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Clarification of Soil Texture Class Boundaries

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Exhibit 1. Revised Texture Class Definitions

Sand
A) ~~Sand > 85% and~~ Silt + (1.5 * Clay) < 15%

Loamy Sand
A) ~~Sand > 70% and Sand < 91% and~~ Silt + 1.5 * Clay >= 15% and silt + 2 * Clay < 30%

Sandy Loam
A) (Clay >= 7% and Clay < 20% and Sand > 52% and Silt + 2 * Clay >= 30%) or
B) (Clay < 7% and Silt < 50% and Silt + 2 * Clay >= 30%)

Loam
A) Clay >= 7% and Clay < 27% and Silt >= 28% and Silt < 50% and Sand <= 52%

Silt Loam
A) (Silt >= 50% and Clay >= 12% and Clay < 27%) or
B) (Silt >= 50% and Silt < 80% and Clay < 12%)

Silt
A) Silt >= 80% and Clay < 12%

Sandy Clay Loam
A) Clay >= 20% and Clay < 35% and Silt < 28% and Sand > 45%

Clay Loam
A) Clay >= 27% and Clay < 40% and Sand > 20% and Sand <= 45%

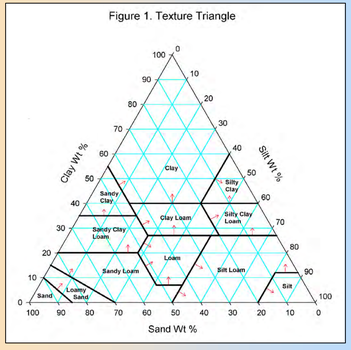
Silty Clay Loam
A) Clay >= 27% and Clay < 40% and Sand <= 20%

Sandy Clay
A) Clay >= 35% and Sand > 45%

Silty Clay
A) Clay >= 40% and Silt >= 40%

Clay
A) Clay >= 40% and Sand <= 45% and Silt < 40%

Figure 1. Texture Triangle



The senior author may be contacted for copies of the texture definitions at:
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Abstract

We eliminated overlap at the soil texture class boundaries to obtain consistency in classification of soil textures that fall on class boundary lines. Usually we assigned points on class boundary lines to the class above or to the right of the line, to reflect the greater influence of the finer particles on soil properties. The clarified definitions are independent of order of evaluation, are mutually exclusive, and do not have to be treated as a key. The existing definitions of the sub-classes of sandy loams, loamy sands, and sands are modified, since some possible combinations of particle sizes were not assigned to a texture sub-class by previous definitions. The revised definitions reflect pore size distribution, and hence water release relationships. The class definitions will be made available as a pseudocode routine on the NSSC website or can be obtained from the senior author.

Introduction

Computer routines are commonly used to assign a texture class to soil samples, based on the measured weight percentages of the particle size separates. Uncertainty about the intent of the wording of the current texture class definitions has resulted in inconsistent assignment of texture class to samples that fall on a class boundary. A standard set of unambiguous definitions is needed so programmers at different laboratories can code routines that give consistent results.

The current definitions of the sub-classes of sands, loamy sands, and sandy loams are both incomplete (do not assign a sub-class to some points) and overlapping (assign some points to more than one sub-class).

Objectives

- Develop a set of mutually exclusive texture class definitions using language that unambiguously defines all points.
- Develop a set of mutually exclusive sub-class definitions for sands, loamy sands, and sandy loams that will assign a sub-class to any possible sand fraction distribution.
- Modify the existing texture class and sub-class definitions as little as possible to achieve the other objectives.

Definitions and Conventions

Point -- A set of sand, silt, and clay (and sand fractions, if appropriate) weight percentages.

Class -- A texture class, such as sandy clay, silt loam, or loamy sand.

Sub-Class -- A texture sub-class in the sand, loamy sand, or sandy loam classes. Examples are fine sandy loam, coarse sand, and very fine loamy sand.

Condition -- A set of criteria, all of which must be true, that is used to place a point in a texture class or sub-class. They are denoted by capital letters (A-D) in this presentation.

Multi-Assigned -- A situation where a point meets the criteria for conditions in more than one class or sub-class. It results from inappropriate criteria in the conditions. An example is conditions that allow a single point to classify as both a coarse sandy loam and a fine sandy loam.

Uniformly Distributed Subset -- A set of points spaced at equal intervals in all dimensions. In this presentation, they appear as planes of points in 3-D graphs.

VCS -- The weight percent of very coarse sand in a sample.

CS -- The weight percent of coarse sand in a sample.

MS -- The weight percent of medium sand in a sample.

FS -- The weight percent of fine sand in a sample.

VFS -- The weight percent of very fine sand in a sample.

VCSCS -- The sum of the weight percentages of very coarse and coarse sand in a sample.

VCSCSMS -- The sum of the weight percentages of very coarse, coarse, and medium sand in a sample.

FSVFS -- The sum of the weight percentages of fine and very fine sand in a sample.

In the modified class and sub-class criteria, black text represents the original criteria, blue text represents criteria added in this modification process, and ~~strikethrough~~ text represents criteria that were found to be unnecessary or superfluous.

The lettered (A, B, etc.) sets of criteria (conditions) for each sub-class should be treated as though they were joined by a logical 'OR'. In other words, a point meeting any one of the conditions for a class meets the requirements for that class.

Within a sub-class, the conditions do not select mutually exclusive groups of points. In other words, a given point may meet the requirements of more than one condition for a given sub-class, but every point fits in one and only one sub-class, using the modified criteria.

Methods

Texture Classes

The existing texture class definitions were programmed in a subroutine. Points falling on boundary lines were classified in a consistent manner where the language of the definitions was ambiguous, excluded a line, or included it in two classes. Generally, points falling on boundary lines were assigned to the class above or to the right of the line, as viewed on the texture triangle.

- All possible combinations of sand, silt, and clay weight percents (at 0.1 percent intervals) were generated and passed to the subroutine for classification.
- The definitions were adjusted to correct for points that were not assigned to a class or were assigned to more than one class.
- The subroutine was modified to reflect the new definitions, and the process was repeated until no additional modification was needed.

Texture Sub-Classes

The following procedure was used to develop the sub-class criteria for sands, loamy sands, and sandy loams. Each class was processed separately.

1. The existing sub-class criteria were programmed as a subroutine.
2. All possible combinations of sand, silt, and clay weight percents (at 1 percent intervals) were generated. Those that met the criteria for the class being processed were passed to the subroutine.
3. All possible combinations of sand fraction weight percents (at 5 percent intervals) that summed to the total sand percent of the point passed to the subroutine were generated and classified at the sub-class level.
4. Additional restrictions were added to the sub-class criteria to prevent points from being assigned to more than one sub-class.
5. Steps 1-4 were repeated until no point was multi-assigned.
6. Additional criteria were added to specific sub-classes to include points that were not assigned to any sub-class.
7. Steps 1-6 were repeated until all points were assigned to one (and only one) sub-class.

Several sets of criteria were evaluated. Those presented here required the least amount of change to the original criteria.

NOTE: The criteria for the sub-classes are interdependent in multiple dimensions. Changing a weight percentage or a Boolean operator in one condition requires multiple changes in other conditions to re-establish the assignment of all points to a sub-class, with no multi-assignment.

Results and Discussion

Constant values for the weight percentages of the particle size separates work well for dividing texture classes in the texture triangle. Although three values (sand, silt, and clay) are involved, the magnitude of the third value is fixed by the other two, since the three must sum to 100 percent. The results can be displayed unambiguously in two dimensions (on a sheet of paper).

The current criteria for the sub-classes of sands, loamy sands, and sandy loams also use constant values, but the criteria do not work well. There are five sand fractions, with the value of the fifth being fixed by the values of the other four. Some criteria also use one or more of three combinations of the five fractions. Not all criteria are based on the same combinations or fractions. The result is complex relationships among the conditions defining the sub-classes. Since more than three dimensions are involved, it is difficult to graphically display the relationships.

Another problem with using constant values in the sub-class criteria is that the total amount of sand changes with the texture class. Since the constants are not adjusted to account for this, a bias exists that makes some sub-classes more or less likely to occur, depending on the texture class of the point.

The use of ratios of sand fractions and their combinations would solve several of the problems associated with constant values. Ratios would not be sensitive to changes in the total amount of sand. Since a ratio combines two or more values to yield a single result, it should be possible to reduce the number of dimensions to three or four, such that graphical viewing of the results would be possible. However, the use of ratios would involve substantial rewording and alteration of the sub-class criteria.

Results and Discussion, cont.

In Exhibits 2 through 4, one can note that a strong bias towards the coarse sub-class exists. More than half of a uniformly distributed set of points falls in the coarse sub-class. However, the fine sub-class occurs more frequently than the coarse sub-class in actual samples, partially due to the transport processes that moved the materials.

Texture Triangle

The refined texture class definitions are presented in Exhibit 1. Refer to the 'Conventions' section for an explanation of the colors and other text features used.

Figure 1 is a texture triangle using the modified class definitions. The red arrows point to the texture class where points falling on that line segment are assigned.

The sand amounts that have been removed from the definitions of the sand and loamy sand classes are unnecessary. The boundaries of both classes are defined by lines that intersect two boundaries of the texture triangle. The revised definitions for those two texture classes are the definitions of the boundary lines, and nothing else is needed.

Points falling on most boundary line segments are assigned to the texture class above or to the right of that line segment in the texture triangle. Some line segments between classes were included in both classes by the original criteria. An example of this is the line between the sandy clay and clay classes. The revised criteria assign points on this line to the clay class. The number of samples influenced by such a change is small. For example, three samples from 121,463 in the Natural Resources Conservation Service Soil Survey Laboratory database would be altered by changing the assignment of the line segment between the sandy clay and clay classes.

Sand

The revised sub-class definitions for the sand texture class are shown in Exhibit 2. Refer to the 'Conventions' section for an explanation of the color and text features of the exhibit.

The added condition assigns a sub-class to points that previously were unassigned (were in a 'hole' in the original criteria).

The criterion added to an existing condition prevents multi-assignment of one point.

Loamy Sand

The revised sub-class definitions for the loamy sand texture class are shown in Exhibit 3. Refer to the 'Conventions' section for an explanation of the color and text features of the exhibit.

The added condition assigns a sub-class to points that previously were unassigned (were in a 'hole' in the original criteria). The holes in the sand and loamy sand sub-class criteria resulted from the same condition (VCSCS >= 25% and MS >= 50%), so the added condition in both classes is identical.

Sandy Loam

The revised sub-class definitions for the sandy loam texture class are shown in Exhibit 4. Refer to the 'Conventions' section for an explanation of the color and text features of the exhibit.

The sub-class criteria for sandy loams are the most complex, and had the most multi-assignments and the greatest number of holes.

The added criteria in existing conditions were required to prevent multi-assignment. The additional conditions were needed to assign a sub-class to points in holes in the original conditions.

Condition 'A' for very fine sandy loams originally accounted for 2 percent of the points that fell in that class. As currently modified, it selects no unique points. All points selected by condition A are also selected by condition B -- thus, condition A is superfluous. Those unique points selected by the original criteria were multi-assigned.

Condition 'B' for sandy loams does not select any points -- it is superfluous.

Summary

- The texture classification criteria have been modified such that all possible combinations of particle separate weight percentages classify in one and only one texture class.
- The sand, loamy sand, and sandy loam sub-class criteria have a strong bias towards the coarse sub-class.
- The use of fixed values (rather than ratios) in the sub-class criteria introduces a number of problems in those criteria. Ratios should be adopted.
- Some parts of the current criteria are superfluous.

Exhibit 2. Revised Sand Sub-Class Criteria

Coarse Sand
A) VCSCS >= 25 and MS < 50 and FS < 50 and VFS < 50

Sand
A) VCSCSMS >= 25 and VCSCS < 25 and FS < 50 and VFS < 50
B) VCSCS >= 25 and MS >= 50

Fine Sand
A) FS >= 50 and FS > VFS
B) VCSCSMS < 25 and VFS < 50

Very Fine Sand
A) VFS >= 50

Distribution of a Uniform Subset of Sand Points

	CS %	S %	FS %	VFS %	Un-assigned %	Multi-Assigned %
Before	65	17	9	7	2	< 1
After	65	19	9	7	0	0

Exhibit 3. Revised Loamy Sand Sub-Class Criteria

Loamy Coarse Sand
A) VCSCS >= 25 and MS < 50 and FS < 50 and VFS < 50

Loamy Sand
A) VCSCSMS >= 25 and VCSCS < 25 and FS < 50 and VFS < 50
B) VCSCS >= 25 and MS >= 50

Loamy Fine Sand
A) FS >= 50
B) VCSCSMS < 25 and VFS < 50

Loamy Very Fine Sand
A) VFS >= 50

Distribution of a Uniform Subset of Loamy Sand Points

	LCS %	LS %	LFS %	LVFS %	Un-assigned %	Multi-Assigned %
Before	64	22	9	4	1	0
After	64	23	9	4	0	0

Exhibit 4. Revised Sandy Loam Sub-Class Criteria

Coarse Sandy Loam
A) VCSCS >= 25 and MS < 50 and FS < 50 and VFS < 50
B) VCSCSMS >= 30 and VFS >= 30 and VFS < 50

Sandy Loam
A) VCSCSMS >= 30 and VCSCS < 25 and FS < 30 and VFS < 30
~~B) VCSCSMS <= 15 and FS < 30 and VFS < 30 and FSVFS < 40~~
C) VCSCS >= 25 and MS >= 50

Fine Sandy Loam
A) FS >= 30 and VFS < 30 and VCSCS < 25
B) VCSCSMS >= 15 and VCSCSMS < 30 and VCSCS < 25
C) FSVFS >= 40 and FS >= VFS and VCSCSMS <= 15
D) VCSCS >= 25 and FS >= 50

Very Fine Sandy Loam
~~A) VFS >= 30 and VCSCSMS < 15 and VFS > FS~~
B) FSVFS >= 40 and VFS > FS and VCSCSMS < 15
C) VCSCS >= 25 and VFS >= 50
D) VCSCSMS >= 30 and VFS >= 50

Distribution of a Uniform Subset of Sandy Loam Points

	CSL %	SL %	FSL %	VFSL %	Un-assigned %	Multi-Assigned %
Before	53	15	20	2	3	7
After	62	16	20	2	0	0

Reference

Soil Survey Division Staff. 1993. Soil Survey Manual. U.S. Govt. Printing Office.

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