PRELIMINARY ANALYSES OF FIVE YEARS OF SOIL DATA FROM THE AESA SOIL QUALITY BENCHMARK SITES[1]

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ABSTRACT

The AESA (Alberta Environmentally Sustainable Agriculture) Soil Quality Benchmark Program was established in 1998 to provide a monitoring network across Alberta. From each of 43 Ecodistricts within seven Ecoregions, one site was chosen to represent the soil-landscape patterns and agronomic practices of that Ecodistrict. The sites are within farmers' fields and subject to the farmers' management practices. Soil topographic sequences (upper, mid and lower slope positions) are monitored at each site. Samples taken in 2002 represent the fifth consecutive year of monitoring. Although the overall objective of the benchmarks is to serve as a cross validation dataset across Alberta for soil quality modeling, changes in soil quality over time and the effects of management and soil/landscapes can also be monitored.

Soil properties that tend to change slowly over time (pH, EC, P and K) were fairly consistent from year to year at many of the sites, but at least 3 of the above properties were quite variable at 13 of the 43 sites. The variation from year to year in light fraction (LF) organic matter and NO_3 was high. Significant differences in soil properties occurred across the three slope positions at many of the sites. These important differences would be masked if average values had been obtained from composite samples taken across slope positions (field composite samples).

INTRODUCTION

In recent years, recognition of the importance of soils to environmental management has generated numerous studies of the effects of 'improved' management practices on soil quality. In 1997, the AESA Soil Quality Monitoring Program was initiated to determine the state of soil quality across Alberta and to evaluate the change in soil quality under different management practices. The objectives of establishing the AESA Soil Quality benchmark sites are to provide a cross validation dataset to test and validate simulation modeling, provide baseline soil information, determine landscape and soil quality variability and monitor changes in soil quality over time (Cannon and Leskiw 1999).

Janzen et al. (1998) indicated that two main approaches have been used to evaluate C sequestration in response to changes in management such as measurement of changes in SOC by repeated analysis over time or, quantification of the difference in SOC between a 'new' practice and a control (e.g., no-till vs. conventional tillage). These types of studies are generally conducted using randomized, replicated treatments that allow an estimate of the measurement and sampling error. The approach used in this study was to monitor a wide range of soil properties over a large geographic area. The sites were selected to represent typical soil/landscapes and management practices throughout the province. Changes are to be determined by repeated measurements (annually) over time.

The AESA Soil Quality benchmark sites have been sampled for the past five years. Preliminary analysis of this five-year data block examined the following:

1. Variation in soil properties from year to year within sites to estimate when significant change could be determined.

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2. Differences among Ecoregions [Peace Lowland (PL), Mixed Boreal Uplands (MB), Boreal Transition (BT), Aspen Parkland (AP), Moist Mixed Grassland (MM), Fescue Grasslands (FG), and Mixed Grassland (MG)].
3. Differences among slope positions (upper, mid and lower slopes were sampled at each of the 43 benchmark sites).
4. Effects of management (cropping systems or tillage).

METHODS

Identifying changes in soil quality over time benefits from an assessment of measurement error of the properties being monitored. The greatest source of error in soil testing is generally that associated with sampling. The error associated with laboratory analysis can be readily quantified by repeated analysis. The sampling protocol in this study does not include replicate sampling. (In a study of this scale, replicate sampling would be time consuming and costly). Therefore a direct assessment of sampling error was not possible. In order to estimate sampling error, soil properties such as pH, EC, P, and K were assumed to change only slowly over time compared to NO_3 and LF.

Data were examined from soil samples (0-15 cm and 15-30 cm) taken for soil fertility analysis during the first 5 years of the study. Soil samples are taken in the fall, after harvest, but before freeze-up and prior to fall fertilization. Composite samples of five to ten cores were collected within a radius of two meters from the central marker at each of the landscape positions (upper, mid and lower slope positions). The soil analyses included pH in water (pHw), EC, free lime ($CaCO_3$), NO_3, P, K, S, light fraction (LF) organic matter, and bulk density (BD).

Descriptive statistical procedures [mean, max, min, standard deviation (SD) and coefficient of variation (CV)] were used for initial examination of the data and to evaluate yearly variation in soil properties at each sampling site (upper, mid and lower slope positions at the 43 benchmark sites). Analysis of variance (GLM procedure in SAS) was used to examine differences among Ecoregions, slope positions, and management practices. Years were treated as replicates and SNK was used for mean comparisons when the F test was significant ($p \leq 0.05$).

RESULTS AND DISCUSSION

Variation In Soil Properties

Variability for several parameters at each of the sites within Ecoregions and within slope positions was determined across all five years. As well, variability for each site within separate sampling years was determined across all Ecoregions and slope positions. The mean coefficients of variations (CV) for both NO_3 and LF, within Ecoregions, are higher than for pHw, EC, P, K and BD (Table 1). Similar values of CV occur within slope positions. NO3 variability is high since it varies with growing season conditions, crop removal and fertilizer additions and placement. LF is also variable and because it consists of rapidly cycling organic matter is a measure of organic matter derived from relatively recent additions of crop residue. LF can be affected by cropping systems, tillage and climate conditions. The variability of NO_3 and LF within each sampling year is lower then when compared to the five-year data (Table 1). For example the CV for NO_3 is around 66 within Ecoregions and slope positions, but around 40 within separate sampling years. This suggests that variability from year to year may reflect management and climate conditions as well as sampling variability.

Table 1. Coefficient of variation (CV) for Ecodistricts averaged within Ecoregions, slope positions and years for the past five years for several soil properties (0-15 cm). *(Note: The CV for pH is not directly comparable because pH is a log value).*

Ecoregion	No. of Sites	pHw	EC	P	K	LF	NO_3	BD
PL (Peace Lowland)	**10**	3.2	32	16	20	47	65	9.9
MB (Mixed Boreal Uplands	**1**	5.6	40	43	42	74	104	20.9
BT (Boreal Transition)	**8**	2.5	33	21	20	44	68	10.0
AP (Aspen Parkland)	**9**	4.1	41	27	29	41	64	9.1
MM (Moist Mixed Grassland)	**5**	4.5	33	30	20	46	66	12.2
FG (Fescue Grasslands)	**2**	4.8	40	31	25	80	70	11.4
MG (Mixed Grassland)	**8**	3.5	29	30	26	38	61	9.7
Mean	**43**	**3.6**	**34**	**25**	**24**	**46**	**66**	**10.0**
Slope Position								
Upper	**43**	3.8	36	28	25	45	65	9.2
Mid	**43**	3.4	35	25	23	45	67	9.6
Lower	**43**	3.9	32	23	24	45	65	12.3
Years								
1998	**42**	6.1	29	43	33	37	41	8.3
1999	**42**	5.1	35	42	30	31	45	8.7
2000	**43**	5.4	30	37	26	30	41	9.2
2001	**43**	4.7	29	35	23	28	40	8.5
2002	**43**	5.6	28	36	27	39	39	9.4

Variation from year to year in the more stable soil properties (pHw, EC, P and K) from some sites was much more variable than in others. For example:

- Variability was lowest in the PL and BT Ecoregions, and highest in the AP, FG, and MB Ecoregions (note: there were only two sites in the FG Ecoregion and one site in the MB Ecoregion;
- Several of the properties that are considered stable were quite variable at 13 of the 43 sites;
- 12 of the 13 sites categorized as highly variable were on morainal (till) parent material and one was on fluvial material. Of the 43 sites, 30 are classified as morainal, 6 as lacustrine, and 2 as fluvial lacustrine/morainal.

While the variation among years for the more stable properties was lower than for NO_3, it was still relatively high at many sites, indicating that large changes in these properties would have to occur before significant trends could be detected.

Differences Among Ecoregions

There were relatively few significantly differences in soil properties among the Ecoregions, indicating that differences within Ecoregions were often as large as between Ecoregions (Table 2). Soil properties were averaged across all three landscape positions and corresponding sites for each Ecoregion. There were no significant differences in pHw, EC, NO_3, or P among any of the Ecoregions. LF, OC, and CEC were lower and $CaCO_3$ was higher in the MG Ecoregion than in the other Ecoregions, but there were no differences among the other Ecoregions.

LF in the MG Ecoregion was lower than in the FG Ecoregions. LF in the MB Ecoregion was higher then in other Ecoregions but the MB Ecoregion is represented by only one site, which has some atypical characteristics (the upper slope position is likely on an area where large amounts of straw or brush piles were burned). If sites from the MB and FG Ecoregions are removed from the dataset (because of high variability in LF and having only one or two sites in their respective Ecoregions) then a significant difference in LF across the Ecoregions occurs with LF being significantly lower in the MB Ecoregion compared to other Ecoregions.

Table 2. Effect of Ecoregions on some soil properties[1] (0-15 cm) averaged across all landscape positions for the past five years.

Eco-region	No. of Sites	pHw	EC (dS/m)	NO_3 (mg/kg)	P (mg/kg)	K (mg/kg)	LF (%)	BD (g/cm^3)	CLAY (%)	OC (%)	CEC (meq/100g)	$CaCO_3$ (%)
PL	**10**	6.5	0.57	16	22	248b*	0.69b	1.31ab	36a	3.5a	29a	0.7b
MB	**1**	6.7	0.68	24	39	254b	1.88a	1.08b	16	4.6	21	1.5
BT	**8**	6.4	0.45	8	17	188b	0.72b	1.33ab	26b	3.1a	24a	0.8b
AP	**9**	6.4	0.52	14	22	280b	0.74b	1.31ab	21b	3.5a	25a	0.7b
MM	**5**	6.3	0.48	13	26	380b	0.72b	1.33ab	18b	2.8a	19ab	0.7b
FG	**2**	6.3	0.34	10	24	495a	0.88b	1.29ab	29ab	3.2a	26a	0.7b
MG	**8**	7.3	0.58	9	17	326b	0.37b	1.47a	24b	1.0b	16b	1.7a

[1] pHw, EC, NO_3, P, K, LF and BD sampled every year; OC, clay, CEC, $CaCO_3$ sampled only in the establishment year.
* significantly different between Ecoregions at $p \leq 0.05$

Differences Among Slope Positions

Significant differences in soil parameters among slope positions were observed for pH, NO_3, P, K, OC, BD, and clay (Table 3). In this case, soil properties were averaged across all 43 sites within the province. Generally, the lower slope position is significantly different from the mid and upper slope positions. There were no significant differences among slope positions for LF, CEC, or $CaCO_3$ (Table 3). Again, if the sites from the MB and FG Ecoregions are removed from the data set, then there is a difference in LF with the lower slope position having a significantly higher LF value than the upper and mid slope positions.

In contrast to Ecoregions where relatively large differences were not significant, relatively small differences among slope positions were often significant. For example, the mean pH of sites in the MG Ecoregion (7.3) was not significantly different from the MM Ecoregion (6.3), but the mean pH of upper slopes (6.7) was significantly higher than for the mid and lower slopes (6.5) [Tables 2 and 3]. Mean soil properties were averaged across all sites when looking at slope positions, and averaged across all slope positions and corresponding sites when looking at Ecoregions.

Effect Of Management

There were no significant effects of cropping system or tillage on the soil properties measured, except that LF was higher on tilled than on minimum or no-till sites. This is opposite to what would be expected. Factors other than tillage, such as cropping systems and climate, can affect LF.

Table 3. Effect of slope position on some soil properties[1] (0-15 cm) averaged across all sites for the past five years.

Slope Position	pHw	EC (dS/m)	NO_3 (mg/kg)	P (mg/kg)	K (mg/kg)	LF (%)	BD (g/cm^3)	Clay (%)	OC (%)	CEC (meq/100g)	$CaCO_3$ (%)
Upper	6.7a*	0.55a	10.6b	19b	261b	0.180a	1.38a	27b	2.34b	22.4a	1.08a
Mid	6.5b	0.48a	11.8b	18b	257b	0.188a	1.35a	25a	2.72b	22.3a	0.80a
Lower	6.5b	0.54a	13.8a	26a	326a	0.206a	1.26b	26a	3.50a	24.2a	0.79a

[1] pHw, EC, NO_3, P, K, LF and BD sampled every year; OC, clay, CEC, $CaCO_3$ sampled only in the establishment year.

* significantly different between slope positions at $p \leq 0.05$

SUMMARY

The inherent spatial variability of soil properties (both within defined soil/landforms as seen in variation among individual cores or composites of a small number of cores; or larger scale variability across soil/landforms) creates difficulties in identifying change. If variation among samples taken from the same sampling location is high, then large changes in soil properties must occur to identify a significant trend.

In field experiments where differences in management practices are imposed in a randomized and replicated pattern, a minimum of 5 to 10 years is often required to identify significant changes in soil properties. Field plots are designed to eliminate or minimize soil variability in order to isolate treatment effects. Conversely, the design of the benchmarks to include landform differences can result in relatively high variability in the data from the benchmark sites. Therefore, it will likely take more than 10 years to detect significant changes in soil properties. By encompassing variability into the benchmark design, the resulting database can be used in the validation of modeling efforts and for use in scaling up agronomic and soil quality information to a provincial scale.

Data from the 43 AESA benchmark sites have revealed differences in several parameters within different Ecoregions and within slope positions. Within Ecoregions, differences in OC, LF, K, BD, Clay, CEC and $CaCO_3$ were observed. Within landscape positions, differences in pHw, NO_3, P, K, OC, LF and BD were observed. The importance of landscape sampling can't be emphasized enough since average values from composite samples taken across slope positions would not have demonstrated significant differences for several soil parameters.

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ACKNOWLEDGEMENTS

The authors would like to thank the AESA Program for funding in establishing the provincial soil quality benchmark site program. We also acknowledge Jody Winder for her help in data management and in preparing tables and figures. Finally, we want to thank the owner/operators of the benchmark sites and the AESA Regional Conservation Teams for their continuing participation in the success of the benchmark program.