1.0 INTRODUCTION

This report describes the micronutrient and trace element status of the AESA (Alberta Environmentally Sustainable Agriculture) Soil Quality Benchmark Sites. Previous reports completed for this study include:

1. *Baseline soil physical and chemical properties of forty-three soil quality benchmark sites in Alberta.*
2. *Preliminary statistical analysis of baseline soil organic carbon and nitrogen data of forty-three soil quality benchmark sites in Alberta.*
3. *Preliminary statistical analysis of baseline soil fertility data of forty-three soil quality benchmark sites in Alberta.*
4. *Micronutrient (Cu, Fe, Mn, and Zn) status of forty-three soil quality benchmark sites in Alberta.*
5. *Analyses of five years of soil data from the AESA soil quality benchmark sites.*

This ongoing study includes forty-three benchmark sites distributed across the agricultural regions of Alberta. The sites are located in seven ecoregions, namely: Peace Lowlands (PL); Mixed Boreal Upland (MB); Boreal Transition (BT); Aspen Parkland (AP); Moist Mixed Grassland (MM); Fescue Grassland (FG) and Mixed Grassland (MG). These ecoregions fall within the Boreal Plains and Prairie ecozones (Figure 1). A description of the ecoregions can be found in *A National Ecological Framework for Canada* (Ecological Stratification Working Group, 1995). Each site has been characterized in detail with respect to landform, soil profile and physical and chemical properties at an upper, mid, and lower slope position along a catena (Report No. 1 above). Historical management information was recorded and information on current management practices is collected each year from the cooperating farmers. Soil and crop samples are taken from upper, mid and lower slope positions each year to monitor soil fertility, crop yield and nutrient uptake.

Soil samples taken in the fall of 2002 were analyzed for thirty elements. This report describes the influence of ecoregions, soil properties, and historic management practices on boron (B), chloride (Cl), cobalt (Co), molybdenum (Mo), nickel (Ni), silicon (Si), chromium (Cr), cadmium (Cd), and selenium (Se) [Appendix 1 and 2]. The data for the additional twenty-one elements are presented in Appendices 3 and 4, but are not discussed in this report. Report Number 4 above discusses the results of copper, iron, manganese, and zinc analyses on samples taken in 2000.

This broad scan of the micronutrient and trace element status of the Soil Quality Benchmark Sites provides useful baseline information regarding the variability and range of element concentrations within ecoregions, soil types and landscapes. However, the literature for many of the elements does not provide a basis to assess their status as deficient, normal or high. Of the nine elements discussed in this report, only B and Cl are routinely analysed in this region (the Northern Great Plains). There is limited information for some of the other elements, but generally not for the extraction methods used in this study.

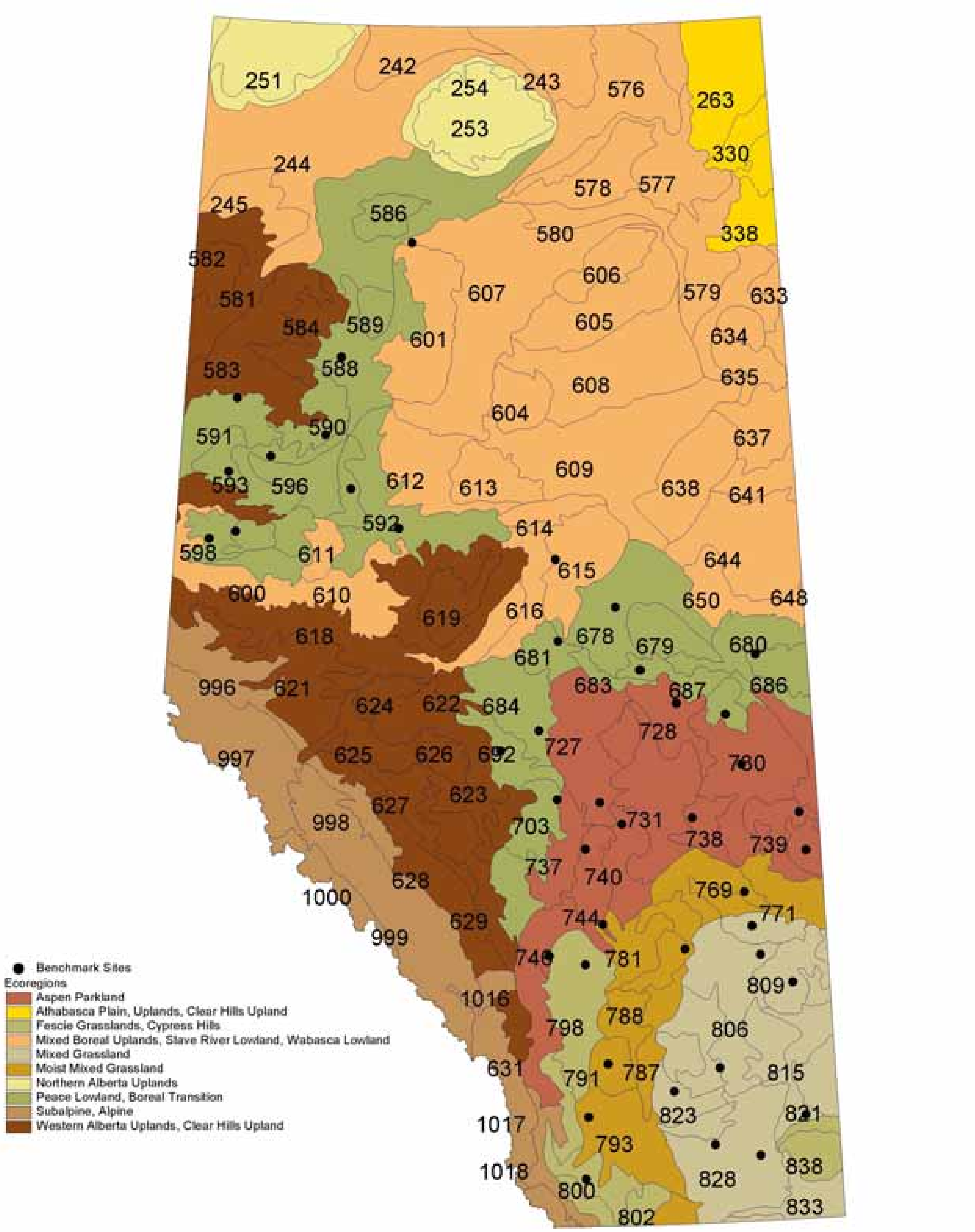

Figure 1. Location of 43 benchmark sites across Alberta.

2.0 OBJECTIVES

The objectives of this report were to describe and evaluate the micronutrient and trace element status of the benchmark sites with respect to:

1. Ecozones and Ecoregions;
2. Site characteristics – soil/landform, pedology, and physical and chemical properties;
3. Cropping and soil management history;
4. Typical values reported for Alberta, the Northern Great Plains, and other regions of the world;
5. Potential deficiencies or toxicities for crop production;
6. Their availability to crops as influenced by soil properties such as pH, OM, texture, free lime and other nutrients.

3.0 BACKGROUND

Nutrients essential for plant growth are categorized as macronutrients and micronutrients. Micronutrients are just as essential as macronutrients but are required by plants in smaller amounts. There are eight essential micronutrients (iron, zinc, copper, manganese, boron, chloride, molybdenum and nickel) plus others that are considered to be beneficial (sodium, silicon and vanadium). Cobalt is also included, since it is required for nitrogen fixation by microorganisms (Rhizobia and blue-green algae).

It has been stated that micronutrient deficiencies are less common in Alberta than in many other regions of the world. This statement is generally true for the Northern Great Plains Region of North America. For example, it is estimated that 40 percent of the worlds cultivated soils are low in available iron (Shorrocks, 1984) whereas in Alberta, iron deficiency has only been observed on trees, shrubs and ornamental plants adapted to acid soils (McKenzie, 1992). The reasons generally given for the relatively low frequency of micronutrient deficiencies in this region are:

1. Our soils are not highly weathered because they are: i) geologically young (formed since the last glacial period – 10,000 plus years ago); and ii) in a temperate climate with low precipitation, which results in a slow rate of weathering.

2. Our soils have only been cultivated for 50 to 100 years compared to hundreds and thousands of years for many agricultural soils. Therefore, there has been less crop removal.

4.0 METHODOLOGY

4.1 Soil Sampling and Analyses

The site selection and sampling methods used for the benchmark sites were described in Leskiw, et al. (2000). Each site consisted of three sampling locations (upper, mid and lower slope positions) along a catena and from two depths (0-15 cm and 15-30 cm). Therefore, a total of 129 samples were collected from 43 sites for each sampling depth. Soil samples from three or four principle horizons (A, B, BC and/or C) were collected as part of the site characterization. The analyses performed (Norwest Labs, Edmonton) included: particle size by hydrometer (texture), CEC, pH in $CaCl_2$ and H_20, EC in saturated paste extract, SAR was calculated from soluble Ca, Mg, and Na ions of the saturated paste (when EC was >4), total N, organic carbon and $CaCO_3$. Bulk densities in topsoil (3 cm to 15 cm) and subsoil (20 cm to 50 cm) were determined on duplicate samples by CAN-AG Enterprises Ltd.

Composite samples (5 to 10 cores) for 0 – 15 cm and 15 – 30 cm depths are taken each year for soil fertility analyses [NH_4, NO_3, P, K, SO_4, pH, EC and organic carbon (OC)]. In 2002, these samples were also analysed for 30 micronutrients and trace elements.

Chloride was extracted in 0.01 M $Ca(NO_3)_2$ *(Extraction based on Soil Science Society of America Book Series No. 3. Soil Testing and Plant Analysis, 1990. Chapter 10, Testing soils for S, B, Mo, and Cl, pp 265-273).* Chloride was analyzed by colorimetric centripetal analyzer *(Analysis based on American Public Health Association. Standard Method for the Examination of Water and Wastewater, 20th ed., 1998. APHA 4500-Cl$^-$E, Automated Ferricyanide Method).*

The elements Al, Sb, As, Ba, Be, Bi, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, P, Se, Si, Ag, Sr, S, Sn, Ti, Tl, V and Zn were extracted with DTPA-TEA *(Method 4.65. J.A. McKeague. Manual on Soil Sampling and Methods of Analysis, 1978).* The elements Sb, As, B, Se, Co, Cu, Pb, Mo, Ni, Si and Zn were extracted with hot water *(Method 4.61, Hot Water Sol. B – Azomethine-H method. J.A. McKeague. Manual of Soil Sampling and Methods of Analysis, 1978).* The analysis of both the DTPA-TEA and hot water extracts were based on the American Public Heath Assoc. – Standard Methods for Examination of Water and Wastewater, 20th ed., 1998. APHA 3120B, Inductively Coupled Plasma (ICP) method.

Total Se was determined by a hydride AA method on aqua-regia digests.

In this report, discussion and comparisons are based on the hot water extractable B, Mo, and Si; DTPA extractable Ni, Co, Cr and Cd; 0.01 M $Ca(NO_3)_2$ extractable Cl and total Se. Data for all the other elements are presented in Appendices 3 and 4, but are not discussed in this report.

While a single soil test is not always definitive in identifying deficient or toxic levels of nutrients for crops, they are useful in categorizing soils into deficient, marginal and adequate ranges. Whether or not deficiencies or toxicities occur is influenced by soil properties, crop type, and variety and management practices. The micronutrient status of the benchmark sites is discussed in relations to other soil properties, differences among ecoregions, slope positions and management practices. However, it is important to recognize that critical levels are arbitrary. A wide range of critical levels for extractable micronutrients has been reported (Mortvedt et al., 1991). For many of the elements discussed in this report, critical levels have not been established for the methods used.

4.2 Data Analyses

1. Descriptive statistical procedures (mean, median, max, min, standard deviation, etc.) were conducted on the micronutrients plus selected soil properties (Appendix 2). The soil properties used in the analyses were selected from a review of the literature, which

has identified soil properties that affect micronutrient availability. Analysis of variance was conducted using the General Linear Model (GLM) procedure in SAS (1999) to determine if significant differences ($p \leq 0.05$) in micronutrients and selected soil properties occurred among ecoregions, slope positions, etc. Where significant differences were found, Tukey's Studentized Range Test (unbalanced design) was used for mean comparisons ($p \leq 0.05$).

2. The frequency (%) of element concentrations that could by potentially deficient or toxic was reviewed overall and by ecoregion.

3. Correlation:

   - Correlation was used to identify relationships with soil properties and other trace elements.

4. As part of the Soil Quality Benchmark study, the farmer co-operators were asked to complete information sheets on the management history of the sites. This information has not yet been compiled and in some cases is incomplete. A preliminary assessment of the information was undertaken with the following objectives:

   - To determine if cropping history (number of years the land has been cultivated, crop rotation and type, frequency of summer fallow, etc.) influenced micronutrient levels;
   - To determine if management practices (fertilizer rate and type, and manure application) influenced micronutrient levels.