.00	5.52	0.1430	0.605
190	501	4650	3320	33.5	12500	186	28.9	50.8	0.265	5.74	36.6	9.71	3.95	11300	544	6.97	9.83	257	85.9	0.572	6.65	6.00	0.0629	0.560
191	605	5000	3530	17.1	12400	209	26.1	31.1	0.149	5.56	35.8	6.33	2.40	11300	613	3.30	19.20	212	38.3	0.232	5.39	1.86		0.034
192	580	7850	5210	18.9	12000	195	22.9	30.7	0.127	5.36	36.6	5.99	2.30	10500	661	3.27	14.40	201	68.0	0.273	7.10	1.27		0.061
193	552	3750	2630	14.1	11400	198	25.0	27.2	0.130	5.26	30.0	6.06	2.63	11500	481	2.56	32.40	167	36.4	0.240	2.85	4.15	0.0601	0.317
194	611	5440	3180	18.6	10200	146	22.9	33.7	0.173	5.02	34.7	6.39	2.04	11500	773	4.88	19.20	217	52.7	0.286	5.60	3.13	0.0090	0.232
195	558	5700	3710	14.7	12000	182	21.5	28.2	0.126	5.20	34.2	5.31	2.11	11100	613	2.81	16.70	233	58.1	0.205	4.24	1.22		0.014
196	485	6530	4180	17.6	11500	174	33.6	31.9	0.131	5.36	36.1	6.23	2.15	10800	678	2.99	3.13	315	72.7	0.246	2.28	2.18		0.159
197	466	5070	3480	22.0	9950	156	25.5	34.3	0.195	4.87	29.8	7.63	2.80	9840	557	6.97	16.40	198	55.3	0.392	9.81	6.95	0.0494	0.510
198	417	4010	2380	31.9	9010	106	23.6	45.3	0.293	4.73	29.1	9.33	3.40	10700	430	9.38	17.80	284	52.5	0.444	12.30	5.24	0.1470	1.050
204	409	2770	1490	51.9	9350	280	21.6	54.7	0.318	3.59	17.5	10.30	6.66	6250	365	8.20	18.40	182	23.6	1.130	28.30	43.70	0.7210	2.370
205	424	3470	1960	40.9	9020	261	23.5	50.3	0.285	4.28	24.2	9.89	4.17	8740	439	5.80	18.80	196	24.7	0.651	16.60	31.20	0.4990	1.720
207	544	6180	3900	32.6	13900	262	28.7	50.3	0.275	6.46	39.8	9.09	3.33	11500	719	4.69	3.11	322	90.8	0.502	3.48	7.57		0.595
210	436	3760	2420	30.6	9400	134	24.9	43.1	0.215	4.50	27.2	9.02	3.92	9440	558	8.15	14.30	217	63.7	0.731	10.30	8.32	0.2050	0.912
211	459	5430	3070	33.7	10900	225	30.4	48.4	0.301	5.24	33.5	8.50	3.47	10700	540	7.02	9.80	320	87.1	0.491	4.53	8.29	0.2050	0.492
212	495	5050	3310	35.7	12200	325	29.6	53.4	0.292	6.14	35.6	9.56	3.61	11100	598	5.55	5.08	265	79.5	0.516	7.27	12.00	0.0595	0.601
351	623	12600	8150	19.5	13700	240	23.2	32.3	0.093	6.10	44.5	5.11	1.88	10000	784	1.02	2.26	169	49.3	0.175	2.16	0.22		
352	596	9980	6740	26.6	13600	266	26.1	42.5	0.156	6.72	43.8	6.31	2.41	11000	672	2.35	7.21	286	80.3	0.343	1.71	1.11		0.188
385	458	5130	3190	31.7	10100	134	24.2	45.2	0.232	4.97	29.1	8.87	3.10	10900	570	3.83	10.30	198	70.8	0.366	5.20	1.86		0.287
585	612	4320	2660	41.1	10300	120	24.8	54.2	0.290	4.82	31.5	10.60	4.19	12100	656	9.17	21.00	224	58.0	0.929	35.50	7.41	0.4960	2.580

SID	SMU	L_U_Cat	North	East	%_C	% Sand	%Silt	% Clay	pHH2O	pHCaCl2	AV_Al	AV_Ca	AV_Cu	AV_Fe	AV_K
1			482539	5156915	2.4200	0.0000	85.3610	14.6380	7.3500	6.5900	0.73000	103.0		0.90000	3.28
2		Forested	481968	5156800	2.3500	1.1340	88.1610	10.7040	7.8300	6.7900	1.13000	84.1	0.06100	1.67000	2.52
3	Azilda SiL	Forested	481622	5156828	2.3400	1.5420	87.1880	11.2700	7.9000	9.9800	0.98300	80.3		1.31000	3.11
4	Azilda SiL	Forested	481217	5156890	2.6400	3.2420	84.6070	12.1540	7.5100	7.4500	4.57000	107.0		4.98000	4.42
5	Azilda SiL	Abandoned	480630	5156890	2.6000	0.0000	79.2830	20.7150	7.7790	6.3100		114.0		0.34500	4.96
6		Forested	480253	5156891	1.1300	0.0000	85.8340	14.1630	7.7040	7.3470	1.98000	112.0	0.04420	1.80000	3.01
		Low Intensity	479861	5156902	2.4500	0.0000	77.4520	22.5450	8.3650	7.5720	0.30300	105.0		0.46400	2.31
8		Abandoned	482357	5156385	0.1780	18.7530	69.1620	12.0860	6.9870	6.2480	7.79000	73.1		9.18000	0.80
9		Forested	482008	5156391	0.1890	66.2760	30.1390	3.5830	6.2270	5.6710	27.60000	43.2	0.09440	28.70000	2.22
10		Intensive	481527	5156378	1.9500	1.8590	86.5830	11.5550	8.2720	7.6010	0.87000	86.5		1.13000	1.75
11	BradleyVFSaL	Intensive	481136	5156410	2.3600	0.0000	85.0020	14.9960	8.3150	7.6000	0.46000	99.3	0.01740	0.58500	1.30
12	BradleyVFSaL	Low Intensity	480778	5156384	1.5800	0.0000	86.1160	13.8850	8.2550	7.6300	1.12000	116.0	0.01440	1.34000	2.20
13	BradleyVFSaL	Abandoned	480193	5156477	2.1400	1.6920	88.6790	9.6310	8.2820	7.6850	1.18000	72.1		1.38000	2.48
14	BradleyVFSaL	Intensive	479861	5156502	1.1600	11.2140	79.5460	9.2400	8.2280	7.5550	0.99200	81.1	0.02070	1.07000	0.01
15		Low Intensity	482411	5155910	0.0722	88.4600	9.4050	2.1370	7.3130	6.6510	1.65000	25.0	0.01560	4.10000	1.73
16	Wolf Loam	Abandoned	481930	5156085	0.4630	39.8870	52.8060	7.3050	7.9780	7.3110	4.02000	54.8	0.03980	6.05000	3.57
17	BradleyVFSaL	Forested	481529	5155942	1.4100	20.5290	73.0970	6.3750	8.4550	7.7190	0.66700	66.5	0.02390	0.84900	2.33
18	BradleyVFSaL	Low Intensity	481120	5156124	1.8800	7.4660	84.0660	8.4690	8.4210	7.7330	0.81300	67.2	0.02990	0.90800	2.43
19		Low Intensity	480678	5156054	1.4800	0.0000	83.7090	16.2900	7.9680	7.4610	0.59600	108.0	0.00567	1.03000	1.12
20	BradleyVFSaL	Forested	480218	5156140	2.2400	1.8110	87.2810	10.9080	8.1700	7.6440	0.88400	71.7	0.02230	1.06000	3.73
21	BradleyVFSaL	Intensive	479920	5156057	1.4300	9.9260	81.6910	8.3830	8.4140	7.5400	0.54600	74.5	0.03170	1.09000	3.02
22	Wolf Loam	Low Intensity	482530	5155506	0.0907	65.8840	30.3900	3.7300	6.0170	5.1810	0.97500	33.7	0.02260	0.73400	1.65
23	Wolf Loam	Abandoned	482074	5155536	0.7070	2.0310	86.4760	11.4960	7.7090	7.2000	0.72400	77.8		0.90400	0.03
24	BradleyVFSaL	Intensive	481641	5155485	0.1220	45.9540	49.0560	4.9900	5.8470	5.1090	0.08710	24.3	0.02420	0.17100	2.15
25		Intensive	481234	5155603	1.8000	2.9090	85.9110	11.1790	8.1640	7.3330	0.81200	76.8	0.01980	0.99400	0.74
26		Forested	480695	5155551	1.7500	0.3650	85.7140	13.9210	8.0860	7.3760	6.43000	94.1		6.62000	1.38
27	BradleyVFSaL	Sod			2.1900	0.0000	84.0290	15.9680	8.3100	7.6290	2.56000	97.1		2.84000	2.52
28	BradleyVFSaL	Sod	479819	5155504	2.5400	0.0000	82.3140	17.6860	8.1590	7.5960	1.51000	92.8		1.67000	2.81
29		Low Intensity	482525	5155145	0.1470	61.9030	34.1590	3.9420	5.9520	5.1160	9.09000	29.3		9.77000	1.46
30		Intensive	482118	5155153	0.1840	3.2110	84.0080	12.7840	5.3640	5.3200	2.11000	58.3	0.01140	2.23000	2.61
31		Intensive	481589	5155174	0.1710	68.2500	28.1260	3.6220	5.7440	5.1420	4.70000	25.7	0.01390	4.42000	1.60
32	BradleyVFSaL	Forested	481343	5155235	0.1590	30.8080	61.8610	7.3300	5.8020	4.8090	5.52000	38.1	<MDL	4.61000	1.76
33	BradleyVFSaL	Forested	480685	5155238	0.3440	83.5130	14.0040	2.4810	5.6120	4.8850	25.20000	26.2	0.00819	27.20000	3.13
34	BradleyVFSaL	Sod	480210	5155185	1.3600	19.8530	72.5540	7.5920	8.2440	7.4190	1.27000	76.9	0.00986	1.80000	3.44
35	BradleyVFSaL	Sod	479942	5155173	1.3100	22.3880	70.7650	6.8460	8.2880	7.5950	2.86000	60.0	0.00695	2.80000	1.78
36	CapreolFSaL	Abandoned	488381	5159621	0.3250	46.8560	48.9950	4.1460	5.1290	4.6470	2.30000	15.6	0.00454	1.01000	2.32
37	CapreolFSaL	Forested	487956	5159597	0.3820	50.3120	45.4890	4.1990	4.7630	4.4370	4.06000	9.6		1.17000	2.76
38	CapreolFSaL	Low Intensity	487503	5159470	0.3750	7.7520	84.5920	7.6560	5.0150	4.5480	1.95000	33.9		0.19800	5.96
39		Abandoned	488272	5159235	0.5440	1.1550	87.1910	11.6530	7.4350	6.9290	16.10000	103.0	0.06670	12.90000	1.77
40		Low Intensity	487807	5159180	0.4490	0.3960	86.9330	12.6700	7.4350	6.9290	15.30000	100.0		13.60000	1.96
41	CapreolFSaL	Low Intensity	487518	5159107	0.2210	0.7900	86.2920	12.9170	5.9260	5.0930	12.10000	55.8		12.10000	13.60
42	CapreolFSaL	Low Intensity	486983	5159242	0.2510				5.4060	4.7730	1.66000	17.0	0.05370	0.53100	3.56
43	Azilda SiL	Forested	488253	5158714	1.6900	0.4290	87.1500	12.4200	7.7480	7.4410	6.92000	88.9		7.31000	2.88
44	Azilda SiL	Forested	487850	5158804	2.0500	0.6310	86.2790	13.0920	8.1690	7.4700	3.67000	107.0	0.04460	4.04000	2.36
45		Forested	487539	5158849	2.3800	0.1510	86.4200	13.4270	8.3390	7.7170	1.92000	94.4		2.51000	3.06
46	CapreolFSaL	Intensive	486828	5158752	0.6700	8.6060	82.6770	8.7150	8.0120	7.3430	6.15000	80.0		7.44000	4.00
47		Low Intensity	488730	5158335	2.4900	0.1420	85.8660	13.9900	8.1580	7.7720	0.58100	123.0		0.89400	7.07
48	Azilda SiL	Forested	488308	5158210	0.6090	0.0000	84.3580	15.6440	8.0780	7.4910	2.15000	113.0	0.01230	2.16000	0.67
49	Azilda SiL	Forested	487779	5158308	1.2900	0.9010	87.4190	11.6800	8.0990	7.4720	4.63000	110.0		4.74000	2.91
50	Azilda SiL	Abandoned	487388	5158224	1.6100	0.0000	84.3820	15.6150	8.2550	7.7050	2.73000	113.0	0.01500	2.74000	2.60

SID	SMU	L_U_Cat	North	East	%_C	% Sand	%Silt	% Clay	pHH2O	pHCaCl2	AV_Al	AV_Ca	AV_Cu	AV_Fe	AV_K
51	CapreolFSaL	Abandoned	486997	5158218	1.8500	2.5160	87.1530	10.3340	8.2550	7.7050	3.18000	96.5		3.61000	0.95
52	Azilda SiL	Low Intensity	488717	5157869	1.8200	0.1500	87.2130	12.6360	8.2180	7.5880	2.80000	110.0		3.01000	2.71
53	Azilda SiL	Abandoned	488304	5157877	1.8400	0.3040	86.8440	12.8490	8.2950	7.6510	3.98000	112.0		4.57000	2.44
54	Azilda SiL	Abandoned	487889	5157887	1.7600	34.1500	59.3070	6.5410	7.8700	7.6280	4.62000	99.4		6.43000	4.20
55	Azilda SiL	Abandoned	487450	5157863	1.3100	9.3480	80.5260	10.1250	8.1900	7.7380	1.23000	100.0		4.37000	3.69
56		Abandoned	486893	5157894	2.5000	0.0000	86.0460	13.9570	8.2920	7.7510	0.79800	107.0		0.90500	3.14
57		Forested	488842	5157391	2.3600	0.0000	85.1520	14.8490	8.2920	7.7510	1.71000	111.0		2.00000	3.18
58		Abandoned	488277	5157528	2.0200	3.7120	84.8240	11.4640	8.2890	7.7410	1.22000	94.6		1.56000	3.62
59	Azilda SiL	Abandoned	487951	5157413	0.0661	54.7740	39.4550	5.7710	6.6800	5.8980	40.70000	34.0	0.14500	59.30000	4.88
60	Azilda SiL	Abandoned	487477	5157416	0.8110	64.0790	32.5720	3.3500	8.2510	7.7190	3.03000	70.7		5.25000	1.69
61	Azilda SiL	Abandoned	487130	5157476	2.0700	0.1830	86.0390	13.7790	8.3070	7.7460	1.38000	101.0		1.57000	2.31
62	Azilda SiL	Abandoned	489622	5156953	0.4790	56.4400	38.2940	5.2660	8.2650	7.6240	11.30000	71.0	0.08750	20.30000	3.63
63	Wolf SiL	Forested	489141	5157037	1.0600	17.2810	74.8550	7.8640	8.0380	7.3200	5.80000	90.3	<MDL	7.74000	2.64
65	Azilda SiL	Abandoned	488324	5157183	0.5520	0.0000	85.9390	14.0600	7.9100	7.0500	8.89000	102.0	0.01700	8.40000	2.08
66	Azilda SiL	Abandoned	487844	5157131	1.8900	5.7050	84.1410	10.1570	8.0700	6.9400	4.62000	92.1	<MDL	7.54000	5.25
67	Azilda SiL	Intensive	487398	5157072	0.4050	0.6420	85.5880	13.7700	7.7650	7.1830	16.30000	102.0	0.03130	15.30000	3.45
68	Azilda SiL	Abandoned	487033	5157103	0.4380	0.1050	85.9110	13.9850	7.6060	7.1580	6.39000	132.0	0.06700	6.83000	4.15
69	Azilda SiL	Intensive	488720	5158832	2.2500	1.0430	87.6730	11.2840	8.2700	7.7460	2.03000	86.8	<MDL	2.21000	5.10
70		Low Intensity	488713	5159190	0.2130	0.7050	86.7140	12.5820	6.6700	6.1700	16.60000	69.7	0.06130	18.50000	4.92
74	Wolf SiL	Forested	490124	5157551	1.9200	0.3120	86.1310	13.5540	8.0510	7.5390	0.97600	113.0	<MDL	1.35000	3.12
75	Wolf SiL	Abandoned	490603	5157484	0.4120				7.8890	7.6330	0.40200	74.9	0.00440	0.84800	2.52
76	Wolf SiL	Forested	490887	5157501	1.6900	11.1260	79.9670	8.9080	8.3350	7.7070	2.47000	85.9	<MDL	2.98000	2.64
77	Wolf SiL	Abandoned	491396	5157565	0.1400	65.1140	30.4890	4.3940	7.8820	7.0990	18.70000	41.8	<MDL	16.70000	2.79
78	Wolf SiL	Intensive	490014	5157857	2.2400	0.1420	86.6520	13.2060	8.3210	7.7040	2.01000	124.0	<MDL	2.52000	2.47
79	Wolf SiL	Abandoned	490501	5157764	2.3000	4.3080	85.0070	10.6820	8.2770	7.6820	8.90000	75.7	<MDL	15.10000	6.56
80	Wolf SiL	Abandoned	491103	5157830	0.3120	0.3930	85.6800	13.9250	7.2060	6.5750	21.10000	82.7	0.00533	19.90000	2.88
81	Wolf SiL	Low Intensity	491384	5157857	1.6200	0.1400	86.8880	12.9730	8.1240	7.3550	6.52000	98.9	0.01600	7.07000	1.50
83	Wolf SiL	Forested	490080	5158355	1.0700	27.6210	64.8560	7.5210	7.9460	7.3920	7.11000	103.0	0.01130	8.12000	1.23
84	Wolf SiL	Forested	490501	5158293	2.1900	0.3980	86.8640	12.7380	8.2350	7.6700	2.85000	111.0	<MDL	3.75000	2.35
85	Wolf SiL	Forested	491075	5158255	1.0500	0.1390	85.1350	14.7270	7.8750	7.3600	8.40000	97.8	<MDL	9.02000	2.75
86		Low Intensity	491376	5158278	0.9360	0.7070	87.7420	11.5500	7.7450	7.2780	6.38000	117.0	0.03820	6.55000	1.24
87	CapreolVFSaL	Low Intensity	491871	5158244	1.9400	0.1690	86.9790	12.8540	8.2800	7.6210	2.90000	108.0	<MDL	3.26000	1.70
88	CapreolVFSaL	Low Intensity	492167	5158329	1.1400	0.1900	87.0570	12.7540	7.9960	7.2460	0.89600	86.6	<MDL	1.28000	2.38
89	CapreolVFSaL	Low Intensity	492748	5158470	1.1300	13.9330	74.9590	11.1080	8.1260	7.4030	3.76000	98.1	<MDL	4.86000	2.51
90	Azilda SiL	Low Intensity	489098	5158758	0.2340	0.1700	85.7560	14.0760	7.4400	6.8200	16.50000	96.4	0.02660	14.70000	3.41
91	Azilda SiL	Forested	489514	5158824	2.2100	0.3400	86.7420	12.9170	8.1800	7.5200	1.70000	121.0	0.01540	1.94000	5.28
92	Azilda SiL	Potato	490088	5158762	2.2400	0.1390	87.2000	12.6620	8.3980	7.5530	0.70200	101.0	<MDL	0.98300	2.06
93	Wolf SiL	Potato	490556	5158786	0.9020	0.6170	88.9950	10.3890	7.8920	7.1730	8.37000	98.9	<MDL	8.63000	1.85
94		Low Intensity	490960	5158846	2.0400	4.2750	86.9970	8.7290	8.3300	7.6210	1.15000	85.8	<MDL	1.89000	2.44
95	CapreolVFSaL	Low Intensity	491522	5158878	0.4120	0.6890	87.4830	11.8290	7.8320	7.1540	9.48000	106.0	0.01110	10.20000	2.19
96	CapreolVFSaL	Abandoned	491897	5158860	1.6200	0.6240	87.6560	11.7200	8.2400	7.2000	5.84000	124.0	<MDL	7.16000	1.79
97	CapreolVFSaL	Sod	492359	5158779	0.2080	48.8390	45.4990	5.6610	6.0250	5.4540					
98	CapreolVFSaL	Forested	492765	5158771	1.0400	4.6240	84.0080	11.3670	7.8440	7.0990	14.40000	91.9	0.03610	14.90000	2.18
99	CapreolVFSaL	Potato	493169	5158763	1.4600	37.7950	56.8690	5.3360	7.5560	7.5080	6.78000	78.7	0.02810	7.75000	3.30
100		Low Intensity	489143	5159128	0.3200	0.7250	87.6060	11.6680	7.6970	7.2460	6.98000	93.3	<MDL	7.45000	1.16
101		Low Intensity	489568	5159159	1.3300	2.0740	86.6980	11.2270	7.8370	7.2720	7.55000	102.0	0.04730	8.00000	2.74
102		Potato	490212	5159143	0.2590	0.9660	87.6130	11.4210	7.2260	6.5770	24.10000	77.0	<MDL	18.10000	3.66
103	BradleyFSaL	Abandoned	490579	5159295	0.2460	0.9710	86.8420	12.1880	7.8010	7.0260	19.60000	107.0	0.05120	17.80000	1.85
104	BradleyFSaL	Potato	490966	5159289		0.4380	86.1910	13.3680	7.6890	6.7800	11.20000	86.6	0.01740	11.20000	2.73
105		Sod	491478	5159234	1.5800	2.5240	87.4190	10.0560	8.0320	7.3540	3.21000	67.8	<MDL	3.61000	0.16

SID	SMU	L_U_Cat	North	East	%_C	% Sand	%Silt	% Clay	pHH2O	pHCaCl2	AV_Al	AV_Ca	AV_Cu	AV_Fe	AV_K
106		Sod	491830	5159252	1.6200	3.6280	86.5510	9.8200	7.7890	7.1170	7.73000	79.2	<MDL	7.78000	1.05
107		Sod	492366	5159214	0.2150	1.0990	85.9060	12.9970	6.1360	5.4090	20.60000	75.3	<MDL	17.70000	3.94
108	CapreolVFSaL	Sod	492778	5159217	0.2090	0.7550	86.3440	12.9020	6.0600	5.4040	22.30000	70.9	0.03950	21.60000	4.45
109	CapreolVFSaL	Low Intensity	493177	5159256	1.6600	2.6050	86.0050	11.3920	7.9440	7.0090	5.77000	86.4	<MDL	6.29000	0.24
112	BradleyFSaL	Potato	490072	5159593	0.1650	1.8190	86.5790	11.6000	6.5960	6.0280	11.40000	80.1	0.01800	12.60000	3.53
113	BradleyFSaL	Potato	490584	5159717	0.2270	1.8850	86.6970	11.4180	5.3990	4.5700	7.09000	64.4	<MDL	7.48000	3.29
114	BradleyFSaL	Sod	490976	5159767	0.2450	6.4770	85.2080	8.3170	4.9790	4.1990	4.03000	44.4	<MDL	2.23000	2.83
115	BradleyFSaL	Sod	491528	5159691	0.1160	2.5290	86.8410	10.6280	6.3820	5.5810	8.06000	53.3	<MDL	9.95000	3.00
116	BradleyFSaL	Potato	491959	5159642	0.1220	2.6360	86.7740	10.5860	6.0240	5.5170	4.86000	85.7	<MDL	5.22000	6.50
117	BradleyFSaL	Potato	492365	5159635	0.1160	1.8190	86.5790	11.6000	6.5760	5.8140	13.10000	73.5	<MDL	13.90000	3.63
118		Potato	492772	5159700	0.1470	1.3300	87.0860	11.5820	5.2590	4.3060	2.01000	48.6	<MDL	1.11000	26.90
119	CapreolVFSaL	Potato	493178	5159756	0.0725	61.4180	34.9500	3.6350	5.1820	4.2820	2.82000	18.5	<MDL	2.13000	3.43
120	CapreolVFSaL	Potato	493612	5159285	0.1780	0.4230	86.7950	12.7800	6.4100	5.5330	9.48000	68.8	<MDL	10.10000	2.12
121	CapreolVFSaL	Potato	494161	5159386	0.6870	23.6720	68.2710	8.0600	5.8590	6.6750	4.11000	44.0	<MDL	5.29000	0.07
122	CapreolVFSaL	Potato	493614	5159702	0.1220	61.4960	35.1520	3.3510	3.9940	4.2380	2.70000	25.7	<MDL	0.38100	6.36
123	CapreolVFSaL	Potato	494177	5159808	0.0725	7.6880	84.0860	8.2260	5.2600	4.5310	0.70100	35.0	<MDL	0.58500	5.17
124			495570	5160664	0.1090	78.9620	17.8460	3.1950	4.4860	4.3630	1.28000	13.3	<MDL	0.19100	5.42
125		Forested	509874	5164953	0.1520	26.3920	67.2490	6.3560	5.2440	4.6410	7.63000	40.3	<MDL	7.84000	1.25
126	BradleyVFSaL	Low Intensity	509353	5165071	0.0908	86.4420	11.3190	2.2360	5.1960	4.7050	26.40000	15.8	<MDL	33.20000	3.47
127	BradleyVFSaL	Abandoned	509854	5165473	0.0787	35.6760	58.3560	5.9710	5.0760	4.6720	0.24700	32.8	<MDL	0.21900	4.84
128	BradleyVFSaL	Low Intensity	509410	5165521	0.1410	22.1320	70.1090	7.7610	4.9370	4.1330	0.96900	31.1	<MDL	0.31000	3.05
129	BradleyVFSaL	Abandoned	509809	5165940	1.0500	17.0690	75.1870	7.7440	7.3010	6.7930	10.20000	66.5	0.05720	12.30000	2.45
130	BradleyVFSaL	Low Intensity	509274	5165872	0.0969	29.2230	63.3250	7.4520	5.4950	4.6440	0.28400	28.8	<MDL	0.17700	9.99
131		Abandoned	508787	5165860	0.0905	46.7270	48.2120	5.0620	5.2820	4.4700	1.08000	21.9	<MDL	0.31600	0.93
132	BradleyVFSaL	Low Intensity	509676	5166525	0.2410	45.8720	49.5340	4.5940	6.4800	5.6000	5.94000	40.0	<MDL	3.52000	1.05
133		Low Intensity	509334	5166439	0.1280	46.6700	48.6000	4.7310	5.4000	4.4600	4.48000	5.4	<MDL	0.15400	9.71
134	Naiden	Abandoned	508739	5166509	0.1280	64.2910	31.8990	3.8070	4.8000	4.2700	5.91000	2.6	<MDL	0.27700	2.07
135	BradleyVFSaL	Low Intensity	509950	5166963	0.1590	36.2380	57.8770	5.8870	4.8000	4.4300	1.84000	17.8	<MDL	0.24100	2.51
136		Low Intensity	509240	5166813	0.0972	75.0220	21.6260	3.3520	5.3500	4.5400	0.44800	17.6	<MDL	<MDL	1.92
137	Naiden	Abandoned	508775	5166896	0.4200	56.2100	39.9930	3.7980	4.5200	4.2000	8.75000	5.7	<MDL	1.41000	3.34
138	CapreolFSaL	Potato	495571	5161047	0.2400	28.3760	64.1210	7.5020	6.2000	5.5000	5.47000	59.7	0.04260	5.99000	2.42
139	CapreolFSaL	Potato	495035	5161062	0.1530	61.8000	34.3670	3.8350	4.9200	4.5300	0.92400	56.3	<MDL	0.22500	6.38
140	BradleyFSaL	Potato	493663	5161117	0.1470	51.0820	44.4830	4.4350	4.7730	4.2060	1.83000	20.9	<MDL	0.17100	5.96
141	CapreolFSaL	Potato	495566	5161411	0.2830	22.3700	71.6660	5.9650	4.9330	4.3730	1.94000	25.1	0.01260	0.01550	8.12
142	CapreolFSaL	Potato	495071	5161409	0.0713	25.5500	68.5300	5.9190	5.2500	4.3800	1.10000	20.7	<MDL	0.41700	25.50
145	CapreolFSaL	Potato	493774	5161429	0.1150	16.2760	75.9950	7.7310	5.4140	4.3150	0.82900	44.6	<MDL	0.47000	4.21
147	CapreolFSaL	Low Intensity	495948	5161928	0.1270	18.7940	73.0140	8.1930	4.7710	4.2110	0.86000	38.4	0.01290	0.06690	17.90
148	CapreolFSaL	Abandoned	495577	5161920	0.0900	17.6910	73.7390	8.5680	5.3350	4.4500	0.20300	37.4	<MDL	0.45300	3.42
150	CapreolFSaL	Forested	495017	5161958	0.0900	32.5920	61.1030	6.3050	6.1410	5.5310	46.60000	63.6	0.07470	33.80000	5.09
151	CapreolFSaL	Potato	494190	5162040	1.5300	12.4570	79.6580	7.8830	7.8610	7.1200	7.56000	88.1	0.07070	10.90000	3.04
152	CapreolFSaL	Low Intensity	493223	5161928	0.2150	42.4730	52.8190	4.7060	4.7700	4.3100	5.68000	10.7	<MDL	0.98100	2.15
154		Low Intensity	495977	5162361	1.4900	23.8880	69.4760	6.6330	8.0300	7.2620	1.45000	78.2	<MDL	2.61000	5.04
155	CapreolFSaL	Intensive	495583	5162405	0.1550	18.8620	74.6040	6.5350	5.2860	4.5130	1.12000	33.6	0.00652	0.09420	5.13
157	CapreolFSaL	Forested	494981	5162371		32.2780	61.5940	6.1280	5.8440	5.0110	4.23000	50.0	0.02790	4.95000	2.16
158	CapreolFSaL	Low Intensity	494118	5162358	0.1090	13.5730	78.8070	7.6220	6.4050	6.1630	18.50000	65.3	0.03280	19.50000	4.72
160		Low Intensity	493252	5162359	0.4020	11.0340	80.8300	8.1350	7.3950	6.6280	31.20000	72.5	0.14100	28.00000	5.90
161		Low Intensity	495976	5162809	1.5100	12.8050	79.2070	7.9820	8.1940	7.2760	1.80000	74.6	<MDL	2.10000	1.12
162	CapreolFSaL	Intensive	495570	5162756	1.4200	7.1730	83.9680	8.8580	7.8760	6.9540	6.03000	71.3	0.05580	6.99000	1.88
166	BradleyFSaL	Potato	492747	5161039	0.1760	27.0390	66.1000	6.8650	5.5130	4.4200	2.27000	26.5	0.05050	0.22600	17.20
167		Potato	492744	5161386	0.0718	31.5870	61.8490	6.5670	4.8300	4.3170	0.67200	52.4	0.02640	0.15000	5.84

SID	SMU	L_U_Cat	North	East	%_C	% Sand	%Silt	% Clay	pHH2O	pHCaCl2	AV_Al	AV_Ca	AV_Cu	AV_Fe	AV_K
168	BradleyFSaL	Sod	492375	5161014	0.0657	81.4760	14.3550	4.1700	4.8260	4.8070	1.22000	9.2	<MDL	0.53300	25.20
169	BradleyFSaL	Sod	492363	5161428	0.0778	14.2790	76.9690	8.7530	5.4960	4.8650	0.07520	36.4	0.01950	0.19300	5.41
170	BradleyFSaL	Sod	491963	5161095	0.1030	12.8060	79.6120	7.5840	5.1700	4.5920	0.80100	37.3	<MDL	0.08450	3.23
171	BradleyFSaL	Sod	491957	5161503	0.0779	35.6220	58.2610	6.1180	5.1540	4.3240	0.50200	33.1	<MDL	0.31700	2.12
172	BradleyFSaL	Potato	491569	5161009	0.1340	24.8540	68.9490	6.1990	5.1760	4.4490	1.52000	21.8	0.03670	0.65500	8.07
173	BradleyFSaL	Sod	491563	5161426	0.1090	41.9360	53.0150	5.0520	5.5550	4.8810	51.10000	46.8	0.10200	29.50000	21.50
174	BradleyFSaL	Potato	491025	5160975	0.1210	88.0010	9.5000	2.4950	5.0820	5.2130	1.25000	16.2	<MDL	0.14200	19.70
175	BradleyFSaL	Potato	490976	5161474	0.1200	31.9560	61.5530	6.4920	5.1110	4.6660	0.95800	61.2	<MDL	0.57500	22.80
176	BradleyFSaL	Sod	490637	5161082	0.9630	27.5860	65.0440	7.3710	7.7130	7.1960	4.13000	64.7	0.00842	5.07000	2.85
177	BradleyFSaL	Potato	490557	5161459	0.1510	30.0190	63.1000	6.8830	5.5560	4.8170	2.00000	40.2	0.07110	1.16000	3.05
178	BradleyFSaL	Potato	490155	5161061	0.0843	28.1350	65.3820	6.4840	5.7930	4.8530	0.48500	29.4	<MDL	0.34700	4.82
179	BradleyFSaL	Potato	490146	5161436	0.1580	6.1980	83.8470	9.9560	5.1850	4.4740	1.03000	42.8	0.03060	0.17100	4.19
180		Forested	497719	5162798	0.0965	37.8210	56.1400	6.0380	5.2900	4.6660		29.1	<MDL	<MDL	3.79
181		Forested	496843	5162741	0.1520	40.7390	53.3770	5.8830	5.3530	4.5770	7.48000	30.0	<MDL	9.42000	2.75
182	BradleyFSaL	Forested	496343	5162777	0.3410	4.3750	86.4820	9.1430	5.1060	4.4880	2.61000	44.2	<MDL	0.38700	1.01
183	BradleyFSaL	Potato	497727	5163283	0.1030	14.2650	77.8110	7.9250	5.5350	4.7730	2.55000	32.7	0.04820	2.35000	3.74
184	BradleyFSaL	Forested	497269	5163197	0.1330	15.9860	76.5760	7.4370	5.4530	4.6460	1.17000	32.0	<MDL	0.25200	6.68
185	BradleyFSaL	Low Intensity	496743	5163252	0.0843	24.2780	68.5910	7.1350	6.2950	5.3000	2.88000	60.7	0.03670	3.38000	4.85
186	BradleyFSaL	Forested	496431	5163200	0.6320				7.7530	7.0400	9.14000	66.2	<MDL	11.20000	0.99
188	BradleyFSaL	Forested	497293	5163765	0.1570				6.6480	5.6950	20.30000	56.7	0.06370	26.10000	3.74
189		Abandoned	496746	5163731	0.0775				6.0900	5.2040	2.14000	39.4	<MDL	2.71000	3.35
190		Abandoned	496358	5163702	1.5500				8.2630	7.3750	0.98800	103.0	0.05540	1.44000	2.00
191	BradleyFSaL	Sod	491358	5161933	0.1200				7.2740	6.6360	33.10000	60.9	0.10700	38.80000	7.73
192	BradleyFSaL	Sod	490926	5161925	0.4930				7.6630	7.1330	9.22000	63.9	0.06580	11.00000	2.57
193	BradleyFSaL	Sod	491441	5162360	0.1330				5.2660	4.7810	1.23000	40.3	<MDL	0.57800	1.00
194	BradleyFSaL	Abandoned	490954	5162353	0.0903				5.6740	4.9480	2.93000	38.9	<MDL	1.75000	13.40
195		Sod	491392	5162872	1.4000				7.8270	7.4160	3.40000	95.0	<MDL	3.60000	2.71
196		Sod	490954	5162807	2.3500				8.5860	7.7340	1.09000	76.6	0.02500	1.18000	1.48
197	BradleyFSaL	Forested	490619	5162107	0.0718				6.1850	5.4310	39.20000	32.5	0.14000	85.70000	4.18
198	BradleyFSaL	Forested	490564	5162397	0.2070				5.2690	4.6760	1.63000	9.9	<MDL	0.89100	0.80
200			495002	5160669	0.0651				6.2270	5.5180	33.10000	30.7	0.15700	50.50000	7.50
204		Forested	498167	5162841	0.1650	78.9980	16.4910	4.5120	4.8100	4.4940	3.80000	3.5	<MDL	1.05000	0.81
205	BradleyFSaL	Forested	498236	5163260	0.0899				5.2040	4.4100	5.41000	34.5	<MDL	5.40000	3.37
207		Low Intensity	493286	5162792	0.5420				7.7490	7.1460	9.48000	75.2	0.07880	8.93000	3.95
210	CapreolFSaL	Abandoned	493760	5161970					8.3680	7.4640	2.43000	77.1	<MDL	2.95000	2.66
211	CapreolFSaL	Abandoned	493750	5162304	0.1390				6.1610	5.7410	28.00000	53.1	<MDL	34.90000	4.23
212	CapreolFSaL	abandoned	493691	5162841	0.7080				7.7770	7.1580	10.80000	89.7	0.06900	10.90000	1.57
385		Abandoned	496044	5163283					5.6470	4.9620	19.50000	46.5	0.09490	14.40000	1.86
386			489760	5161100	0.1630				5.7470	4.9190	5.72000	58.0	0.01430	6.00000	7.01
351	Wolf SiL	Topsoil Removed	490049	5156538		8.0540	81.8950	10.0520	6.7800	6.1800	3.25000	87.9	0.03330	4.02000	2.68
352	Wolf SiL	Topsoil Removed	490375	5156432		7.0350	82.7040	10.2600	7.1800	6.3500	16.50000	81.0	0.02130	19.60000	3.96
387			489754	5161453	0.1690				5.5350	4.4380	0.90100	38.1	<MDL	0.61100	3.05
585	CapreolFSaL	Forested	494944	5162716	0.2740	5.5220	4.9500	19.3000	5.5220	4.9500	19.30000	46.8	0.01340	14.20000	1.67

SID	AV_Mg	AV_Mn	AV_Mo	AV_Na	AV_P	T_Al	T_Ca	T_Cu	T_Fe	T_K	T_Mg	T_Mn	T_Na	T_P	T_Zn
1	16.6	0.02770	<MDL	7.360	0.3530	9830	49400	11.60	10700	909	13000	226	1130	472	19.8
2	17.5	0.03860	0.02060	6.110	0.2310	7430	47500	11.60	9540	630	12400	214	877	431	20.4
3	16.9	0.03010	0.01340	5.100	0.2410	7810	48000	12.70	9570	682	12000	206	970	447	17.3
4	17.9	0.15700	0.04230	6.010	0.3450	7260	44800	11.00	8460	586	11600	205	873	404	16.7
5	24.7	0.04310	0.02570	14.700	0.2500	10100	55900	16.40	13400	1140	13100	289	1120	467	25.6
6	34.2	0.05110	<MDL	6.970	0.3830	12500	19100	12.90	13800	765	9770	158	772	521	26.0
	17.1	0.01470	0.02170	6.360	0.2830	11400	53200	16.80	13700	1100	13000	286	1070	467	26.4
8	28.7	0.30700	0.01330	6.870	0.3690	9540	4670	13.30	11100	600	3820	203	577	491	18.3
9	13.1	1.14000	0.00365	4.030	0.4420	5710	3020	6.24	7590	334	2470	138	432	397	11.9
10	15.9	0.02850	<MDL	4.750	0.3160	8130	40200	13.00	9830	664	12400	205	889	472	18.8
11	17.9	0.01760	0.01630	5.570	0.2040	9610	49400	13.80	11100	788	13200	237	898	457	21.0
12	26.0	0.05230	<MDL	5.050	0.3270	10300	30000	14.60	12000	732	11800	252	828	500	22.1
13	16.6	0.04570	<MDL	4.390	0.2350	6960	43600	12.00	8930	627	12000	218	913	428	15.6
14	24.0	0.02820	0.01010	5.020	0.1900	7750	24200	10.90	8720	490	10200	121	785	464	17.1
15	8.6	1.34000	<MDL	2.280	0.0594	4280	3160	8.60	6780	330	2320	300	420	378	10.5
16	21.2	0.11400	0.00369	5.050	0.5820	6020	11400	7.11	7940	515	6040	156	681	483	13.1
17	15.8	0.01900	<MDL	4.670	0.1710	5830	31800	9.91	7460	534	10200	144	770	446	13.0
18	14.3	0.01860	0.02410	4.490	0.1920	8620	43400	10.30	9490	960	12100	178	1240	440	16.6
19	25.9	0.04290	0.00640	4.590	0.2590	11300	29200	15.60	12800	860	12000	276	947	525	23.1
20	14.9	0.02190	<MDL	4.660	0.2060	7290	49100	11.80	9280	789	12400	215	951	454	16.7
21	14.2	0.01770	0.00656	5.890	0.1420	6530	30600	9.59	9130	600	11100	144	850	472	15.1
22	7.5	0.61400	0.02140	7.960	0.0590	5610	3020	6.82	7460	335	2310	129	461	441	12.2
23	33.5	0.02180	<MDL	5.630	0.1750	10500	17100	14.60	12000	679	8880	278	830	519	22.2
24	12.1	0.51400	0.00499	7.590	<MDL	6580	3060	9.35	8120	381	2450	140	423	454	12.8
25	21.5	0.03530	<MDL	4.570	0.1830	8850	37000	15.70	10700	683	12900	273	842	460	19.2
26	30.7	0.08780	<MDL	5.870	0.4490	10300	34400	17.30	12000	780	13000	255	827	488	24.2
27	20.4	0.03910	<MDL	5.820	0.3620	10300	47900	14.80	11700	854	13400	252	1010	492	23.4
28	16.8	0.02710	0.01420	4.990	0.2200	9690	56500	14.10	11200	891	13300	238	991	468	22.3
29	8.1	0.74300	<MDL	4.150	0.1730	6840	2900	8.58	8160	400	2630	141	406	411	13.4
30	9.6	0.52200	<MDL	9.950	0.1960	9690	3740	12.80	11000	473	3550	201	553	432	22.0
31	8.3	0.67700	0.02090	4.810	0.2890	6380	2610	4.51	8600	407	2520	219	414	388	15.6
32	8.2	0.70500	0.01310	6.160	0.1880	8660	3270	10.40	9790	405	3220	188	440	426	17.0
33	8.5	1.42000	<MDL	2.250	0.6700	5450	2480	4.43	8060	335	2350	147	356	343	14.2
34	17.2	0.03140	<MDL	14.400	0.3030	6350	31500	10.50	8490	571	11100	155	929	452	14.9
35	12.1	0.03500	<MDL	4.180	0.2920	5390	28600	9.92	7630	482	9680	136	750	518	15.1
36	2.7	0.76200	<MDL	2.670	0.1550	6850	2730	5.90	8580	365	2350	81	396	442	15.2
37	2.8	1.86000	<MDL	3.100	0.2290	7020	2310	9.11	8830	314	2390	130	336	371	13.5
38	6.4	2.37000	0.00934	8.450	0.2360	10000	3620	9.21	10100	491	3140	183	532	521	16.9
39	45.7	0.23800	0.01490	6.020	0.6030	11900	11100	12.40	13400	646	6630	270	739	605	22.7
40	44.5	0.28600	<MDL	12.400	0.6320	12000	8130	14.30	14100	733	5580	309	733	630	28.0
41	19.6	1.09000	0.05210	7.790	0.3550	12000	5160	12.60	13300	666	4470	308	636	583	23.0
42	3.4	1.72000	<MDL	3.650	0.2140	6670	2760	5.30	7900	408	2280	138	389	448	13.6
43	32.8	0.08160	0.00949	4.630		9090	35300	14.30	10900	687	12900	235	875	500	23.1
44	19.5	0.02140	0.01390	4.360		8570	46900	13.40	10600	722	13300	216	970	480	19.9
45	23.4	0.00549	0.02720	5.120		8690	55500	12.30	10500	785	14000	226	1090	464	19.3
46	31.7	0.11600	0.03150	5.990	0.0433	7770	18100	11.70	9540	529	8530	191	746	524	19.4
47	21.9	0.18300	0.01760	7.340		8670	54200	12.90	11100	921	13700	235	1070	458	21.3
48	36.8	0.13900	0.02620	5.250		11200	14900	13.50	13800	689	8120	339	822	598	25.9
49	25.4	0.05450	0.01820	5.060		9470	28300	14.20	11600	700	11600	206	888	510	22.6
50	32.9	0.01440	0.00840	6.260		10900	34200	15.50	12400	780	12800	268	852	549	25.0

SID	AV_Mg	AV_Mn	AV_Mo	AV_Na	AV_P	T_Al	T_Ca	T_Cu	T_Fe	T_K	T_Mg	T_Mn	T_Na	T_P	T_Zn
51	18.6	0.02500	0.00496	4.630		7620	42800	11.60	9400	556	12500	201	868	458	19.4
52	25.1	0.00912	0.02400	5.690		9500	38800	14.00	11600	686	13600	236	933	522	21.1
53	20.8	0.05820	0.01020	4.780		9010	39600	13.80	10900	697	13200	231	966	515	20.1
54	19.6	0.42000	0.03860	5.570		7100	40200	12.30	9760	700	12100	1070	935	514	20.1
55	18.3	0.08030	0.00835	3.950		3380	10100	4.20	5740	369	4460	130	518	163	9.6
56	18.9		0.01640	5.490		9600	59500	13.20	11500	874	13600	245	930	488	24.0
57	16.9	0.01010	0.00996	4.350		9210	57300	14.00	11300	859	14000	240	934	493	22.9
58	16.7	0.00312	<MDL	4.170		7960	49600	12.70	10000	743	12800	392	969	472	21.4
59	19.1	1.29000	0.00591	4.390	0.2240	4620	3550	7.26	7520	334	2280	113	473	483	13.7
60	11.7	0.72100	0.00335	3.280	0.1370	4500	21000	9.53	7120	420	6560	254	603	528	16.2
61	21.2	<MDL	0.01790	4.620		8750	47700	13.10	11100	696	13800	232	885	511	22.0
62	14.0	0.27700	0.01480	5.200	0.1250	4600	12800	7.38	7150	400	5290	91	520	418	14.8
63	23.1	0.34600	0.02520	3.590	0.0454	5860	24900	9.00	9230	478	9800	351	734	621	25.3
65	41.8	0.10600	0.01270	7.330	0.2870	11500	14700	17.30	14600	754	8370	312	795	609	26.7
66	17.7	0.09980	<MDL	5.750		6910	48100	12.00	10500	689	12700	359	928	496	19.7
67	41.9	0.29100	<MDL	7.980	0.2990	10300	11200	13.60	13500	603	6580	268	708	629	26.1
68	40.9	0.15900	0.04580	6.690	0.3140	12300	10200	14.80	15300	733	6610	326	604	666	28.2
69	13.8	<MDL	0.00859	4.240		9640	57800	10.50	12100	1460	14300	248	1440	526	30.5
70	28.5	0.69600	0.10600	8.520	0.0865	10500	5910	14.30	13500	551	4500	287	708	649	24.3
74	21.2	<MDL	0.02680	5.860		9570	41600	13.50	12400	777	14400	257	794	541	23.2
75	15.5	0.50800	0.02610	3.310		4390	11100	10.20	6920	392	4940	2300	473	367	14.3
76	16.3	0.03330	0.00849	3.860		7100	42500	11.40	9760	595	12600	214	872	521	18.4
77	18.9	0.65600	0.00866	3.410	0.1240	5020	4620	5.93	7830	338	2940	107	460	460	15.2
78	18.5	0.04300	0.00858	4.550	0.0087	8930	53700	14.10	11700	693	14100	246	871	533	22.9
79	19.9	0.11900	0.01610	3.530	0.0365	7740	58900	11.60	12800	1070	14200	253	1020	583	23.7
80	32.1	0.27100	0.01640	4.770	0.2150	12100	6860	13.30	15400	630	5090	295	596	684	30.2
81	41.1	0.15800	0.01230	5.480	0.0931	9890	37400	15.00	13000	691	13700	279	807	562	25.2
83	36.0	0.15600	0.01950	4.860	0.0855	10100	25800	12.10	13600	671	11500	336	772	625	24.6
84	24.0	0.07120	0.02660	7.250	0.0950	8300	57100	12.70	11600	720	14500	298	889	523	23.7
85	42.6	0.10100	0.00580	6.050	0.1240	10400	26400	15.30	13500	685	11300	300	714	610	25.4
86	53.7	0.18700	0.04720	13.600	0.3510	9270	45200	13.80	12300	652	14700	248	924	573	25.2
87	20.4	0.03150	<MDL	5.460	0.0135	10200	17600	12.40	12200	629	9630	241	730	524	21.3
88	14.0	0.04050	0.01450	3.070		6190	23800	10.10	8290	510	9790	614	695	424	16.3
89	23.7	0.00696	0.00679	7.100	0.2230	7300	23000	10.50	9610	585	10100	113	678	439	20.1
90	23.4	0.22400	0.01690	5.560	0.2800	11600	6080	10.90	14500	654	4760	396	594	601	23.5
91	22.4	0.01010	0.01120	6.830	0.1110	8610	45000	12.30	10600	772	14000	218	877	469	19.5
92	15.6		<MDL	5.960		8400	49800	11.60	10500	669	13600	213	860	468	18.2
93	41.0	0.11800	0.00811	7.060	0.2010	9850	20100	12.90	12100	689	10100	270	695	553	20.5
94	12.4		0.00391	5.150		5820	44800	10.30	8930	550	13000	164	757	569	12.9
95	38.2	0.20000	0.00776	7.670	0.2940	9690	10900	11.50	12400	627	6770	277	658	569	22.9
96	23.4	0.11400	0.01800	4.850	0.1350	8690	32700	11.70	11100	635	12900	234	736	480	20.7
97						6920	3570	6.90	9270	462	2880	133	493	510	15.1
98	39.5	0.15100	<MDL	5.200	0.2730	9070	21600	12.20	11400	603	10500	241	695	504	20.6
99	18.4	0.03980	0.00448	3.780	0.1300	5210	21500	8.52	7710	492	8740	139	653	446	15.8
100	33.0	0.11900	0.04300	5.400	0.0460	8500	30000	12.10	10600	599	12700	210	718	510	19.8
101	37.1	0.18700	0.02010	11.100	0.1630	9290	27400	13.20	11400	621	11900	226	698	557	19.9
102	29.9	0.19700	0.03040	4.700	0.2600	11100	6160	9.49	14000	602	4470	248	564	634	23.6
103	31.2	0.22400	0.01960	5.710	0.3400	9990	7000	10.10	13000	522	4770	254	588	591	19.7
104	36.3	0.17000	0.01110	6.890	0.2550	9850	8950	14.50	13400	600	5940	286	722	594	22.8
105	19.7	0.03440	0.01330	2.420		7900	33000	11.50	10400	594	13200	218	712	495	19.1

SID	AV_Mg	AV_Mn	AV_Mo	AV_Na	AV_P	T_Al	T_Ca	T_Cu	T_Fe	T_K	T_Mg	T_Mn	T_Na	T_P	T_Zn
106	31.1	0.07340	0.01200	5.270	0.0285	7550	32300	11.50	9840	590	12900	191	704	498	22.9
107	23.9	1.06000	0.03680	9.290	0.1100	11400	5300	8.56	13800	567	4480	284	606	600	22.2
108	27.7	0.68000	0.00594	13.700	0.2530	10800	5450	10.60	13200	582	4490	265	609	589	22.7
109	33.9	0.07280	0.01350	5.010	0.1110	8510	33700	11.80	10900	597	13400	231	690	482	19.0
112	28.2	0.36700	0.00627	11.700	0.0173	10200	5030	12.20	13400	489	4160	271	604	569	21.3
113	10.2	1.68000	0.01150	7.860		10300	4430	11.90	12700	478	3790	256	504	547	18.1
114	9.6	2.50000	0.00984	9.440											
115	19.9	0.39500	0.07750	10.400		8860	5190	12.80	12300	524	3860	240	635	579	21.7
116	22.2	0.39600	0.04080	13.800	0.1740	8930	5160	10.30	12100	514	3670	268	618	620	21.8
117	29.1	0.44200	0.00934	10.700	0.1320	10700	5300	9.39	13600	516	4370	270	651	571	22.8
118	8.2	2.26000	0.01100	6.650		10700	4630	10.00	13900	656	4050	353	585	594	22.6
119	8.0	1.64000	0.01370	4.070		5520	3380	6.88	8470	342	2390	147	509	527	15.0
120	23.8	0.33100	0.01340	10.400		10800	5630	11.50	14100	575	4530	280	726	617	24.7
121	19.8	0.07200	0.03500	3.530		7750	15900	12.20	10400	503	8230	214	732	514	19.9
122	3.6	2.05000	0.01760	3.570		5260	3070	6.20	7910	312	2290	126	443	431	18.9
123	15.3	0.39300	0.02030	4.170		8020	4460	10.20	11100	456	3370	147	619	591	20.0
124	1.7	1.21000	0.02160	3.270		5680	2550	4.80	8660	300	2920	160	363	356	12.7
125	5.2	0.67400	0.02250	3.880		7960	4190	7.69	10000	403	2860	184	617	616	17.3
126	8.2	0.84300	0.01390	2.450	0.0696	5460	2900	5.12	8100	355	2680	99	468	375	14.3
127	5.7	0.50900	0.01150	4.170		6650	4100	7.82	9800	463	2720	179	559	567	15.0
128	7.2	1.98000	0.01950	6.550		7900	3810	9.44	10600	409	2910	219	524	566	14.9
129	11.9	0.15400	<MDL	3.310	0.0097	6760	24600	11.30	9140	549	10800	131	799	496	16.5
130	9.1	1.16000	0.00819	5.830		7720	3650	9.91	10800	459	3150	197	587	516	16.8
131	9.4	1.19000	0.03270	3.820		6770	3280	7.58	9350	396	2730	154	591	519	14.5
132	8.2	1.52000	0.00577	4.390	0.0315	7970	3620	6.84	9620	411	2820	218	474	561	16.4
133	1.5	2.47000	0.01260	2.580		7320	3120	5.89	9410	471	2730	166	459	523	19.6
134	0.4	3.18000	0.03410	2.140		6270	2860	4.96	8490	390	2320	157	459	502	17.2
135	6.5	2.43000	0.00844	3.240		8060	3030	9.78	10000	389	2740	203	442	511	20.9
136	2.8	0.85300	<MDL	2.170	0.1110	5410	2860	5.61	7990	367	2420	125	485	478	13.9
137	1.0	2.15000	<MDL	2.150	0.5260	6900	2780	4.65	8920	351	2380	118	401	505	17.0
138	18.9	0.15000	<MDL	4.200	0.2740	5900	7170	8.55	9190	430	3810	162	688	617	15.8
139	5.1	2.37000	<MDL	5.090	0.0200	6120	3070	7.16	8770	391	2470	185	486	483	14.3
140	1.2	2.29000	<MDL	2.480	0.2930	6080	3260	5.89	8930	412	2570	151	538	523	15.7
141	6.7	1.94000	<MDL	2.500	0.1010	8610	3860	6.72	10700	453	2950	199	539	659	15.8
142	8.3	1.03000	<MDL	4.220	0.1180	6350	3710	6.98	9370	468	2580	173	552	612	14.5
145	2.7	0.90200	<MDL	5.690	0.1420	7440	4240	7.69	10100	493	2980	193	662	610	18.9
147	10.5	2.16000	<MDL	5.600	0.1310	9220	3440	8.77	12000	454	2990	223	482	610	15.9
148	8.0	0.92500	<MDL	6.360	0.1320	7010	4970	9.08	10500	435	2950	194	744	720	16.2
150	19.5	0.26100	0.14300	4.770	0.3730										
151	17.9	0.23900	<MDL	3.880	0.3600	5420	36800	7.40	8440	523	13000	203	818	596	14.0
152	1.7	1.68000	0.03470	3.470		8280	2960	7.58	10300	357	2790	170	463	497	15.9
154	14.0	0.10800	<MDL	4.290	0.2040	5550	40700	8.28	9220	650	12000	295	922	529	15.0
155	6.7	2.12000	<MDL	3.750	0.1430	8060	3830	6.58	10200	393	2810	183	550	618	16.1
157	5.7	0.58300	<MDL	10.400	0.1490	6740	3830	7.77	8880	379	2540	148	606	581	14.5
158	29.1	0.53300	<MDL	6.340	0.6420	7110	4840	6.90	10500	475	3210	190	717	640	15.4
160	31.1	0.20700	<MDL	6.310	0.6890	6030	13300	7.07	7390	456	6250	81	809	682	14.1
161	20.2	0.08250	<MDL	5.030	0.2990	5970	40400	8.86	9070	540	13200	161	852	572	15.9
162	32.4	0.17500	<MDL	4.570	0.4150	6550	32900	8.48	9300	580	13300	157	817	582	15.7
166	6.9	1.40000	<MDL	2.150	0.0942	8120	3650	7.64	10300	466	3000	181	581	620	16.0
167	19.3	2.68000	<MDL	9.470	0.1560	6990	3680	6.95	9070	461	2800	170	606	582	14.4

SID	AV_Mg	AV_Mn	AV_Mo	AV_Na	AV_P	T_Al	T_Ca	T_Cu	T_Fe	T_K	T_Mg	T_Mn	T_Na	T_P	T_Zn
168	2.9	1.33000	<MDL	1.640	0.0508	5060	2340	3.70	8460	361	2910	127	377	318	13.0
169	9.4	0.83900	<MDL	4.140		7110	4500	9.12	10700	517	3180	201	684	629	16.3
170	6.1	1.80000	<MDL	7.690	0.0394	7960	4020	9.23	10200	475	3080	190	639	651	17.2
171	8.0	0.38000	<MDL	6.180		6450	3280	6.28	8640	385	2510	105	651	539	13.0
172	9.3	1.60000	<MDL	3.110	0.0986	6880	3430	6.81	9030	496	2530	159	557	638	12.8
173	15.4	1.36000	<MDL	4.480	0.9860	6150	3800	5.83	6630	520	2350	93	663	621	13.9
174	4.2	1.15000	<MDL	1.330	0.2660	4840	1970	3.19	6930	416	2600	105	421	287	12.1
175	15.6	3.13000	<MDL	14.100	0.0938	6320	3730	6.28	8510	539	2530	174	737	611	13.3
176	23.6	0.09180	<MDL	4.610	0.1650	5100	23100	6.99	8330	589	10200	126	839	552	14.4
177	6.7	1.08000	<MDL	6.570	0.1930	7090	3750	6.23	9420	531	2850	169	719	580	15.1
178	5.9	0.64900	<MDL	4.810	0.1350	6140	3630	6.23	9290	471	2520	146	637	642	12.1
179	8.2	1.80000	<MDL	7.130	0.0597	9370	3640	9.45	11000	461	3570	211	413	478	16.9
180	10.4	0.77800	<MDL	4.240	0.0750	6250	3090	7.78	8880	352	2620	146	417	491	12.4
181	10.8	1.43000	<MDL	5.310	0.1440	6420	3270	7.63	8210	424	2660	152	738	444	12.8
182	4.8	3.50000	<MDL	5.650	0.1520	11000	3590	7.95	11500	463	3290	277	650	549	16.3
183	13.8	1.11000	<MDL	6.620	0.0295	8170	3870	8.90	9470	528	3100	196	705	544	14.4
184	3.7	1.37000	<MDL	2.680	0.0455	8270	3690	6.64	9420	475	2960	191	684	559	14.4
185	12.8	1.53000	<MDL	13.700	0.0992	6860	3830	8.34	8390	493	2700	172	824	525	13.1
186	33.1	0.26800	<MDL	6.450	0.4800	7570	13400	9.69	9240	525	7550	182	909	543	15.2
188	20.7	1.06000	<MDL	9.980	0.3380	8460	4630	7.57	10400	516	3180	220	908	635	14.9
189	16.4	0.52200	<MDL	6.470	0.1030	8290	4210	8.54	9720	524	3140	196	984	618	15.5
190	18.6	0.05000	<MDL	3.720	0.1470	6210	34600	6.33	8000	662	12600	150	1110	566	13.0
191	30.6	0.77300	<MDL	4.040	0.6730	7640	4460	8.36	9520	592	3330	197	928	571	15.5
192	28.0	0.29100	<MDL	3.450	0.3530	6520	11000	9.97	8230	482	6620	218	713	476	13.1
193	7.2	1.76000	<MDL	4.200	0.0484	7500	2660	5.35	8320	468	2510	187	579	487	11.3
194	9.8	0.25400	<MDL	15.900	0.8810	6810	3450	8.76	6150	563	2530	72	733	573	13.0
195	27.5	0.10500	<MDL	9.110	0.1610	6610	23500	6.34	8490	665	12200	161	840	471	14.7
196	22.3	0.03590	<MDL	6.720	0.1430	7110	44300	9.53	9620	774	15000	178	917	468	16.0
197	17.4	2.00000	<MDL	9.580	0.5050	5380	2140	3.25	6110	535	2220	78	622	317	9.5
198	1.9	0.20800	<MDL	3.010	0.0412	5950	1970	2.56	7420	488	2350	64	494	367	9.5
200	24.4	1.09000	<MDL	7.510	0.6710	5820	2190	5.11	6840	675	2760	89	720	329	10.4
204	0.7	0.21400	<MDL	1.740	0.2370	4950	1120	0.76	3790	474	1920	43	385	257	8.2
205	7.2	0.75700	<MDL	11.000	0.2060	5250	1270	3.58	4210	514	1520	55	476	385	7.3
207	31.6	0.15100	<MDL	12.300	0.4450	5730	4100	5.14	5120	591	4340	80	535	495	10.3
210	13.7	0.07000	<MDL	3.040	0.1600	3440	11900	4.47	3470	521	7510	59	517	368	7.6
211	19.4	1.22000	<MDL	12.000	0.5770	3200	495	0.95	2700	215	890	28	260	411	5.9
212	41.7	0.22500	<MDL	4.050	0.6470	3540	2340	3.93	3210	345	3480	47	357	426	8.1
385	10.8	0.30800	<MDL	4.090	0.4750	2260	282		1830	162	572	14	201	385	4.3
386	12.0	1.16000	<MDL	27.000	0.2740	3000	265	2.75	2420	266	1090	37	196	439	7.2
351	17.2	0.07830	<MDL	5.030	0.1760	8950	42900	11.90	11700	708	19400	216	1270	312	18.3
352	36.6	0.46700	<MDL	6.680	0.4600	10100	13300	13.40	12900	687	8590	249	1210	334	19.8
387	5.4	0.89900	<MDL	26.900	0.0974	10900	4570	11.00	12300	629	3590	230	1040	308	18.3
585	10.2	0.30700	0.02980	11.900	0.3440	7650	3760	6.01	8900	571	2400	90	910	287	13.0