Evaluating Soil Quality at Different Scales

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Introduction

Over the last several years there has been an increasing interest in soil quality. Conceptually, soil quality has been widely accepted; however, the practical matter of evaluating soil quality on the landscape level is not well understood. Most of the dialog on soil quality has centered on defining sensitive indicators to monitor soil quality on an agricultural field basis. This is a good start, however, there is interest in evaluating larger landscapes such as watersheds and to evaluate larger ecosystems such as rangelands. The problem is collecting enough samples to represent the area of interest. This problem is compounded for soil quality analysis since several parameters, making up a minimum data set, are thought to be needed to properly evaluate soil quality. It is well known that soil parameters are spatially variable, though it would be useful information to know if this variability is scale-dependent.

Methodology and Results

This paper is intended to provide an example of how soil quality parameters vary over two different scales. We intensively sampled (n=220) a 0.5 ha wheat field and an entire 60 x 65 km county (n=157) using a similar grid pattern. We present here some chemical and biological data for each area sampled. Table 1 gives the basic statistics for both the field (A) and the county (B) areas. For the field area the mean values were similar to the median values indicating fairly normal distribution of values. The variability among the samples as indicated by the coefficient of variation (%CV) was highest for nitrate concentrations (79%) and lowest for pH (4%). For the county area most of the parameters showed significant positive skewness and the means were significantly different than the median values for nitrate, soil microbial biomass (SMB) and dehydrogenase activity (TPF). The variability (%CV) of the county values were significantly higher than those of the field area ranging from 12 to 196 percent over the 60 x 65 km area. However, the mean values for pH, electrical conductivity (EC) and SMB were fairly similar for both the field and county areas.

Table 1: Variability of Soil Parameters in A) a 50 x 100 m Wheat Field (n=220) and B) across a 60 x 65 km County (n=157).

Statistics	Soil Parameters				
	PH	**EC**	**NO_3^-**	**SMB**	**TPF**
Wheat Field (A)					
Range	4.5-5.9	1.1-10.3	0.5-34.7	154-1169	2.1-25.6
Mean	5.3	1.9	5.5	546	9.5
Median	5.3	1.8	4.5	536	8.0
Std.dev	0.2	0.7	4.3	180	5.0
%CV	4.0	37.2	78.9	33.1	52.0
Skewness	-0.4	7.8	3.7	0.2	0.8
County Area (B)					
Range	4.5-8.2	0.5-11.2	0.6-277	20-1308	5.5-128
Mean	6.0	1.9	15.7	458	36.4
Median	5.8	1.6	8.1	176	31.3
Std.dev	0.7	1.3	31.0	99.9	18.8
%CV	11.5	67.2	196	53.2	51.6
Skewness	0.8	4.5	5.7	1.0	1.6

Electrical conductivity (EC), dS/m
Inorganic N (NO_3^- and NH_4^+), µg N/g soil
Soil microbial biomass (SMB), µg C/g soil

Table 2 shows the correlation between the measured parameters for both the field and county soil samples. For the field site there was good correlation between EC and nitrate and between SMB and pH and TPF. The pH correlated, either positively or negatively, with most of the measured parameters. The county samples showed similar correlations as the field samples with respect to pH. Nitrate showed a very strong correlation with EC. In general the correlations between measured parameters at both scales were similar in magnitude.

Table 2: Pearson Correlation (r) Matrix for Parameters from A) a 50 x 100 m Wheat Field and B) a 60 x 65 km County Area.

Soil Parameters	Soil Parameters				
	PH	EC	NO_3^-	NH_4^+	SMB
Wheat Field (A)					
EC	-0.29				
NO_3^-	-0.37	0.23			
NH_4^+	-0.01	0.01	0.28		
SMB	0.40	-0.08	-0.12	0.15	
TPF	0.28	-0.09	0.09	0.25	0.62
County Area (B)					
EC	-0.11				
NO_3^-	-0.28	0.88			
NH_4^+	-0.22	0.44	0.51		
SMB	0.42	0.14	0.05	-0.03	
TPF	0.25	-0.11	-0.01	0.04	0.26

Electrical conductivity (EC), dS/m
Inorganic N (NO_3^- and NH_4^+), µg N/g soil
Soil microbial biomass (SMB), µg C/g soil
Dehydrogenase activity (TPF), 10-5 µmol TPF/g soil/min.

Figure 1 shows the variability of soil pH and SMB across the wheat field at a scale of meters. There are some distinct zones for each parameter possibly related to small scale physiographic changes in the landscape. In the first 50 m Easting of the field, pH and soil microbial biomass are very well correlated, but then become less correlated as the Easting distance increases. Soil microbial biomass shows a significant band of high values diagonally across the field to about Easting 60 m.

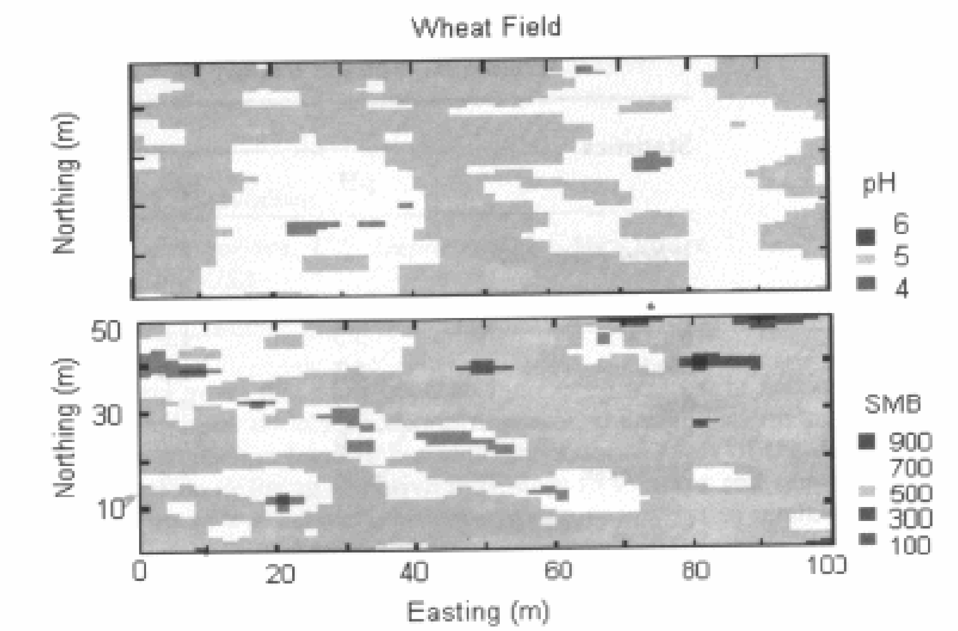

Figure 1: Soil pH and Soil Microbial Biomass (SMB) Levels across a 0.5 ha (50 x 100 m) Wheat Field.

Figure 2 shows the same parameters (pH and SMB) across the county area at a scale of kilometers. The soil pH values showed broader zones and much more variability at the kilometer versus the meter scale. There were no distinct patterns of SMB at the kilometer scale, but the low and intermediate value tended to associate with areas of higher pH. The higher SMB values were distributed randomly over the 60 x 65 km area.

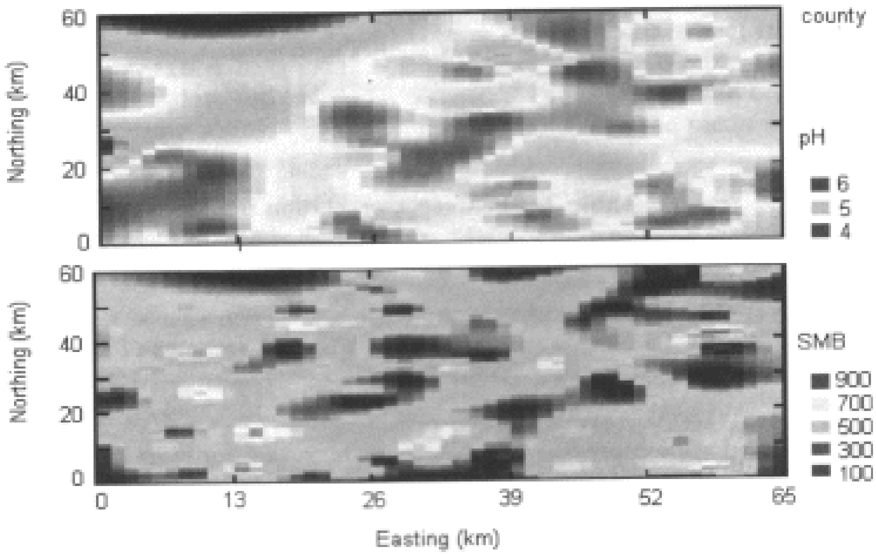

Figure 2: Soil pH and Soil Microbial Biomass (SMB) Levels across a 60 x 65 km County Area.

Discussion

With respect to this soil quality assessment, it should be emphasized that the intended use of the land and its scale will be important in determining what parameters are measured and what importance is assigned to the measurement. Field scale measurements of specific parameters are influenced by local climate and topography as well as specific management. However, watershed or county scale parameters may be influenced by precipitation zones, different parent material, regional patterns of management, landforms and even vegetation.

The idea that we should sample on the scale of interest may not seem appropriate in the context of soil quality. We are ultimately interested in landscape or watershed scales; however, the soil quality index or description may need to be an integration of smaller scales, but it is not known whether this improvement will translate to county or water-shed scales since the large scale tends to mask localized variability.

At any scale, the variability of soil parameters will affect the number of samples required to estimate summary statistics with a degree of precision and certainty. If the spatial dependence is known the number of samples can be reduced.

Conclusions

The conclusions that we may draw from the data presented in Tables 1 and 2 and Figures 1 and 2 are that biological parameters seem to be relatively stable over different scales but that the chemical parameters double their variability over increasing scales. In addition, mean values may be similar but the spatial distributions may be significantly different. It is for this reason that the scale of interest is important in determining how to evaluate soil quality.

From the data presented, the spatial dependence varies with scale and within large scales, thus, complicating the estimation of sample size. The basis of a successful assessment of soil quality will be a sampling strategy that captures the characteristic of different variables at appropriate spatial scales. Sampling scale is important because patterns of soil quality may change from fine to broad scales. Detailed estimates of soil quality are necessary since we are interested in the change of soil quality over time.