



Soil Classification

Newsletter No. 4

Fall 2012



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Message from the Chair

I am pleased to introduce the 4th Soil Classification newsletter from IUSS Comm. 1.4.

The queen hands out a tiny village which amazes them both. Looking down on their mystical land of Lithuania. Visionary thinker, prodide in homeland. No one’s soil maps will be taken away. The new village could be a place of wonder for us all.

Please visit our site <http://clic.cses.vt.edu/IUSS1.4/> for the hottest news on soil classification

We started the previous issue of the Newsletter with some speculations about the fractal nature of soil classification. Though it was just a collection of abstract thoughts, we had to mention that the original ideas came from the works of Juan-José Ibáñez, who is developing these ideas for many years (we wish to thank him for reminding that). For details please see, e.g.:

- Ibáñez, J. J., Ruiz-Ramos, M. and Tarquis, A. 2006. The mathematical structures of biological and pedological taxonomies, *Geoderma*, vol 134, no 3, pp360–372
- Ibáñez, J. J., Arnold, R. and Sánchez Díaz, J. 2006. The magical numbers of the USDA Soil Taxonomy: Towards an outline of a theory of natural resource taxonomies, in *Abstracts of the 18th World Congress of Soil Science*, 9–15 July 2006, Philadelphia, PA, p424

- Ibáñez, J.J., Arnold, R. W., Baquero, Y. 2008. Building Taxonomies: Structure, Function and Representations. International Conference on Soil Classification; Soils: A Work of Art of the Nature. Abstracts Book, p. 17. Universidad de Chile, Santiago de Chile.
- Ibáñez, J.J. , Arnold, R.W. , Ahrens, R.J. 2009 The fractal mind of pedologists (soil taxonomists and soil surveyors). Ecological complexity. v. 6, issue 3.
- and many others...

The cover page uses the painting of Mikalojus Ciurlionis "The fairy-tale of kings" (1908).

Reports on the meetings

Universal Soil Classification Business Meeting Lincoln, Nebraska, June 15, 2012

The business meeting followed the Soil Classification conference held in Lincoln, Nebraska, this June.

Participants of the BM: Jon Hempel, Erika Micheli, Peter Schad, Lucia Anjos, Cornie Van Hayssteen, Anda Markus, Curtis Monger, Thomas Reinsch, John Galbraith, Ganlin Zhang, Pavel Krasilnikov, Sergey Goryacjkin, Alex McBratney, Stephen Cattle, Catherine A. Fox, Ben Harms, Doug Wysocki, Philip Schoeneberger, Juan Comerma, Vince Lang, Joe Chiaretti

Updates:

Mike Golden resigned from his membership on this group as he is in a new position.

Thomas Reinsch will be the new addition to this group replacing Mike Golden.

Working Groups/Task Groups:

- Need to create working groups
- The website should be posted in multiple locations
- The website should provide more information and could be used as a great source of marketing
- Improve marketing; send more information out to the public
- Direct marketing works better because we send out information to the public
- Proposal: set up a setting on the website that would send out an email to all employees and staff every time the website is updated.
- Publish final results and notes
- Send out alerts to the soil community
- In the future an email will be going out to the working groups about what has been done and what is going on
- Each task group will need to create a circular to send out
- The tasks groups are the unit and the leaders of the source of information shared
- Information needs to be descriptive, make a summary of bullets if needed
- Proposal: create a transitional product; use the circular concept, create bulletins, IUSS bulletins (every 6 months), send out invitations for others to join as progress is made

Funding:

Upcoming symposium opportunities - Divisional and WCC symposiums

- Available opportunities
- Defined two groups:
 1. Soil Classification Issues relating to the Universal Soil Classification Concept - symposium will address soil classification considerations, in a variety of soil conditions that are necessary for consistency.
 2. Diagnostic and Soil Profile Harmonization - Symposium will address issues relating to harmonization of diagnostic criteria, horizon nomenclature and field profile descriptions for universal application
- Communication symposium-
 - 18 symposiums for Division 1; also invited the soil mineralogists - Division 2?
- Symposium relating to harmonization, comparative discussion
- Narrow to a specific topic
- Excess of meeting, conferences, and events
- Open vs. closed symposiums (Open - people can send papers about topics, closed - just for members)
- USC and commission need to have at least 2 symposiums

Classification:

The idea is to localize the great groups of soil taxonomy, make a point and recorrelate the existent

- 344 great groups
- Middle level of classification as a starting point(?)
 - Evidence: Medium level provides the greatest information
 - Evidence: medium level is the best part to start looking for informational commonality
 - Define entities at the medium level

Minutes of the business meeting - USC subgroup on cold soils, Fairbanks, Alaska

Thursday, November 1st Synthesis

The expectations of this workshop, as defined by the group at the beginning of the meeting, were as follows:

1. Define cold soils
2. Outline central Great Soil Groups
3. a) Define properties and ecosystem function of cold soils distinct from other soils
b) Define diagnostic criteria for cold soils
4. Identify all available data for calculation of data-driven group centroids
5. Describe one unified method for characterizing the morphology of cold soils
6. Capture Arctic, Antarctic, alpine and boreal differences in the USC
7. Address unique situations: depth of permafrost in shallow soils and “ultracontinental” climates
8. Define meaning of pedon

1. Define cold soils

The definition of cold soils will be used to define the limits of the responsibilities of this working group.

The **current working definition of cold soils** includes those soils with:

- 1) permafrost in the top 100 cm;
- 2) permafrost at some depth and the presence of gelic materials within the control section¹ ;
- 3) presence of active cryoturbation² in the control section; or
- 4) gelic temperature regime (MAST < 0 °C at 50 cm).

¹This includes two distinct classes according to Soil Taxonomy: i) permafrost in top 200 cm and gelic materials, which would be a gelisol and ii) permafrost deeper than 200 cm and presence of gelic materials in the control section, which is not a gelisol, but can be considered a *permafrost-affected soil*.

²In Soil Taxonomy cannot have gelic material in permafrost free regions because it is defined in terms of the active layer.

There was by no means consensus on this final definition and some strong opinions were voiced against it. (CT: “This is a terrible, terrible definition. “)

Discussion:

The definition originally proposed by SG included two categories, the permafrost soils or *zimosols* (using the Polish word for cold to avoid bias to any one classification system) and *permafrost-affected soils*.

Zimosols:

- permafrost in the top 100 cm; or
- permafrost in the top 200 cm and gelic materials.

Permafrost-affected soils:

- permafrost deeper than 200 cm and presence of gelic materials in the control section;
- presence of active cryoturbation in the control section
- gelic temperature regime (MAST < 0C at 50 cm)

There was a great deal of discussion and counter-proposals for a simpler and broader definition. Much of the support for simpler definitions focused around a definition based on soil temperature regime (STR), while broader definitions relaxed the permafrost-depth threshold.

STR Discussion

MK proposed that temperature regime should come first. The presence of a Gelic temperature regime defines cold soils, the other categories are not necessary. CLP proposed that cold soils are all those with cryic and gelic STR. MB proposes including all soils that are frigid, cryic or gelic temperature STR. SG would include frigid STR if there is frostheave/cryoturbation.

In contrast, EM thinks temperature should be removed completely from the definition to make diagnostics simpler. Would constraining definition to a gelic STR exclude soils described by CK? Why include gelic temperature regime? Spitzbergen soils are gelic, but don't have permafrost or cryoturbation.

CT asked why there was so much emphasis on cryoturbation and not other cryogenic features. Because in Soil Taxonomy one cannot have gelic material in permafrost free regions because it is defined in terms of the active layer.

MK is concerned that you could have adjacent material that would not be a cold soil because it does not have frost susceptible material which is why we need to box things in with a temperature criteria.

Permafrost-depth Discussion

An alternative proposal to change the first three items in the definition to include any soil with permafrost or active cryoturbation in the top 200 cm received broad support (CT, PO, EM, LB, CLP), but was not adopted. CT reminded us that the 100 cm permafrost table is so dynamic that it is confusing to have a boundary at 100 cm. We would keep this as a "zimosol" despite the fluctuation of the active layer below 100 cm in some years

There was also some support to consider soils with permafrost deeper than 200 cm. SG argued strongly against taking into account features below 2 m. He asked is anyone could provide an example where soils with deep permafrost have a different ecologic function then those without deep permafrost. He argues that if permafrost is at 2 m it is not important for ecologic function. But with cryoturbation it is, because of the change in the distribution of organic matter.

Other

JB expressed concern that paleo cryoturbated soils would be considered cold soils, so we added the 'active cryoturbation' clarifier. SG agrees that relic features should not be included, must have frost. JB briefly proposed that we should go ahead and include paleo features but there was not much support for this idea. There was fear that it makes the system too complicated.

Alternative definition: permafrost or other active cryogenic features in the top 200 cm and/or a gelic soil temperature regime.

Action Items:

none at this time

2. Outline Great Soil Groups

SG made a proposal to include three new sub-orders in the 'zimosol' order, including lithims for cold, but very shallow soils. A list of the proposed sub-orders and a partial list of Great Groups is given below. The initial emphasis is to focus on great groups, and address orders and sub-orders later.

Zimosols					
Histims	Turbims	Haplims	Aridims	Aquims	Lithims
Foli	Ahumi		Ahumidims	Turbi	Ahumi
Fibri	Spodi		Cambidims		Spodi
Hemi	Luvi				Foli
Sapri	Foli				Molli
Limni	Histi				
Hydro	Molli				
Glaci	Umbri				
	Natri				
	Aqui				
	Oxyaqui				

Some key principals:

- Climate should not be in great groups, it should come in at a lower level than great groups.
- Histims should use about the same number of great groups as what are in histosols
- Need some description of OM in turbims: foli, histi, molli. Umbri
- About the same groups will be in ortims (central concept is ordinary, but in gelsols there is nothing ordinary). Group agreed to replace with Haplims.
- For other orders (when permafrost > 200 cm and cryoturbation or just cryoturbation) we propose the following great groups: Turbortents, Turbaquolls and Turbnatrale
- Lithims will be a complicated situation. We should use the same criteria as the lithic sub-group -> lithic contact within 25 cm, rock temperature below 0 °C. SG is fine with this, but feels there are contradictions with the definition of control section, so need to clarify the language in Chapter 1.

Discussion:

Do we need more distinction between Arctic and Antarctic soils with respect to OC?

Russian soils in permafrost zone, a lot of spodisols compared to NA.

The definition of the 'turb's' must be consistent with other soil orders, they cannot be completely different.

Turbiaquim versus Aquiturbim. What is the difference? Aquic sub-order is often first in ST? There can be a lot of degrees of excess moisture in gelsols. CLP says that aquic feature will often be a subset of turbims because of perched water table above frost, so having both there will be a lot of back and forth. There is this situation in other ST orders.

Should there be a seventh sub-order for the sandy soils? SG thinks they will be with Haplims.

JB permafrost tends to be deeper in bedrock than in unconsolidated material. So he doesn't care if we have lithims. MB quite likes the lithim sub-order.

Can you recognize permafrost in metamorphic rocks? Yes – based on borehole temperature. If you have impermeable bedrock, it behaves like permafrost, and these should be gelisols. If you have permeable dry bedrock water can move through it and these should not be gelisols. CT supports the idea (we'll try it). MC doesn't think that this situation occurs in Alaska.

Action Items:

1) SG will prepare a draft of the great groups table and circulate it to the group.

3. Define properties and ecosystem function of cold soils and diagnostic criteria for cold soils

The following properties were identified as needed to describe and characterize cold soils uniquely from other soils:

1. Depth of the active layer/depth to permafrost
2. Form of permafrost: dry versus ice cemented or rock
3. Extent of cryoturbation (as percentage within the control section (active layer or 200 cm, whichever is shallower))
4. Ice percentage
5. Pattern ground form and size (vertical/horizontal to define the pedon)
6. EC
7. Anion/cation
8. Weathering stage
9. Salt stages
10. Crystratigraphy or cryogenic structure (ice lens, wedge, ground ice)

These are not diagnostics, but will feed into the definition of diagnostics.

In addition, the following "normal" properties will certainly still be used when identifying cold soils:

1. Carbon content
2. pH
3. Horizon names
4. Redox features
5. Soil texture

Discussion:

Description of patterned ground will include presence or absence, microfeatures, style, rock size. EM asked how this will be used. MB said it is needed to determine sub-groups. CLP suggested that such landscape scale features should show up in the morphology. This is not a soil property, but a site description. It defines the pedon.

Are these properties in common databases? JB says they are in his and in the "Land care database". MC says they are not categorical because national pedon database does not include these categories.

Action Items:

1) Rannevig Guichamaud and Cezary Kabala volunteered to work on assigning diagnostic criteria to list of cold soil properties.

4. Identify all available data for calculation of data-driven group centroids

Action Items:

Phillip Owens and Erika Micheli will pull together the list of databases they have and data quality required for the group to add to.

5. Describe one unified method for characterizing the morphology of cold soils

CT and CLP both have written descriptions already for describing cold soil morphology. They will work together to merge their approaches into one document.

Action Items:

- 1) Charles Tarnocai and CL Ping will collaborate to merge their written descriptions on methodology for describing the morphology of cold soils.
- 2) Megan will send everyone a link to the location on the ANTPAS website for sampling and classifying Antarctic soils including: description method, weathering stages and salt stages.

6. Capture Arctic, Antarctic, alpine and boreal differences in the USC

CLP will work with PO to get at something for alpine and boreal environments. CLP says they are looking at soil temperature regime and amplitude of the diurnal temperature change in alpine environments, how does it fit.

Action Items:

- 1) CL Ping will work with Phillip Owens to define the soil temperature regime and diurnal temperature variation for alpine and boreal environments.

7. Address unique situations

Permafrost can be defined in underlying rock when there is a shallow lithic layer.

Ultracontinental climates are not captured well with cold soils but warm summers. JB suggested using Subgelic, pergelic, gelic, hypergelic to describe regions of extreme variations. This requires additional review. Phillip Owen's task group can take this on.

Action Items:

- 1) Phillip Owen's soil moisture/temperature task group will evaluate cold soils with high temperature variability.

8. Define meaning of pedon

Pedon should be defined largely enough to capture the scale of the features. Landscape scale features such as the presence of patterned ground should be used to define the size of the pedon.

Action Items:

None at this time

Final Action Items

It is requested that each action item will result in a technical note or report to the Working Group.

Action Item	Target Date
1) SG will prepare draft of the great groups list and circulate it to the group.	November 30, 2012
Response from working group	December 31, 2012
Document for wider circulation (NRCS will post on-line when finalized)	June 30, 2013
Meeting to vet with the broader community (cryopedology meeting)	August 2013
2) Phillip and Erika will pull together the list of databases they have and data quality required	November 30, 2012
Group will submit data to working group database	December 31, 2012
3) Rannveig & Cezary will assign diagnostic criteria to list of cold soil properties. Circulate first draft to working group.	January 15, 2013
4) Phillip's soil moisture/temperature task group will evaluate cold soils with high temperature variability. Mark will work with him. Circulate analysis.	January 31, 2013
5) Megan will send everyone a link to the location on the ANTPAS website for sampling and classifying Antarctic soils including: description method, weathering stages and salt stages.	November 30, 2012
6) Charles and CLP will collaborate to merge their written descriptions on methodology for describing the morphology of cold soils. Coordinate with Joe Chiaretti – looking at everything outside of cold soils.	November 30, 2012
7) CLP will work with Phillip to define soil temperature regime and diurnal temperature variation for alpine environments.	2015

Report on the soil classification related presentations at the 2012 Annual SSSA meeting, Cincinnati, Ohio, USA. Available at: <http://scisoc.confex.com/scisoc/2012am/webprogram/>

Session: Soil Genesis and Classification Poster Presentations

Characterizing Soil Chemical Weathering Using Portable X-Ray Fluorescence Spectrometer

Yuanda Zhu, David Weindorf and Noura Bakr, Louisiana State University Agricultural Center, Baton Rouge, LA

- [SSSA2012-Zhu.pdf](#) (4.0 MB)

Soil chemical weathering under natural conditions is one of essential processes for sustainability assessment of agriculture and land use, as well as for the identification of acid sensitive regions through the estimation of critical loads, which requires information on spatial differences in weathering rates. In the other hand, the intensity and status of the climate-driven chemical weathering were often well recorded in soil pedons in the course of soil formation; these pedologic records potentially contain substantial amount of paleoclimatic information, which are critical to interpretations and retrospective understanding of the change of climate in the history. In general, two distinct approaches can be applied to quantify weathering rates of soils; the first one is based on mass balance concept, requiring observations of inputs and outputs of the system (e.g., profiles and watersheds), and the second one is an approximation method based on the depletion of minerals with respect to an unweathered horizon under natural or laboratory conditions. The latter method demands geochemical characteristics of the soils in high resolution, vertically and/or horizontally. As portable X-ray fluorescence (PXRF) spectrometer provides an analytical approach to a broad range of elements in a time- and cost- efficient manner, the weathering rates of soils can therefore be efficiently characterized with PXRF, avoiding tedious sampling preparation and analysis. The major objectives of this study are to 1) characterize chemical weathering in terms of vertical variations of in different profiles and spatial differences in the fields based on PXRF readings, 2) compare the calculated chemical weathering rates based on PXRF readings and other methods, and 3) rationalize the cause of the variations.

Horizon Nomenclature for Quartzipsamments in the Carolina and Georgia Sand Hills, South Carolina

*Charles Ogg¹, Jackie Reed¹ and Jarrod Miller², (1)USDA-NRCS, Bishopville, SC
(2)USDA-ARS, Florence, SC*

Horizon Nomenclature for Quartzipsamments in the

Carolina and Georgia Sand Hills, South Carolina

Charles M. Ogg, Jackie M. Reed, and Jarrod O. Miller

Quartzipsamments comprise about 189,600 ha (9.5 percent) of the Carolina and Georgia Sand Hills region (MLRA 137). Official Series Descriptions (OSDs) typically have A - C (Lakeland Series; Typic subgroup) or A - E - E and Bt (Alpin Series; Lamellic subgroup) horizon designation. Horizon colors, along with a slight increase of clay and silt in the upper 100 cm of the sola, suggest a horizon other than C or E occurs in soils of both subgroups. Twenty-nine pedons were sampled in South Carolina. Pedons were described in the field and sampled by horizon for particle-size analysis (PSA). Munsell colors (moist) of the horizon in the upper sola are hue of 10YR or 7.5YR, value of 5 or 6, and chroma of 6 or 8. This horizon was designated Bw (non-cambic) for both Typic and Lamellic subgroups because it has lower value and higher chroma than the overlying horizon. Particle-size analysis determined textures are primarily coarse sand or sand and verified an absolute clay increase less than 3 percent. Both clay and silt decrease below the Bw, but horizon colors in the lower sola, compared to clean sand after PSA, suggest these are not C horizons. Lower sola horizons for Typic subgroups were designated Bw, BE, or Bw/E; the latter designation accounts for small, low chroma zones of non-redoximorphic sand. The lower sola for Lamellic subgroups were designated E and Bt because it is presumed clay translocated through the soil matrix (the E part) and accumulated as lamellae (the Bt part). Clay percentages in the Bt part range from 3.0 to 12.0 percent and 2.0 to 10.0 percent more than the E part.

Relations of Iron, Aluminum, and Carbon Along Transitions From Udults to Aquods

*C. Banik¹, Willie G. Harris¹, S. Balboa¹, Larry Ellis² and G. Wade Hurr³, (1)Soil and Water Science Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL
(2)Box 110290, University of Florida, Gainesville, FL
(3)University of Florida, Gainesville, FL*

Poster Presentation

- [SSSA posterFinal 2012.pdf](#) (1.6 MB)

Depth and morphological expression of Bh horizons were studied with respect to iron (Fe), aluminum (Al) & carbon (C) concentrations along four transects encompassing transitions from poorly-drained Aquods to better drained soils. The Bh horizons of Aquods were well-expressed, but Bh horizons along the transition toward better – drained soils became shallower and less-well expressed, ultimately fading into the surface horizon. Organically-complexed and amorphous Fe and Al were extracted by pyrophosphate and ammonium oxalate, respectively, and measured by inductively coupled plasma spectrometry. Pyrophosphate-extractable C and total C were measured by flash combustion. Extractable Al in Bh horizons correlated positively with extractable- and total C as well as with measures of Bh expression and depth to upper boundary. However, extractable Fe correlated negatively with these variables. Weak Bh horizons of better-drained soils had higher Fe concentrations and Fe/Al ratios than did more strongly expressed Bh horizons of poorly-drained soils. Results suggest that pedogenic processes fostering Bh formation in Aquods are hindered by the presence of Fe in the grain coatings of better drained soils.

Soil Morphology Revisited; A Comparison of Various National and International Systems

Laurelin M. Henderson¹, *Phillip Owens¹ and Joseph Chiaretti²*, (1)Agronomy, Purdue University, West Lafayette, IN
(2)USDA-NRCS, Lincoln, NE

Soil science, as with all science, is developing globally and there is a growing need to develop a taxonomic system to communication soils information across national boundaries. Each taxonomic system uses a descriptive system as a parameter for determining the taxonomy of a soil. The Universal Soil Classification system was proposed, and a committee within the IUSS is currently evaluating soil taxonomic systems and language used to describe soils. In this project, we compared the descriptive systems used in World Reference Base, US Soil Taxonomy, Brazilian Soil Taxonomy and the Australian soil taxonomic system to determine the similarities and differences between the rules for describing soil texture and structure. The texture classes were similar amongst the soil taxonomic systems; however, there were slight differences. Other researchers suggested that the Australian system adopt the particle-size fraction of 50 micrometers for silt, used in WRB, Brazilian Soil Taxonomy and US Soil Taxonomy. The use of a particle-size fraction of 20 micrometers for silt within the Australian system contributes to confusion when comparing textures. The structure classes were also similar amongst the soil taxonomic systems; however, there were slight differences as well. Soil structure and texture are important soil properties and developing consistent terminology would be beneficial for communicating soil information.

Soil Color Measurement: Munsell Soil Color Charts Vs. the GLOBE Soil Color Book

Adam Pollio¹, *James A. Thompson¹ and Philip Turk²*, (1)Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV
(2)Department of Statistics, West Virginia University, Morgantown, WV

Color is a commonly measured soil property during field investigations of soils. Consequently, a soil color book is amongst the equipment carried by almost every field soil scientist. Furthermore, almost all of these soil color books are Munsell Soil Color Charts (X-Rite, 4300 44th St. SE, Grand Rapids, MI 49512, USA), which have been in use for over 50 years to classify soil color in Munsell notation (hue, value, chroma). With the most recent revision in 2009, the Munsell Soil Color Charts have a list price of \$198.00. More recently, an alternative collection of color charts has been produced for the Global Learning and Observations to Benefit the Environment (GLOBE) program. The GLOBE Soil Color Book (Visual Color Systems, Inc., PO Box 93, Mountandale, New York 12763, USA) also contains color standards for Munsell colors commonly identified in field soils. However, the price for the GLOBE Soil Color Book is approximately \$50.00. Our objective was to determine if there was a significant difference between the color representations between these two sets of color charts. Using 10 new copies of each brand of color charts, the Munsell hue, value, and chroma was measured for all color chips with a handheld chroma meter. Differences between the expected and measured color were determined using the standard thresholds for soil color contrast (faint, distinct, prominent), such that if the contrast between the expected and measured color was faint, the two colors were considered to be a match. We report results on the effects of book type (Munsell vs. GLOBE) and color (hue, value, and chroma) on measured differences, as well as book-to-book variation.

Effect of Simulated Alluvial Burial On Soil Carbon

Scott T. Fine and *Brian J. Carter*, *Plant and Soil Science, Oklahoma State University, Stillwater, OK*

Floodplain stratigraphy commonly contains buried soils that are used as indicators of paleoclimatic conditions (landscape stability, ecology, etc.). This study was conducted to evaluate the effects of rapid sedimentation on soil organic carbon; both in relative storage value/stability and discrimination of carbon isotope values ($\delta^{13}C$) currently used in paleoclimatic reconstruction. In spring of 2005, plots were set up on a Teller fine sandy loam (fine-loamy, mixed, active, thermic, Udic Argiustoll) located south of Stillwater, OK. Experiment consisted of 4 treatments of simulated alluvial burial (0, 8, 16, 24 cm in depth) by a fine sandy loam deposit. Native vegetation of the plots was dominated by tall prairie grasses. After six years of burial, both the surface and buried A horizons were evaluated for changes in SOC and carbon isotopic values. All buried horizons significantly decreased in SOC compared to the control. Control (unburied) averaged 1.6 % SOC while the buried horizons averaged 0.83 %; almost a 50 % drop in SOC. Significant changes in $\delta^{13}C$ values were observed between the control, buried, and new soil surface. Buried A horizons $\delta^{13}C$ values were significantly more positive compared to the control, while the newly formed soil was more negative than the control. Burial/discontinuation of organic matter additions results in significant reductions in SOC and the alteration of $\delta^{13}C$ values reaffirming the loss of easily oxidizable carbon.

Soil Genesis and Classification Oral Session

Assessment of Classification of Minesoils According to Soil Taxonomy and Icomanth Proposals.

Cassi S. Jones, *Agronomy and Soils, Auburn University, Auburn, AL* and **John Ammons**, *Biosystems Engineering and Soil Science, University of Tennessee Knoxville, Knoxville, TN*

The physical and chemical properties of minesoils are of vital interest to future land users because their properties are unique compared to surrounding native soils. For many land planners, soil surveys provide the classifications of soils in a particular area, which are intended to provide important information about the properties of a given soil. For decades, however, land users have complained that classifications according to *Soil Taxonomy*, the classification scheme used in the US, of minesoils and other anthropogenically-altered soils are non-descript and do not reflect the unique properties of these soils.

Minesoils mapped in the BSF were classified according to the eleventh edition of *Keys to Soil Taxonomy* to judge how well the classifications described the soils. Further, the same minesoils were classified according to the recently proposed amendments to *Soil Taxonomy* by the International Committee of Anthropogenic Soils (ICOMANTH): several of the recommendations of this group have been accepted by the Soil Survey Staff and incorporated into *Soil Taxonomy* over the past several years. Because the goal of ICOMANTH is to, as seamlessly as possible, adjust *Soil Taxonomy* to include anthropogenically-altered soils in general, it was important to assess whether the amendments were suited to descriptively classify coal minesoils, which sprawl over large tracts of land in the US. Additional recommendations were made and the minesoils were again classified according to these recommendations. Compared to both the *Soil Taxonomy* and the ICOMANTH classifications, those according to the proposed additional amendments revealed more of the unique properties of the minesoils studied in this project. The results of this effort can provide ICOMANTH and the Soil Survey Staff with field validation of the proposed amendments and with suggestions for further improvement.

Initial Summary of Soil Carbon Stocks From the Rapid Assessment of Carbon Project.

Skye Wills¹, **Cleiton Sequeira**², **Larry West**³, **Kenneth F. Scheffe**⁴, **Ellis Benham**¹, **Rich Ferguson**¹, **George Teachman**¹ and **Deborah Harms**¹, (1)USDA, NRCS, Lincoln, NE
(2)School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE
(3)USDA-NRCS, Lincoln, NE
(4)National Soil Survey Center, USDA-NRCS, Lincoln, NE

The Rapid Assessment of Carbon (RaCA) project was undertaken to inventory soil carbon stocks to a depth of 1m across the conterminous United States. A multi-level stratified sampling scheme was used to spread the evaluation and workload across the country. The USDA-NRCS separates the country into major land resource area (MLRA) regional office areas (MOs). For logistical reasons, the RaCA sampling was stratified by MO first. Within each MO, RaCA sites were selected based on soil groups and broad land cover/use categories. Soil groups were created from individual soil series properties and linked to SSURGO map units by dominant component. Land cover/use was initially assigned based on National Resource Inventory and National Land Cover Dataset information. Both soil group and land cover/use were verified before sampling a site. At each site, 5 pedons were sampled at the exact site location and 30m in each cardinal direction. Pedons were sampled from 0-5cm and by horizon to 100cm. Samples of known volume were taken for the upper 50cm so that bulk density could be calculated. Bulk/grab samples were taken from 50 – 100 cm and bulk density will be modeled with pedotransfer functions for those samples. A visible-near infrared spectrometer was used to predict soil organic and inorganic carbon content on all samples. A subset of 3% of pedons will have laboratory analysis done for quality control and error estimation. This study was designed to give an average carbon stock for individual MOs and across the U.S. The results can also be used to examine average differences in land cover/use carbon stocks across a wide variety of soil conditions.

Optimization of Soil Structure Under Differing Climatic Regimes.

Daniel Hirmas¹, **Nathaniel Brunself**² and **David Mechem**², (1)1475 Jayhawk Blvd., Lindley Hall Room 415A, University of Kansas, Lawrence, KS
(2)Department of Geography - Atmospheric Science Program, University of Kansas, Lawrence, KS

The complex aggregation patterns of soil particles—soil structure—result in a concomitant arrangement of pores within the soil media. The presence of this soil-particle organization has the effect of creating pores between aggregates (interpedal pores) that are larger than the pores within aggregates (matrix pores). These interpedal macropores can act as effective conduits for the transmission of water and thus have profound effects on soil water infiltration, redistribution, and drainage. In this study, we sought to discover how natural systems might theoretically optimize soil structure under varying climatic regimes. We developed a low-dimensional single-layer model to simulate the response of soil structural evolution to various frequencies and magnitudes of precipitation. We used a weighting coefficient in a dual-porosity model of water retention as the description of soil structure to distinguish pores resulting from aggregation from those in the matrix. The weighting coefficient was allowed to vary in order to optimize water flux through the soil column averaged over a yearly timescale. A stochastic precipitation model was used to simulate infiltrating water and evaporative demand at the top of the soil column. Simulation results from the model will be presented and implications for pedology will be discussed.

Using Buried Soils to Reconstruct Past Climate: A Quantitative Approach.

Ashley B. Zung¹, Johannes J. Feddema¹ and Rolfe D. Mandel², (1)Geography, University of Kansas, Lawrence, KS
(2)Kansas Geological Survey, University of Kansas, Lawrence, KS

Climatic factors that govern soil water supply and water movement through the soil strongly influence pedogenesis. Pedogenic pathways produce predictable soil properties, and A horizon organic carbon content, calcium carbonate accumulation in the subsoil, and clay translocation through the soil solum of modern soils have been quantitatively linked to modern climate (e.g. Rasmussen et al. 2005; Dai and Huang 2006; Gray et al. 2009; Scull 2010). Climate is arguably the dominant factor dictating pedogenic pathways on the Great Plains, U.S., where topographic and geologic spatial gradients are quite subtle. Buried soils, representing past episodes of landscape stability and soil formation, are commonly preserved in alluvial and eolian deposits on the Great Plains. Because soils are often preserved in the stratigraphic record and climate significantly effects pedogenesis in the region there is potential to quantitatively reconstruct past climate on the Great Plains based on buried soil properties.

We conducted a statistical analysis of modern soil-climate relationships on the Great Plains as a proxy for soil-climate associations during the late Quaternary. Soil characterization data from the NCSS Soil Characterization database and long-term climatologies from the University of Delaware Center for Climatic Research Climate Data Archive were used to develop multiple regression models. Soils that served as modern analogues to those preserved in alluvial and eolian sequences on the Great Plains were selected from the database based on soil order, parent material, and geography. Models predicting mean annual precipitation and annual moisture index based on soil properties were highly significant ($R^2 > .3$, $p < .0001$), with residual standard errors of 117 mm and 0.14, respectively. Efforts to control for potential confounding factors, such as biotic and geomorphic factors and time, and considerations for applying the model in the field will also be discussed.

Fragipan Influence On Hydropedological Properties of Benchmark Soils in West Virginia.

John Beck, USDA-NRCS, St. Paul, MN, James A. Thompson, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV and Nicolas Zegre, Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV

Soil wetness and the interactions between soil and water influence the potential uses of soil and must be considered when making decisions regarding soil use and management. The strategic placement of hydrologic monitoring instrumentation on a benchmark soilscape is critical toward providing the users of soil information with reliable predictability of water movement at the soil-water interface. A hydropedologically significant study site that satisfies the benchmark soilscape criteria as defined by the Natural Resources Conservation Service (NRCS) was selected for this research. Because of the high cost of performing investigations and research, benchmark soils are targeted and the information gleaned from those studies is extrapolated to other like regions. The area of this research consists of a 53 ha catchment located approximately 15 km east of Morgantown, West Virginia in Coopers Rock State Forest. The catchment is in a mature deciduous forest in Major Land Resource Area 127. Piezometric data confirm that the depth to the water is consistent with the first encounter of redoximorphic depletions as identified in the soil profile descriptions. Results reveal that water is present in the layer immediately above the fragipan zone at all hillslope locations with the exception of the backslope, at which results are mixed and can be attributed to the sub-landforms commonly encountered across the backslope. As hypothesized, the footslope location exhibits a higher frequency and duration of saturation than any other position on the hillslope.

Wetland Soils oral session

Optimizing Soil Classification for Hydrologic Purposes.

Navin Kumarr Twarakavi, Division of Hydrologic Sciences, Desert Research Institute, Las Vegas, NV

Abstract will be submitted later

New Insights Into the Factors Affecting Urban Soil Development.

Poster Number **2511**

See more from this Division: [S11 Soils & Environmental Quality](#)

See more from this Session: [Urban Agriculture: I](#)

Tuesday, October 23, 2012

Duke Energy Convention Center, Exhibit Hall AB, Level 1

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Donald Hagan¹, Francisco Escobedo², Gurpal Toor³, Nilesh Timilsina² and Cynamon Dobbs⁴, (1)University of Florida, Gainesville, FL

(2)School of Forest Resources and Conservation, University of Florida, Gainesville, FL

(3)Soil & Water Quality Laboratory, Gulf Coast Research & Education Center. University of Florida, Wimauma, FL

(4)Australian Research Centre for Urban Ecology, University of Melbourne, Victoria, Australia

We conducted a study to assess the relationships between anthropogenic factors and urban soil properties in Tampa, Florida. Specifically, we explored the effects of (1) urbanization as measured by land use, land cover, population density, and years since development and (2) socioeconomics as measured by household income and property values, on key soil physical and chemical properties. Results indicate that Tampa's soils were affected –to varying degrees–by these factors, with property value and land cover having the most significant effects. Urban soil chemical properties, in general, were more variable than physical properties. Soil phosphorus (P) and sodium (Na) contents were highest in residential land uses and soil calcium (Ca) was highest in commercial land uses. Soils in urban forests had lower bulk densities, were more acidic, and had lower nutrient and heavy metal contents than soils in other land covers. Soil P and Na were lowest in recently urbanized sites. Significant relationships were found between socioeconomic factors and several soil chemical properties. Soil Ca and Mg contents, for example, were significantly greater in lower income areas and pH, P, Ca and Na were lowest in the lowest property value class (<\$60,000 USD). Our findings provide insight into the complexity of subtropical, coastal urban soils and the multiple scale drivers affecting urban soil quality and ecosystem services. They also highlight the inadequacies of the traditional US soil survey approach for urban soil classification.

Soil Series Predictions Using Three Different Satellite Remote Sensing Images in the Everglades, Florida.

Poster Number **1533**

See more from this Division: [S05 Pedology](#)

See more from this Session: [New Challenges for Digital Soil Mapping: II](#)

Monday, October 22, 2012

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Jongsung Kim¹, Sabine Grunwald¹, Rosanna Rivero¹ and Rick Robbins², (1)Soil and Water Science Department, University of Florida, Gainesville, FL

(2)Natural Resources Conservation Service, Gainesville, FL

Remote sensing provides rapid data collection and dense information grids that allow inference on various biophysical properties across large landscapes. Soil prediction models incorporated with remote sensing images have shown success to improve the predictive power in upland ecosystems. However, not much is known if these models also perform well in wetland ecosystems, especially for prediction of soil classes. The objectives of this study were to (i) develop spectral informed soil taxonomic prediction models and assess their accuracy; (ii) quantify the relationships between soil classes and environmental co-variables derived from remote sensing and geospatial sources; and (iii) compare the effects of spatial resolution (10, 30, and 250 m) of three remote sensing images to delineate soil classes in a subtropical wetland: Water Conservation Area-2A, the Florida Everglades, U.S. Soil series were collected at 108 sites and three satellite images acquired (i) Satellite Pour l'Observation de la Terre (SPOT, 10m), (ii) Landsat Enhanced Thematic Mapper Plus (ETM+, 30 m), and (iii) Moderate Resolution Imaging Spectroradiometer (MODIS, 250 m). Classification trees were used to predict soil series using spectral data and geospatial environmental ancillary datasets. The single tree model using SPOT image derived spectral input variables with environmental data yielded an average accuracy of 85.6%, overall accuracy of 71.3%, and Kappa coefficient of 61.1 %, which was the best prediction results. Both, ETM+ and MODIS informed soil series predictions demonstrated moderate predictive power with average accuracy of 85.5% and 78.0%, overall accuracy of 67.6% and 60.2%, and Kappa of 57.2% and 47.7%, respectively. Results suggest that the variability of soil series can be explained by bedrock/parent material > topographic variables > vegetation properties derived from remote sensing.

Mapping and Classifying Anthropocene Changes in Our Soil Environment for Sustainable Management.

See more from this Division: [S05 Pedology](#)

See more from this Session: [Advancing Pedology - How Is the Anthropocene Transforming Pedology?](#)

Monday, October 22, 2012: 2:25 PM

Duke Energy Convention Center, Room 250, Level 2

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John Galbraith, Crop and Soil Environmental Science, Virginia Tech, Blacksburg, VA

One historical focus in Pedology has been on making and interpreting soil maps for agronomic, engineering, silvicultural, and environmental purposes. Globally, initial basic soil property maps are being produced through remote sensing. In the United States, almost all private land already has a digital on-line soil map. Therefore US Pedologists are now closely investigating areas where profound changes have occurred, with concerns for environmental and food quality and human health and safety. Soil Taxonomy was developed to allocate natural soil materials into taxa, but during the last several hundred years humans have intentionally plowed, logged, drained, flooded, excavated, filled, and inadvertently eroded and polluted vast areas. With more people living on or near human transformed landforms and soils, detailed soil maps are being requested for sustainable management of resources. Since soils and ecosystems are now altered, conventional Pedology needed to evolve. New terms were added to describe artificial landforms, artifacts and manufactured materials in the soil and new tools/methods/guides needed to identify evidence of intentional human alteration and transportation of material. Soil Taxonomy modifications allowed new allocations at the series, family, and subgroup levels for easy establishment of new series, detailed mapping and interpretation unique to highly altered landscapes (anthrosapes). The first iteration of additions to Soil Taxonomy and the USDA system is being field-tested and reviewed. Recognizing, locating, researching, and classifying Anthropocene soils at several scales will help to identify the extent and impact of forcings that henceforth affect sustainable best use and management in varied environments.

Soil Morphology Revisited; A Comparison of Various National and International Systems. **Poster Number 1610**

See more from this Division: [S05 Pedology](#)

See more from this Session: [Soil Genesis and Classification: I](#)

Tuesday, October 23, 2012

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*Laurelin M. Henderson¹, Phillip Owens¹ and Joseph Chiaretti², (1)Agronomy, Purdue University, West Lafayette, IN
(2)USDA-NRCS, Lincoln, NE*

Soil science, as with all science, is developing globally and there is a growing need to develop a taxonomic system to communicate soil information across national boundaries. Each taxonomic system uses a descriptive system as a parameter for determining the taxonomy of a soil. The Universal Soil Classification system was proposed, and a committee within the IUSS is currently evaluating soil taxonomic systems and language used to describe soils. In this project, we compared the descriptive systems used in World Reference Base, US Soil Taxonomy, Brazilian Soil Taxonomy and the Australian soil taxonomic system to determine the similarities and differences between the rules for describing soil texture and structure. The texture classes were similar amongst the soil taxonomic systems; however, there were slight differences. Other researchers suggested that the Australian system adopt the particle-size fraction of 50 micrometers for silt, used in WRB, Brazilian Soil Taxonomy and US Soil Taxonomy. The use of a particle-size fraction of 20 micrometers for silt within the Australian system contributes to confusion when comparing textures. The structure classes were also similar amongst the soil taxonomic systems; however, there were slight differences as well. Soil structure and texture are important soil properties and developing consistent terminology would be beneficial for communicating soil information.

Persistent Land Use (clearing, agriculture, abandonment, forest regrowth) Legacy for Soil Chemical Properties in Central New York.

See more from this Division: [S07 Forest, Range & Wildland Soils](#)

See more from this Session: [Forest, Range, and Wildland Soils: I. General Topics](#)

Monday, October 22, 2012: 3:15 PM

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*Russell D. Briggs¹, Christopher A. Nowak² and Charles E. Schirmer², (1)One Forestry Dr., SUNY-ESF (College of Environmental Science & Forestry), Syracuse, NY
(2)SUNY-ESF (College of Environmental Science & Forestry), Syracuse, NY*

Historic changes in land use influence species composition and soil chemical properties. Abandoned lands, originally deeded to NY veterans of the Revolutionary War and cleared for subsistence agriculture during the 1800s, currently support northern hardwood forests and Norway spruce plantations. These abandoned farm sites, easily identified by the presence of foundations,

refuse piles and large diameter sugar maple, comprise important cultural resources linking past practices to current vegetation composition and soil characteristics. We studied three abandoned farms in central NY and compared A horizon soil properties among three site conditions common to each: (i) homestead, (ii) hardwood forest, and (iii) Norway spruce plantation. The silt loam soils, formed in glacial till, were classified as well- and moderately-well drained Lordstown and Mardin series, respectively. The legacy imparted by past land use practices on soil chemistry is readily apparent today, 60 - 85 years following abandonment and subsequent forest regrowth. Levels of exchangeable ($1\text{ N NH}_4\text{Cl}$) cations (K, Ca, Mg), extractable P (Truog), and pH of soil from abandoned homesteads significantly exceeded corresponding values for soil from adjacent hardwood forest and Norway spruce plantations. These differences likely reflect direct human (i.e. disposal of wastes including shells and bones) and animal (feed and manure) impacts on the homestead sites. In contrast, soil organic matter, total C, stable isotope ratio ($^{13}\text{C}/^{12}\text{C}$) and total N did not differ among site conditions. We advocate protection and maintenance of these sites as cultural resources that reflect the history of settlement in central New York. Such sites provide opportunities for retrospective study that can contribute new knowledge related to contemporary problems associated with long- and short-term impact on humans of biogeochemistry and other forest ecosystem states and processes.

Using Buried Soils to Reconstruct Past Climate: A Quantitative Approach.

See more from this Division: [S05 Pedology](#)

See more from this Session: [Soil Genesis and Classification: II](#)

Wednesday, October 24, 2012: 1:50 PM

Duke Energy Convention Center, Room 235, Level 2

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Ashley B. Zung¹, Johannes J. Feddema¹ and Rolfe D. Mandel², (1)Geography, University of Kansas, Lawrence, KS
(2)Kansas Geological Survey, University of Kansas, Lawrence, KS

Climatic factors that govern soil water supply and water movement through the soil strongly influence pedogenesis. Pedogenic pathways produce predictable soil properties, and A horizon organic carbon content, calcium carbonate accumulation in the subsoil, and clay translocation through the soil solum of modern soils have been quantitatively linked to modern climate (e.g. Rasmussen et al. 2005; Dai and Huang 2006; Gray et al. 2009; Scull 2010). Climate is arguably the dominant factor dictating pedogenic pathways on the Great Plains, U.S., where topographic and geologic spatial gradients are quite subtle. Buried soils, representing past episodes of landscape stability and soil formation, are commonly preserved in alluvial and eolian deposits on the Great Plains. Because soils are often preserved in the stratigraphic record and climate significantly effects pedogenesis in the region there is potential to quantitatively reconstruct past climate on the Great Plains based on buried soil properties.

We conducted a statistical analysis of modern soil-climate relationships on the Great Plains as a proxy for soil-climate associations during the late Quaternary. Soil characterization data from the NCSS Soil Characterization database and long-term climatologies from the University of Delaware Center for Climatic Research Climate Data Archive were used to develop multiple regression models. Soils that served as modern analogues to those preserved in alluvial and eolian sequences on the Great Plains were selected from the database based on soil order, parent material, and geography. Models predicting mean annual precipitation and annual moisture index based on soil properties were highly significant ($R^2 > .3$, $p < .0001$), with residual standard errors of 117 mm and 0.14, respectively. Efforts to control for potential confounding factors, such as biotic and geomorphic factors and time, and considerations for applying the model in the field will also be discussed.

Conversations with a Soil Forming Factor.

See more from this Division: [S05 Pedology](#)

See more from this Session: [Advancing Pedology - How Is the Anthropocene Transforming Pedology?](#)

Monday, October 22, 2012: 10:55 AM

Duke Energy Convention Center, Room 250, Level 2

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Wendy Greenberg, Bemidji State University, Bemidji, MN

Certainly, the anthropocene has dramatically affected pedogenesis. By definition, the anthropocene has affected pedology too, since humans cannot study pedogenesis before the time of humans. Ironically, it's only recently that pedology has included human impacts in a comprehensive way beyond token designations such as the plagen epipedon and urban areas being depicted as 'disturbed land' on soil maps. Within the last decade, Soil Taxonomy and the World Reference Base have added designations for observed human created soil layers and properties found when evaluating soil pedons. Pedologists could

expand pedology further by exploring and expanding ways to converse directly with the human soil forming factor as a means of determining when was time zero, what was done to create each property and horizon, and even why.

Assessing Anthropogenic Soil Changes Via Portable x-Ray Fluorescence Spectrometry.

See more from this Division: [S05 Pedology](#)

See more from this Session: [Advancing Pedology - How Is the Anthropocene Transforming Pedology?](#)

Monday, October 22, 2012: 1:35 PM

Duke Energy Convention Center, Room 250, Level 2

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David Weindorf¹, Yuanda Zhu¹, Noura Bakr¹, Sara Nuss¹, Amanda McWhirt¹, Beatrix Haggard¹ and Josh Lofton², (1)Louisiana State University Agricultural Center, Baton Rouge, LA

(2)Macon Ridge Research Station, Louisiana State University AgCenter, Winnsboro, LA

Portable x-ray fluorescence (PXRF) spectrometry is a rapid, proximal sensing technique capable of providing quantitative elemental data in-situ. The technology has previously been used extensively for geological, metallurgical, and environmental assessment applications. Originally developed as a large laboratory-based instrument, recent advances have made the instrument not only portable, but handheld. The US Environmental Protection Agency is among many agencies and scientists who have endorsed PXRF's application to soil and sediments (EPA Method 6200). Adoption of other field portable, proximal sensing systems (ground penetrating radar, visible near infrared diffuse reflectance spectroscopy) by field soil scientists has become popular given substantial savings in sample analysis, rapid data acquisition, and high accuracy of results. Over the past 5 years, a research team at the Louisiana State University Agricultural Center has worked to evaluate a number of different soil science applications for PXRF. Among them are studies utilizing PXRF for: 1) assessment of heavy metal spatial variability in peri-urban agricultural lands, 2) quantification of soil gypsum, 3) enhanced pedon horizonation, 4) soil textural analysis, and 5) diagnostic subsurface horizon characterization; topics applicable to assessment of anthropogenic influence on soil which will be reviewed in this presentation. Beyond these applications, this presentation seeks to open dialog on even more soil science applications of PXRF such as salinity assessment and source sediment identification from subaqueous soil cores, with a goal of broadening the scope of scientific inquiry and building a compelling body of peer reviewed literature in support of its adoption by the USDA-NRCS as a sanctioned tool for field soil survey.

Forthcoming meetings

UNIVERSITÄT HOHENHEIM



Soils in Space and Time

Ulm - Germany

Date: **September 30th - October 5th 2013**

Venue: **Ulm University**

"Soils in Space and Time" is one of the key issues documenting the variability of the pedosphere. Soils are so variable. But all of us have a limited experience. Therefore it is of utmost importance to exchange knowledge from time to time and from place to place.

Division I was established by IUSS pedologists working in related fields of soil morphology, micromorphology, soil genesis, soil geography and soil classification. Division I aims to bring these disciplines together to join their efforts in order to improve and communicate their knowledge. Especially the dynamic new commissions paleopedology and pedometrics can add substantial new methods and findings to improve our work. This particularly holds true also for the IUSS working groups feeling related to Division I like Acid Sulphate Soils, Cryosols, Digital Soil Mapping, Forest Soils, Land Degradation, Proximal soil sensors, Salt affected soils, Soil monitoring, Urban soils, Universal Soil Classification and WRB.

The symposia related to soil classification include:

Organized by the Commission:

- Soil classification and soil assessment: turning the theory into practice
- Man-made, deeply transformed and marginal soils

Organized by the USC Working Group:

- Diagnostics and soil profile harmonization

Also the WRB Working Group is planning to present the advances of the 3rd edition of the World Reference Base.

The registration is open, for details please see the web site:

<https://iuss-division1.uni-hohenheim.de/>

IUSS Working Group WRB
IUSS Commission on Soil Classification
IUSS Working Group USC
IUSS Working Group Cryosols
Dokuchaev Soil Science Society



MAMMOTH

Ultra-Continental WRB field workshop
 17-23 of August 2013
 1st Announcement

The Commission on Soil Classification and the WRB (World Reference Base) and USC (Universal Soil Classification) Working Groups of the International Union of Soil Science together with Dokuchaev (Russian) Soil Science Society are pleased to welcome you to the Ultra-Continental Field Trip to the heart of the Eurasian continent - the region of Central Sakha (Yakutia), East Siberia, to examine and discuss the genesis and classification of unique ultra-continental permafrost-affected soils.

The scientific excursion would include trips around the city of Yakutsk (<http://en.wikipedia.org/wiki/Yakutsk>) and an excursion to the Lena Pillars (UNESCO Heritage, see <http://whc.unesco.org/en/list/1299>).



Important dates:

March, 1	notice of intent deadline
March, 15	2 nd Announcement released (sent to those who submitted the notice of intent)
May, 1	payments deadline
17-23 of August	field excursion, including:
Saturday, August 17, early morning	arrival of participants, indoor meeting in Permafrost Institute, excursion to the basement to observe permafrost, city tour
Sunday, August 18, to Wednesday, August 21	field trips (15 soil profiles)
Thursday, August 22	ship excursion to Lena Pillars
Friday, August 23	departure of participants

Scientific program:

During the excursion the participants would see:

- ✓ Permafrost, ice cores, pingos (bulgunniah) and other cryogenic structures;
- ✓ Mysterious permafrost-affected “pale soils” (Cryosols, Cambisols?);
- ✓ Permafrost-affected steppe soils (Chernozems, Solodic Planosols?);
- ✓ Saline and sodic soils (Solonchaks and Solonetz);
- ✓ Unique “alas” landscapes - steep-sided depressions formed by thermokarst (the thawing of permafrost) with a lake and corresponding post-limnic soils;
- ✓ Soils formed in sandy deposits (Stagnosols?).



Cultural program

Apart from the scientific program the participants would have an opportunity to enjoy the mode of life and traditional dishes of local Sakha people (we shall have an overnight stay in a Sakha village), visit the famous Lena Pillars site, and to see the style of life in the city of Yakutsk built on permafrost. Do not forget to buy local handicrafts, especially those made of mammoth tusk.

Cost

The final cost will be announced in the 2nd Announcement, because it would depend on the overall economic situation that affects the hotel prices, transport costs etc. Estimated costs are ~EURO 1200 (single room) or ~EURO 900 (double-bed room), that include accommodations, excursion guide, excursion transport, ship excursion to Lena Pillars, all meals, and social events.

Payment detail will be also available in the 2nd Announcement.

Transportation

The only way to get to the city of Yakutsk is an airplane. Yakutsk has a modern international airport connected by reasonably frequent flights with Moscow, Beijing, Harbin, Ulan-Bator, Vladivostok and a number of Siberian cities.

Provisional costs of return flights from Berlin (via Moscow) ~EURO 800, from New York (via Berlin and Moscow) ~EURO 1500, Los-Angeles (via Beijing) ~EURO 1700, Beijing (direct) ~EURO 500, Auckland (via Beijing) ~EURO 1500.

Please note that during the summer vacation season the economy class tickets may be difficult to get, thus it is recommended to reserve the air tickets in advance.

Visas

Most of the foreign citizens need visas to enter Russian Federation. The list of countries that have agreements with Russia for visa-free entrance is available here:

<http://www.visahouse.com/visafreecountries.asp>.

Great news is that the entrance for the citizens of the USA and EU is strongly facilitated during the last few years is encouraging. Also, some countries (like Germany) have now a simplified visa arrangement procedure for scientists. If you need an invitation that states the fact that you would attend a scientific meeting, please do not hesitate to get in touch with the organizers (see below the contact information).

Organizers

The excursion is organized by an extensive group of specialists. The persons responsible for the organization are:

- ✓ Prof. Sergey Goryachkin (*Institute of Geography, Moscow; Dokuchaev Soil Science Society*)
- ✓ Prof. Pavel Krasilnikov (*Moscow State University; Soil Classification Commission IUSS*)
- ✓ Prof. Roman Desyatkin (*Institute of Biological Problems of Cryosphere, Russian Academy of Sciences, Yakutsk*)
- ✓ Dr. Peter Schad (*Technological University of Munich, Freising, Germany; IUSS Working Group WRB*)

Related events

Those who are planning a long conference marathon may consider the following events coinciding in the time schedule with the tour.

An event before the tour will be in Russia: International Conference “Paleosols, pedosediments and landscape morphology as environmental archives” 10-15.08.2013, Kursk & Voronezh, Russia.
<http://paleopedology.msu.ru/paleopedology2013>

A thematically related event after the tour will take place in Poland: 6th International Conference on Cryopedology “Frost-affected soils: dynamic soils in the dynamic world”, Cracow-Poland, 24-29.08.2013.
<http://www.geo.uj.edu.pl/konferencja/cryosols2013/>

Apply now

The number of participants is limited to 30 persons. So, the organizers follow the principle “first-come, first served”. Please, send your intensions ASAP to Pavel Krasilnikov (pavel.krasilnikov@gmail.com) with a copy to Sergey Goryachkin (sergey.gory@gmail.com).

NOTICE OF INTENT

Family name(s)	
Given Name(s)	
Country	
Affiliation	
Single/double accommodation	
If double accommodation, the name of preferred roommate	
Special requirements (e.g. smoking/no smoking room)	

Soil Classification at the 20th World Congress of Soil Science

Jeju, Korea, June 8-13, 2014

The 20th WCSS will be an opportunity to get on top of the changes in soil science and to envision new perspectives for basic and applied soil research. The local Organizing Committee is planning to set up the various programs to encourage the participation of many soil scientists from every corner of the world.

The year 2014 seem to be far ahead, but the time runs quickly, and we encourage everybody to think over the topics proposed for the World Congress.

The soil classification-related topics include the following (the conveners are provisional ones):

- **The progress in the development and harmonization of soil classifications** (proposed convenor *Pavel Krasilnikov*)
- **Marginal soils: the classification of technogenic, subaqueous, and extraterrestrial soil-like bodies** (proposed convenor *John M. Galbraith*)
- **Folk soil knowledge for soil taxonomy, soil assessment (Div. 1 and Div. 3)** (proposed convenor *Francisco Bautista-Zuñiga*)
- **WRB - lessons learned during the development of the third edition 2014** (proposed convenor *Cornie van Huyssteen*)

For more details please see the web site of the Congress: <http://www.20wcscs.org/>

EXPERIENCE WITH SOIL TAXONOMY OF THE UNITED STATES¹

Marlin G. Cline

Department of Agronomy, Cornell University, Ithaca, New York

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I. INTRODUCTION

Readers should recognize that much of the literature cited in this article is based on an incomplete preliminary draft of Soil Taxonomy, known widely as "The Seventh Approximation" (Soil Survey Staff, 1960), and on four supplements issued in 1964, 1966, 1967, and 1968. During the 15 years from release of

¹Department of Agronomy Series Paper No. 1333.

the Seventh Approximation until the complete text was published for general distribution (Soil Survey Staff, 1975), the number of great groups recognized in the system increased from 112 to 230, and the number of subgroups, from 281 to 1251. The basic concepts and principles, however, changed much less. The National Cooperative Soil Survey of the United States has used the system as its official taxonomic classification since January 1965. The date of an article cited may be used as an approximate indicator of the stage of development of the system on which it is based. The author has been selective to avoid citing conclusions that would have been clearly outdated by subsequent changes in the system.

To bring the information available up to date, the author requested leading soil scientists of 46 countries to respond to specific questions about use of the system in the areas they represent, including (1) how much and in what ways it is used; (2) problems encountered in the mechanics of its application; (3) problems of classifying soils by its criteria; (4) its impact on soil surveys; and (5) its usefulness for development of soil interpretations for applied purposes. Fifty-three individuals, representing 31 foreign countries, responded. Four others responded for multicountry areas. Sixteen responded for five agencies of the United States. The individuals are identified by the countries or areas they represent in footnote 2. Information from these sources is identified in the text as "personal communication" by the convention (PC) and is cited in the present tense to distinguish it from that derived from published literature.²

²The author is most grateful to the individuals named below for invaluable assistance. All responded to the author's request for information, either by answering specific questions or by referring the inquiry to others. Many added relevant comments or supplied documents that would not otherwise have been seen. For foreign countries: Argentina—C. D. Scoppa; Australia—K. H. Northcote and R. F. Isbell; Belgium—R. Langohr; Brazil—M. Camargo; Canada—G. M. Coen, L. M. Lavkulich, W. W. Pettapiece, I. Snedden, and C. Tarnocai; Chile—M. Carrasco, J. Munito, W. Luzio, and J. Salgado; Colombia—R. Guerrero; Costa Rica—A. Alvarado; England and Wales—B. W. Avery, P. Bullock, and B. Clayden; Federal Republic of Germany—E. Mueckenhausen; Hungary—I. Szabolcs; India—S. B. Deshpande, R. S. Murthy, and S. S. K. Nanda; Iraq—F. H. Altaie; Ireland—T. Walsh and M. Gardiner; Japan—M. Oyama; Kenya—F. N. Muchena and P. M. Ahn; Netherlands—J. Schelling and W. G. Sombroek; New Zealand—B. C. Barrat, E. Griffiths, M. L. Leamy, and W. C. Rijkse; Norway—J. Lag; Pakistan—M. B. Choudhri; Peoples Republic of China—Lien-Chieh Li; Romania—A. Canarache and C. Rauta; Scotland—J. M. Ragg; South Africa—C. N. MacVicar and M. C. Laker; Sri Lanka—K. A. De Alwis and R. Tinsley; Sudan—M. A. Ali; Thailand—S. Panichapong; Trinidad—N. Ahmad; USSR—I. P. Gerasimov; Venezuela—J. Comerma; Zimbabwe Rhodesia—J. M. DeVillers and W. D. Purves. For the United States: Soil Conservation Service—K. W. Flach, R. L. Guthrie, J. E. McClelland, M. Stout, J. M. Williams, and J. E. Witty; Forest Service—R. G. Cline, D. Eagleston, M. Kaplan, R. Poff, W. Sexton, A. Sherrell, and G. Warrington; Iowa—T. E. Fenton; North Carolina—S. W. Buol; Texas—L. P. Wilding. For multicountry areas: G. D. Smith, general perspective; C. Charreau, French-speaking Africa; F. Moorman, Africa and Southeast Asia; S. W. Buol, Latin America; W. B. Peters, World Bank. Citations of the personal communications from these individuals are identified in the text by (PC).

II. GENERAL REACTIONS TO THE SYSTEM

General reactions to Soil Taxonomy in the literature have ranged from absolute rejection to substantial endorsement, each in the context of the author's precepts of principles of classification and of order in relationships among soils. Some of the literature cited here illustrates an observation by Mulcahy and Humphries (1967) that "It is the subjective, and therefore, emotionally involved nature of most soil classifications which turns the scientist from the narrow path of detached reason."

The extremely negative reaction of Russian soil science is not easily rationalized. Gerasimov's (1962) initial review was a critical but reasoned statement. He noted some merits of the Seventh Approximation and was critical of several of its attributes, including his interpretation that it had abandoned the principles of Dokuchaiev. In 1964, a series of 11 articles in *Pochvovedenie* (No. 4, pp. 14-48) found little merit in the system's logic or in its applications to soil classification of specific areas, to soil genesis, to soil survey, or to soil geography. A translation of the summary paper (Gerasimov, 1964) characterized the system as an empirical scheme "justified by references to the most widespread modern bourgeois-philosophical, subjective-idealistic trends" and of "limited positive interest." Later reviews have been similarly critical (Gerasimov, 1969, 1978).

Soil Taxonomy is a major departure from the philosophy of classification followed by the Russian school. D'Hoore (1968) noted that Russian soil classification relies heavily on factors of soil formation as criteria of the higher categories. Soil Taxonomy uses intrinsic soil properties selected with the effects of soil formation as criteria, but Yerokhina and Sokolova (1964) appear to consider this a violation of Dokuchaiev's principles. Fridland (1964) denied that soil classifications are not truth but are contrivances to suit people's purposes, as declared by the authors of Soil Taxonomy, apparently accepting genetic theory as truth in detail. These kinds of differences and the fact that translations of English to Russian may not convey the bases of Soil Taxonomy fully could account for parts of the critical reviews, but they do not explain them fully.

Muir (1962) was critical of the Seventh Approximation, largely on grounds that it provided no statement of basic principles as he conceived them. Webster (1968a) found the strictly defined limits of the criteria of the Seventh Approximation unjustified in view of errors of their measurement and, like Avery (1968), maintained that a hierarchal system is not appropriate for soils. He found no relevance in the concepts of pedon and soil individual (polypedon) and concluded that the system exhibits circular reasoning. Mitchell (1973) published a rebuttal to both Webster and Avery, questioning the validity of their analyses. Webster (1968b) also discussed faults of the system for use by geographers and advised them to avoid using it. Bunting (1969) promptly published a note in the same

journal characterizing Webster's review as most subjective and unjust. These are examples of diametrically opposing viewpoints related to concepts and biases of individuals.

Australian soil scientists generally have been critical of Soil Taxonomy, though judgments have varied among individuals. A committee of the Australian Society of Soil Science reviewed the Seventh Approximation in detail. They reported it a great improvement over earlier schemes but with serious problems for soils of Australia (Butler *et al.*, 1961). Stephens (1963) took exception to a number of assumptions, criteria, and definitions and considered the system more nearly a key than a classification. He too found serious deficiencies for soils of Australia. At a time when factual keys were gaining acceptance in Australia, Mulcahy and Humphries (1967) reported that the Seventh Approximation was an entirely commendable attempt to maximize information content but that the use of criteria reflecting soil genesis was logically indefensible. They characterized the choice and weighting of criteria as subjective and so biased by conditions in the United States that application in Australia was not satisfactory. Currently, Northcote (PC) reports that few Australian soil scientists are inclined to devote time to use of Soil Taxonomy. In contrast, Moore (1978) has concluded that Soil Taxonomy has good potential as a medium for transfer of technology in Australia.

MacVicar *et al.* (1977) have not been completely satisfied with the results of application of Soil Taxonomy in South Africa. They commented, however, that the system is "refreshing" and has "loosened the shackles of traditionalism and stimulated rethinking on soil classification." Laker (PC) writes that the system has had a revolutionary impact on ideas about soil classification and soil survey in South Africa, although it is not used as a national system.

Sehgal and Sys (1970) found a need for changes in detail of some criteria to accommodate important properties of soils of the Punjab. They emphasized, however, that criticism based on departure from theories of soil genesis is invalid and that genetic relationships are shown more specifically than ever before. They noted the lack of geographic bias for Entisols, Vertisols, Histosols, and Inceptisols but commended the strengthening of relationships between soil classification and soil geography through the concepts of the pedon and polypedon.

Langhor (PC) disagrees with ideas expressed in Soil Taxonomy about genesis of fragipans and argillic horizons, which influence choice and weighting of criteria strongly. He would construct some parts of the system differently. Nevertheless, he considers it the most precise and best system for international communication though not well suited to definition of mapping units in the soil survey of Belgium. Like many others, he deplores the complicated writing of the published system.

One of the most objective and comprehensive studies of the system has been reported by Ragg and Clayden (1973). They concluded that use of quantitative

criteria, the concept of diagnostic horizons, emphasis on criteria not readily altered by man, and the nomenclature are valuable contributions. They saw great value in the system as a medium for international reference but found problems for its application in Britain. They identified the complexity created by large numbers of taxa above soil families, the complexity of definitions, emphasis on the mollic epipedon and base status as criteria, and need to amend definitions of some criteria as deficiencies for classification of British soils. They concluded, however, that the system had brought traditional British groupings rightfully into question and had placed soil classification on a more acceptable scientific level.

Leahey (1963) reported that Canadians were greatly impressed by the Seventh Approximation but for national purposes preferred to continue with the system they were constructing. The two systems have been developed concurrently with considerable interaction and commonality of language and structure. Coen (PC) writes that many, if not most, criteria of the Canadian system (Clayton *et al.*, 1977) have been strongly influenced by Soil Taxonomy; some are identical. It should also be noted that Canadians have contributed to Soil Taxonomy.

Rauta (PC) reports that although Romania uses its own classification, Soil Taxonomy is respected as a secondary system. He cites its use of intrinsic soil properties, quantitative diagnostic criteria, and connotative nomenclature as important attributes. He is critical of the use of the same properties as diagnostic criteria at different levels in the system and of the complexity of both definitions and their presentation. Some Romanian soil scientists have contributed to Soil Taxonomy and take special interest in it.

Duchaufour (1963) noted deficiencies of the Seventh Approximation for use in France but considered it a mark of real progress in soil classification. Kesseba *et al.* (1972) found it the most comprehensive framework for assessing Tanzanian soil resources even though it did not fit well everywhere.

Conflicting viewpoints involving national pride are revealed by a resolution of the New Zealand Society of Soil Science requesting reconsideration of a decision by the Soil Bureau to use Soil Taxonomy on a trial basis. Miller (1978) provided a concise review of experience in New Zealand, the level of interest in Soil Taxonomy, and reasons for experimenting with it.

III. USE OF SOIL TAXONOMY INTERNATIONALLY

Table I summarizes the predominant intensity and frequency of use of Soil Taxonomy by scientists of the major institutions concerned with soils in countries for which information is available. Scientists of most countries that are not listed probably use the system infrequently if at all.

Table I
The Intensity and Frequency of Use of Soil Taxonomy by Country^a

Used continually as a primary system	Used frequently as a secondary system	Used infrequently or not used
Argentina	Belgium	Australia
Chile	Bolivia ^b	China, Peoples Republic
Colombia	Brazil	France ^d
Ecuador ^b	Canada	Germany, Federal Republic
Guyana ^c	Costa Rica	Guatemala ^c
India	England and Wales	Haiti ^c
Iraq	Ghana ^d	Hungary
New Zealand	Iran ^d	Mali ^c
Pakistan	Ireland	Mauritania ^c
Sudan	Japan	Mexico ^c
United States	Kenya	Netherlands
Venezuela	Nigeria ^d	Niger ^e
	Peru ^b	Norway
	Romania	Panama ^c
	Sierra Leone ^d	Scotland
	Sri Lanka	Senegal ^c
	Thailand	South Africa
	Tanzania ^d	Upper Volta ^c
	Trinidad	USSR
		Zimbabwe Rhodesia

^a Based on personal communication with scientists in the countries, except as noted.

^b Information provided by S. Buol, North Carolina State University.

^c From an unpublished survey of "Soil Taxonomy in the Tropics" by R. Guerrero, University of Puerto Rico.

^d Based on evidence in the literature.

^e Information provided by C. Charreau, ICRISAT, Dakar, Senegal.

A. COUNTRIES WHERE SOIL TAXONOMY IS USED AS A PRIMARY SYSTEM

Soil Taxonomy has been used as the official taxonomic system of the National Cooperative Soil Survey of the United States since January 1965. The United States Forest Service also uses the system for taxonomic classification of soils, although their mapping units are identified in other terms for in-service use in some parts of the country. The system is taught in soils courses of major universities. Soils are identified in terms of its taxa in most articles concerned with pedology in the major journals and bulletins of the United States.

Guerrero reports (in an unpublished survey of Soil Taxonomy in the Tropics) that four Latin American countries in addition to the six listed in Table I used Soil

Taxonomy exclusively in their national soil survey operations, but he did not identify them. He reports that Guyana is currently converting from the 1938 USDA system to Soil Taxonomy. C. Scoppa (PC) reports that soil series and their phases are used for soil mapping at scales larger than 1:100,000 in Argentina; subgroups and families are used at smaller scales. Westin (1963) and Comerma (1971) have discussed the advantages of the Seventh Approximation for soil surveys in Venezuela; Comerma also identified some problems that were encountered in its application.

Murthy (PC) reports that 700 copies of an Indian edition of Soil Taxonomy have been distributed and that short courses and regional workshops are being conducted to facilitate its use. In spite of some problems associated with an inadequate data base, Murthy *et al.* (1977) have identified major advantages of the system for India. Articles by Deshpande *et al.* (1971) and Murthy (1979) provide examples of its use.

M. B. Choudhri (PC) reports that Soil Taxonomy is used as a primary taxonomic system for soil surveys of Pakistan in conjunction with FAO units (FAO-UNESCO, 1974). Ahmad *et al.* (1977) identified soils of the Pakistan Punjab by taxa of Soil Taxonomy without comment. The initial steps of converting from a national soil classification for Iraq to Soil Taxonomy have been described by Altaie *et al.* (1969).

Cook (1975) found Soil Taxonomy generally applicable to soils of the Sudan. He reported problems related mainly to deficiencies of information and training of personnel, but he noted that reasonable approximations of classification by the system can be made even though data necessary for precision are lacking. M. A. Ali (PC) reports that the Seventh Approximation was introduced in the Sudan in the 1960s during development of the Soil Survey Administration under FAO auspices. The soil survey of the Sudan is currently correlating taxa of Soil Taxonomy with units of the FAO/UNESCO legend, as is done in Pakistan. Some problems have been encountered with criteria of Vertisols (Ali, 1972). Ali (PC) also reports that the legend for the soil map of Arab countries is based on subgroups of Soil Taxonomy.

The Soil Bureau of New Zealand adopted Soil Taxonomy in 1977 for an extended trial (Miller, 1978). A final decision on its continued use depends on results of that trial.

Some individuals in most of the countries that use Soil Taxonomy as a primary system for soil surveys still prefer other schemes. Individuals contacted by the author in Chile, India, and New Zealand indicate that they use Soil Taxonomy mainly as a secondary system for communication. Guerrero's unpublished survey, cited above, showed that teaching of Soil Taxonomy in universities of many Latin American countries is weak and that a significant number of individuals still rely mainly on systems that were used previously. Guerrero notes in his report that use of these systems is decreasing as workers gain experience with Soil Taxonomy.

B. COUNTRIES WHERE SOIL TAXONOMY IS USED AS A SECONDARY SYSTEM

In the 19 countries listed in the second column of Table I, national soils programs depend on taxonomies designed for their conditions or on more comprehensive schemes, such as the FAO/UNESCO legend, the French system, or the 1938 USDA classification. Soil scientists of these countries, however, commonly use Soil Taxonomy for international communication and for correlation of their soils with those of other countries. Butler *et al.* (1961), Deckers (1966), Ragg and Clayden (1973), Beinroth (1975), and Moore (1978) recommended its use for these purposes because of its precision and comprehensive scope, though they preferred other schemes for national purposes. C. Rauta (PC) reports that Soil Taxonomy is not used in Romania for national programs of soil survey and classification but is used frequently in scientific papers, reports for both national and international meetings and symposia, guidebooks, manuals, and Ph.D. theses. De Coninck *et al.* (1976), for example, identified the soils in terms of Soil Taxonomy for a study of clay mineralogy in Romania.

In some of the countries listed, Soil Taxonomy is used in national programs as a secondary system for people of high technical competence, though a less complex scheme is given preference for general use. Dent and Changprai (1973) outlined Soil Taxonomy as the "primary" system for the country's most competent soil scientists in the Soil Survey Handbook of Thailand, but they retained the national system as a scheme more consistent with the technical competence of most workers. Dewan and Famouri (1964) outlined the Seventh Approximation in their publication on soils of Iran but identified soils of the country in terms of the 1938 USDA classification.

Authors who use Soil Taxonomy as a secondary system use taxa of categorical levels ranging from orders to families, depending on the purpose and scale of the study, the level at which soils can be identified with the data available, and the familiarity of the individual with the system.

Orders, suborders, and great groups are used most commonly for studies involving broad perspective. Harris *et al.* (1971) correlated soil zones of Costa Rica at the order level for a very general picture of the soil geography of that country. Aubert and Tavernier (1972) used suborders and great groups as reference taxa for their small-scale soil map of the humid tropics. Moorman and Van Breemen (1978) used great groups to identify soils of the principal rice-growing areas of the world. Camargo and Falesi (1975) and Zamora (1975) identified large areas of Brazil and Peru, respectively, in terms of great groups for broad perspective. Sanchez and Buol (1974) used Soil Taxonomy for their study of soils of the upper Amazon basin, correlating the taxa with units of both the FAO and Peru systems.

Subgroups are used commonly for geographic studies of intermediate intensity

and scale, as in Dijkerman's (1969) report on soil resources of Sierra Leone. Many authors use subgroups in preference to taxa of lower categories to identify soils used for studies of morphology and genesis. Examples include those by Lepsch *et al.* (1977) in Brazil, Walmsley and Lavkulich (1975) and Hendershot and Lavkulich (1978) in Canada, Ojanuga *et al.* (1976) and Harpstead (1973) in Nigeria, Flores *et al.* (1978) in Peru, and De Alwis and Pluth (1976) in Sri Lanka. Some of these were studies of specific pedons for which data should have been adequate for classification at the family level. Many authors appear to prefer to use subgroups, perhaps because they are taxa of the lowest category in which the criteria have strong genetic bias.

Soil families are identified in some studies involving practical interpretations and transfer of technology. The criteria for distinctions at the family level were selected specifically to enhance interpretive value for applied purposes. Uehara (1978) has described the potential of phases of soil families for transfer of technology internationally. North Carolina State University (Soil Science Department, 1978) has used soil families for quantitative identification of soils at experimental sites in the tropics as a basis for transfer of experimental results. Soil families are also used by some authors to identify soils used in studies of morphology and genesis. Family criteria below the subgroup level may be relevant to such studies, as in those by Snedden *et al.* (1972) and Hakimian (1977).

C. COUNTRIES WHERE SOIL TAXONOMY IS USED INFREQUENTLY

In most of the 20 countries listed for this group in Table I, some individuals have at least studied Soil Taxonomy. Australian soil scientists have studied the system in detail as noted in Section II, but most do not use it. Yet R. F. Isbell (PC) reports that he uses it as a secondary system. Soil Taxonomy is not known generally in the People's Republic of China, but Lien Chieh Li (PC) writes that he has a copy and would welcome assistance in using it. The system is well known by leading soil scientists of France. The new French classification (Fauck *et al.*, 1979) uses some of its principles, concepts, and elements of nomenclature, though the taxa and their organization are markedly different. E. Muckenhausen (PC) writes that the system is used little in the Federal Republic of Germany, though it is well known by some individuals.

Guerrero's unpublished study of Soil Taxonomy in the Tropics reveals that Guatemala and Panama use no taxonomic system and that Mexico and Haiti use other schemes exclusively. Even secondary use is unlikely in these countries. C. Charreau (PC) writes that the French-speaking soil scientists of Mali, Mauritania, Niger, Senegal, and Upper Volta use the French system in which they have been trained. From time to time, they do attempt correlations with Soil Taxonomy for surveys sponsored by international agencies. Responses from

individuals contacted in the Netherlands, Scotland, South Africa, and Zimbabwe indicate interest in the system by the leaders in soil science, though it is not used significantly. There has been no indication that Soil Taxonomy is used in any way in Hungary or the USSR, but the Russian literature on the subject is ample evidence of awareness. It should be noted that soil scientists of Iran may not use Soil Taxonomy currently. Iran is listed under countries using Soil Taxonomy as a secondary system in Table I on the basis of evidence in the older literature.

IV. PROBLEMS FOR USERS OF SOIL TAXONOMY

A COMPLEXITY, PRESENTATION, AND BACKGROUND

With few exceptions, the 53 foreign respondents to the author's inquiry identified the complexity of the system, its presentation, or both as obstacles to its use. Beinroth (1975), Butler *et al.* (1961), Cook (1975), Ragg and Clayden (1973), Stephens (1963), and Webster (1968a) have published the same criticisms. The numbers of taxa and the quantitative precision of definitive criteria require complicated definitions and keys, which demand intense concentration and substantial competence if they are to be applied precisely. The difficulty is magnified by the manner in which these are presented in publishing documents. In many instances, precise interpretation of definitions and keys depends on the presence or absence of a comma or the use of the conjunction "and" or "or." A number of individuals with whom the author has discussed the subject assert that the manner of presentation makes application of the system unnecessarily complicated.

These attributes of the system created problems for field scientists in the United States when Soil Taxonomy was first adopted. Only part of their difficulties could be attributed to the system and its presentation; a significant part was due to their background of qualitative or semiquantitative field methods and thought. This is probably true in other countries where Soil Taxonomy has been used. In the United States, difficulties of applying criteria largely disappeared for individuals working with a limited range of soils as they gained experience with that part of the system which was relevant to their work. Experience was fortified by special training not only in use of the system but also through the example of supervisory personnel in the methods of quantitative science. Temporary difficulties in application of the system commonly reappear, though to a lesser degree, when even experienced field scientists encounter soils far removed from those parts of Soil Taxonomy with which they are familiar.

These kinds of problems are major obstacles for individuals of countries where Soil Taxonomy is relatively new or is not used regularly. They are especially troublesome where English is not the common language. Respondents to the

author's questionnaire from 21 countries, including 6 where English is the common language, report that soil scientists classify soils incorrectly in a significant proportion of their placements because of misinterpretation of the keys or definitions. Respondents of only two countries reported that this is not a problem; the author questions their appraisal. Respondents of only three countries where English is not the common language report that translation is a source of error. Others familiar with the work, however, report that translation is a major problem. Buol (PC), responding from his perspective of the work in Latin America, observes that workers who are not fluent in English tend to use narrative descriptions rather than the keys. Consequently, they overlook the order of precedence of criteria, which is critical for classification in the system. He also notes that such problems are "surprisingly few" considering the handicaps under which Latin American soil scientists work.

The author is convinced that the paucity of published information about the evolution of the ideas that shaped Soil Taxonomy and the reasons for seemingly arbitrary decisions about definitions of criteria and distinctions between taxa create problems for those who apply the system. Field personnel he supervised were commonly uncertain about the correct interpretation of keys and skeptical of distinctions until they understood the intent and reasons for it. General principles that control the system have been published in the Seventh Approximation (Soil Survey Staff, 1960), by Smith (1963, 1965), and in the "complete" publication (Soil Survey Staff, 1975). To understand the underlying rationale of the system and the bases of decisions it reflects, however, it is necessary to know relevant detail for an enormous amount of data assembled for thousands of individual soils, the results of testing each of six approximations against these data, the conflicts between theory and fact this testing revealed, and the conclusions from debate about ways to accommodate newly discovered facts. Nowhere is that information generally available, and no individual could assemble it in detail. Nor are the underlying precepts of soil genesis which shaped the system obvious in the literature. The system is presented as a device suitable for application empirically, which the inquiring mind finds both unsatisfying and, in parts, unreasonable. To rectify to a limited degree this enormous gap in background information, the author has recently compiled that part available to him (Cline, 1979), but much more is needed from those more intimately involved in development of the system.

B. APPLICATION OF CRITERIA

1. Field Criteria

The application of diagnostic features of the argillic horizon was identified as a problem most frequently by respondents to the author's questionnaire. It has also

been reported as a problem by Kesseba *et al.* (1972), Murthy *et al.* (1977), Nettleton *et al.* (1969), Odell *et al.* (1974), and Van Wambeke (1967). In 1977 Isbell presented a comprehensive summary of difficulties in identification of argillic horizons (scheduled for publication in the transactions of the meeting of Commissions IV and V of the International Society of Soil Science at Kuala Lumpur, Malaysia). The problems focus on identification of clay skins, estimation of their relative volumes, and conflicting evidence for genetic origin of both clay increases with depth and of clay skins. A second paper by Isbell at the same conference, currently unpublished, discusses the problem in relation to soils of Queensland, Hawaii, Brazil, Natal, and Mauritius.

The criteria for plinthite require predicting whether or not the material will harden on exposure. Harpstead (1973) has described assumptions made in such predictions for Nigeria. Daniels *et al.* (1978) have described the problem and have suggested solutions.

The criteria for identifying fragipans are more descriptive than definitive. Deckers (1966) has described some of the problems encountered in the field. From personal experience, the author knows that identification of fragipans is not consistent among workers in the United States.

2. *Laboratory Data*

Inadequate laboratory data is identified as a major problem by respondents from 22 nations. The cost of obtaining the data is considered limiting by respondents from most developing nations. Articles by Beinroth (1975), Butler *et al.* (1961), and Cook (1975) express similar concern. Antoine (1977) noted that for northern and western Africa lack of laboratory data is a serious limitation that can be corrected only by a massive laboratory program, for which resources are limited. Deficiencies of laboratory data were problems in the United States while Soil Taxonomy was being developed, and some individuals were critical of criteria that require them. With the resources of the United States, the deficiency was largely corrected, and soil science advanced enormously as a result. Responses to the author's questionnaire show that supporting laboratory work has increased substantially in several developing nations as a consequence of adoption of Soil Taxonomy. Presumably soil science has advanced in those countries accordingly. Nevertheless, lack of adequate laboratory data is a problem in countries where resources are limited and will continue to be an obstacle to precise use of Soil Taxonomy for the foreseeable future.

There does appear to be some misconception of the amount and sophistication of laboratory data that are essential. Obviously, not every pedon examined can be sampled and analyzed, nor is highly intensive sampling for laboratory work essential for realistic use of Soil Taxonomy. Enough data are needed to establish norms and to identify field clues that will permit reasonable estimates. This is the

pattern followed in the United States. Murthy *et al.* (1977) have noted that reasonable approximations of many criteria can be made without resorting to sophisticated procedures. Cook (1975) reported that realistic estimates of criteria for classification were made in the Sudan even when laboratory data were inadequate for high precision.

3. *Inferred Criteria*

Lack of data to establish soil temperature and moisture regimes is identified as a major problem by a large proportion of the respondents to the author's queries. Ideally, direct measurement of these properties over time is preferred, but the time required, especially for soil moisture regimes, discourages workers in many countries. Consequently, these attributes are commonly inferred from other information.

Uncertainty about estimates of soil moisture regime has been reported much more frequently than about estimates of soil temperature. Cook (1975) reported that estimating soil moisture regimes is a major problem for the Sudan; Antoine (1977), for northern and western Africa; Deckers (1966), for the Belgian Ardenne; Kesseba *et al.* (1972), for Tanzania; Isbell and Field (1977), for Australia and Brazil; and Murthy *et al.* (1977), for India. Antoine (1977) has emphasized that better correlations are needed between soil moisture regimes and both atmospheric climate and plant-water relations for reliable estimates.

Respondents to the author's questionnaire from the U.S. Forest Service and from Canada report that estimates of both soil moisture and soil temperature regimes are unreliable in vertically zoned mountainous areas. Establishing the necessary data base in these areas would be costly and time-consuming. Guidelines for estimating soil temperature regime (Smith *et al.*, 1964) provide bases for reasonable approximations of soil temperature regimes in many areas if air temperature data are available. The guidelines need modification for regions where climates and vegetative cover differ markedly from those where the relationships were established.

C. TRAINING AND BIAS OF PERSONNEL

Precise use of Soil Taxonomy demands expertise in field techniques, diligence in their application, and subordination of preconceived ideas about classification of soils. In the United States, Soil Taxonomy forced a major transformation of most of the field staff from qualitative observers in an atmosphere of historically derived concepts to quantitative investigators in an environment of detached reasoning. The transformation was not made easily or quickly, nor is it complete. It has involved intensive training, both formally and informally, which continues

as new personnel enter service. The system is no less demanding in other countries.

Respondents from 10 foreign countries, including 3 of the developed nations, report that field workers commonly overlook definitive properties or fail to determine them precisely. Cook (1975) reported that inexperienced personnel prepared inadequate soil descriptions and mixed critical horizons when sampling for laboratory studies to determine criteria of the system. Personal communication with individuals who have observed field operations in several countries indicates that errors of these kinds are more widespread than the responses suggest. Buol (PC) comments that essentially all of the leading soil scientists of Latin America are trying diligently to use the system correctly but with too little direction in more than empirical application. These are problems that only experience and training can correct.

Errors in application of Soil Taxonomy are not confined to field personnel. One response to the author's questionnaire, for example, reports need for an "andic" subgroup of Ustox on the grounds that the soil is dominated by clay of high activity. This individual apparently does not understand that the Oxisol order, of which such a subgroup would be a member, is defined specifically to include only those soils which are so highly weathered that clays of high activity would *not* be present. He did not question the concept of Oxisols.

Personal bias is, and probably always will be, a problem of soil taxonomists. (The term bias is not used in a derogatory sense.) It is exhibited among users of Soil Taxonomy in many ways, ranging from sincere disagreement with the system's own bias to intellectual dishonesty in its application. Among the former, a number of respondents to the author's inquiries report that Soil Taxonomy classifies some soils "incorrectly" because it separates them from other soils that are considered members of the same taxon in another system. The most common "problem" of this kind is the complaint that many, if not most, Latosols (Laterite, Lateritic soils) are not Oxisols by criteria of Soil Taxonomy. The complaint may or may not have merit, but the real problem is that individuals base their criticisms on preconceived ideas rather than on the merits of the alternatives.

Respondents from three countries say that some individuals deliberately classify soils incorrectly by criteria of Soil Taxonomy to preserve groupings of another system they have used. Six others report that some deliberately classify incorrectly to show similarities of soil potentials for use. Other misrepresentations of soils in the system arise from the mistaken idea that the system is infallible. Some workers distort or overlook factual evidence to make soils fit the system (Cline, 1977). Wilding (PC) mentions failure to report observations of facts that do not fit the system. These kinds of omissions and distortions conceal errors in the system, which was designed deliberately to expose them.

Most countries that use Soil Taxonomy as a primary system have some provi-

sion for training, if only informally by supervisory personnel. Buol (PC) indicates that this too commonly consists only of instruction in empirical application. India provides one of the more intensive training programs (Murthy, PC). Antoine (1977) has emphasized that in North Africa, where Soil Taxonomy is used little, acceptance of the system would depend on training prior to attempts to have field workers use it. Guerrero's unpublished survey of Soil Taxonomy in the Tropics rates teaching of the system in Latin American universities as generally weak. Teaching and training are likely to remain problems in countries where resources are limited. The needs for training in many countries include instruction not only in use of the system but also in basic soil science and in scientific attitudes and ethics.

V. TAXONOMIC PROBLEMS

Well over 100 "problems" are reported by respondents to the author's questionnaire. Many are local problems for which solutions proposed would adversely affect classification of soils of other areas. Others are problems reflecting the personal bias and incorrect use of criteria discussed in the preceding section. Some are clearly deficiencies of the system and affect classification of soils in the world scene. The major ones of these are discussed here.

A. NEED FOR ADDITIONAL TAXA

This is the taxonomic problem mentioned most frequently by respondents. G. D. Smith (PC) notes that lack of an appropriate taxon to accommodate unique kinds of soils is a problem he has encountered frequently in his extensive travels. It results in classification of unlike soils in the same taxon. The system was constructed to permit additions (Flach, 1963), so incomplete classification can be corrected. Uninhibited additions of taxa could, however, result in a chaotic mélange replete with contradictions. Some device is needed to weigh the merits of proposed new taxa in terms of the need for them, impact on other parts of the system, and appropriate criteria to define them. The main proposals for additional taxa which have come to this author's attention are reported here, mainly with little comment for lack of bases to appraise them.

Guthrie (PC) reports need for five great groups of Arents based on soil moisture regimes for the southeastern United States. He also suggests alfic, ultic, spodic, ochreptic, and oxic subgroups of one or more of them. Arents are currently unclassified below the suborder level. Isbell (PC) notes the inadequacy of current great groups of Ultisols for Australia. Coover *et al.* (1975) have

proposed Halaqualf and Halaquept great groups with typic, salic, and histic subgroups for 1.5 million hectares of coastal marshlands of the United States. Their analysis of the problem has been reinforced by Coultas and Gross (1975). Westin *et al.* (1968) have reported need for a "Tropoll" suborder for Mollisols of ustic isohyperthermic regimes to distinguish them from Ustolls of temperate regions. The "Trop-" designation may be inconsistent with this use.

Most of the proposals are for additional subgroups. Need for andic subgroups of a wide range of great groups is reported by respondents from regions having volcanic deposits: Alvarado (Costa Rica), Muchena (Kenya), Rijkse (New Zealand), Cline (U.S. Forest Service). These problems are related to those of Andepts discussed later. Need for additional halic, salic, and natric subgroups are also noted by several respondents and authors: Salic Udifluvent (India), Salic Natrargid (Sudan), Natric Torrifluvent (Pakistan), Halic Hydraquent (Coover *et al.*, 1975), salic and salic-natric subgroups of Calciorthids, Camborthids, and Haplustalfs for the Indo-Gangetic Plain (Sehgal *et al.*, 1975).

Langohr (PC) describes a polysequum having a thick cambiclike horizon over an argillic horizon in Belgium. He considers these soils members of an unnamed subgroup of Hapludalfs. Ragg and Clayden (1973) reported unrecognized varieties of Placaquods. Leamy (PC) reports need for an ustic subgroup of Fragiocdrepts. Two representatives of the U.S. Forest Service (PC) describe soils that fall in the Paleboralf great group because of their depths to the argillic horizon, yet have a fragipan. These are not accommodated well at present and may justify a new subgroup.

Lewis (1977) has described an Argiudoll with vertic properties and near-ustic moisture regime, which he would classify as an Ustertic Argiudoll. Luzio and Menis (1975) described evidence of illuvial clay in lower horizons of Vertisols, and Luzio (1978) found argillans in some horizons of Pelloxererts, Durandepts, and Xerofluvents. Although potential alfic subgroups may be inferred, this is part of the argillic horizon problem described later. Kesseba *et al.* (1972) have reported need for an alfic intergrade to Ultisols.

Guerrero (PC) reports need for additional subgroups of Ustalfs, Ustolls, and Oxisols in Colombia without specifying kinds. Sherrell (PC) suggests additional subgroups of Durumbrepts and Haplohumults in areas mapped by the U.S. Forest Service. Tan *et al.* (1970) proposed a new subgroup for some Spodosols of the tropics.

B. SOILS OF THE TROPICS

Soil Taxonomy (Soil Survey Staff, 1975) calls attention to the fact that the classification of soils of the tropics remained to be tested as the manuscript went

to press. That of Oxisols in particular was described as a compromise of conflicting judgments which might well satisfy no one. Problems that have been found are by no means confined to the Oxisols.

The definition of the Oxisol order, including the range of soils it should encompass, remains a matter of controversy. An international committee has been charged with recommending solutions. Progress by the committee has been slow.

One of the most troublesome problems involves relationships between the Oxisol order and the orders of Alfisols and Ultisols. Soils of extensive areas of the tropics are classified as Alfisols and Ultisols on the basis of presence of an argillic horizon. Many of these soils are characterized by properties associated with clays of low activity not strikingly different from those of the Oxidic horizon. The contrast between those soils and their counterparts of the Alfisol and Ultisol orders in temperate zones is striking. The problem is widespread. Camargo (Brazil), Murthy (India), Buol (Latin America), De Alwis (Sri Lanka), Comerma (Venezuela), MacVicar (South Africa), and Ali (Sudan) identify it in responses to the author's questionnaire. Gowaiker (1972), Murthy *et al.* (1977), and Rengasamy *et al.* (1978) have published reports about this problem for India. Van Wambeke (1967) identified the problem early in the development of the system. Sanchez and Buol (1974) have discussed it for soils of the upper Amazon basin; Lepsch and Buol (1974), for Sao Paulo State of Brazil. Isbell and Field (1977) were unable to classify certain soils of Brazil and Australia with confidence in either the Oxisol or Ultisol order because of uncertainty about presence or absence of an argillic horizon. Isbell has described the problem in detail (for the Proceedings of the 1977 International Workshop on Soil Classification held in Malaysia and Thailand). He suggested broadening the definition of Oxisols to resolve it. An international committee has been working on the problem over a period of several years. It has considered a number of options, including definition of special "kandi" great groups of Alfisol and Ultisol orders to accommodate these soils. Firm decisions have not been reached.

Soil moisture regimes for the tropics also remain a controversial issue. Isbell has commented on it in his unpublished paper cited above. An international committee has been formed to recommend a solution, but its conclusions have not been reported.

Reconsideration of great groups for soils of the tropics is also needed (Smith *et al.*, 1975) not only for Oxisols but also for some Alfisols and Ultisols. Among respondents to the questionnaire, Sombroek (East Africa), Murthy (India), Muchena (Kenya), and De Alwis (Sri Lanka) variously report problems differentiating between Pale-, Rhod-, and Hapl- great groups of Ustalfs. Similarly, Buol (Latin America) and Sombroek (East Africa) identify problems distinguishing between Pale-, Rhod-, and Hapl- great groups of Udults, Ustults, and

Aquults. Great groups of soils of the tropics are listed as problems needing attention by McClelland (Soil Conservation Service), but no international committee is known to be assigned the problem at this time.

C. ANDEPTS

The range of properties of the Andept suborder is very broad and is not adequately subdivided in lower categories. Bases can range 100-fold; soil moisture regimes include udic, ustic, and xeric; soil temperature regimes are even more varied. Problems related to this variation have been communicated by G. D. Smith, R. Cline and Warrington (U.S. Forest Service), Williams (Soil Conservation Service), Salgado (Chile), Alvarado (Costa Rica), and Rijkse and Leamy (New Zealand). Identification is an additional problem. The determination of thixotropy, for example, is highly subjective. Cortez and Franzmeier (1972) have questioned the limits for volcanic glass. These problems extend to Andic subgroups of a number of other suborders.

The classification of Andepts is being studied by an international committee. One proposal would elevate the Andepts to order status, which would allow more options for distinguishing varieties by criteria consistent with those of other orders of the system. Proponents argue that this would recognize the character of the group at a level more nearly consistent with its uniqueness. As of this writing, the committee has not made recommendations.

D. PERGELIC SOILS

Few respondents to the questionnaire mentioned the Pergelic soils, and the literature on applications of Soil Taxonomy to them is limited. Pettapiece (1975), however, has identified major problems in Canada.

Currently, these soils are identified largely as pergelic subgroups of a variety of great groups, permafrost being treated as an "extragrade" property. Pettapiece and a number of authors whom he cites have documented extreme physical processes of disruption and mixing associated with cryoturbation, especially in wet soils. The resulting hummocky microrelief marks an abrupt break in soil character horizontally. Pettapiece finds genetic interrelationships between soils of the depressions and of the hummocks. The cyclic character of the resulting soils has led Pettapiece to the conclusion that the classification of these soils should be analogous to that of Vertisols, perhaps involving a sampling unit that includes depression and hummock as a unit. Pettapiece reported that a committee of Canadian Soil Survey has proposed a "Cryosolic" order in their system, paralleling the Vertisol order of Soil Taxonomy.

In addition to Pettapiece, Tarnocai of the Canadian Land Resource Institute

(PC) deplores the low level in Soil Taxonomy at which soils with pergelic temperature regimes are identified and the lack of good devices to separate cryoturbated soils. McClelland (Soil Conservation Service) lists the classification of these soils as problems demanding attention.

E. VERTISOLS

Ali (1972) has reported that many of the cracking clays of the Sudan, commonly considered good examples, fail to meet criteria defined for Vertisols. Slickensides may not intersect; gilgai relief may be minimal; and aggregates may be platy instead of parallelepiped in a given soil unit. He also found that the distinction between Chromusterts and Pellusterts on the basis of chroma and the differentiation of subgroups on the basis of color value do not make the most meaningful distinctions. He reports that hue is useful in some instances.

G. D. Smith (PC) lists Pellusterts and Chromusterts as groups presenting serious problems due to low correlation of chroma with drainage or erosion. He also cites failure to use acidity as a criterion for soil families as a deficiency. Murthy (PC) reports similar conclusions about use of chroma for India, as does Comerma for Venezuela. Comerma (PC) suggests also that a suborder of Aquerts is needed.

Luzio (PC) reports a need for salic and natric subgroups of Xererts. Luzio (1978) and Luzio and Menis (1975) have described weak argillans in deep horizons of soils classified as Vertisols; Comerma (1971) reported uncertainty about distinguishing between Vertisols and vertic varieties of Alfisols, which may be related to Luzio's findings.

F. DIAGNOSTIC CRITERIA

The weighting, definition, and role of the argillic horizon are subjects of much controversy. The horizon is used in Soil Taxonomy as a mark of the illuviation of clay, which is weighted heavily in the system on the belief that it is an extremely important genetic process. Its definition is based on properties believed to be evidence of that process and allows for limits of observation and measurement. Problems of identification and those involving the horizon in Alfisols and Ultisols having low-activity clays have been discussed in preceding sections.

Isbell (paper for publication in the 1977 transactions of Commissions IV and V, International Society of Soil Science, Kuala Lumpur, Malaysia) has summarized much of the criticism. He questions the genetic implications attributed to the horizon, as does Langhor (PC). MacVicar (PC), Isbell, and others believe that Soil Taxonomy weights illuviation of clay too heavily by using the argillic horizon as a criterion at the highest level in the system. Much of the problem with

Alfisol and Ultisol having low-activity clays can be attributed to its use at that level. Isbell as well as Nettleton *et al.* (1969), Gile and Grossman (1968), and Beinroth *et al.* (1974) have cited evidence that the presence or absence of argillans is not infallible proof that illuviation has, or has not, been significant. Oertel (1968) contended that the ratio of fine to total clay is not a trustworthy criterion. Bullock (PC) questions the universal validity of both criteria. Few soil scientists appear to question the significance of argillic horizons at some level in the system, but many are critical of its definitive criteria and the weight given to it. It has been this author's observation that field personnel commonly "stretch" the defined limits in their enthusiasm to find the horizon.

Problems with criteria of the spodic horizon have persisted throughout the development of Soil Taxonomy and to the present. Avery *et al.* (1978) found that chemical criteria exclude from Spodosols many soils which are "spodic" by morphology. Witty (Northeastern States), Stout (Midwestern States), Gardiner (Ireland), Schelling (Netherlands), Lag (Norway), Ragg (Scotland), and R. Cline (Forest Service) support that observation in personal communications. McClelland (PC) lists criteria for the spodic horizon as a problem the Soil Conservation Service is studying.

Criteria of wetness continue to cause problems in some soils. Pilgrim and Harter (1977) have reported that masking of low chroma mottles by iron and humus of the spodic horizon results in inclusion of a high proportion of wet Spodosols in Typic Haplorthods. Lavkulich (PC) also identifies this as a serious problem. Buol (PC) has difficulty with soils that classify as Typic Paleustults because chroma is not less than three, though the water table may be within the solum for long periods. Avery (PC) also describes water table studies which show that wet soils do not necessarily have mottles of two chroma or less. He attributed significance to ferruginous mottles in some soils. Sehgal and Sys (1970) have reported difficulties with criteria of wetness in the Punjab.

G. MISCELLANEOUS PROBLEMS

In addition to the major problems discussed above, a number of relatively less widespread difficulties were reported by respondents to the author's inquiries or were found in the literature. Examples of these are described here, excluding those which were clearly related to misinterpretation of criteria or to personal bias.

De Bakker (1971) reported that stratification in soils of Dutch fluvial and marine sediments appears to occur capriciously locally. As stratification is the critical criterion determining presence or absence of gleyed cambic horizons in these soils, Aquepts and Aquepts are intimately intermingled with little apparent relation to landscape units or differences in genesis.

Both Fenton and Stout (PC) are concerned with application of criteria for the

mollic epipedon to eroded former Mollisols in the midwestern States. Technically, the eroded soils are no longer Mollisols, but they are intimately intermingled with Mollisols in the landscape.

Both Avery and Clayden (PC) report that base status as a definitive criterion separates Eutrochrepts and Dystrochrepts in an intricate rectangular pattern where a long history of liming has changed the base saturation of soils in some fields but not in others. Avery also reports that man-made mollic epipedons create analogous complex patterns of soils distinguished at the order level.

The foregoing are mentioned because they all represent mapping problems as artifacts of the system. Devices exist for handling such geographic mixtures in legends, but they are commonly awkward. As some respondents have indicated, changes to accommodate such situations may well create others elsewhere.

Some difficulties have been reported for the clay mineralogy criteria at the family level. Witty (PC) reports that the definition of oxidic mineralogy classifies many soil series of New England in oxidic families. These are soils on very young glacial deposits. De Alwis (PC) reports problems distinguishing between oxidic and kaolinitic mineralogy in Sri Lanka. Fenton (PC) finds that failure to differentiate montmorillonitic and illitic mineralogy in fine loamy and fine silty families detracts seriously from the interpretive value of soil families in Iowa.

Comerma (PC) has difficulty rationalizing the classification of those Haplustalfs that lack zones of carbonate accumulation in the udic subgroup when they clearly have an ustic moisture regime. Both Murthy and Nanda (PC) report the same problem with Udic Haplustalfs and Udic Paleustalfs in India. Scoppa (PC) is faced with a "pale-" great group of Mollisols having a udic moisture regime but with petrocalcic horizons. The key classifies these as Paleustolls.

Sehgal *et al.* (1975) have reported that soils having salinity or sodicity limitations on the Indo-Gangetic Plain do not key out of typic or aquic subgroups of Calciorthiss, Camborthiss, and Haplustalfs. They have proposed salic and salic-natric subgroups.

Both Leamy and Williams (PC) write that bulk density requirements keep some soils having other properties of andic subgroups out of those taxa, with serious consequences for interpretation. R. Cline (PC) reports from the Forest Service that some soils are classified as Andic Dystrochrepts by methods defined for base saturation, though research indicates that the soils are nearly base saturated at the pH of soils in the field.

VI. IMPACT OF SOIL TAXONOMY INTERNATIONALLY

A. SOIL CLASSIFICATION

The impact of Soil Taxonomy on soil classification internationally varies from adoption of a few concepts or terms in some countries to use as a primary system

in others. The evidence for impact in countries that have not adopted the system consists mainly of similarities between the innovative aspects of Soil Taxonomy and those of other schemes. Such evidence must be appraised cautiously. Some similarities might have developed independently. Others are known to be the result of ideas that originated with foreign soil scientists and were incorporated in Soil Taxonomy. The author has tried to confine his reporting to those aspects that would probably have taken somewhat different form in foreign countries had Soil Taxonomy not been available *and* to those that evolved through mutual exchange of ideas internationally at the initiative of Dr. Smith and his associates.

The Canadian soil classification (Clayton *et al.*, 1977) is most nearly like Soil Taxonomy among systems in general use. Although it differs from Soil Taxonomy somewhat in organization and uses different names, the greatest difference in principle is probably its use of diagnostic features that may easily be altered by man. The two systems were developed with frequent interchange of ideas, though they were not the results of a joint effort.

The soil classification for the Soil Survey of England and Wales (Avery, 1973) departs substantially from Soil Taxonomy but uses quantitatively defined criteria, a three-dimensional "profile" comparable to the pedon, and some criteria and terms of Soil Taxonomy. Ragg and Clayden (1973) noted that Soil Taxonomy had prompted scrutiny of traditional British soil classification. The new French taxonomy (Fauck *et al.*, 1979), like Soil Taxonomy, uses genetic theory with a strong bias for practical application, though the weighting of elements of genesis is greatly different. It uses the pedon and polypedon concepts. The nomenclature is similar in construction, though the terms are mainly different.

The FAO legend for the soil map of the world (FAO-UNESCO, 1974) is used as a primary or secondary classification in many countries. Although far from similar in outline and detail, it uses many of the devices of Soil Taxonomy. The nomenclature of some parts is similar in construction. Diagnostic horizons defined quantitatively are used as criteria; many are identified by terms used in Soil Taxonomy and are defined similarly. The correlations of the map units with taxa of Soil Taxonomy, however, are far from perfect (Beinroth, 1975).

Rauta (PC) reports that Soil Taxonomy has influenced soil classification in Romania through increased precision of definitions and use of some of its diagnostic criteria. Some soil orders are the same. Thailand (Dent and Changprai, 1973) classifies soils by Soil Taxonomy, though it uses a national system for local use. Gardiner (PC) reports introduction of quantitative criteria from Soil Taxonomy into the system used in Ireland.

Laker (PC) writes that the Seventh Approximation had a revolutionary impact on perspective of soils in South Africa, though a greatly different classification is used. Oyama (PC) states that "without the Seventh Approximation and Soil Taxonomy, soil science in Japan would be far from science. In that sense, the

influence of Soil Taxonomy in Japan cannot be written." This kind of impact is probably more important to soil classification world-wide than the adoption of specific concepts and devices in individual countries.

B. SOIL SURVEYS

1. Soil Survey Operations

In the United States, Soil Taxonomy brought about an enormous increase in the precision and detail of field descriptions and a large increase in both kinds and numbers of supporting laboratory determinations. More importantly, it transformed the field force by necessity from qualitatively oriented observers to quantitatively inclined investigators. It had relatively little impact on the field methods of surveys, but it substituted quantitative criteria for much of the personal judgment that had dominated soil correlation and the development of legends.

In the other 11 countries that use Soil Taxonomy as a primary system, the impact has been much less. Individuals from 9 of the 11 countries responded to the authors inquiries about the impact on soil surveys. All except the respondent from Pakistan report an increase in both the detail and the precision of field descriptions. Respondents from Argentina, Chile, Colombia, India, New Zealand, and Venezuela report an increase in laboratory support, mainly by the addition of determinations required for diagnostic criteria. The total input of laboratory technician time, however, ranges from a high of 14 man-years to a low of 0.25 man-year annually.

Correlation in the soil surveys of developing nations of this group is notoriously weak. Responses to the author's inquiries show that only New Zealand, Venezuela, and Colombia use the criteria of Soil Taxonomy both to define mapping units in field legends and to correlate mapping units when the field work is complete. In Argentina, India, and the Sudan, the criteria of Soil Taxonomy are apparently used mainly *after* field work is complete to combine some units for publication and to correlate the published units with taxa of Soil Taxonomy. Murthy (PC), for example, reports that correlation of the 700 soil series established for mapping in India is only beginning.

The situation in India is analogous to that in the United States in the 1950s, though the number of established series is much less. Soil Taxonomy required major revisions of existing soil series definitions before its criteria could be applied consistently in the development of legends for detailed surveys. Similar adjustments will be a major undertaking in countries that adopt the system. Some appreciation of the size of that task, including the necessary training, may be obtained from Cook's (1975) report on use of Soil Taxonomy in the Sudan.

Indirect impact of Soil Taxonomy on soil survey operations is reported by respondents from Canada, Kenya, Sri Lanka, Trinidad, Romania, Ireland, Brazil, England, Japan, Belgium, and Costa Rica among countries that use the system only in a secondary role. They indicate that standards of precision, detail, or both have increased to some degree for field descriptions. Six of the 11 also report addition of new laboratory determinations for criteria used in classification. One respondent from Australia, which uses the system little, mentions some effect on field descriptions and addition of a few laboratory determinations.

2. Soil Maps and Mapping

a. Soil Boundaries. Orvedal and Austin (1963) predicted little change in the number and location of soil boundaries in detailed soil surveys of the United States as a consequence of Soil Taxonomy. The boundaries of most delineations are based on the visible landscape. The *identity* of some mapping units did change as soil series were redefined and new series were established, but soil scientists contacted in the United States confirm that the effects on mapping were small. Six individuals report that "some" additional boundaries are drawn to accommodate criteria of Soil Taxonomy. Only two say that "some" boundaries that would have been drawn previously are located differently.

Orvedal and Austin (1963) also compared compiled maps using the 1938 system with maps based on Soil Taxonomy for scales of 1:5,000,000 and 1:20,000,000. They found that some adjustment of boundaries was necessary, mainly to accommodate the new soil temperature and soil moisture criteria that Soil Taxonomy introduced.

Respondents from five foreign countries that use Soil Taxonomy as a primary system report that mappers use its criteria to make distinctions in the field. Only three of the five, however, report that the criteria are incorporated in legends; one may assume that use of the criteria is minimal for the other two. Four report that "some" boundaries that would not otherwise have been recognized are drawn; only two report that the location of other boundaries is affected. All of those reporting a significant impact on mapping are from countries where mapping intensity is less than for detailed soil surveys of the United States and where quality control has historically been poor.

Respondents from eight countries where the system is used only in a secondary role report that soil mappers do use some of its criteria in the field. Respondents from Belgium, Brazil, Romania, and Sri Lanka report that some new boundaries are drawn as a result. None consider that location of other boundaries is affected significantly.

b. Purity of Mapping Units. If, as reported, the location and number of soil boundaries drawn in the field is affected little by using Soil Taxonomy, it follows that the change of soil variation within delineations should be equally small.

Assuming that any relocation or addition of boundaries accurately reflects adjustment to conform with new criteria, any change in purity should be positive *when measured against composition according to taxa of the new system*.

Experience in the United States shows that the *apparent* purity of mapping units of detailed soil surveys may decrease when the criteria of Soil Taxonomy are applied as the basis of measurement. In an extreme instance, McCormack and Wilding (1969) studied the composition of mapping units in an area having intricate patterns of soils in stratified lake sediments. They measured the composition of delineated areas in terms of soil series present, first using concepts of series that predated Soil Taxonomy and then using series defined by the limits of criteria of the new system. They found that the proportion of the total area outside the ranges of series named increased by about one-third. Although the areas were not remapped using criteria of Soil Taxonomy, it has been this author's experience in similar areas that mapping would have changed little.

The apparent increase in inclusions is mainly an artifact of the quantitatively defined limits of taxa. The limits of criteria of all categories accumulate as limits of soil series. Thus, a pedon selected from a polypedon identified as a series of a coarse loamy family is outside the range of its series if it contains 19% clay—1% above the upper family limit. The accumulated limits at the series level cleave conceptual "splinters" of soil of another *potential* series from soil bodies that are identifiable as natural units. Commonly, these differ in only a minor degree of one or two properties from the series identified in mapping. Many are unclassified at the series level. The term "taxadjunct" has been coined to characterize unclassified soils that differ from established series to such a minor degree that soil potential for use is substantially the same. These are treated as if they were members of the parent series for practical purposes.

c. Quantitative Limits. The discussion of the preceding section leads to reconsideration of quantitative limits and their application to bodies of soil in the field. The quantitatively defined criteria of Soil Taxonomy have been identified as one of the system's most laudable attributes by 22 of the respondents to the author's inquiries and by authors such as Antoine (1977), Beinroth (1975), Butler *et al.* (1961), and Ragg and Clayden (1973). It is the characteristic of the system that has had the greatest impact on soil science in general, soil classification in particular, and the scientific attitudes of soil survey workers. Webster (1968a, 1968b) has emphasized, however, that the absolute limits of Soil Taxonomy are not consistent with the errors of estimates of criteria in practice. Wilding (PC) expresses similar concern and notes that too few field workers appreciate the errors inherent not only in observation and measurement but also in field sampling.

It is apparently not commonly appreciated that precise definition of limits for differentiating criteria does not *a priori* imply unyielding application of those limits to the conceptual boundaries of taxa. Wilding (PC) contends that although

limits of criteria should be defined in terms of single values, as at present, they should be applied to boundaries of taxa with latitude for variation consistent with the probable error of the estimate. To carry that idea one step further, not only could the degree of allowable departure from defined "limits" be prescribed but also how many criteria in combination might be permitted to violate their "limits" to that degree for determining the boundaries of taxa. This is effectively what is done in the definition of taxadjuncts, most of which would become members of their parent series in concept as well as in practice if such a device were adopted as general procedure. Such a convention would require substantial study and testing, and it would probably result in some loss of consistency of classification among individuals. It might, however, provide solutions to a number of the "problems" reported by respondents to the author's questionnaire.

C. INTERPRETATIONS FOR APPLIED OBJECTIVES

A sharp distinction is made in this section between the evaluation of soil taxa for applied objectives and predictions about potentials, limitations, and management needs of the real bodies of soil that are identified by the names of taxa on soil maps.

1. Evaluation of Taxa

Bartelli (1978) has listed 11 objectives for which soil surveys are routinely interpreted in the United States. Although these interpretations are presented as predictions for mapping units that represent real soil bodies, they are, in fact, based mainly on the defined attributes of the phases of soil series used to name the mapping units. They do not usually evaluate the effects of the inclusions that are normally present.

Phases of soil series are not new to Soil Taxonomy; comparable units would have been identified and interpreted if Soil Taxonomy had not been developed. Respondents of the Soil Conservation Service, the Forest Service, and several states report, however, that Soil Taxonomy has resulted in significantly more precise interpretation because of the quantitative limits it has imposed on the range of properties of soil series. It should be understood, however, that this increase of precision applies mainly to conceptual units of classification, not necessarily to the real bodies of soil that are identified by their names.

Respondents from Argentina, Chile, India, New Zealand, the Sudan, and Venezuela report that adoption of Soil Taxonomy has increased both the precision and number of soil interpretations. Respondents from 4 of the 10 countries where Soil Taxonomy is used only as a secondary system report some increase in

precision. The author would judge that the impact has been relatively small in all of these countries, which have either adopted Soil Taxonomy very recently or have limited programs for soil interpretation. As in the United States, increased precision applies primarily to taxonomic units, not mapping units.

The foregoing refers mainly to interpretations for phases of soil series or their equivalents. Orvedal (1977) has stressed the sacrifice of information on which interpretations can be based as the taxa increase in heterogeneity from soil series to higher categories. Westin (1974) showed that the coefficient of variability of the selling price of land approximately doubled from strata representing soil series to strata representing orders. Chan (1978) found that soil series are correlated with productivity of *Hevea* in peninsular Malaysia; he could assign subgroups to five classes of productivity but the range of variability within subgroups was large. He found that the range of productivity was very large within great groups, though the best clones of *Hevea* realized their full potential only on soils of a few specific great groups.

While the range of soil properties within taxa increases from series to families, phases of soil families are believed by a number of workers to be homogeneous enough to serve as basic units for transfer of technology on a broad geographic scale. Uehara (1978) has described the rationale for this function of the family. Preliminary results of research to test the hypothesis have been published (Anonymous, 1978). North Carolina State University uses soil families to provide unequivocal identity of soils at experimental sites in the tropics (Soil Science Department, 1978). Respondents to the author's questionnaire suggest that soil families are suitable taxa for characterizing the soil factor in some Forest Service land inventories for predicting forest productivity, revegetation potential, soil stability, and similar elements of forestry operations. Respondents from India, New Zealand, the Sudan, and Venezuela report that soil families have been tried and have proved useful for some applied interpretations, but their experience is limited.

At successively higher categorical levels, the range of properties within taxa obviously restricts soil interpretation to increasingly broad objectives. Nevertheless, respondents from five countries report interpretive value of taxa at levels as high as the suborder. Ten cited the introduction of soil climatic parameters at a high level as an important element for enhancement of the interpretation potential of taxa of the higher categories. Ikawa (1978) has discussed this in some detail. It is possible, for example, to identify soils in which wetness is limiting at the suborder level. Specific examples of interpretations for taxa above the family level are rare, however.

Others report deficiencies of Soil Taxonomy as a base from which applied interpretations can be made. Stephens (1963) criticized the system because it separates similar soils in Australia and reduces the correlation of taxa with land use potential. This is not a unique attribute, nor is it limiting. Soils of similar

potential are classified in different taxa in most, if not all, taxonomies and are routinely grouped in technical classifications for applied uses (Bartelli, 1978).

Problems are more serious if Soil Taxonomy fails to distinguish between soils of unlike potential. Instances of this kind reported by respondents include the following:

1. The range of soil temperature regimes is too wide.
2. Soils having fragipans are not distinguished from "pale-" great groups.
3. Color criteria of Vertisols do not make meaningful separations.
4. Some soils with pronounced ustic moisture regimes are classified as udic subgroups.

Buol (PC) reports that failure of the system to make distinctions on the basis of properties of surface horizons leaves soils having significantly different potentials for primitive farming in the same taxon at the family level. Buol's concern is with the loss of confidence of soil scientists who expect too much of the system—not with the omission of properties of surface horizons. The examples given above are, of course, appropriate criteria for soil series or for phases of families.

None of the deficiencies reported is unique in principle to Soil Taxonomy nor is insurmountable if the principles and techniques of soil interpretation are understood. Low levels of technological understanding are more critical than deficiencies of the system. Guerrero's survey of Soil Taxonomy in the Tropics, for example, reports vigorous criticism because (1) the taxa are not interpretive groups and (2) the interpretive potential decreases from low to high categories. Both of these attributes are characteristic of any hierarchal taxonomic system. It is quite possible that the subtitle, "A Basic System of Soil Classification for Making *and Interpreting* Soil Surveys," has unwittingly inspired expectations of direct interpretive meaning of the taxa for workers having weak technical backgrounds.

2. Predictions for Map Units

These entail predictions that encompass soil potentials of not only the taxa identified in map unit names but also the inclusions and, in addition, the effects of interactions between the two on use of land areas. Almost all interpretations of detailed soil surveys consider only the taxa identified in names. Soil Taxonomy has had essentially no effect on this practice. The system has increased the precision of predictions for the named taxa, but if as indicated in Section VI,B,2 it has had little effect on mapping, the net error of the predictions for delineated areas should have increased.

From personal observation, the author believes that the "purity" of mapping units in terms of soil potentials for use has increased substantially in detailed soil

surveys of the United States over the past 15 years, but not as an effect of Soil Taxonomy. During that period the pressures for both greater variety and greater accuracy of predictions about the potentials and limitations of soil mapping units have increased dramatically. These pressures have been translated into legends tailored for predictive value and into greater diligence on the part of mappers. Mappers strive to exclude from their delineations small areas of soil having markedly lower potential than the taxa identified in the names. They are less concerned with small inclusions of soil having higher potential. The fact that mappers may still be located where they can be held accountable when some users apply the predictions is a potent compulsion for diligence. These elements are largely lacking in other countries that use Soil Taxonomy.

Interpretation of small-scale maps is a neglected subject in soil science. Most of those that have been made are primitive. Orvedal (1977) has emphasized the loss of geographic information and its precision as map scale decreases. Interpretations that can be made must be correspondingly general in purpose and in geographic detail. Small-scale maps based on Soil Taxonomy or any other taxonomic system can be interpreted only within these limitations.

It is common misconception that units of small-scale maps can be identified with precision in terms of taxa of higher categories. At small scales and correspondingly large minimum size of mappable areas, soil heterogeneity within delineations necessarily is large. No taxonomic device can alter that fact. When map units that represent large land areas are identified by taxa of high categories, part of that heterogeneity is represented by the broad ranges of the taxa; the remainder can be identified in terms of the contrasting taxa present. If the taxa have strong geographic bias, the latter can be minimized by appropriate location of boundaries.

There is strong geographic bias in the Alfisol, Aridisol, Mollisol, Oxisol, Spodosol, and Ultisol orders of Soil Taxonomy. Sehgal and Sys (1970) have correctly noted, however, that the Entisol, Inceptisol, Histosol, and Vertisol orders have much more limited geographic connotations. Areas of Entisols and Inceptisols ranging from a fraction of a hectare to a few thousand hectares, for example, are commonly intimately intermingled with areas of one or more of the six orders that have stronger general geographic connotations. Consequently, soil map units at scales so small that minimum delineations represent hundreds of square kilometers are typically geographic mixtures of contrasting soil orders. At the suborder level, soils having aquic moisture regimes are separated from their nonaquic counterparts of the same order. These contrasting taxa at the suborder level are typically even more intricately intermingled in the landscape and cannot be delineated separately on small-scale maps. Thus, prediction of the soil potentials of the large areas mappable at small scales usually involves appraisal of geographic mixtures of contrasting soils, even though they may be identified at the highest levels of Soil Taxonomy.

Small-scale maps, like those of Aubert and Tavernier (1972) and Moorman and van Breemen (1978), identify map units in terms of one or a few dominant taxa at the highest levels of Soil Taxonomy, but it is understood that the areas are likely to contain major proportions of soils that may be highly contrasting. The maps at larger scales produced by the low-intensity surveys common in developing nations also delineate intimate mixtures of soils that not only are members of different taxa of Soil Taxonomy but also have markedly different potentials for use. Many maps of this kind identify map units in terms of a single dominant taxon and thereby lose much of their potential interpretive value. The kinds, amounts, and patterns of associated contrasting soils are commonly not recorded. Buol (PC) reports that many workers in Latin America are disappointed and critical when they discover that such map units cannot be interpreted with confidence for the site-specific requirements of small farms.

Even if the composition of map units is known, relatively few soil scientists have the understanding and experience with geographic interpretations to take advantage of the potential such soil maps present. Most predictions for them stop with generalizations based on the dominant taxa. While the data do not permit site-specific predictions, they do provide the information necessary for quantitative estimates of the relative proportions of map units having different soil potentials. They also provide the information necessary for estimates of probability that soil of a given potential will be found at a given site. Cline and Marshall (1977) have published an interpretation of this kind.

VII. SUMMARY

Response to international distribution of Soil Taxonomy has ranged from acceptance as an official system to absolute rejection. The scheme is used as the primary classification for national soils programs in 12 countries. It is used commonly by soil scientists of 19 other countries for international communication, though the national programs of these countries depend on other systems. It is used infrequently in 20 others for which information is available. In a few of the latter, it is rejected almost completely.

The system addresses the world-wide range of soils in detail. Its scope is praised by advocates; the complexity which this attribute necessarily entails is deplored by critics. Among its innovations, the use of quantitative criteria and concepts of diagnostic horizons are acclaimed by its supporters; the complicated definitions and keys that result are cited as defects by many. The innovative nomenclature is welcomed by some but condemned by others.

Problems in applying the new approaches and criteria developed for Soil Taxonomy were inevitable. Some have been problems inherent in its potential users, such as personal bias and lack of training and experience. Deficiencies in published explanations of reasons for the choice and application of criteria have

created an appearance of empirical or capricious decisions and uncertainties among some of its potential users.

Some attributes of the system itself are obstacles to users. The system is highly demanding, and the manner in which it is presented in published form magnifies the problem. Some field criteria, such as those for argillic horizons, plinthite, and fragipans, are difficult to apply with precision. Lack of laboratory support for determination of some criteria and lack of data from which soil moisture and temperature regimes can be estimated have been cited by many as obstacles.

The system is still in a process of evolution as data about soils of the world accumulate and expose taxonomic problems. Need for additional taxa, which can be accommodated, has been reported by many users. The system is incomplete for soils of the tropics. International committees have been appointed to consider the definition of Oxisols, the problems with soils having low-activity clays and argillic horizons in the tropics, and the questions about soil moisture regimes for these regions.

A committee is studying a more nearly adequate subdivision of the Andept suborder, including the possibility of elevating the group to order status. Workers in regions of cold climates find classification of cryoturbated soils associated with permafrost inadequate. The criteria for subdivision of Vertisols, and for distinguishing the Vertisol order, do not everywhere make the distinctions anticipated. Taxonomic problems with some diagnostic horizons and several criteria have been found. Among these, the validity of the heavy weight given the argillic horizon in the system is questioned by many. Criteria for the spodic horizon continue to be troublesome. The criteria of wetness appear to need adjustment for some soils.

The impact of Soil Taxonomy on soil classification world-wide has been far greater than that of any other development in the discipline during the past 50 years. In addition to its use as a primary system in 12 countries, elements of its principles, concepts, and devices have been incorporated to varying extent in both general and national schemes used in many countries. More importantly, it has prompted a changed perspective of soils and the beginnings of transformation from a qualitative to a quantitative approach to soil classification in many countries. The impact on soil surveys and soil interpretations has been much less.

Major improvements remain to be made. Among these, devices that will adapt quantitative limits of criteria more realistically to soil variation in the field are needed to reconcile the conceptual framework of taxonomy with the reality of soils in nature.

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