1.0 INTRODUCTION

Soils are dynamic living systems whose quality is dependent on various attributes encompassing the physical, chemical and biological realms. The quality of a soil is best defined in relation to the functions it performs within natural or agro-ecosystems. The basic definition and a broader interpretation of soil quality is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al. 1997).

Soils are the storehouses for water and nutrients, they regulate water flow, can be sources or sinks of carbon dioxide, and can store and degrade substances that can become pollutants. Therefore, soils have considerable direct and indirect impacts on water quality, the global climate and agricultural systems (NRC 1993), making the measurement of soil quality multifaceted.

Since soil quality cannot be determined by measuring only one parameter, it is necessary to rely on evaluation of a range of indicators. Indicators such as texture, permeability, depth, biological activity, the extent to which soil can store water and nutrients, and the amount of organic matter it contains are essential characteristics used to determine the quality of a soil (NRC 1993). An assessment of soil quality provides information about the functional status of a soil at a specific point in time (USDA 2001a). The information acquired from the evaluation can be used to help identify problem areas, areas of special interest, or to compare the effects of varying management systems.

Various methods are available to evaluate soil quality. One such method is the Alberta Soil Quality Card (AAFRD 2003), which is utilized in the field to qualitatively describe and measure farm level indicators. It is a non-technical procedure in which various indicators, such as drainage, crusting, and residue cover, are ranked either low, medium or preferred (unhealthy, impaired, or healthy) based on visual observations of the conditions in the field. No quantitative measurements are taken.

Another method to assess soil quality is the Soil Quality Test Kit (USDA 1999) developed by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS). This easy to use, low-cost kit includes components that quantitatively measure the physical, chemical, and biological soil indicators *in situ*. These tests include bulk density, infiltration rate, aggregate stability, pH, electrical conductivity, and soil respiration. The indicators included in the kit are meant to provide quick results to determine differences in management systems, detect changes in soil quality over time, and diagnose possible soil problems. While the kit encompasses a variety of indicators to evaluate soil quality it leaves out a direct assessment of an essential indicator, soil organic matter. The kit utilizes proxy measures or derivative traits of soil organic matter like infiltration, aggregate stability and slaking.

Soil organic matter, or soil organic carbon (SOC) as it is often reported, is described as being the single most important indicator of soil quality and productivity (NRC 1993). It affects several critical soil functions including aggregation, infiltration, compaction, moisture holding capacity, resistance to erosion, bulk density, and nutrient retention (AAFRD 1985, USDA 2001b). Soil

organic matter is influenced by land management practices and it is vital in agricultural settings. Soil organic matter is composed of a variety of components. These include raw plant residues and microorganisms, well decomposed residues that are considered to be stable or resistant, often referred to as humus, and the active or labile portion (AAFRD 1985, Bowman and Peterson 1997). Measuring soil organic matter provides important information, however, because of the high proportion of recalcitrant carbon, slight changes in soil organic matter due to alterations in soil management are often difficult to detect. The active fraction of soil organic matter is the most highly influenced component and is most directly related to important biological processes in the soil (NRC 1993). Changes in this component may provide a better indication of management impacts on soil quality. The active carbon component consists of microbial biomass carbon, particulate organic matter, and soil carbohydrates (Weil et al. 2003). One way to measure the active carbon pool is to isolate the light fraction portion, which is derived primarily from plant residues but also includes significant amounts of microfaunal and microbial debris (Janzen et al. 1992).

Traditionally, the analysis of soil organic matter in analytical laboratories has been conducted by either dry combustion or wet digestion procedures (Carter 1993, Bowman et al. 1991). Until recently a method that is quick, accurate, inexpensive, and can be carried out in a field setting had not been developed. Two field methods have been proposed to attempt to meet the above criteria, one is a method developed by Weil et al. (2003) to determine the amount of active carbon and the other, developed by Bowman (1997), visually estimates the amount of soil organic carbon.

1.1 Background to Field Methodologies

In a study by Weil et al. (2003) a methodology was developed to test soil samples in the field for active carbon content (Appendix 1.1). The purpose of the study was to test and develop changes to methodology created by Blair et al. (1995) in order to generate a quantitative procedure that was simple, repeatable, and provided reliable results from which to base management decisions. The authors tested various aspects of the procedure outlined by Blair et al. (1995) including molarity of the potassium permanganate solution, shake time, soil-drying properties related to organic matter and tested the repeatability and reliability of the procedures by comparing their results to laboratory results. A 0.2M solution of potassium permanganate ($KMnO_4$) was used, as portions of the soil organic carbon will react with the $KMnO_4$ to reduce the deep purple color of the solution to a lighter shade depending on the amount of oxidizable carbon in the soil. Potassium permanganate is a good indicator and safe for use in the field. The color change of the $KMnO_4$ was measured by a hand-held colorimeter (generic 550 nm colorimeter, Hach® Company, Boulder, CO) (Figure 1).

Weil et al. (2003) determined that the procedure was easy to follow, repeatable, and suitable for use in the field as all the components could be readily transported and employed. The authors found the simplified methodology provided results that were similar to those obtained by using more complex laboratory procedures. Weil et al. (2003) concluded that the newly developed procedure was more sensitive to management effects and related to soil productivity and soil properties, such as respiration, aggregation, and microbial biomass, better than procedures based on measurements of total organic carbon.

Figure 1. Hand-held colorimeter used for methodology of Weil et al. (2003)

A second methodology developed by the United Stated Department of Agriculture (USDA), estimates the amount of soil organic matter using a solution of Basic Ethylenedinitro Tetraacetic Acid, or EDTA (Bowman 1997). Basic EDTA is comprised of sodium hydroxide (NaOH) and EDTA disodium salt (Na_2EDTA) and is described as being relatively safe to handle. The NaOH works by solubilizing the organic carbon and the EDTA chelates metal cations to increase the efficiency of the soil organic matter extraction (Bowman and Moir 1993). The release of soil organic matter is directionally proportional to the intensity of the color of the filtrate. The protocol involves basic steps that are designed to be easy to follow and requires that standards are generated from soils in the general area of study with varying, but known degrees of soil organic matter content (Appendix 1.2). The method relies on qualitative visual comparisons of the colors of standards to the filtrate from each of the soil-EDTA solutions.

2.0 OBJECTIVES

This study has three main objectives:

- Test two field methods using soil samples from across Alberta which vary in management treatments, soil-landscape patterns, and are representative of the agricultural areas of Alberta
- Compare the results of the methodologies to standard laboratory analysis of the same soil to determine reliability
- Determine if the methodologies are realistic for use in the field (i.e. easy to use, applicable in various field conditions, repeatable and if either would be a reasonable addition to the USDA-ARS Soil Quality Test Kit for use in Alberta).

3.0 MATERIALS AND METHODS

3.1 Samples

Soil samples used for the purposes of this study were taken from 41 benchmark sites throughout Alberta. The benchmark sites (Leskiw et al. 2000, Cannon 2002) are located throughout the cultivated areas of Alberta and represent the soil-landscape patterns and agronomic practices of 41 ecodistricts in the province (Figure 2). The benchmark sites are unique in that they encompass a wide array of soil, climatic and vegetative zones. The management systems within the network of benchmark sites vary considerably and include continuous cropping and fallow systems, no-till and cultivation, and various crop rotations, including forages, and have a wide range of organic matter content.

Alberta Agriculture, Food and Rural Development (AAFRD) Regional Conservation teams collected the soil samples used for this study after harvesting had occurred in the fall of 2003, prior to fall fertilization and before freeze-up as part of the annual Soil Quality Benchmark soil sampling. Using DGPS equipment, the benchmark sampling locations are relocated each year. Five to ten cores within 2 meters of the marker at the specific landscape position were taken using a hand sampler. The cores were then bulked, mixed, bagged and labeled. Sub-samples from the upper (0-15 cm) depth of the mid-slope position were taken for this study. The samples were kept frozen until they could be analyzed (Appendix 2). Analysis of the samples for organic carbon was completed at Norwest Labs. The light fraction C analysis was done at the University of Alberta. Prior to analysis, the soils were air-dried and ground to <2 mm diameter (pass through a 20 mesh sieve).

Analysis of the samples for active C content and percent organic matter according to the field methods was completed at the AAFRD Bonaventure shop located in Edmonton, AB. The tests were performed in the main room at the shop and ran from January 13 to March 5 2004. Three replicates of each test were performed on 41 samples, for a total of 123 samples.

3.2 Active C Field Method

We tested specific aspects of the procedure followed by Weil et al. (2003) for variability and made modifications to the procedure based on our findings. These aspects included: readings of standard solutions, the ten-minute settling time, the effects of light and temperature on standard readings, the measurement of soil, and the drying time (Appendix 3).

The procedure we followed was nearly identical to that of Weil et al. (2003). Deviations from the protocol included: testing greater numbers of soils at one time, using 3.91 grams of soil instead of 5 grams, letting the soil-$KMnO_4$ solutions sit for a maximum of 17 minutes, and including a fourth standard solution of 0.015M. For a complete list of materials needed and the detailed protocol refer to Appendix 4.1 and 4.2. Calculations used to determine active C are shown in Appendix 4.3.

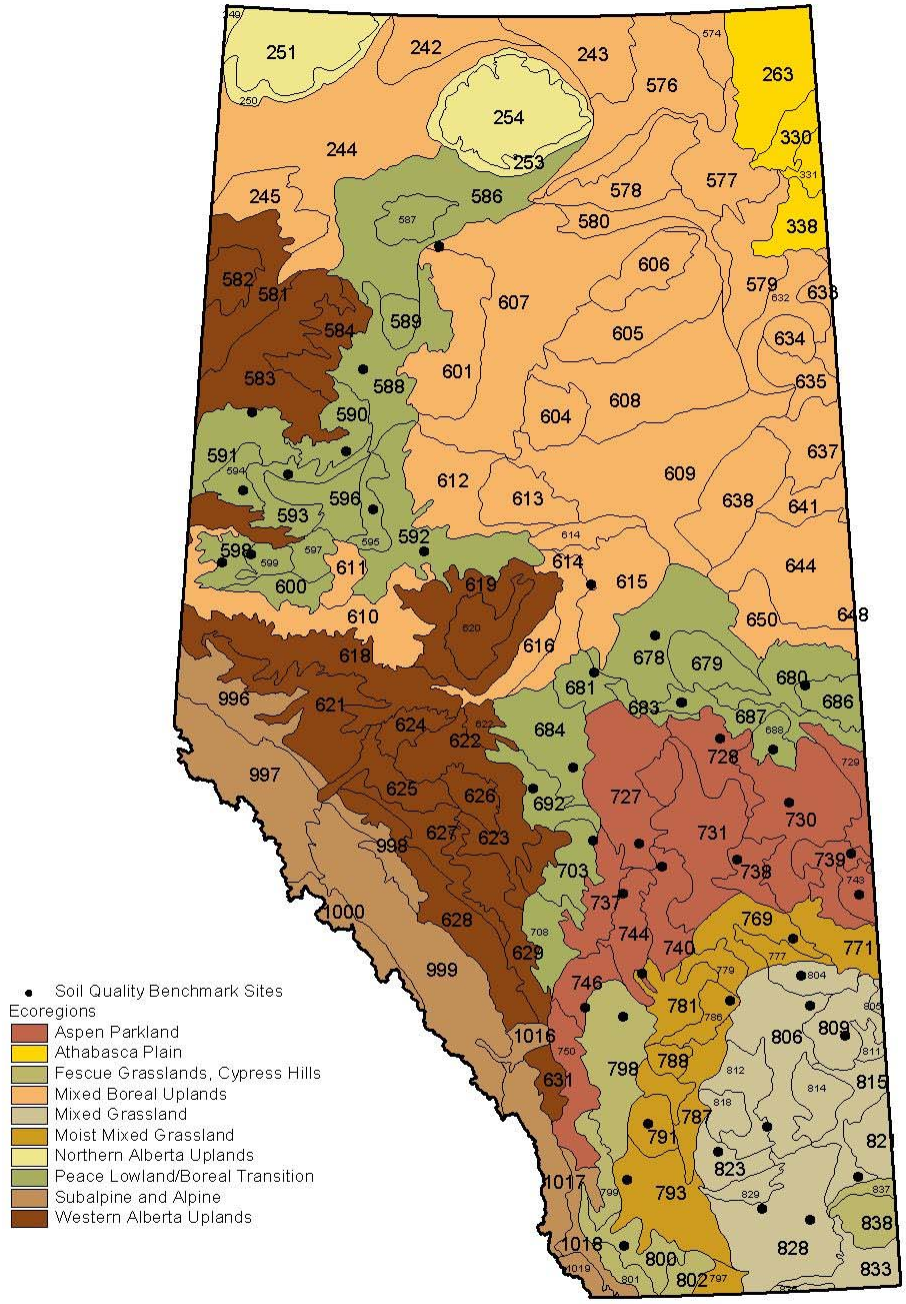

Figure 2. Location of benchmark sites and corresponding ecoregions and ecodistricts in Alberta

3.3 Basic EDTA Field Method

The protocol followed and materials used during this study varied only slightly from the procedure outlined in Bowman (1997). See Appendix 5.1 and 5.2. Samples to be used for the standards were chosen from the 41 benchmark soils. The percent organic matter values from 2001 to 2003 lab results were compared for all samples. Those soils with the values closest to the necessary standard values were selected (Appendix 5.3). We chose to increase the number of standards used for comparison. Instead of preparing four standards (<1%, 2%, 3%, and 4%), we prepared ten (0%, ~1.5%, 2%, 3%, 4%, 6%, 7%, 9%, 10%, and 12%) to encompass the range of organic matter values of the soil samples from Alberta. We also conducted a test to determine the accuracy of the measuring scoop used for this procedure (Appendix 5.4), like the one utilized to test the procedure of Weil et al. (2003).