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A Morphology Index for Soil Quality Evaluation of Near-Surface Mineral Horizons

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ABSTRACT

We present a soil quality morphological index for the uppermost 30 cm that combines structure, rupture resistance, dry crust strength and thickness, and surface-connected macropores. Raindrop impact crust reduces the index and surface-connected macropores or cracks increases the index as depth increases. A number is obtained between 0 and 100. The soil is at or above field capacity. Properties are each placed in one of 5 classes of soil quality. Rupture resistance compared to structure is more important for coarser textures. An index is computed for each 10 cm subzone. The 0-30 cm index is based on weighting the 10 cm zones 4, 2 and 1 with increasing depth.

INTRODUCTION

We present a protocol for the morphological evaluation of the near surface that would be implemented by field soil survey personnel to obtain information for soil quality evaluation. For several reasons, near-surface field soil morphology has not been actively applied to soil quality evaluation: (1) soil quality as a discipline has been largely developed outside of the soil survey; (2) the data base of the National Cooperative Soil Survey does not recognize land use unless soil classification changes; (3) for cultivated soils, it is common to recognize only one horizon to the depth of tillage; (4) soil survey personnel focus closely on mapping and/or implementation of NRCS programs; and (5) protocols for applying morphological information to soil quality are largely unavailable. This last reason is the focus of this paper.

THE PROTOCOL

The near surface in the context here is from the mineral soil surface to 30 cm or to a root restrictive layer if shallower. Structure, moist rupture resistance, raindrop impact crust, and surface connected macropores and cracks are the diagnostic properties. All features and measurements used are from the Soil Survey Manual (Soil Survey Staff, 1993). All layers except the crust must be *moderately moist* or wetter. Layers within the 30 cm depth zone should be recognized wherever there is a change in the quality class of a feature. In order for a freshly tilled zone to be considered, at least 50 mm of water must have passed through it after tillage, and all parts must have alternated at least once between *wet or very moist* and *slightly moist or dry*. Five quality classes are provided for each of the morphological properties. The class sets are ranked with 5 being the best and 1 the worst. The class sets are combined following rules to be discussed later to produce a 2-digit index number between 1 and 5 (e.g., 4.2). Index numbers may be expressed to a 100 base: $Index_{100} = 100 - ((5\text{-}Index_5) \times 25)$.

Four classes of texture designated A through D are used for our purpose: (A) Sand, Loamy sand; (B) Not A and Clay <18%; (C) Clay 18-40%; and (D) Clay ≥40%. Skeletal is the same as non-skeletal and fragmental is not considered.

Structure and rupture resistance are combined to obtain the placement for the sub zone. The relative weight for structure is decreased as texture becomes coarser because maximum structural expression decreases and is less diagnostic of soil quality. The rules for combining structure and rupture resistance class placements are:

Textural Class	Rule
A	Use rupture resistance only
B	Use whichever the higher class placement of the two properties
C	Weight structure twice rupture resistance except, if *very friable*, then use rupture resistance alone.
D	Use structure class.

Tables 1 and 2 contain the classes for structure and rupture resistance. Two aspects of the classes for structure need elaboration: First, *very coarse* platy irrespective of rupture resistance is placed in class 1. For other sizes of platiness, if horizontal rupture resistance is *very friable*, the placement is class 3; if *friable*, class 2; and if stronger than *friable*, class 1. Secondly, if a sub zone from the surface to 5 cm or less has weak structure or massive conditions, *very friable* is designated 2 rather than 5. The reason is that commonly after appreciable precipitation freshly tilled soils with weak aggregate stability tend to exhibit massiveness or weak structure and *very friable* rupture resistance. The combination is conducive to water erosion and perhaps wind erosion. Therefore, for this surficial zone up to 5 cm in thickness the class of *very friable* is reduced.

Table 3 contains the classes for air-dry raindrop impact crust. The specimen is a plate 1 to 2 cm on edge and 0.5 cm thick. Thickness pertains to the portion of the crust specimen that has been reconstituted and is massive. Stress is applied parallel to one of the two larger dimensions. In addition to the test on the air-dry crust, the moist crust in place is a subhorizon. Freeze-thaw crust is not considered because the

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Table 1. Soil quality classes of structure while *moderately moist* and *wetter*.

Class	Criteria
1.	All structures with common or many stress surfaces irrespective of other features, massive, platy with firm or stronger horizontal rupture resistance, all weak structure except granular, moderate very coarse prismatic, all columnar.
2	All structures with few stress surfaces irrespective of other features, platy with friable horizontal rupture resistance, weak granular, moderate very coarse and coarse blocky and coarse and medium prismatic, strong coarse and very coarse prismatic.
3	No stress surfaces, platy with very friable horizontal rupture resistance, moderate medium blocky and very fine and fine prismatic, strong very coarse blocky and medium prismatic.
4	No stress surfaces, moderate granular, moderate very fine and fine blocky and very fine prismatic, strong fine prismatic and coarse blocky.
5	No stress surfaces, strong granular, strong very fine through medium blocky and very fine prismatic.

If the structure is described as "parting to" use the stronger of the two structures. If intermediate structure classes are described, use intermediate classes here.

Table 3. Soil quality classes for crust based on thickness of the reconstituted zone, and the dry rupture resistance subdivided on texture class.

Thickness Reconstituted Zone	Dry Rupture Resistance (in Newtons): Very Weak - <1N			Weak – 1 to 3N			Moderate, Moderately Strong, Strong – 3 to 40N			Very Strong, Extremely Strong - ≥40N		
	Texture Class			Texture Class			Texture Class			Texture Class		
	A	B, C	D	A	B, C	D	A	B, C	D	A	B, C	D
mm												
<1	5	5	5	5	5	4	4	4	3	4	3	3
1-2	5	5	5	5	4	3	4	3	2	3	2	2
2-4	5	5	5	4	3	2	3	2	1	3	2	1
4-8	5	5	4	4	3	2	3	2	1	2	1	1
8-20	5	5	4	4	3	2	3	2	1	2	1	1
≥20	5	4	3	4	2	1	2	1	1	2	1	1

Table 2. Soil quality classes of moist rupture resistance.

Texture Class	Moist Rupture Resistance[†]: Loose	Very Friable	Friable	Firm	Very Firm & Stronger
A	2	3	3	2	1
B	3	4	3	2	1
C	4	5	3	2	1
D	5	5	3	1	1

[†]If continuously from the surface downward *very friable* and structure in classes 1 or 2, place in class 2. Depth for adjustment ≤5 cm.

associated cracks should increase the infiltration rate.

Table 4 gives the classes for surface-connected macropores. The water state at the ground surface should be *moderately moist* or wetter. The macropores must exceed 2-mm diameter at the ground surface and must exceed 0.5 mm to 10 cm. Surface-connected cracks (table 5) must be present after the near surface has been moderately moist or wetter continuously for 1 week or more and have a depth, as measured by gentle insertion of a blunt 2 mm diameter wire, exceeding 10 cm. The higher of the class placement for macropores or for cracks is used. The adjustment is made over the upper 20 cm. The increase in the index cannot exceed 2.0.

Table 6 contains illustrative observations for crust and surface features and table 7 contains a hypothetical example of the calculation of the overall 0-30 cm index. The structure-rupture resistance index (SRI) is the first indice. The second index (SRCI) includes crust and the

Table 4. Soil quality classes for surface-connected macropores.

Class	Abundance, Size
1	Few or no medium, coarse, or very coarse
2	Common medium or coarse
3	Common coarse and very coarse
4	Many medium or coarse
5	Many coarse and very coarse

Table 5. Soil quality classes for surface-connected cracks.

Class	Areal Percent
1	<0.5 percent of the area
2	0.5-1 percent of the area
3	1-2 percent of the area
4	2-5 percent of the area
5	≥5 percent of the area

Table 6. Hypothetical illustrative soil quality input of crust and surface features.

Feature	Observations	Class
Raindrop impact Crust	Class C texture 10 mm thick Moderately Strong	2.0
Surface-connected macropores	Many Medium and coarse	4.0
Surface-connected cracks	<0.5 percent of area	1.0

Table 8. Comparison of the morphology index for traffic and non-traffic interrows in a long term controlled traffic experiment.†‡

Depth	Structure, Rupture Resistance	SRI§
cm	**Non-Traffic**	
0-3	Moderate to weak fine granular, Very friable	3.7
3-6	Moderate very fine subangular, Very friable	4.3
6-14	Moderate to strong, fine blocky, Friable	4.0
14-20	Moderate fine to medium blocky, Friable	3.3
20-25	Moderate fine blocky, Very Friable	4.3
25-30	Moderate fine blocky, Very Friable	4.3
0-10		4.0
10-20		3.6
20-30		4.3
0-30		3.9 (73)
	Traffic	
0-3	Strong very coarse platy, friable	1.7
3-18	Massive, Firm	1.3
18-22	Moderate medium to coarse blocky, Firm	2.3
22-30	Moderate Fine blocky, Very friable	4.3
0-10		1.4
10-20		1.5
20-30		3.9
0-30		1.8 (20)

†At Rogers Farm, University of Nebraska, located in Southeast Lancaster County (Brown, et al., 1980). The soil is Wymore, an Aquertic Argiudoll, fine, smectitic, mesic. The map unit is ShD. All parts 0-30 cm are fine-silty or fine. The observations were made 7/19/97.

‡Ksat by a constant-level borehold device (Amoozegar and Warrick. 1986. Methods of Soil Analysis). Water column 10-25 cm. For traffic 0.10 cm hr^{-1} and for non-traffic 5.8 cm hr^{-1}.

§Structure-Rupture Resistance Index. Raindrop-impact crust, macropores, and cracks not present.

Table 7. Illustrative hypothetical soil quality record.

Depth (cm)	Horizon	Texture Class	Structure/Rupture Resistance	Indices† SRI	SRCI	SRCSI‡
0-1	Crust (Ap_1)	C	Massive, Friable	1.7	1.7	2.9
1-2	Ap_2	C	Moderate Fine Granular, Very Friable	4.3	3.2	3.6
2-5	Ap_3	C	Moderate Very Fine Subangular, Very Friable	4.3	3.2	3.6
5-10	Ap_4	C	Weak Medium Blocky, Friable	1.7	1.7	2.9
10-18	Ap_5	C	Moderate Coarse Blocky, Firm	2.0	2.0	2.0
18-24	AB	D	Moderate Medium Blocky, Friable	3.0	2.5	2.5
24-30	Bt	D	Strong Very Fine Blocky, Very Friable	5.0	3.5	3.5
0-10				2.7	2.3	3.2
10-20				2.2	2.1	2.1
20-30				4.2	3.1	3.1
0-30				2.8 (45)	2.3 (33)	2.9 (48)

†SRI--Structure-rupture resistance index; SRCI--Structure-rupture resistance-crust index; SRCSI--Structure-rupture resistance-crust-surface features index.

‡Assume macropores and/or cracks extend to 18 cm and hence make adjustments to 10 cm.

third (SRCSI) surface-connected features as well as crust.

The structure/rupture resistance index (SIR) is calculated using data in Table 6 by the previously given rules of combination of structure and rupture resistance. It may then be adjusted first for crust and next for surface-connected features. For the index inclusive of the crust (SRCI), the first step is to subtract the crust placement from that for structure and rupture resistance combined (SRI). Negative or zero differences are ignored. Half of positive differences are subtracted from SRI over 0 to 30 cm.

The structure-rupture resistance-crust index (SRCI) next is subtracted from the surface-connected features index as obtained from Table 6. Half of positive differences are added to the structure-rupture resistance-crust index to obtain SRCSI. The increase from incorporation of the surface-connected features cannot exceed 2.0 units and is applied through the upper 20 cm or to 10 cm if the features do not reach 20 cm.

Finally, an overall index is computed from the constituent layers 0 to 30 cm (Table 7). Weighted averages are calculated for the three 10 cm zones or for the total thickness divided by 3 if there is a root restriction above 30 cm. Next the indices for the three zones are weighted 4, 2, and 1 with increasing depth and the weighted average computed for 0-30 cm. Report as 1.0 to 5.0 index to the nearest 0.1 or on a 100 base.

DISCUSSION

Table 8 compares the morphology index for traffic and non-traffic rows within a long term controlled traffic experiment. The indices of 73 and 20 are about the maximum range encountered for the soil studied and similar associated soils under cultivation.

Two studies are indicative of the expected morphology index for the northern Great Plains. One study is in northeast Colorado and the other is in southeast Nebraska. The soils in Colorado are most commonly Argiudolls with loam surface horizons. Winter wheat is the predominant crop. Measurements were made on 9 soil series in the spring and the fall over 2 ½ years for a total of 38 measurements on cropland. The mean index was 47. In southeast Nebraska, the Aksarben soil has been studied, which is a Typic Argiudoll with a silty clay loam to silty clay surface horizon. Eight measurements were made in the early spring after soybeans, each in a different field. The mean index is the same as for Colorado.

Weighting of the three 10 cm zones 4, 2, 1 with increasing depth places strong emphasis on the uppermost 10 cm. An alternative, which places less emphasis on the uppermost part, is to employ the lowest index and its depth. Suppose the minimum 0-30 cm index was 3.0 and the shallowest depth at which 3.0 occurs was 10-16 cm. The index might be the product of the midpoint depth of the zone with the lowest index and the value of the index. This would be 13x3.0=39. The index value and its depth would be combined.

The index described here can be part of several in place physical tests. These may include infiltration, bulk density, and penetration resistance. If all layers to 30 cm have an index above 3.0 or 50 on a 100 base, then infiltration, bulk density or penetration resistance are probably not limiting.

The protocol given pertains only to the upper 30 cm. The quality of the soil as a whole may require deeper observations. A soil may have excellent quality 0-30 cm but have a root-limiting contact immediately below. The 30 cm depth was selected because observation with a spade was easily made and the depth encompassed much of the effect of use for most situations.

Finally, three comments: First, it is much more important to pay more attention to the description of the near surface, particularly for cultivated soils, than the manner of reduction of the information. Secondly, calculation of near surface morphological information to an index should help communication with Natural Resources Conservation Service field office staff and others outside the soil survey program. And thirdly, if soil quality becomes part of federally mandated conservation programs, then some kind of numerical assessment of near-surface morphology may become obligatory.

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