Determining minimum data set for soil quality assessment of organic farming system in Korea

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Abstract
Soil quality is the most important factor for crop production and consequently soil quality assessment is necessary for organic farming systems because of limited usage of fertilizer. For this reason, a minimum data set (MDS) was determined with principle component analysis (PCA) for soil quality assessment in organic farming and soil quality was evaluated based on normalized scoring function. Among other soil properties, NH_4-N, NO_3-N, pH, EC, and water contents were chosen as a MDS for soil quality assessment in organic farming system. In addition, the result of soil quality evaluation with normalized scoring function in examined organic farming revealed that 85% of organic farming soil was within the optimum range for soil pH while only 30% for EC and 15% for orthophosphorus were within the optimum range. Therefore, adequate management for EC and orthophosphate are necessary to enhance the soil quality in study area. The result of this study could provide general guideline to manage organic farming systems.

Key Words
Organic farming system, soil, minimum data set, scoring function, management.

Introduction
Organic farming systems have been mainly initiated since 1990s due to environmental and health concerns for conventional farming system (Monokrousos *et al.* 2006). In organic farming systems, plant production mainly depends on nutrient transformation in soil because only a limited amount of fertilizer is used. Therefore, evaluation of soil quality including physicochemical and biological properties is necessary for organic farming systems. However, the evaluation of soil quality is a quite complex and also time and labour intensive (Wander and Bollero 1999). For this reason, the main objectives of this research were i) determining minimum data set (MDS) for evaluating soil quality of organic farming system using multivariate analysis and ii) developing scoring function for soil quality assessment of organic farming system in Korea.

Methods
Soil sampling
Soil samples were collected from 8 locations where organic farming systems have been adopted for crop cultivation. Surface (0-15cm) and subsurface (15-30cm) soils were collected at each sampling event and a total of 3 sampling events (May, July, October) were conducted in 2009. Collected soil samples were completely air dried at 25℃ and ground to pass through a 2 mm sieve for chemical and biological analysis.

Soil analysis
Soil density, soil temperature, and infiltration rate were measured in field and soil texture was determined using the hydrometer method. For soil chemical analysis, soil organic carbon (SOC) was determined following Walkley-Black method and total nitrogen and available phosphorus were measured using the Kjeldahl method and ascorbic acid methods respectively. In case of soil biological analysis, soil microbial biomass C (MBC) was measured by the fumigation incubation method of Jenkinson and Powlson (1976). Soil microbial biomass N (MBN) was determined by the fumigation extraction method using a factor of 0.54 (Brooks *et al.* 1985). Methods of soil analysis are summarized in Table 1.

Multivariate analysis
Multivariate analysis was performed to determine the minimum data set (MDS) for soil quality assessment in organic farming system. All measured soil properties were compared with principle component analysis (PCA) and only factors with eigenvalues > 1 were used. Statistical analysis was conducted using SAS version 9.1 software (SAS institute 2002-2003).

Table 1. Physicochemical and biological analysis methods for soil.

Parameters	Method	Instrument
Soil texture	Hydrometer method	
pH	1:5 (solid:water)	pH meter
EC	1:5 (solid:water)	EC meter
Soil organic matter	Walkley-Black method	UV/Vis Spectrophotometer
Total nitrogen	Kjeldahl method	Automated Kjeldahl distillater
Available phosphorus	Ascobic acid method	UV/Vis Spectrophotometer
Cation exchange capacity	1M NH4OAc (pH 7.0)	Atomic Adsorption Spetrometer
Soil microbial biomass C	Fumigation incubation method	
Soil microbial biomass N	Fumigation incubation method	

Scoring function

General scoring function was adapted from previous study (Karen and Stott, 1994). In this study, normalized scoring curves were developed based on normalized indicator parameters. Normalized score equation is shown in Eq. 1. Using the normalized scoring curve, three types of standardized scoring function was generated: i) more is better, ii) less is better, iii) optimum depending on soil properties (Table 2). In order to develop normalized scoring curve, total of 1,650 upland soil properties were used.

$$\frac{1}{[1+((B-L)/(x-L))^{2S(B+x-2L)}]} \qquad (1)$$

Where B: the baseline value of the soil property, L: lower threshold, S: slope of the tangent to the curve at the baseline, x: soil property value

Table 2. Scoring system of soil properties.

More is better	Optimum	Less is better
Infiltration rate, Soil organic Matter, Cation exchange capacity, etc.	pH, EC, Avail.-P_2O_5, etc.	Bulk density, Erosion, etc.

Results

Soil analysis

Average values of soil physicochemical and biological properties are summarized in Table 3 and 4. Soil texture was generally sandy clay loam for all sampling sites and soil density ranged 0.87-1.72 Mg/m^3. Soil pH at all sampling sites was weak acidic condition except for sampling site E and the highest EC, TN and CEC were measured at sampling site C.

Table 3. Physical properties of soil at sampling sites.

Sites	Particle size distribution (%)			Soil density	Water contents	Temperature	Infiltration rate
	Sand	Silt	Clay	Mg/m^3	%	□	cm/sec
A	53.04	25.09	21.87	1.34	20.32	25.30	7.1 x 10^{-5}
B	62.92	19.42	17.66	1.00	23.56	24.30	7.3 x 10^{-3}
C	63.80	15.51	20.69	1.63	22.04	18.40	4.5 x 10^{-5}
D	82.32	5.89	11.79	1.72	12.08	23.30	2.9 x 10^{-3}
E	58.47	38.09	3.44	0.87	21.66	22.20	3.8 x 10^{-2}
F	57.07	36.37	6.56	0.91	18.36	23.20	9.2 x 10^{-3}
G	68.87	24.57	6.56	1.19	16.12	25.50	3.5 x 10^{-3}
H	18.97	62.32	18.72	1.20	12.17	24.30	7.0 x 10^{-3}

Table 4. Chemical and biological properties of soil in sampling sites.

Sites	pH	EC	TN	SOM	CEC	P_2O_5	MBN	MBC
		dS/m	mg/kg	%	$cmol_c$/kg	mg/kg	mg/kg	
A	6.70	0.43	1,731.9	3.90	11.86	137.48	37.85	22.47
B	5.78	1.09	1,968.5	4.29	13.69	169.24	23.28	7.05
C	5.24	5.15	4,277.5	6.81	28.25	215.44	49.00	6.09
D	6.11	1.74	1,938.9	3.00	12.92	94.76	31.15	5.79
E	7.43	0.32	866.5	6.88	14.89	68.16	25.43	15.09
F	6.03	0.72	2,989.0	6.55	19.07	78.95	27.78	28.29
G	5.02	0.90	2,630.5	6.16	16.58	306.54	16.65	29.35
H	6.74	0.25	3,825.5	7.42	14.66	173.64	17.38	28.25

Minimum data set determination

The result of principle component analysis (PCA) is shown in Table 5. Considering factors with eigenvalue > 1, factor 1, 2 and 3 were selected for soil quality indicator and cumulative percentage for the first 3 accounts 84% of the total variance. In factor 1, NH_4-N (0.78) and NO_3-N (0.85) showed high positive loading indicating that nitrogen measurement might be necessary for soil quality assessment. In factor 2 and 3, pH (0.83), EC (0.67), and water contents (0.79) showed high positive loading indicating that those soil properties should be considered for soil quality assessment in organic farming systems.

Table 5. Result of PCA with physicochemical properties of soil.

	Factor 1	Factor 2	Factor 3	Factor 4
Eigenvalue (%)	3.62	1.87	1.23	0.65
Proportion (%)	0.45	0.23	0.15	0.08
Cumulative (%)	0.45	0.68	0.84	0.92
pH	-0.34	0.83	-0.01	-0.29
SOM	-0.95	0.13	0.09	0.09
EC	-0.60	0.67	0.02	0.01
Water contents	0.16	-0.38	0.79	-0.42
NH_4-N	0.78	0.51	0.11	-0.11
NO_3-N	0.85	0.46	0.06	-0.12
P_2O_5	-0.51	-0.29	-0.54	-0.58
CEC	-0.80	0.07	0.54	0.05

Normalized scoring function for soil quality assessment

In order to assess soil quality in organic farming system, the normalized scoring function was calculated using Eq. 1 and scoring function parameters were estimated with measured soil properties of upland soils (Table 6). Considering optimum score is 0.5 in normalized scoring function, the result of soil quality assessment in organic farming system showed that 85% of soil was within the optimum range for pH while only 30% of soil satisfied the optimum range for EC. In case of P_2O_5, only 15% of examined soil was within the optimum range and lower scoring of P_2O_5 was observed for the rest of 85% soils (Figure 1). This result indicated that management for EC and P_2O_5 in organic farming systems is necessary for better crop production.

Table 6. Estimated scoring function parameters for normalized scoring function calculation.

Parameters	LT	UT	LB	UB	Slope
pH	3.30	8.40	5.3	6.5	1.30
EC	0.01	9.50	0.3	0.8	2.23
P_2O_5	4.50	2,275.0	310.0	750.0	0.05
CEC	0.02	90.50	20.0	45.0	0.12
OM	0.50	234.50	16.0	30.0	0.01

LT: Lower threshold, UT: Upper threshold, LB: Lower baseline, UB: Upper baseline

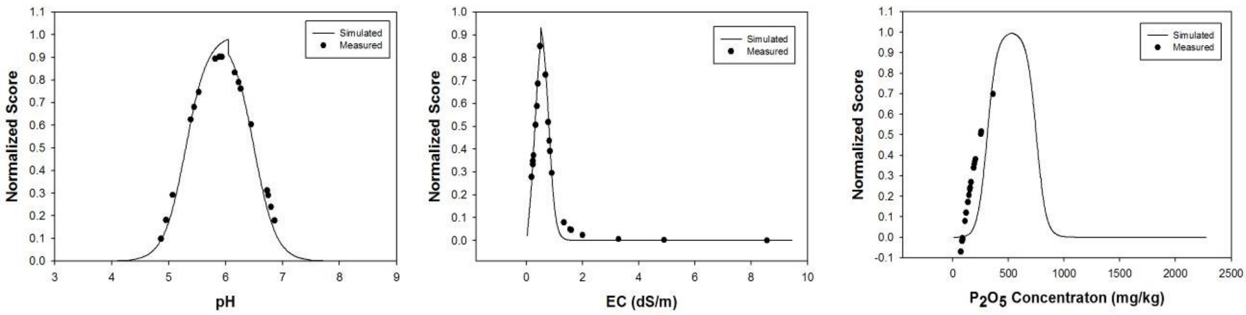

Figure 1. Result of soil quality assessment with normalized scoring function in organic farming systems.

Conclusion

Minimum data set (MDS) was determined with principle component analysis (PCA) for soil quality assessment in organic farming. The result of PCA showed that among other soil properties, NH_4-N, NO_3-N, pH, EC, and water contents are need to be considered for soil quality assessment. Furthermore, soil quality was evaluated with the calculated scoring function and the result revealed that 85% of organic farming soil was within the optimum range for soil pH. However, only 30% for EC and 15% for phosphorus were within the optimum range. This result indicated that management of EC and phosphorus are necessary for better crop production. Overall, the result of this study could provide general guideline to manage organic farming system.

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