Soil Classification

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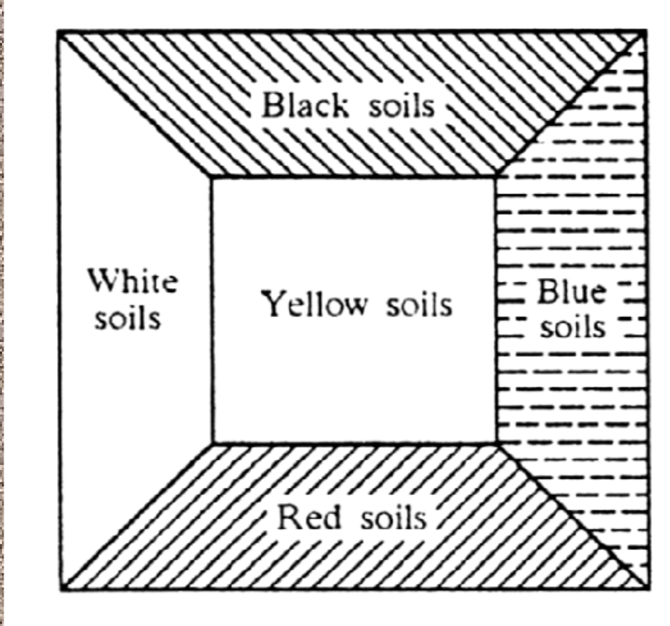

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Please visit our site http://clic.cses.vt.edu/IUSS1.4/ for news on soil classification

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The five-colored ‘‘sacrificial altar’’ established in 1421 of the Ming Dynasty has been preserved at Zhongshan Park, Beijing. Its highest layer is 15.8 m^2 in area, paved with five types of soils in different colors: the soils in the east are blue; south red; west white; north black; and central yellow. It is consistent with the general soil distribution of the country: in the east of the country, most soils are bluish in color because of stagnation and gleization; in the south, the dominant soils are reddish Ferrolsols; in the northwest, Aridosols and saline soils often are whitish; and in the center, the Cambosols in the Loess Plateau are yellowish in color as are many of the Agrosols. See the paper *Gong, Z., Zhang, X., Chen, J., & Zhang, G. (2003). Origin and development of soil science in ancient China. Geoderma*, *115(1), 3-13*. Also note that many other cultures used red colour for the south, black for the north, white for the west, and blue for the east. It is not clear, if this division is related in any way to the distribution of soils in China.

Message from the Chair

I am pleased to introduce the 6th Soil Classification newsletter from IUSS Comm. 1.4. We are reminded of the importance of soil classification, properties, and best management in ancient civilizations through the publication by Gong (2003) in *Geoderma*, *115(1), 3-13*. Using the Chinese culture and civilization as an example, humans have been recognizing different soil types and their distribution through writings around 2500 years ago and very likely through symbolic shrines about 700 years ago. These records demonstrate the importance placed on soil types by a people that have been practicing agriculture since around 9,000 years ago. Recognizing soil types, properties, and distribution provided the basis for their understanding of associated organisms and sustainable methods.

The recent proclamation by Head of the Secretariat of Global Soil Partnership Ronald Vargas, that "the 68th United Nations General Assembly has designated 5th of December as World Soil Day and declared 2015 as the International Year of Soils", is indeed a modern milestone for the soil science and the agricultural community. This recognition by the United Nations comes at a time in history when many critical climatic, natural resource, social, economic, religious, and military issues face the world and fill the headlines. Many people in highly urbanized areas have lost the association between soil resources and management and their culture's ability to obtain their needs and survive under changing conditions. Some do not know where their food comes from or what role soil plays in food production. Yet the foundation for future sustainable production of food, feed, fiber, and fuel lies in the soil, and we hope that the International Year of Soils will help many more recognize the role of wise land and resource use.

By reading about the ancient recognition of soil and more modern understandings of soil genesis processes that relate to classification (as explained by Simonson), we can bridge the time from realization through recognition of the importance of soil. As we develop a Global Soil Partnership, continue the Global Soil Map project, approach the 4th anniversary of the effort to build a Universal Soil Classification System, and continue our improvement of WRB and US Soil Taxonomy, we are now cooperatively learning from the past in order to preserve the quality of life in Anthropocene for us and for our children.

Congratulations for the World Soils Day

The International Union of Soil Sciences (IUSS) adopted in 2002 a resolution to propose to designate **5 of December** as World Soil Day. This date was chosen to honour His Majesty Bhumibol Adulyadej, King of Thailand, for his untiring efforts in the promotion of soil science and soil resources conservation and sustainable management. FAO Members expressed support to the recognition of 5 December as World Soil Day (during a presentation made at the 144th Session of the FAO Council of June 2012 and subsequently at the 145th Session of December 2012) and requested to institutionalize its observance according to UN system practice. Activities in connection with the observance of World Soil Day by national governments, international and national organizations and civil society should greatly assist in raising awareness about soil as an essential, finite and non-renewable natural resource and mobilizing the international community to act towards its sustainable management.

The World Soil Day was celebrated by many soil scientists since 2002, but only in the last two years it became a real worldwide holiday due to the efforts of FAO. This year for the second time FAO organized a series of event devoted to the World Soil Day in its Headquarters in Rome. This year FAO opened a new soil web portal as a gift to the entire soil science community: http://www.fao.org/soils-portal/en/

Within the framework of the GSP, the Government of the Kingdom of Thailand also proposed the celebration of an International Year of Soils (IYS). “Healthy soils for a healthy life” was proposed as a theme to raise awareness for the importance of sustainable soil management. This was initially presented to the 144th Session of the FAO Council.

We received the following message from the Head of the Secretariat of Global Soil Partnership Ronald Vargas (the text is slightly reduced to shorten technical details related to the UN bureaucratic procedures):

“The 68th United Nations General Assembly has designated 5th of December as World Soil Day and declared 2015 as the International Year of Soils!
It took two years of hard work from all the partners under the leadership of Thailand and the FAO Global Soil Partnership in order to inform members that soil is a crucial resource that requires urgent attention if to address the various challenges ahead.
We want to take this opportunity to thank all the partners who have been very active and supportive in this process. We have a huge responsibility in front of us, as this will be a unique opportunity for soil scientists to position soils in the development agenda beyond 2015.
The GSP Secretariat will serve as the Secretariat of the International Year of Soils and thus, will immediately establish an organizing committee composed by willing partners in order to prepare a joint plan of activities for the year. Our goal is to make IYS 2015 as a memorable year demonstrating that the soils community could really contribute to the efforts for food security, hunger eradication, climate change adaptation, poverty reduction and sustainable development.”

Global Soil Partnership Requires Efforts for Soil Data and Soil Classification Harmonization

Global Soil Partnership (GSP) is the most challenging initiative for soil science recently launched by FAO. The GSP is based on five pillars, namely:

- Pillar 1: Promote sustainable management of soil resources.
- Pillar 2: Encourage investment, technical cooperation, policy, education awareness and extension in soils.
- Pillar 3: Promote targeted soil research and development focusing on identified gaps and priorities.
- Pillar 4: Enhance the quantity and quality of soil data and information.
- Pillar 5: Support harmonization of methods, measurements and indicators for sustainable soil management.

The GSP Secretariat notes the following about the place of soil classification in the **Pillar 5**:

"*Ongoing efforts as well as standards developed by the International Union of Soil Sciences (IUSS) and by other regional and national standardization committees and institutions, need to be brought within a common framework to reduce duplication of efforts and the proliferation of standards and methods (both laboratory and field) that are often not compatible. A well-documented example of lack of coordination and political will is soil classification, with still two (or more) main systems used in many parts of the world that are difficult to compare (correlate) and harmonize (like the US Soil Taxonomy of USDA and the World Reference Base (WRB) of the International Union of Soil Sciences (IUSS) endorsed by FAO). The recent initiative towards development of a common Universal Soil Classification (USC) should be facilitated by the GSP to provide a common platform for such a future system.*"

As we can see, the issues of soil classification should be address in the GSP. Actually the GSP Secretariat is calling for experts from the different regions to engage in challenging formulation tasks regarding Pillar 5:

"*The GSP Secretariat is currently implementing the decisions taken by the Plenary Assembly related to the formulation of cogent Plans of Action for the GSP pillars. Drafts of these Plans of Action will be submitted to the Intergovernmental Technical Panel on Soils (likely timing of the meeting is in early April 2014) and subsequently to the Plenary Assembly. As per the agreed Rules of Procedure of the GSP, working groups need to be established for developing such draft plans of action. These working groups should reflect a regionally balanced participation. As the GSP is designed to be a genuine, inclusive, voluntary and participatory process, the Secretariat is calling for experts from the different regions to engage in these challenging formulation tasks.*

In case you are interested to join the working groups for Pillar 5 (described below), please send an email to GSP-Secretariat@fao.org indicating your interest and which Pillar you would like to be involved with. Please, also include a short version of your CV."

Reports of Past Meetings

UNIVERSITÄT HOHENHEIM

Division I Congress “Soils in Space and Time”, Ulm, Germany

The conference took place in Ulm University in Ulm, Germany from September 30th to October 5th of 2013. Also a number of other German universities, especially the University of Hehenheim, contributed to the organization of the meeting. The Chair of the Scientific and local Organizing Committees was Professor Karl Stahr who is acting as a Chair of the Division I of the IUSS. It was the concluding scientific event he has organized before his retirement, and we use an opportunity to thank him not only for this enjoyable meeting, but also for his long devoted service to soil science and to soil science community. We hope that Karl will continue his activities even after the retirement, and we shall have a pleasure to meet him further.

The topic of soil classification was well represented at the conference. Peter Schad presented a plenary talk “WRB 2014: How logic helps to span an umbrella over contrasting national soil classification systems”. The symposia related to soil classification included No. 12. “Soil classification and soil assessment: turning the theory into practice” and No. 13 “Man-made, deeply transformed and marginal soils”. Also along almost the entire meeting the WRB Working Group organized a workshop for preparation of the 3rd edition of the World Reference Base the be presented at the World Congress of Soil Science in Jeju, Korea.

The Symposium 12 was coordinated by Pavel Krasilnikov. Two of the five presenters were not present that allowed an extended discussion of the three talks at the symposium. The presentations were the following:

- Dondeyne, S., Legrain, X., Ampe, C., Cools, N., Vancampenhout, K., Baert, G., Langohr, R., Van Ranst, E. and Deckers, J. “Soil classification, map legends and GIS logic: experiences from converting the legend of the soil map of Belgium into WRB”, presented by Stefaan Dondeyne;
- Eberhardt, E., Schad, P., Kühn, D. and Bauriegel, A. “Software tool for deriving WRB soil names from national soil data results”, presented by Einar Eberhardt;
- Weller, U., Vogel, H.-J. “Soils in space – data driven vs. genetic approaches”, presented by Ulrich Weller.

The Symposium 13 was conducted by Tatiana Prokofieva and Wolfgang Burghardt, four of the five presenters attended the meeting and presented the following talks:

- Prokofieva, T., Gerasimova, M. “Integrating the systematic of urban soils into the new Russian soil classification system: Diagnostic tools for urban soil characterization”, presented by Tatiana Prokofieva;

- Golyeva, A., Zazovskaia, E. and Turova, I. “Properties and advances in classification in ancient deeply transformed man-made soils (ancient cultural layers) by the example of Early Iron Age sites in Central Russia”, presented by Elya Zazovskaya;
- Gorbov, S. and Bezuglova, O. “Ecology-genetic soil characteristics in Rostov-on-Don city”. Presented by Sergey Gorbov;
- Burghardt, W. and Hoeke, S. “Role of dust for soil formation in urban, industrial and mining areas”, presented by Wolfgang Burghardt.

Since this symposium had many contributions, it was decided to organize a joint oral session of the Symposia 11 and 13. The session was entitled “Initial and man-made soils, their formation and classification”, and the conveners were Zbigniew Zagorski, Michal Jankowski, Lukasz Uzarowicz and Tatiana Prokofieva. The following talks have been presented:

1. Bakhmatova, K.A. and Matinian, N.N. “Classification of Saint-Petersburg urban soils”, presented by Ksenia Bakhmatova;
2. Nurcholis, M. “Degraded soil at the abandoned tin mine land in Bangka Island Indonesia”;
3. Mergelov, N., Goryachkin, S., Shorkunov, I., Dolgikh, A. “Soils inside the rocks”, presented by Nikita Mergelov;
4. Jankowski, M. “Patterns of soil development at initial stages in sandy areas of northern Poland.

Also a number of poster presentations have been presented at the meeting.

The scientific program of the conference included several field excursions, which could be attended as mid-conference or post-conference tours, or both.

Oral presentations made at the Soil Science Society of America meeting 3-6 November , 2013. Tampa, Florida, USA

(https://scisoc.confex.com/crops/2013am/webprogram/S5.html)

Effects of Periglacial Processes On Soil Formation in Subarctic Alaska

Eric Geisler, Unviersity of Alaska Fairbanks; Chien-Lu Ping, University of Alaska-Fairbanks

The Steese Mountains of Alaska are located approximately 100 km northeast of Fairbanks and stretch northeast about 60 km. The elevation ranges from 300 -1200 m. During the initial soil surveys of the area a close relationship between the periglacial features and vegetation communities was noted along a toposequence. The summit is dominated by sorted circles stone (circles) with bare to sparse shrub cover. The nearly rounded stone circle becomes elongated on the shoulder slopes with shrub/tundra vegetation cover. The stone circles developed into stripes on the upper and mid-back slopes with forest tundra cover. Slope movement erased most stripes on the lower back slopes and toe slopes where black spruce dominates. The summits are usually too fragmental to maintain permafrost thus Haplogelepts formed in this landfom. Permafrost is common on shoulder and back slopes thus Ruptic-Histic Aquiturbels developed on mid to upper back slopes and Histic Aquiturbels developed on lower back slopes. The periglacial processes resulted in unique patterned grounds and highly cryoturbated soils in the alpine environment of Steese Mountains.

Procedures to Simulate Missing Soil Parameters in the Florida Soils Characteristics

Osvaldo Gargiulo, University of Florida

In this study, we used the Florida Soils Characterization Database (FSCD) as source of physical and chemical soil parameters for the development of a soils characteristics dataset usable by crop growth models. Unfortunately, as with other soil surveys, this database has missing soil parameters within the various soil horizons. Three main objectives of this study were to: (1) develop procedures to extract soil characteristics data from available soil data sources, (2) convert soil profile data into a format usable by simulation models, and (3) create and evaluate multiple regression models to simulate missing soil parameters. We used the conditional distribution model to investigate empirical relationships within available measured soil data. A multi regression model, as the one described in this paper, is a valuable tool that can be used to fill singular or multiple missing soil data in the incomplete list of the FSCD. Statistical indexes as RMSE and Nash-Sutcliffe-efficiency were used to test the behavior of multi regression model in simulating missing soil values in the 0-20cm horizon. The results showed that silt, clay, organic carbon, cation exchange capacity, bulk density, and sand can be predicted with a model performance that ranges from very good to satisfactory. However, pH and saturated hydraulic conductivity are not simulated with satisfactory performance levels. The approach taken in this paper to simulate missing soil parameters is universal; meaning that it can be developed anywhere having available representative source of measured soil data of the study area.

Digital Soil Mapping Standards and Specifications for GlobalSoilMap

Jonathan W. Hempel, USDA-NRCS; Dominique Arrouarys, INRA-French National Institute for Agricultural Research; Neil Mckenzie, CSIRO; Alex McBratney, The University of Sydney

GlobalSoilMap is a globally coordinated project aimed at producing a set of consistent functional soil properties using digital soil mapping techniques and technology. The data are designed to be used for better understanding environmental degradation, issues of food security and food production, the importance of soils in biodiversity, the role of soils in areas of water scarcity and quality and for quantifying the effect of soils in climate change.

A globally coordinated set of standards and specifications have been produced to help guide the development of the soils data. These standards are designed to address the collation and presentation of finalized products, but do not to prescribe how products will be made. A coordinated dataset based on universally accepted standards will provide soils data that can be used to produce consistent information across geopolitical boundaries.

There are 5 basic tenants to the standards and specifications: (1) the spatial entity, (2) the soil properties to be predicted (and the date associated with the prediction), (3) the uncertainty values for each soil property, (4) the age of the data or information used to estimate the predicted properties, and (5) the validation measure that was used to make the predictions.

The twelve soil properties to be mapped are: (1) total profile depth (cm), (2) plant exploitable or effective soil depth (cm), (3) organic carbon (g/kg), (4) pH (x10), (5) sand (k/kg), (6) silt (k/kg), (7) clay (k/kg), (8) gravel (m3/m-3), (9) ECEC (cmol/kg), (10) bulk density of the fine earth (<2mm fraction (excludes gravel) (Mg/m3) and available water capacity (mm).

Various countries around the world are actively applying these standards and specifications to produce soils information. The project is being coordinated by a global consortium of institutions that are engaged in the production, research, interpretation and application of soils data. The standards and specifications are being coordinated by the GlobalSoilMap scientific Committee.

Carbonate-Rich Discharge Histosols: Formation Processes and Classification

Douglas A. Wysocki, USDA-NRCS; Lance Howe, USDA-NRCS; Steve Winter, USDA-NRCS; P. Michael Whited, USDA-NRCS

In the upper glaciated Midcontinent USA (IA, MN, ND, SD, WI), fens with calcareous organic soils (Histosols) form where carbonate-laden water discharges at permanent springs or seeps. Such discharge sites occur along late Wisconsin moraines in eastern SD. The hydrology (upward vector) and geochemistry (redox) drive two main soil-forming processes - organic matter accumulation and mineral precipitation, which yields Histosols of unique character. The organics (fibric and hemic material) form a low bulk density matrix that engulfs a mineral fraction dominated by precipitated carbonates, Fe-mn oxides, and other trace metal oxides. In these soils, silicate minerals are a minor constituent. Traditional soil genesis models and present classification systems do not consider water flow vector or mineral fractions dominated by precipitated, authigenic minerals. We propose three specific Soil Taxonomy modifications for classifying carbonate-rich Histosols: 1). Revise the “subaqueous soil” criteria from water potential to surface water inundation, which is a directly observable property. 2) Create a “Kalkic” family reaction class for Histosols with the criteria of $CaCl_2$ pH > 6.8 and presence of secondary carbonates. And, 3) Exclude authigenic carbonate from the mineral fraction that is considered in the organic versus mineral soil criteria. This set of revisions removes terrestrial discharge soils from classifying as Wassists. The proposed Kalkic reaction class fills a void, as the only existing pH criteria is the euic-dysic limit (CaCl2 pH 4.5). Lastly, authigenic carbonate in these soils, which has distinctly different properties (e.g., CEC, water holding) than the silicate minerals, would not outweigh organic carbon content in Histosol classification.

Measuring Soil Properties and Soil Change in the Wisconsin Central Sand Plain

Heather Diane Watson, University of Wisconsin-Madison; Alfred Hartemink, University of Wisconsin - Madison

The soils of the Central Sand Plain of Wisconsin are widely used for agriculture (e.g. potatoes, sweet corn, soybeans), and minor areas are under pines and prairie vegetation. Land management in agricultural fields involves land leveling, irrigation, and fertilizer and lime additions.

Research was conducted in a $12km^2$ area in Adams County, Wisconsin. The three main soil types according to SSURGO database are Lamellic Udipsamments, Typic Udipsamments, and Arenic Hapludalfs. The landform is an outwash plain. It is assumed that at one point in time these soils were similar (genoform), but some soils have evolved into different phenoforms due to differences in land use. The overall aim of the research is the mapping of these genoforms and phenoforms that can be used to update the soil series information held in the SSURGO database. 59 soil samples to 2m depth were taking at locations along transects.

The agricultural areas are less acidic, have thicker top soils and sometimes more clay as a result of enhanced mineral weathering (more water). Therefore the soils are classified taxonomically different, by additions of organic carbon, accumulations of clay, and increase of pH. It seems that the genoform of the Udipsamments has changed into Mollisols and Alfisols within five decades of cropping by the use of agriculture inputs and irrigation.

Poster presentations made at the Soil Science Society of America meeting 3-6 November, 2013. Tampa, Florida, USA

(https://scisoc.confex.com/crops/2013am/webprogram/S5.html)

Soil Salinity Assessment Via Portable X-Ray Fluorescence Spectrometry. Poster #1620

Samantha Swanhart, Louisiana State University Agricultural Center; David C. Weindorf, Texas Tech University; Autumn Acree, Louisiana State University Agricultural Center; Noura Bakr, Louisiana State University Agricultural Center; Yuanda Zhu, Louisiana State University Agricultural Center;

Courtney Nelson, Louisiana State University Agricultural Center; Kayla Shook, Louisiana State University Agricultural Center

Saline soil has historically been defined as a soil containing sufficient salts more soluble than gypsum (e.g., various combinations of Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, SO_4^{2-}, HCO^{3-} and CO^{3-}) to the extent that soil fertility is severely reduced across a wide array of climates and geological settings. Thus, it is not germane to specific soil characteristics, such as texture or parent material. As technology has advanced, so has soil testing and evaluation for optimal soil health characterization. Traditional methods of measuring soil salinity have proven accurate; however, most are labor intensive and require laboratory analysis. Given the success of previous studies using PXRF as a tool for measuring soil characteristics, the evaluation of soil salinity with PXRF spectrometry seems timely. Not only does this newer technology offer more accurate, quantifiable data to investigators, it produces results in-situ, in seconds. Samples were collected from the soil surface (0-15 cm), sealed in plastic bags, and returned to Louisiana State University for laboratory analysis where they were air-dried and passed through a 2 mm sieve prior to additional analysis. Standard soil characterization was conducted to include loss on ignition (LOI) organic matter, particle size analysis, electrical conductivity, and elemental quantification. Regression models were developed to correlate determined elemental concentration to EC results using statistical analysis software (SAS 9.3). Both simple and multiple linear regressions were employed in this study. In order to meet the assumptions for simple and multiple linear regressions, logarithmic transformation was used to normalize the variables to obtain a normal distribution for the error term (residual, e_i). While both models resulted in similar acceptable R^2 (0.86, and 0.87, respectively), simple linear regression is recommended given its simplicity.

Developing a Simplified Guide to Soil Taxonomy. Poster #1622

J. Cameron Loerch, USDA-NRCS National Soil Survey Center; Michel D. Ransom, Kansas State University; John M. Galbraith, Virginia Tech; David C. Weindorf, Texas Tech University; H. Curtis Monger Jr., New Mexico State University; Joseph V. Chiaretti, USDA-NRCS National Soil Survey Center; Craig Ditzler, USDA-NRCS National Soil Survey Center; Kenneth F. Scheffe, USDA-NRCS National Soil Survey Center

Poster Presentation: Simplified Guide to Soil Taxonomy.pdf (3.2 Mb)

Soil taxonomy is the official classification system for soils in the USA. This dynamic system has been amended and improved to accommodate newly described soils and their diagnostic properties from around the world into a common system. The U.S. National Cooperative Soil Survey (NCSS) program consisting of national, state, university and private sector soil scientists have helped build the system. Soil taxonomy is a detailed system with a complex hierarchy that can be very intimidating to learn and difficult for beginning soil scientists, students and soil practitioners to use. An ad hoc NCSS advisory working group was formed to develop a simplified guide to using Soil Taxonomy. The simplified guide can be used to classify a soil to the great group level of soil taxonomy and will not require an advanced understanding of soil science, extensive field experience, or laboratory data in order to use and appreciate Soil Taxonomy. This collaborative effort targets the needs of beginning soil science and agricultural studies students, natural resource specialists with minimal soils experience, and other professionals who use NCSS products and reports. The guide consists of several sections paralleling the Keys to Soil Taxonomy. It is enhanced with the use of illustrations, horizon and profile photos, maps, and flow diagrams. The description of soil orders is expanded to explain central concepts of the taxa, includes maps of occurrence, explains class criteria in simplified terms, and includes a summary description for characteristics of the great groups. The section on diagnostic surface and subsurface horizons and features is enhanced in a similar manner. The guide conveys the classes and criteria of soil taxonomy through a more prosaic narrative and there is extensive use of hyperlinks for quick reference. The guide lends itself readily to web access and use on smartphones and tablets for use in the field.

Revision and Update of the Soil Survey Manual, Agricultural Handbook #18. Poster #1700

Kenneth F. Scheffe, USDA-NRCS National Soil Survey Center; Janis L. Boettinger, Utah State University; J. Cameron Loerch, USDA-NRCS National Soil Survey Center; Craig Ditzler, USDA-NRCS National Soil Survey Center; Shawn J. Mcvey, USDA-NRCS National Soil Survey Center

Poster Presentation: Scheffe SSM Poster for SSSA Meeting 2013.pdf (3.0 Mb)

The Soil Survey Manual has long been the field soil scientist's guide to conducting soil survey. Originally assembled by Dr. Charles E Kellogg in 1937 as Miscellaneous Publication No. 274, the Soil Survey Manual has served generations of soil scientist's performing soil mapping. The Soil Survey Manual, originally published in a paperback, was updated and released in 1951 as Agricultural Handbook #18, and updated last in 1993. Soil scientists from NRCS and soils faculty at cooperating universities are revising the Soil Survey Manual. This update to the Soil Survey Manual will be digital and take advantage of the flexibility digital publishing affords including expanded use of graphics and photography, tabular data, hyperlinks to other references and research articles, and adapted for viewing on devices such as tablets and smartphones. Technical advances in the science of soils, the methodologies for conducting soil inventories and the advances in data tools for analyzing and displaying soil survey information brings about a need to update the Soil Survey Manual to maintain its usefulness. Subject matter expert guest authors will develop new chapters and sections addressing remote sensing and digital mapping tools. Significant new areas being developed include: digital soil mapping and geospatial analyses utilizing tools such as satellite imagery, LIDAR data geophysical surveys, and other common tools such as GPS and GIS; description and mapping of subaqueous soils; description and mapping of human altered and transported materials (HATM) from ICOMANTH recommendations; soil Climate monitoring, hardware, data management, and analysis.

Soil Landscape Systems as a Framework for Understanding and Comunicating Soil Processes, Geographic Soil Information, and for Designing Soil Investigations. Poster #1701

Philip Schoeneberger, USDA; Zamir Libohava, USDA; Douglas A. Wysocki, USDA-NRCS; Brad D. Lee, University of Kentucky; Samuel J. Indorante, USDA/NRCS Soil Science Division

A soil system is defined as a recurring group of soils that occupies the landscape from the inter-stream divide to the stream (Daniels et al., 1999). It can be defined based on similar soil parent materials, geomorphology, local relief, hydrologic connectivity, geographical extent, climate or ecosystem. The soil system approach empowers data-driven understanding of suites of soils and their interactions. It moves beyond the historical, relatively static, pedon-centric perspective supplemented with expert-assigned estimated data, to a dynamic system whose supporting data is measurement-based. Soil Landscape Systems can (a) link quantified soil property data to processes at multiple scales, (b) provide and help to evolve conceptual models that explain soil patterns and processes which drive/underlie modeling and digital products, (c) to integrate hydropedology into soil distribution and function models, and (d) to present this information in user-friendly ways. Its purpose is to incorporate knowledge of soil properties and behavior, soil-landscape relationships, science-based methods, and the capacity to derive and apply quantitative soil analyses.

Mapping and Modeling Soil Organic Carbon in the Eastern Allegheny Plateau and Mountains Using Legacy Data. Poster #1702

Katey M. Yoast, West Virginia University; James A. Thompson, West Virginia University

Poster Presentation: Yoast Mapping and Modeling Soil Organic Carbon.pdf (6.9 Mb)

The deeply dissected topography and diverse climate of the Eastern Allegheny Plateau and Mountains (Major Land Resource Area (MLRA) 127) create challenges for dynamic ecological and pedogenic modeling. Soil organic carbon (SOC), one of the most dynamic soil properties, has been previously modeled using State Soil Geographic (STATSGO2) and Soil Survey Geographic (SSURGO) databases for MLRA 127, estimating mean SOC to a depth of 1 m to be 2.6 and 4.4 kg m^{-2}, respectively. Previous studies have shown that these approximations underestimate true carbon stock due to unpopulated organic horizons and inconsistencies within the databases. Between 1960 and 2009, the Kellogg Soil Survey Lab (KSSL) sampled and characterized 243 pedons within MLRA 127 based on soil survey needs. Each pedon has a site description and associated chemical and physical lab analyses to support its taxonomic classification. Data mining revealed that 12.6% of these 243 pedons lack organic carbon data for one or more horizons and 49.7% lack bulk density values. Different methods for populating missing bulk density and organic carbon data will be assessed and validated in order to calculate SOC stock. Geographically weighted regression kriging with KSSL pedons and environmental covariates will be used to model SOC stock across MLRA 127. The resulting SOC estimates will be cross-validated with Rapid Carbon Assessment (RaCA) samples and uncertainty will be assessed. The methodology used in this study will serve as the foundation for estimating SOC stock across other MLRAs throughout the United States. Improving SOC stock estimates across MLRA 127 will enhance the understanding of dynamic soil properties and will provide guidance for better land management practices to benefit biological communities.

An Evaluation of Natric Soil Characterization Data in North Dakota: A Challenge for Contemporary Interpretation. Poster #1706

Sukhwinder Bali, North Dakota State University; David G. Hopkins, North Dakota State University; Thomas M. DeSutter, North Dakota State University; Douglas A. Wysocki, USDA-NRCS

There are about 1.9 million ha of sodic soils in North Dakota, distributed across a variety of parent materials and subject to differing degrees of ground water influence and quality. There are about 330 soil series, of these 42 are natric and of these 7 have the Subgroup Glossic (47,200 ha), 13 are Leptic (388,000 ha), 13 are Typic (409,000 ha) and remaining are Aridic, Calcic, Torrertic, Vertic and Natric. A dataset of 125 pedons sampled for progressive soil surveys, irrigation development, and thesis investigations from 1949 to 2009 were compiled for this study. Characterization data were collected from the USDA/NRCS Kellogg Soil Survey Laboratory and from North Dakota State University Agricultural Experiment Station. The major USDA taxonomic subgroups are Leptic, Glossic and Typic Natustolls and Natrudolls, with fewer Natraquolls. The objective of this research was to review the physical, chemical and taxonomic properties of these sodic soils, create flowcharts describing data completeness, and to determine data gaps and discrepancies. Of the 125 pedons, there are 37 Glossic, 27 Leptic, 43 Typic and 18 are other Subgroups. However, only 12 Glossic, 14 Leptic and 6 Typic pedons have complete data with respect to sodic soil properties on the basis of Handbook 60 criteria. In addition, there are 17 Glossic, 1 Leptic and 19 Typic Subgroups that fail to meet sodic criteria. Although much work has been done to characterize sodic soils in North Dakota, many of the characterization pedons do not have chemical data that either identifies these soils as being sodic (SAR, EC, pH) or chemical analyses were never determined. The ability to make comparisons even within respective soil series is challenged by a lack of complete data. Improved characterization and understanding of the genetic controls on sodic soils (i.e., physiography, parent material, ground water) will enable more targeted land management which will allow for improved vegetative production and potential remediation.

Parent Materials of Alabama Blackland Prairie Vertisols. Poster #1707

Cassi S. Jones, Auburn University; Joey N. Shaw, Auburn University; Julie A. Howe, Auburn University; Ben F. Hajek, Auburn University

Alkaline soils (predominately Vertisols) in the Blackland Prairie region of Alabama largely develop from Cretaceous-aged chalk, while proximate acidic Vertisols are believed to have developed from acidic clayey sediments, possibly from the Eocene epoch. However, evidence suggests the more acidic soils may have developed in place (residuum) or from sediments locally deposited after weathering. Considering acid, residual soils have developed over calcareous parent materials in humid environments in several other settings, the potential exists for a residual weathering genesis of these acid Vertisols. The relatively high non-calcareous residues of these Selma chalks (typically 50 to 60% $CaCO_3$) may further promote a weathering hypothesis. Identification of lithologic discontinuities can provide information about parent materials, landform stability, and soil genesis. The objectives include investigation of soil-parent material relationships and evaluation of the degree of parent material uniformity for improved understanding of pedogenesis of Alabama Blackland Prairie Vertisols. Replications of alkaline (Sumter- *Rendollic Eutrudept* and Okolona- *Oxyaquic Hapludert*) and acidic soils (Vaiden- *Aquic Dystrudert* and Oktibbeha- *Chromic Dystrudert*) were sampled to chalk. Particle size analysis was conducted for depth trends and fractionation was utilized to isolate separates for detailed mineralogical and elemental analyses. Coarse silt and sand fractions were digested using lithium metaborate fusion, and concentrations of Sr, Ti, Y, Zr, and rare earth elements (La to Lu) were measured. Calcium carbonate was quantified using thermogravimetric analyses, and clay separates were analyzed using X-ray diffraction. Soil-parent material relationships will be evaluated using elemental, mineralogical and grain size data.

High Resolution Digital Soil Mapping Using Soil Survey and Electrical Conductivity Maps in the Argentinean Pampas. Poster #1708

Mauricio Castro Franco, Instituto Nacional de Tecnología Agropecuaria; Marisa Domenech, Instituto Nacional de Tecnología Agropecuaria; Nahuel Peralta, Instituto Nacional de Tecnología Agropecuaria; Jose Costa, Instituto Nacional de Tecnología Agropecuaria; Virginia Carolina Aparicio, Instituto Nacional de Tecnología Agropecuaria (INTA)

Poster Presentation: High resolution DSM. Poster MCF.pdf (859.8 Kb)

The objective was to test the suitability of using soil survey and apparent electrical conductivity (ECa) maps to elaborate high resolution digital soil mapping (>1:2000). The study was conducted in a 65 hectares field, located within the cartographic unit (CU) Az26 based on the 1:50000 soil mapping. Three soil series were associated in this CU: Azul (Az) (60%), Semillero Buck (SB) (30%) and Cinco Cerros (CC) (10%). Soil ECa was measured at two depths, using the Veris model 3100 sensor cart system, on transects approximately 20 m apart. Based on ECa 0-30 cm measurements, homogeneous zones were delineated and named as ZECa. Additionally, soil sampling was conducted in an intensive manner, using a 50x100 m grid at a depth of 20 cm. Organic matter (OM), clay content (As) and effective depth (ED) were determinate. OM, As, ED and the interaction with ZECa were evaluated using ANOVA. An exploratory dendrogram showed that at 20 cm depth, Az and CC series (Petrocalcic Paleudoll) had higher OM and As, while in SB series both contents were lower. At Low ZECa, ED was upper and As and OM were lower than other zones. Despite at Middle and High ZECa As and OM were upper, in our work was not possible to detect statistically significant differences between zones. The highest ZECa showed lowest ED. Based on this findings, we conclude that Middle and High ZECa could be associated with As and CC series, meanwhile Low ZECa would be with SB series. The use of soil and ECa mapping allowed to determine the distribution and spatial relation of OM, As and ED at high resolution scale.

Semi-Automated Disaggregation of Conventional Soil Maps Using Random Forests, DEMs and ASTER Satellite Imagery in the Sonoran Desert. Poster #1709

Travis Nauman, West Virginia University; James A. Thompson, West Virginia University; Craig Rasmussen, University of Arizona

Conventional Soil Maps (CSM) like the USDA-NRCS Soil Survey Geographic (SSURGO) database have provided baseline soil information for land use planning since their inception in the early 20th century. Although CSM have been widely used, modern demands for high resolution soil information at a field scale are not suitable applications for CSM in many cases. CSM lack a realistic representation of soils at that scale because they were created with polygonal vector mapping format that uses crisp map boundaries and often aggregates multiple soils types within one mapping unit. These spatial issues with SSURGO create added work for natural resource professionals trying to implement conservation planning strategies that utilize soil survey data. We present a repeatable method to disaggregate SSURGO data into a one arc-second (~30-meter pixels) rasterized soil class map that also provides continuous representation of probabilistic map uncertainty, and ability to utilize fuzzy membership of classes if soil intergrades are desirable for end users. Methods included training set creation for each original SSURGO component soil class from soil-landscape descriptive language within the original survey database. Training sets were then used to build a random forest predictive model that utilized 54 environmental covariate maps derived from ASTER satellite imagery and the one arc-second USGS National Elevation Dataset. Results showed agreement at 70% of independent field validation sites and equivalent accuracy between original SSURGO map units and the finer resolution disaggregated map. Uncertainty was mapped by empirically relating prediction frequencies of the underlying trees of the random forest model and the validation sites success rates.

Use of VIS-NIR Spectroscopy for Mapping Specific Management Areas in Oxisols Under Sugar Cane Cultivation. Poster #1712

José Marques JR., FCAV/UNESP, Campus de Jaboticabal; Livia Arantes Camargo, FCAV/UNESP, Campus de Jaboticabal; FAPESP; Gener Tadeu Pereira, FCAV/UNESP, Campus de Jaboticabal

Poster Presentation: VisNIR for mapping Oxisols.pdf (703.7 Kb)

The Diffuse Reflectance Spectroscopy (DRS) technique is an alternative method for soil attributes evaluation with a proven efficiency, low cost and environmental impact. Several studies, using different statistical methods, have shown that the selection of spectral bands or regions can help the performance of the models for soil attributes quantification. Hence, the objective of this study was to evaluate the spectral regions that allow discrimination between geomorphic surfaces (GSs) and soil attributes in mapping purposes for minimum areas of specific management. Soil samples were collected at transect every 25 m (100 samples) and by its sides (100 samples). Geomorphic surfaces (GSs) were mapped within the entire field area. Soil samples (collected from 0.00 to 0.20 m depth) were taken to the laboratory for physical, chemical, mineralogical, magnetic susceptibility and diffuse reflectance spectroscopy analyzes. Data were analyzed by statistical and multivariate geostatistics methods. The PC 1 and 2 scores of the studied spectral regions presented spatial dependence and the PC 2 spatial distribution maps of the entire spectrum and of PC 1 VIS region showed similar limits to those of the GSs. The attributes that have most correlated to PC 2 from the entire spectrum and PC 1 VIS region were clay and iron oxide extracted by dithionite-citrate-bicarbonate. The best spectral regions that allow to discriminate between geomorphic surfaces and soil attributes for minimum area of specific management mapping are the visible region and the entire spectrum.

Rapid Soil Property Analysis by Visible-Near-Infrared Diffuse Reflectance Spectroscopy and Chemometric Modeling in Smallholder Farms in India. Poster #1713

Christopher M Clingensmith, University of Florida; Sabine Grunwald, University of Florida; Amr H. Abd-Elrahman, University of Florida; Suhas Wani, International Crops Research Institute for the Semi-Arid Tropics

Efforts to understand the spatial and temporal distribution of soil properties across landscapes require the analysis of many soil samples. These analyses, in some cases, can be costly and time intensive. Diffuse reflectance spectroscopy has shown success to sense base soil properties rapidly and cost-effectively, however, there is limited knowledge of how visible-near infrared spectra (VNIRS) relate to micro- and macro-nutrients. The latter are profoundly important in smallholder agricultural settings in south-east Asia where cop yield and livelihood depend on soil health and sustainable nutrient levels. VNIRS has the potential to transform soil management in smallholder farm communities, though has rarely been utilized. Our objectives were to (i) use chemometrics to infer base soil properties and macro- and micronutrients in rainfed and irrigated smallholder farms in southern India. We utilized VNIRS as a means of rapid soil analysis. We collected 255 soil samples of Veritsols and vertic Inceptisols and analyzed them for soil texture, soil organic carbon, pH, electrical conductivity, and soil macro- and micronutrients. Sieved soil subsamples were also scanned in the VNIRS range (350 – 2,500 nm) at 1 nm resolution. We applied several spectral processing techniques, including Savitzky-Golay smoothers and first and second derivatives, to reduce noise and enhance signals. Then we employed several multivariate regression methods including partial least squares regression analysis and ensemble regression trees and used rigorous validation analysis to identify the best performing model for each soil property. Results confirm our postulated expectations that VNIRS-soil prediction models offer an alternative to traditional soil mapping in this region. Once spectral soil models are successfully developed and validated for a soil geographic domain they can be applied in the future on new soil samples reducing the need for costly analytical analysis.

Soil-Landscape Modeling of Coastal California Hillslopes Using Terrestrial Lidar. Poster #1715

Sam Prentice III, University of California, Santa Barbara

Digital elevation models (DEMs) are the dominant input to spatially explicit digital soil mapping (DSM) efforts due to their increasing availability and the tight coupling between topography and soil variability. Accurate characterization of this coupling is dependent on DEM spatial resolution and soil sampling density, both of which may limit analyses. For example, DEM resolution may be too coarse to accurately reflect scale-dependent soil properties yet downscaling introduces artifactual uncertainty unrelated to deterministic or stochastic soil processes. We tackle these limitations through a DSM effort that couples moderately high density soil sampling with a very fine scale terrestrial lidar dataset (20 cm) implemented in a semiarid rolling hillslope domain where terrain variables change rapidly but smoothly over short distances. Our guiding hypothesis is that in this diffusion-dominated landscape, soil thickness is readily predicted by continuous terrain attributes coupled with catenary hillslope segmentation. We choose soil thickness as our keystone dependent variable for its geomorphic and hydrologic significance, and its tendency to be a primary input to synthetic ecosystem models. In defining catenary hillslope position we adapt a logical rule-set approach that parses common terrain derivatives of curvature and specific catchment area into discrete landform elements (LE). Variograms and curvature-area plots are used to distill domain-scale terrain thresholds from short range order noise characteristic of very fine-scale spatial data. The revealed spatial thresholds are used to condition LE rule-set inputs, rendering a catenary LE map that leverages the robustness of fine-scale terrain data to create a generalized interpretation of soil geomorphic domains. Preliminary regressions show that continuous terrain variables alone (curvature, specific catchment area) only partially explain soil thickness, and only in a subset of soils. For example, curvature explains 40% of soil thickness variance at <300 cm at scales up to 20 m, while soil thickness >300 cm shows no clear relation to curvature. Further efforts will be aimed at refining the regression model by integrating the spatially-constrained, generalized LE map classes, as well as simulating DEM error for uncertainty analysis.

Carbon Status of the Soils of Iowa State University. Poster #1716

Catherine R. DeLong, Iowa State University; C. Lee Burras, Iowa State University

Poster Presentation: DeLong and Burras Carbon.pdf (2.9 Mb)

Given Iowa State's founding as a “land grant” institution, the university has recently decided to evaluate its land in a broader environmental context. Iowa State owns or manages 77 properties across the state which collectively total 6,392 hectares. Our project quantifies the carbon stocks of these 77 properties as well as assesses the “green” value of various land use practices. Three pools of carbon were assessed: organic, inorganic, and total. Depths of interest were 0.18 and 1.0 meter, and were selected because of their compatibility with ISPAID and USDA-NRCS Web Soil Survey. The following results are for 15 of the major properties, which were selected based on their size and soilscape diversity. Average SOC stocks are 16.8 kg m^{-2} m^{-1} and 5.1 kg m^{-2} $m^{-0.18}$, respectively, with maximum and minimum SOC stocks ranging from 30.6 m^{-2} m^{-1} to 8.0 m^{-2} m^{-1}, and 7.2 to 2.9 m^{-2} $m^{-.18}$. Trends include largest stocks in Aquolls and smallest stocks in Alfisols and eroded Mollisols, as well as a fairly consistent depth distribution – e.g., the top 0.18 m contains 30% of the SOC present to a 1.0 meter depth. Additionally, the “green” value and management practices of these properties are being assessed using the USDA’s COMET-Farm tool in order to evaluate and predict carbon flux.

Advanced Study in the Distribution of Vertisols and Vertic Soils in China. Remote presentation.
Mingda Chen, Natural Resources and Environmental Science, Nanjing Agricultural University; Shanmei Wu, Nanjing Agricultural University; Tiao Shen, Soils and Fertizers Technology Extension of Henan province; Zhongpei Li, Institution of Soil Science, Chinese Academy of Science

The distribution of Vertisols and Vertic Soils in China was first studied by Ruicai Huang and Shanmei Wu in 1981. Then, others also became interested in their distribution. Because the previous studies focused on the middle and south China, only Aquerts, Uderts and Usterts were identified and established. Further studies since 2005 indicates that 3 other suborders, Cryerts, Torrerts and Xererts, have been identified. An abstract “Advance in the study of suborders in China” was accepted by the WSSA Meeting in Aug. 2013. Also, some Uderts, Usterts and Aquerts are also distributed in unstudied area in China.

Cryerts are distributed beyond 46.5^{o} of N. latitude of Songnen River basin. They formed from clayish deposits of shallow lakes in $Qp_{2+3}$and clayish soft rocks (K). They are surrounding with volcanoes.

Torrerts are identified in Xinjiang Uygur Autonomous region which climate belongs to semi-desert and desert. Semi-soft rocks (J, K) and unconsolidated red clayish deposits (N) appear on the land surface surrounding the edge of basins According to X-ray diffraction tests, the smectite content is up to 95% averagely in reddish- clayey profile and the semi-soft rocks (J, K) are the second rich in smectite. The Torrerts distribute on old plains receiving their sediments (Qp_3).

Xererts are distributed in Yili Basin in Xinjiang where belongs to Mediterranean climatic type with unconsolidated reddish- clayey deposits around the Basin. The Xererts are derived from the secondary deposits of the reddish materials by rivers.

Some newly findings on distributions in addition to previous studies are:

Uderts in basins in Jiangxi, in Hubei, in Sichuan provinces and on the basalt tableland in Zhejiang province,

Usterts in south-western Sichuan province where the very long tern influence of volcanic activity (P) appears, also on Loess Plateau including the western Henan province.

Aqerts around the lake and in lowlands on Yunnan Plateau…

A new map of the distribution of Vertisols and Vertic soils in China is compiled.

The Mammoth Ultra-continental WRB Field Workshop

August 17-23, 2013

The Mammoth Ultra-continental World Reference Base (WRB) field workshop was held from 17 to 23 August 2013 in the Central Sakha region of Russia, with Yakutia as base. The workshop was presented by the International Union of Soil Science (IUSS) Working Group WRB, the IUSS Commission on Soil Classification, the IUSS Working Group Universal Soil Classification, the IUSS Working Group Cryosols, and the Dokuchaev Soil Science Society.

The Institute of Biological Problems of Cryolithozone, Siberian Branch of Russian Academy of Sciences (RAS), Yakutsk; the Institute of Geography, RAS, Moscow; the Lomonosov Moscow State University; the Dokuchaev Soil Science Institute, Russian Academy of Agricultural science, Moscow; the Melnikov Permafrost Institute, Siberian Branch, RAS, Yakutsk; and the Institute of Biology, Komi Scientific Center, RAS, Syktyvkar all participated in organising the workshop.

Thirty three delegates from nine countries (Australia, Belgium, Germany, Poland, Russia, South Africa, Slovenia, the Netherlands, and the United States of America) participated in the field workshop.

The main aim of the field workshop was to examine and discuss the genesis and classification of ultra-continental, permafrost-affected soils. During the field excursion the participants had the opportunity to see and experience permafrost, ice cores, pingos, and other cryogenic structures; permafrost-affected “pale soils” (Cryosols and Cambisols); Permafrost-affected steppe soils (Chernozems and Solodic Planosols); saline and sodic soils (Solonchaks and Solonetz); unique “alas” landscapes i.e. depressions formed by thermokarst (thawing of permafrost) with a lake and corresponding post-limnic soils; and soils formed in sandy deposits (Stagnosols).

The participants were also treated by the hospitality of the Yakutian people, experienced the exquisite Yakutian cuisine, and had the opportunity to visit the Lena Pillars.

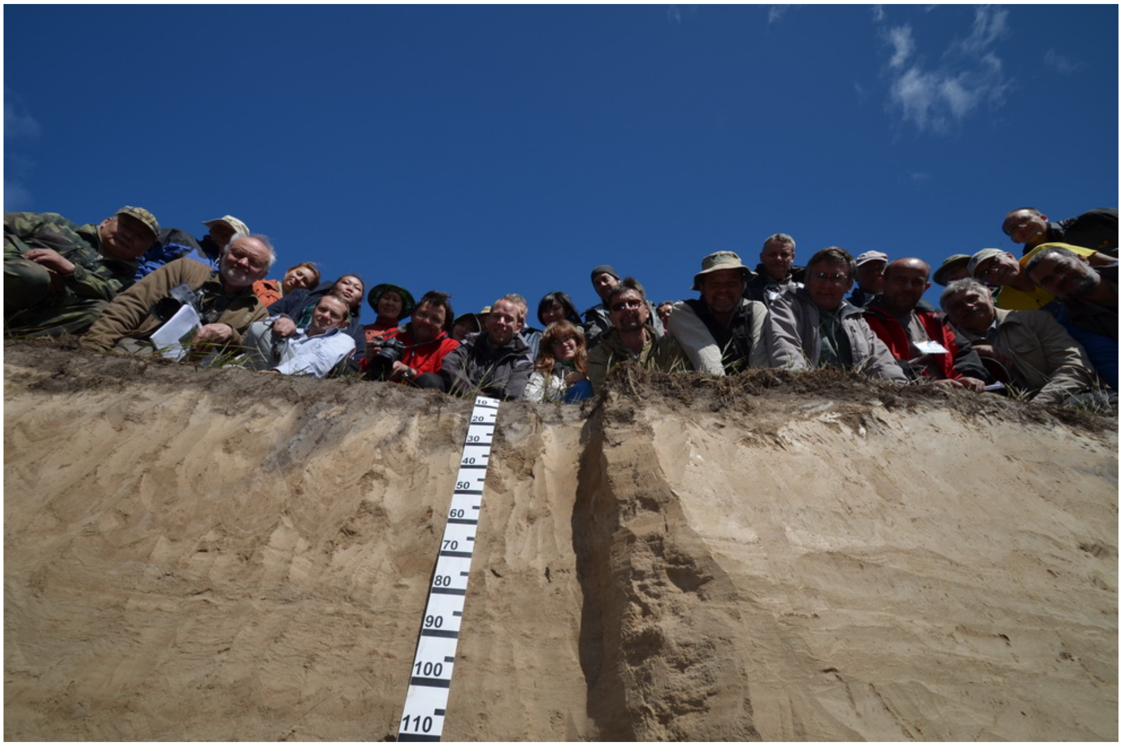
Field workshops like these are indispensable in testing the WRB in all the regions of the world. It also provides the opportunity for participants to correlate their classification to other international systems. The experience gained, and difficulties encountered during these field workshops, are used in the revision of the WRB. A new edition is currently in the final stages of revision and are planned to be distributed at the IUSS conference in June 2014.

CW van Huyssteen

Vice-chair: WRB

26 November 2013

An alas – a carstic (thermokarst) landscape that formed due to thermal erosion.



The participants (photo: Johan van der Waals)

An alas – a carstic (thermokarst) landscape that formed due to thermal erosion.

Cryoturbation in a Cryosol.

Additional report by J.G. Bockheim, Department of Soil Science, University of Wisconsin, Madison

(August 26, 2013)

The "Mammoth" Ultra-Continental WRB Field Workshop was held in Sakha (Yakutia) from August 17-23, 2013. There were 18 foreign scientists in attendance and an approximately equal number of Russian scientists. Two USA representatives were in attendance, including David Smith, director of the Natural Resources Conservation Service, and James Bockheim, professor of soil science at the University of Wisconsin-Madison.

The workshop was organized by Dr. Roman Desyatkin of the Institute for Biological Problems of the Cryolithozone in the Russian Academy of Science (Yakutsk), with the assistance of Drs. Sergey Goryachkin, Dimitri Konyushkiv, and Pavel Krasilnikov. The workshop was sponsored by the Russian Academy of Science, including the Institute of Geography (Moscow), the Institute of Biological Problems of the Cryolithozone (Yakutsk), the Melnikov Permafrost Institute (Yakutsk), and the Institutes of Biology of the Komi Scientific Center (Syktyvkar) and Karelian Research Center (Petrozavodsk); and the Lomonosov Moscow State University, the Dokuchaev Soil Science Institute of the Russian Academy of Agriculture Science (Moscow).

Although the primary purpose of the tour was to improve the classification of Cryosols in the WRB, an added benefit was to identify soil taxa not currently dealt with in *Soil Taxonomy*. The tour covered four locations, including the region to the west of Yakutsk, the region to the south of Yakutsk along the Lena River, the area of the northeast of Yakutsk near the Tyungyulyu village, and the area to the southeast of Yakutsk near the Tabara village.

A few general characteristics of the environmental conditions of the area follow. The Sakha Republic is the largest in the Russian Federation with an area of more than 3 million km^2. Central Yakutia has a cold, ultracontinental climate with deep permafrost, active thermokarst, and diverse soil and vegetation conditions. The soil cover includes dark-colored steppe soils, solonetzes and solonchaks in taiga (boreal forest), and wetlands adjacent to alases (thaw lakes in ice-rich permafrost). Many of the soils occurred on river terraces that range from 8-10 m above the Lena River (late Holocene age) to 300 m (Pliocene age). The terraces are often covered with a "loess-like" silty-loam material.

Central Yakutia is the only region of the world with low precipitation (ca. 200 mm/yr) and extreme seasonal temperature differences; monthly air temperatures range from 18.5°C (July) to -44.5°C (January). Absolute maximum and minimum air temperatures are 38°C and -71°C, respectively. The mean annual air temperature in Central Yakutia has increased from -11.2°C four decades ago to -8.8°C today. As a consequence, the active-layer has increased from around 1 m to more than 3 m and has been accompanied by substantial thermokarst. Permafrost temperatures in the region are comparatively warm, ranging from -2 to -7.1°C. The thickness of permafrost ranges from about 200 to 500 m. Talik zones beneath large lakes enable formation of alas depressions and bulgunnyakh (pingos).

Sandy soils feature Scotch pine (*Pinus sylvestris*), loamy soils commonly have larch (*Larix gmelinii*) and birch (*Betula pendula, B. pubescens*), and wetlands have sedges (*Carex juncella*) and mosses (*Sphagnum*, spp., *Polytrichum commune*).

The dominant soil-forming processes are weak cryoturbation, gleization, weak podzolization, weak ferrugination, humus accumulation, and strong solodization, salinization, and calcification.

A total of 16 pedons were examined. The normal procedure at each pit was to allow participants to take photographs of the soil pits and landforms, to have a host give an overview of the soil-forming factors and land use, to allow the participants to examine the soil in the pit, to appoint a guest to interpret the morphology of the soil, and to appoint representatives to classify the soil in the WRB, ST, the Russian systems, and any other systems of interest to the group (e.g., Australian, South African). Classification of the pedons in ST is given in Table 1, with proposed changes given in boldface. More detailed suggestions regarding needed changes in ST are given in Table 2.

Some of the main findings from the field tour that have implications for *Soil Taxonomy* include the need to: (i) quantify cryoturbation; (ii) revise the Gelisol order to include Aqui- and Aridi- suborders and additional great groups and suborders; (iii) include more Geli- suborders and great groups in ST; (iv) improve the soil temperature and soil moisture regimes to accommodate soils outside North America; (v) stress that permafrost depths (1 or 2 m) should be taken or adjusted to end-of-season conditions, i.e., mid-September in the Northern Hemisphere and early April in the Southern Hemisphere.

Although there was interest in ST and several participants were proficient in its use, there appeared to be greater interest in the WRB. Reasons given for this interest in the WRB include (i) the flexibility of the system through the use of suffix qualifiers and (ii) the ease in which individuals or groups can propose changes in the system.

Table 1. Classification of soils from Mammoth tour in Central Yakutia in Soil Taxonomy.

Profile	Depth to perm-afrost (cm)	Current Soil Taxonomy	Proposed Soil Taxonomy
11	150	Typic Haploturbels	Typic Haploturbels
12	90	Psammentic Aquiturbels	Psammentic Aquiturbels
15	400	Typic Cryopsamments	**Typic Gelipsamments**
14	80	Natric Argiorthels	Natric Argiorthels
13-1	280	Typic Gelaquents	**Sodic** Gelaquents
13-2	>200	Typic Natraqualfs	**Turbic Natrigelalfs**
9-1	80	Typic Sapristels	Typic Sapristels
9-2	250	Typic Endoaquolls	**Typic Gelaquolls**
9-3	300	Turbel Gelaquepts	Turbel Gelaquepts
2-1	250	Turbic Haplogelepts	Turbic Haplogelepts
2-2	250	Turbic Haplogelolls	**Turbic Natrigelolls**
2-3	>150	Turbic Haplogelolls	**Turbic Natrigelolls**
Added	>150	Typic Haplogelolls	**Lamellic Argigelolls**
5	230	Turbic Haplogelolls	Turbic Haplogelepts
6	220	Turbic Haplogelolls	**Turbic Natrigelolls**
7	220	Typic Natrudalfs	**Typic Natrigelalfs**

Table 2. Proposed changes in Soil Taxonomy to accommodate additional soils with deep permafrost.

Order	Suborder	Great group	Subgroups
Alfisols	**Gelalfs**	**Natrigelepts**	**Turbic, Typic**
	Aqualfs	**Gelaqualfs**	**Turbic, Typic**
Entisols	Aquents	Gelaquents	**Sodic**
	Psamments	**Gelipsamments**	**Typic**
Histosols	Fibrists	**Gelifibrists**	**Typic**
	Folists	**Gelifolists**	**Typic**
	Hemists	**Gelihemists**	**Typic**
	Saprists	**Gelisaprists**	**Typic**
Mollisols	Aquolls	**Gelaquolls**	**Typic**
	Gelolls	**Argigelolls**	**Lamellic, Typic**
		Natrigelolls	**Turbic**
Spodosols	Aquods	**Gelaquods**	**Typic**
Vertisols	Aquerts	**Gelaquerts**	**Typic**
	Gelerts	**Humigelerts**	**Typic**
		Haplogelerts	**Typic**

Boldface = new taxa

Universal Soil Classification (USC) Core Group Business Meeting
Florianopolis, Brazil
31 July, 2013

Participants:

Jon Hempel, Erika Michéli, Alex McBratney, Phillip R. Owens, Peter Schad, Lucia Anjos, Curtis Monger, Thomas Reinsch, John Galbraith, James Bockheim, Luca Montanarella, Ganlin Zhang, Sergey V. Goryachkin, Humberto Santos, Cornie Van Huyssteen, Didas Kimaro, Ben Harms, Juan Comerma, David Rossiter, Vince Lang, Marta Fuchs, Alessandro, Michele Duarte

General discussion on USC core team issues:

Justification of the use of the "Great group" level as starting point for USC development

Timing and USC working group focus

- Alex McBratney: Report on the improvement, structure of USC in the 20th World Congress of Soil Science, Jeju, Korea is expected from IUSS - and mainly from the scientific community
- Printed document should be developed for the congress

IUSS Soil Taxonomy proposal

- A letter has been sent to the leadership of IUSS requesting the IUSS Council to endorse Soil Taxonomy as an IUSS approved system for soil classification. The IUSS Council will decide about it in Korea
- This proposal is not competing with WRB because Soil Taxonomy will never be the official system of IUSS but it can be a system for international use recommended by IUSS

USC symposium on the 20th WCSS is officially accepted

Soil Taxonomy field guide working group formed

- The authors are trying to develop a guide (simplified version of US Soil Taxonomy) in order to classify soils at the Great Group level with limited laboratory data. The new guide is planned to be more visual, making easier to understand and to teach Soil Taxonomy
- The link of the 1st draft will be circulated

Pillar Five of the Global Soil Partnership

- USC WG can assist, and should have a place in this pillar
- Suggestion: Write a statement out of this USC WG meeting – and propose to take the lead of Pillar Five
- Scientific and institutional acceptance are both needed

WRB progress report summary

Task Groups – Major Categories

1. Soil classification

- 6 different areas were defined at Purdue for soil classification – improvements on topics are waited to be presented:
    - Hydromorphic Soils-Chair: Cornie van Huyssteen
    - Acid Sulfate Soils-Chair: Ben Harms
    - Anthropogenic Soils-Chair: Ganlin Zhang

Tropical Soils-Chair: Lucia Anjos
Cold Soils-Chair: Sergey Goryachkin
Salt Affected Soils-Chair: Erika Micheli

- Organic soils should have separate task group
- For the “Cold soils” task group - not all soils (that are very important) are covered by this list i.e. Spodosols, Mollisols, Alfisols… Those are important neighboring soils to cold soils. Thus there are gaps in soil units.
- Cold soils can’t be separated from their “neighbours” without data
- About 40 cold soil pedons can be found in NASIS but lot of data can be collected from different sources BUT in different format.

2. Diagnostic and Soil profile information

- Dual nomenclature (both scientific and simple vernacular versions are needed)

3. Important information relating to soil classification

- Literature review first – strong spatial patterns were found in soil biology studies. There may be something that should be recognized in classification - could be a property or a covariate
- For example studies on paddy soils shown that Vertisols have different microbial community from other paddy soils.
- Soil biology is very important but the soil related information is very sensitive so a lot of work is needed + Biodiversity changes partly come from land use change
- Need to investigate this (based on the available info) before conclusion. It’s possible that biodiversity is related to soil properties that we are already using in our classification
- Make a contact with Diana Woll from the global soil biodiversity community about possibilities - what do they think about it? And how much data is available from the biodiversity community?

4. Recommend laboratory methods and correlation rules

- There is also an ISO standardization community
- Link up with other international communities
- Suggested methods are provided in Soil Taxonomy as well
- FAO suggested methods are provided in annex of WRB

5. Explore other observation methods (e.g. spectroscopy, gamma radiometrics)

- Single properties are already known and agreed. The list of properties will be sent
- Already working on ways to measure those properties in the field

6. Define potential users interested in soil classification wider than traditional users

- What kind of need of what type of people / users is a very important info – to define the proper level / terminology to communicate with different users
- What about the JRC Soil Atlas? Not just soil scientists are interested in it
- Yes, the atlas is a great success, but people are interested in soils and not in classification
- It’s not really handled in the Soil Taxonomy either - there is not a wide range of users in US, mainly professionals and universities
- In Tanzania we start with 7 physical landscape units that everybody can understand

- At the highest level of USC we have to catch the important, obvious things
- Qualifiers and great groups are the scientific part of a classification system and are very important. But the problem is that we communicate this with the users. We have to know which level to use to approach different people
- Soil series are the scientific technological transfer
- First have to talk with users and develop a system that design users need

Forthcoming Meetings

Soil Classification at the 20th World Congress of Soil Science

Jeju, Korea, June 8-13, 2014

The deadline for submitting the abstracts for the 20th WCSS is gone, but the number of submitted abstracts is still unknown for each session. For the moment the soil classification-related topics at the Congress look as follows:

- **Folk Soil Knowledge For Soil Taxonomy, Soil Assessment (Inter-Divisional Symposium: Div. 1 and Div. 3)** (convener *Francisco Bautista-Zuñiga*, Keynote Speaker – *Joe Tabor*)
- **The Progress in the Development and Harmonization of Soil Classifications** (convener *Sergey Goryachkin)*
- **Marginal Soils: the Classification of Technogenic, Subaqueous, and Extraterrestrial Soil-Like Bodies** (convener *John M. Galbraith*)
- **WRB - Lessons Learned During the Development of the Third Edition 2014** (Organizers and conveners *Cornie van Huyssteen* and *Seppe Deckers,* Keynote Speaker – *Peter Schad*)

Also please note that there will be a joint business meeting of the Commission Soil Classification and the Working Groups WRB and USC during the Congress. The place and time of the meeting will be announced later.

The local Organizing Committee is planning to set up various programs to encourage the participation of many soil scientists, especially the young ones.

The 20WCSS Local Organizing Committee is pleased to offer travel grants to **Young Scientists from Developing Countries.**

Grant

Each nominee will receive a grant based on their current residence.

Eligibility

The congress will offer travel grants to a limited number of Young Scientists from developing countries.

The grants are intended to partially offset travel costs for presenting attendants to attend the 20WCSS. To be eligible for congress travel grant, an abstract must be presented at the congress.

Selection

All young scientists from developing countries who will be presenting an abstract are eligible for travel support. The organizing committee will select a limited number of nominees, whose abstracts have been evaluated as outstanding. The nominee will be notified by e-mail and through the 20WCSS website in late April, 2014.

Application

The deadline for submitting applications is March 20, 2014. Applications must be submitted by e-mail, and incomplete or late applications will not be considered. The nominee must register by the Regular registration Date (May 8, 2014) at the latest. Otherwise, the grants will be automatically cancelled.

For more details please see the web site of the Congress: **http://www.20wcss.org/sub03_6.php**

Soil Classification Publications 2013

First we should note a long-awaited book:

Shahid S. A., Taha F. K., Abdelfattah M. A. (ed.). Developments in soil classification, land use planning and policy implications. Springer, 2013. 913 p.

This is the book of proceedings of the "The International Conference on Soil Classification and Reclamation of Degraded Lands in Arid Environments" that took place in Abu Dhabi from May 17 to May 20, 2010.

This important addition to the technical literature of ecology is a storehouse of information on soil that includes inventories, material on databases, and details of policy developments. Soil may be just brown dirt to most people, but its sustained health is vital to the world's ecosystems, and it is under threat as never before from contamination, degradation and salinization, among other issues. Yet soil is a precious resource: it is the essence of life, the location of innumerable chemical reactions, a filtration and nutritive system for water itself, and a versatile, if vulnerable, growing medium. Care is needed in looking after soil, since it renews itself only slowly. As the world's population continues to expand, maintaining and indeed increasing agricultural productivity is more important than ever, though it is also more difficult than ever in the face of changing weather patterns that in some cases are leading to aridity and desertification. The absence of scientific soil inventories, especially in arid areas, leads to mistaken decisions about soil use that, in the end, reduce a region's capacity to feed its population, or to guarantee a clean water supply. Greater efficiency in soil use is possible when these resources are properly classified using international standards. Focusing on arid regions, this volume details soil classification from many countries. It is only once this information is properly assimilated by policymakers it becomes a foundation for informed decisions in land use planning for rational and sustainable uses.

http://link.springer.com/book/10.1007/978-94-007-5332-7

The contents include various titles for soil classification the first part (**Soil Survey and Classification Strategies in Different Ecological Zones)** would be the most interesting:

1. **Innovative Thinking for Sustainable Use of Terrestrial Resources in Abu Dhabi Emirate Through Scientific Soil Inventory and Policy Development** by Shabbir A. Shahid , Mahmoud A. Abdelfattah , Yasser Othman,Anil Kumar, Faisal K. Taha, John A. Kelley , and Michael A. Wilson
2. **Demands on Soil Classification and Soil Survey Strategies: Special-Purpose Soil Classification Systems for Local Practical Use** by R. W. Fitzpatrick
3. **Reconnaissance Soil Survey for the State of Kuwait** by Samira A. S. Omar and Shabbir A. Shahid
4. **Do the Emerging Methods of Digital Soil Mapping Have Anything to Learn from the Geopedologic Approach to Soil Mapping and Vice Versa?** By Abbas Farshad , Dhruba Pikha Shrestha, and Ruamporn Moonjun
5. **Soil Thematic Map and Land Capability Classification of Dubai Emirate** by Hussein Harahsheh , Mohamed Mashroom , Yousef Marzouqi , Eman Al Khatib , B. R. M. Rao , and M. A. Fyzee

6. **Land Evaluation Interpretations and Decision Support Systems: Soil Survey of Abu Dhabi Emirate** by Peter King , Gerard Grealish , Shabbir A. Shahid, and Mahmoud A. Abdelfattah
7. **Conceptual Soil-Regolith Toposequence Models to Support Soil Survey and Land Evaluation** by Gerard Grealish , R. W. Fitzpatrick , Peter King, and Shabbir A. Shahid
8. **Anhydrite Formation on the Coastal Sabkha of Abu Dhabi, United Arab Emirates** by Michael A. Wilson, Shabbir A. Shahid , Mahmoud A. Abdelfattah, John A. Kelley, and James E. Thomas
9. **Fundamental Steps for Regional and Country Level Soil Surveys** by Norair Toomanian
10. **Assessment of Soil Diversity in Western Siberia Using WRB 2006** by Elena N. Smolentseva
11. **Classification of the Topsoil Fabrics in Arid Soils of Central Asia** by Marina Lebedeva, Maria Gerasimova, and Dmitry L. Golovanov
12. **Digital Mapping of Gypsic Horizon Morphotypes and Soil Salinity in an Old Alluvial Piedmont Plain of Uzbekistan** by Dmitry L. Golovanov and Irina A. Yamnova
13. **Soils in Arid and Semiarid Regions: The Past as Key for the Future** by Bernhard Lucke , Iourii Nikolskii , and Rupert Bäumler
14. **Classification, Characterization and Suitability Evaluation of the Savanna Soils of Oyo North of Nigeria** by J. O. Aruleba and A. S. Ajayi
15. **Use of Soil Survey Database for the Probabilistic Evaluation of Soil Cover Transformation in the Semiarid Zone of Western Siberia** by Irina Mikheeva
16. **Soil Suitability of Northern State of Sudan to Irrigated Agriculture** by Abdelmagid Ali Elmobarak and Fawzi Mohamed Salih
17. **Effects of Plants on Soil-Forming Processes: Case Studies from Arid Environments** by William H. Verboom, John S. Pate, Mahmoud A. Abdelfattah, and Shabbir A. Shahid
18. **The Sand Land Soil System Placement (Taxonomy) and Society** by Ramez A. Mahjoory
19. **Digital Soil Mapping Using Spectral and Terrain Parameters and Statistical Modelling Integrated into GIS-Northwestern Coastal Region of Egypt** by Fawzy Hassan Abdel-Kader
20. **Studies on the Micromorphology of Salt-Affected Soils from El-Fayoum Depression, Egypt** by Tolba S. Abdel Aal and A. M. Ibrahim
21. **Correlation of Students' Estimation and Laboratory Determination of Soil Texture** by Mohamed S. Alhammadi and Mohamed S. Gheblawi
22. **Soil Classification and Genesis in Part of Khorasan Province** by Mohammad Hassan Sayyari-Zahan
23. **Classification, Characterization, and Management of Some Agricultural Soils in the North of Egypt** by Sabry M. Shaheen , Mohamed E. Abo-Waly, and Rafaat A. Ali
24. **Semiarid Soils of Eastern Indonesia: Soil Classification and Land Uses** by Anny Mulyani, Adi Priyono, and Fahmuddin Agus

There were a number of other publications. The first one to be mentioned is an review listed below:

Hartemink, A.E., Bockheim, J.G. 2013. Soil Genesis and Classification. Catena, 104, pp. 251-256.

The formation and classification of soils have been a key area of research in the soil science discipline. Major breakthroughs have been brought about since the mid 1800s and it has evolved from conceptual frameworks, to descriptive studies to more quantitative approaches. Some 50 years ago the American soil scientists Stan Buol and Francis Hole hatched idea for the book Soil Genesis and Classification. Now six editions of the book have been published and it has become a

standard text book in teaching soil science and pedology in the USA. Over 50,000 copies have been sold and this paper reviews how the book evolved over time, and relates the text to trends and developments in soil formation and soil classification.
http://www.sciencedirect.com/science/article/pii/S0341816212002548

We did not try to classify the publications precisely, but made a somewhat provisional division. At the first place we put the papers related to the application of soil classification to soil mapping and correlation, and with the spatial distribution of soils in general.

Dewitte, O., Jones, A., Spaargaren, O., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Michéli, E., Montanarella, L., Thiombiano, L., Van Ranst, E., Yemefack, M., Zougmore, R. 2013. Harmonisation of the soil map of Africa at the continental scale. Geoderma, 211-212, pp. 138-153.
In the context of major global environmental challenges such as food security, climate change, fresh water scarcity and biodiversity loss, the protection and the sustainable management of soil resources in Africa are of paramount importance. To raise the awareness of the general public, stakeholders, policy makers and the science community to the importance of soil in Africa, the Joint Research Centre of the European Commission has produced the Soil Atlas of Africa. To that end, a new harmonised soil map at the continental scale has been produced. The steps of the construction of the new area-class map are presented, the basic information being derived from the Harmonized World Soil Database (HWSD). We show how the original data were updated and modified according to the World Reference Base for Soil Resources classification system. The corrections concerned boundary issues, areas with no information, soil patterns, river and drainage networks, and dynamic features such as sand dunes, water bodies and coastlines. In comparison to the initial map derived from HWSD, the new map represents a correction of 13% of the soil data for the continent. The map is available for downloading.
http://www.sciencedirect.com/science/article/pii/S0016706113002401

Feder, F. 2013. Soil map update: Procedure and problems encountered for the island of Réunion. Catena, 110, pp. 215-224.
Many soil maps were drawn up after World War II with different soil classifications that have significantly evolved since. Updating such old maps with a new version or a new classification system is always complex: (i) we do not always possess all the original information; (ii) the criteria for determining references are often different, and (iii) on the most accurate scales, correlations come up against the complexity and specificities of each classification system. On Reunion, a volcanic tropical island in the Indian Ocean, we undertook a comprehensive overview of the old existing soil studies. This article describes (i) the procedure used to update the soil maps and the toposequence acquired with the old French Commission de Pédologie et de Cartographie des Sols (CPCS) classification system, without any new information, using the World Reference Base for soil resources (WRB); (ii) the construction of a new soil map drawn up with completely new information, and (iii) a comparison of these two approaches. At elevations below 350. m asl (above sea level), without any new pedological information, we updated Brown ferruginous soils, Reddish-brown

ferrallitic soils, and Fersialitic soils into Haplic Nitisols (Humic, Eutric). The acquisition of new data showed that this update was incorrect because not all the diagnostic criteria of the Nitic horizons were met. The correct diagnostic horizons were a Mollic horizon when the thickness was 25. cm or more, or a Cambic horizon. Leptic Phaeozems and Leptic Cambisols were then the correct Reference Soil Group (RSG). At elevations from 350 to 900. m asl, without any new information, Brown and Reddish-brown ferrallitic soils, Andic ferrallitic soils, and Brown and Andic brown soils were updated into Haplic Nitisols (Humic, Dystric) and Andic Umbrisols (Humic). The acquisition of new data showed that this update was incorrect because Andic properties and the diagnostic criteria of the Nitic horizons were not met. Over 900. m asl, Pozols were correctly updated, as were the Andosols except from 900 to 1050. m asl where not all the Andic properties were met. Without any new information, incorrect updates were observed for both the determination of RSG and the qualifiers. Despite the field descriptions, the lack of any analytical determinations on the old soil studies was a source of updating errors for the more developed soils formerly qualified as ferrallitic. In order to update limits for Andic properties and Andosols, the systematic use of analytical determinations has to be considered for updating old soil maps, as the diagnostic criteria are more restrictive than in the past.
http://www.sciencedirect.com/science/article/pii/S0341816213001586

Jafari, A., Ayoubi, S., Khademi, H., Finke, P.A., Toomanian, N. 2013. Selection of a taxonomic level for soil mapping using diversity and map purity indices: A case study from an Iranian arid region. Geomorphology, 201, pp. 86-97.
There is a growing demand for digital soil maps for environmental planning, modeling and management. If mapped soil classes are taken from a hierarchical taxonomic system, a question arises: which taxonomic level is most appropriate to be depicted on the map with a given sample size, available environmental covariates and the strength of predictive relations between covariates and the soil classes? Pedodiversity, the study and measurement of soil diversity, can be considered as a framework to analyze spatial patterns depicted on soil maps. This paper discusses the selection of the taxonomic level for soil mapping in an arid region in southeast Iran on the basis of (1) the purity of a digital soil class map derived from an artificial neural network (ANN) prediction method using environmental covariates and (2) pedodiversity indices of these soil maps. The prediction of soil classes and the calculation of diversity indices were carried out for taxonomic categories of order, suborder, great group, and subgroup. Using the feed forward back-propagation algorithm, three-layer ANNs with input, hidden and output layers were trained for soil class prediction at each category level. In most predictions, the combined use of terrain attributes and geomorphic surfaces provided the best results. When the taxonomic level changed from order to subgroup, the purity decreased, whereas the values of the diversity indices increased. The highest purity and lowest diversity are observed at the order level, indicating a good quality map in terms of its purity, but reflecting only little soil diversity, thus with a low usage potential. On the other hand, soil maps at the level of subgroup illustrate high diversity and low purity, so that the predicted map units are highly uncertain. This map is also inappropriate for users. We introduced an index combining the diversity and purity which indicated that the best taxonomic level for soil mapping in the study area is the great group, with both high diversity and purity.

http://www.sciencedirect.com/science/article/pii/S0169555X13003322

da Silva, A.F., Halmeman, R.J., Zimback, C.R.L. 2013. Dependence of spatial attributes for diagnostic limitation of classes of soil [Dependência espacial de atributos diagnósticos para delimitação de classes de solos]. Geociencias, 32 (1), pp. 93-100.

Soils are classified by their horizons and diagnostics attributes that can be grouped by similarities and provide information about their use. The knowledge the spatial variability of the diagnostic attributes used in the soil classification is very important in the definition of soil management. The aim of this study was to evaluated spatial dependence of diagnostic attributes (redness index attributes, textural gradient and V%) and identify the boundaries between soils classes. The redness index, textural gradient and V% were determined in the soil horizons A and B of a grid of 65 sampling points collected in the "horto" from city of Mogi-Guaçu, SP. The analysis of spatial variability of the attributes was realized by geostatistics considering the spatial dependence in the range of sampling and interpolated by ordinary kriging to obtain the thematic maps. Based on the maps of redness index, textural gradient and V% was possible to generate the map of soil classes. The area showed high occurrence of Red-Yellow soils without clay migration to the B horizon and dystrophic.

http://www.revistageociencias.com.br/

Omuto, C.T. 2013. Major Soil and Data Types in Kenya. Developments in Earth Surface Processes, 16, pp. 123-132.

Soil is a natural resource that supports food production and numerous types of support to life on earth. It occurs on the earth's surface as groups or types, which have special capabilities. To identify these capabilities, soil scientists have developed tools for mapping soil types in the landscape so that their potential uses can be maximised. However, the mapping tool needs sufficient input data that many countries in the world do not have. In Kenya, the input data for soil mapping can be found from several governmental and nongovernmental organisations. This study identified and described publicly available soil data and new tools that can be used to produce high-resolution soil map of Kenya. The spatial distribution of the locations of these soil information sources showed that the northeastern parts of the country have been poorly represented in soil information development. Furthermore, using the available soil data, this study developed a new soil map of Kenya at a higher scale than the currently available area-class map. This soil map depicts the country as consisting of 22 main soil groups according to the FAO-UNESCO classification. These groups are dominated by soil types that have strong crop production limitations under rain-fed agriculture but are good for the development of pastoral resources. This implies that rain-fed crop production in the country cannot adequately sustain the consumptive demand of over 40 million people unless improved farming methods are applied.

http://www.sciencedirect.com/science/article/pii/B9780444595591000116

Monreal, J.C., Martínez, F.S.J., Martí, J.J., Pérez-Gómez, R. 2013. Lacunarity of the spatial distributions of soil types in Europe. Vadose Zone Journal, 12 (3).

Lacunarity as a means of quantifying textural properties of spatial distributions suggests a classification into three main classes of the most abundant soils that cover 92% of Europe. Soils with a well-defined self-similar structure of the linear class are related to widespread spatial patterns that are nondominant but ubiquitous at continental scale. Fractal techniques have been increasingly and successfully applied to identify and describe spatial patterns in natural sciences. However, objects with the same fractal dimension can show very different optical properties because of their spatial arrangement. This work focuses primary attention on the geometrical structure of the geographical patterns of soils in Europe. We made use of the European Soil Database to estimate lacunarity indexes of the most abundant soils that cover 92% of the surface of Europe and investigated textural properties of their spatial distribution. We observed three main classes corresponding to three different patterns that displayed the graphs of lacunarity functions, that is, linear, convex, and mixed. They correspond respectively to homogeneous or self-similar, heterogeneous or clustered and those in which behavior can change at different ranges of scales. Finally, we discuss the pedological implications of that classification. © Soil Science Society of America 5585 Guilford Rd., Madison, WI 53711 USA. All rights reserved.

https://www.soils.org/publications/vzj/abstracts/12/3/vzj2012.0210

Phillips, J.D. 2013. Evaluating taxonomic adjacency as a source of soil map uncertainty. European Journal of Soil Science, 64 (4), pp. 391-400.

Soil types or map units are considered to be taxonomically adjacent if they differ in only one criterion, defined by an arbitrary threshold value. By treating soil types as nodes of a graph and taxonomic adjacency as the graph edges connecting nodes, algebraic graph theory can be used to produce a measurement of the uncertainty in a soil map associated with arbitrary classification boundaries between soil types. The largest eigenvalue of the adjacency matrix of a graph, the spectral radius, is an indication of network complexity. A larger spectral radius indicates a more complex network, and a greater degree of uncertainty or potential error associated with taxonomic adjacency. Benchmark values of spectral radius for cases of no taxonomic adjacency, including a single pair of adjacent soils, a chain or cycle-type graph structure and a fully connected graph, are established so that taxonomic adjacency indices based on the spectral radius can be established. Examples are shown from two contrasting USA soil landscapes in the Ouachita Mountains, Arkansas, and the coastal plain of North Carolina, using both US Soil Taxonomy and the world reference base. The taxonomic adjacency indices are also useful in assessing soil richness and pedodiversity, with smaller values indicating a greater likelihood that identified soils represent distinct entities.

http://onlinelibrary.wiley.com/doi/10.1111/ejss.12049/abstract;jsessionid=FF6C34909DC7CFB3AB905160C4923FB5.f02t04?systemMessage=Wiley+Online+Library+will+be+disrupted+on+7+December+from+10%3A00-15%3A00+BST+%2805%3A00-10%3A00+EDT%29+for+essential+maintenance

Ibáñez, J.J., Feoli, E. 2013. Global relationships of pedodiversity and biodiversity. Vadose Zone Journal, 12 (3).
Biodiversity and pedodiversity conform to the power law at planetary level. The two types of diversity are strongly correlated. When a country has high pedodiversity it has also high biodiversity. A novel "soil-regolith taxonomy" should improve the analysis of pedodiversity-biodiversity relations. Current studies indicate that biodiversity and pedodiversity may have similar patterns, for example diversity-area relationships. This study examines pedodiversity and biodiversity-area relationships on a global scale using countries as spatial units. The Food and Agricultural Organization (FAO) soil database and International Union for the Conservation of Nature-World Commission on Protected Areas (IUCN-WCMC) biological datasets have been used in this analysis. The results show that biodiversity of biological target groups (the number of species of vascular plants, amphibians, reptiles, birds, mammals, and the total number of species of vertebrates) and pedodiversity (the number of pedotaxa or soil types at the second level of FAO classification) conform to the power law. The two types of diversity are strongly correlated at the global level. When a country has high pedodiversity it has also high biodiversity, and since pedodiversity may be interpreted as an expression of environmental heterogeneity in terms of geological parent material, geomorphology, and climate of a given area, this result suggests that the biodiversity of a country depends both on the extent of its area and on its environmental heterogeneity. We are conscious of the limitations of the results due to the inherent imprecision of the data set used for this study; however, we think that this analysis could motivate interest in continuing to study the pedodiversity-biodiversity relationships with a new pedotaxonomy that would take into consideration the deep regolith layers.
https://www.soils.org/publications/vzj/abstracts/12/3/vzj2012.0186

There was a group of publications related to the development of national classification systems.

Van Huyssteen, C.W., Turner, D.P., Le Roux, P.A.L. 2013. Principles of soil classification and the future of the South African system. South African Journal of Plant and Soil, 30 (1), pp. 23-32.
Humans classify their environment to create order, make it understandable, aid recollection and to communicate. The nature of these classifications is not always understood, because they are learnt from an early age. Building on these principles provides a sound basis for any scientific classification. This paper explores these principles, those of the USDA Soil Taxonomy, the World Reference Base for soil resources, and the South African Soil Taxonomy. Knowledge should be ultimate aim of soil classification. A hierarchical system with four levels is proposed for the South African Soil Taxonomy. This can easily be achieved by adding a higher level, proposed to be called a Soil Group, to the current three levels (form, family, and phase). The South African Soil Taxonomy must guard against too many taxa, because humans have a limited ability to comprehend numerous taxa. The distinguishing criteria between taxa should be more clearly defined, while at the same time guarding against becoming too data hungry. The classification should not shy away from intergrades. The object being classified (soils) is a natural system and intergrades will necessarily occur. It is proposed that these should be classified as intergrades, rather than trying to artificially separate natural soil bodies.
http://www.tandfonline.com/doi/abs/10.1080/02571862.2013.771752#.Up9glOL86q4

Turner, D.P. 2013. Perspectives on the principles and structure of the soil classification system in South Africa: Discussion and practical examples. South African Journal of Plant and Soil, 30 (2), pp. 61-68.

The paper discusses revised principles, perspectives and structure for soil classification of natural soils in South Africa. An expanded sphere of pedological interest is proposed through the formal recognition of a wider range of subsurface soil materials. The concept of soil groups has been recognised and is further developed as a formal classification category. In addition, a subgroup category is introduced with discussion using practical examples for the eluvial, yellow-brown apedal, and prismacutanic and pedocutanic horizons with the proposed orthic group of soils. Identification of soils within these examples is proposed to follow a formal key sequence that seeks to identify soils with subsurface gleying, and subsequently progressing from those subsurface horizons of generally more intense to less intense weathering. The key structure retains much of the existing soil-form structure. As such it should be readily suitable for implementation. A description for additional subsurface horizons is introduced, which in selected instances differs slightly from that which is currently understood from present definitions. It is advocated that the principle advantage for introducing an expanded sphere of pedological interest will be gained through improved soil recognition and interpretation that could be given to soil classification classes. The proposed structure is open-ended. This should facilitate a new freedom in the examination of soils that could lead to their improved description in both morphological and numerical soil properties.

http://www.tandfonline.com/doi/abs/10.1080/02571862.2013.789130#.Up9VD-L86q4

Turner, D.P. 2013. A revised perspective on principles of soil classification in South Africa. South African Journal of Plant and Soil, 30 (2), pp. 119-120.

Limited significance has been given to the formal recognition of certain subsoil materials in the South African Soil Classification System. Three principles in the current classification system are discussed using variants of soil profiles associated with the Avalon soil form. The retention of the arbitrary depth criterion is questioned in favour of the recognition of an enlarged sphere of pedological interest extending formal classification to deeper soil materials. This implies that a greater number of soil classes will be required but these additional classes may be accommodated by recognising an additional soil group class in the classification system. It is proposed that the definitions of diagnostic horizons be rewritten to focus on the central concept of the horizon properties, dispensing with limitations on the nature of overlying or underlying horizons. An open class structure to the classification system is advocated. © 2013 Copyright Combined Congress Continuing Committee.

http://www.tandfonline.com/doi/abs/10.1080/02571862.2013.804602#.Up9VW-L86q4

Gerasimova, M.I., Lebedeva, I.I., Khitrov, N.B. 2013. Soil horizon designation: State of the art, problems, and proposals. Eurasian Soil Science, 46 (5), pp. 599-609.

A review of the systems of symbols used for designating the soil horizons and properties identified in the course of profile descriptions has been made with emphasis put on their genetic meaning, adequacy to the principles of the soil classification, and requirements concerning the ways of their

presenting. The review is based on examining the symbols regarded as optional in classification systems (both Russian and foreign) mentioned in publications (mostly in Eurasian Soil Science) and on the experience of the authors and their colleagues. The inconsistencies or contradictions revealed even within one system are discussed, as well as the problems in discriminating between the diagnostically important and "descriptive" symbols. The multiplicity of the designations used with different meanings and differently written hinders the diagnostics and taxonomic definition of soils. The authors' suggestions for designating the morphological elements of soil profiles are in good agreement with the principles of the recent soil classification of Russia and take into account the comments and proposals of the users: professionals, students, and visitors to special sites. The suggestions may hopefully be helpful for the standardization of soil profile descriptions and contribute to the reliability and adequacy of soil diagnostics.
http://link.springer.com/article/10.1134%2FS1064229313050037

de Andrade Bernini, T., Gervasio Pereira, M., Fontana, A., Dos Anjos, L.H.C., Calderano, S.B., Wadt, P.G.S., de Lima Moraes, A.G., Dos Santos, L.L. 2013. Taxonomy of soils developed under sedimentary deposits from Solimões formation in Acre state, Brazil [Taxonomia de solos desenvolvidos sobre depósitos sedimentares da Formação Solimões no Estado do Acre]. Bragantia, 72 (1), pp. 71-80.
The soils from the State of Acre (Brazil) are mostly formed under parent material with influence of Andean orogeny, showing high Ca2+, Mg2+ and Al3+ contents concomitantly associated with different combinations of CEC, V and m values. This study aimed to characterize and classify soils of a topossequence under sedimentary material from Solimões Formation, in the county of Feijó, State of Acre, Brazil. Trenches were opened in three points on a topossequence: shoulder (P1), backslope (P2) and footslope (P3). The soils were analyzed by morphology, particle size (sand, silt and clay), exchangeable cations (Ca2+, Mg2+, Na+, K+ and Al3+), potential acidity (H+Al), P assimilable, pH (water and KCl), specific surface, sulfuric attack (Fe, Al, Ti and Si oxides), and mineralogy (sand, silt and clay). The soils were classified according to the Brazilian System of Soil Classification (SiBCS, 2006) and a classification considering the peculiarities of the soils was proposed. The soils have a low degree of pedogenetic development, with minerals of high activity in the clay fraction, and the presence of primary minerals such as feldspar and plagioclase in the sand and silt fractions. The soils were classified according to the current SiBCS as Argissolo Vermelho Álitico plíntico (P1), Argissolo Acinzentado Distrófico plíntico (P2) e Cambissolo Háplico Ta Eutrófico típico (P3).
http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0006-052013000100010&lng=pt&nrm=iso&tlng=en

Capra, G. F., Vacca, S., Cabula, E., Grilli, E., & Buondonno, A. 2013. Through the Decades: Taxonomic Proposals for Human-Altered and Human-Transported Soil Classification. *Soil Horizons*, *54*(2).
For decades, pedologists all over the world have been debating about anthropogenic (human-altered and human-transported, or HAHT) soil classification. The result has been several taxonomic proposals, based on varying rationale, each aiming to ensure a more correct assignment of HAHT soils to the different U.S. Soil Taxonomy class levels. Starting from such innovative ideas, this study aimed to assess whether or not such proposals may actually be adequate and appropriate when

applied to HAHT soils representing conditions that differ from those for which the relevant changes were proposed and tested. More specifically, reference is made to the soil of an important industrial district of Italy, where human manipulation of earthy materials has given rise to soil entisolization processes, with a consequent taxonomic shift from natural Alfisols to anthropogenic Entisols (HAHT soils). These HAHT soils currently meet the requirements for a "mantle" classifiable as Alfic Xerarents, although this classification gives no information about its having been formed from human transported materials (HTM). On the premise that the intention is not to introduce changes to U.S. Soil Taxonomy, the study presents and discusses an overview of possible new taxonomic accommodations of the investigated HAHT soils by comparing a top-down approach (introduction of a new soil order) to a bottom-up approach (introduction of taxa at subgroup levels). In the first case Alfic Geofragmexerant may be the most suitable designation, while the bottom-up approach results in the more informative Anthroportic Xerorthents Subgroup.
https://dl.sciencesocieties.org/publications/sh/abstracts/54/2/sh12-12-0033

Bockheim, J. G., & Hartemink, A. E. 2013. Distribution and classification of soils with clay-enriched horizons in the USA. *Geoderma*, *209*, 153-160.
In Soil Taxonomy three diagnostic subsurface horizons reflect clay enrichment: the argillic, kandic, and natric horizons. Clay illuviation is recognized in Soil Taxonomy at some level in 10 of the 12 orders, including the order (Alfisols, Ultisols), suborder (Aridisols), great group (Aridisols, Gelisols, Mollisols, Oxisols, Vertisols), and subgroup (Andisols, Aridisols, Inceptisols, Mollisols, Oxisols, Spodosols). Forty-four percent of the soil series in the USA contain taxonomically defined clay-enriched horizons. However, many other soils contain Bt horizons that do not qualify as an argillic or related horizons. Several soil-forming factors are important in their development, including udic and ustic soil climates, lithological discontinuities, parent materials enriched in carbonate-free clays and coarse fragments, well-drained conditions, backslopes rather than eroding shoulders, and a time interval of > 2000 yr or more. The genesis of argillic, kandic, and natric horizons is also dependent on electrolyte concentration, the amount and distribution of precipitation, clay charge, and microfabric.
http://www.sciencedirect.com/science/article/pii/S0016706113002097

We also found several papers related to the development of the methods of numerical soil classification.

Subburayalu, S.K., Slater, B.K. 2013. Soil series mapping by knowledge discovery from an Ohio county soil map. Soil Science Society of America Journal, 77 (4), pp. 1254-1268.
Machine learning can be used to derive predictive spatial models from existing soil maps, for updating soil surveys, improving efficiency of new surveys in similar landscapes, and to disaggregate map units containing multiple soil series, such as in the Soil Survey Geographic Database (SSURGO). One challenge with using aggregated soil map units as a source for training machine learning systems to map series is ambiguity in labeling the training set. Ambiguity emerges while assigning soil series to instances that would be used as training instances in modeling the data, as a map unit

in SSURGO can contain more than one component soil series. Disambiguation of training instances is proposed as a technique to handle ambiguity. The k-nearest neighbor (kNN) algorithm, which classifies the training examples based on closest training examples in attribute space using the list of component soil series information available in the tabular data of SSURGO, is proposed as a viable method to assign most likely soil series to training instances. Two different learning algorithms, J48, a classification tree algorithm, and Random Forest, an ensemble classifier, were applied to evaluate soil series prediction for Monroe County, Ohio. The results showed an improvement in prediction accuracy with disambiguation using kNN. Among the two learning algorithms, Random Forest demonstrated better performance in mapping major soils. However, J48 predicted some minor soils which were not predicted by Random Forest. The maps were useful in identifying areas of uncertainty such as misplacement of polygon boundaries, presence of inclusions, and incorrect labeling, which could serve as a guide for further field investigations and for rationalizing the mapping intensity for SSURGO maps.
https://www.soils.org/publications/sssaj/abstracts/77/4/1254

Beaudette, D.E., Roudier, P., O'Geen, A.T. 2013. Algorithms for quantitative pedology: A toolkit for soil scientists. Computers and Geosciences, 52, pp. 258-268.
Soils are routinely sampled and characterized according to genetic horizons, resulting in data that are associated with principle dimensions: location (x, y), depth (z), and property space (p). The high dimensionality and grouped nature of this type of data can complicate standard analysis, summarization, and visualization. The "aqp" (algorithms for quantitative pedology) package was designed to support data-driven approaches to common soils-related tasks such as visualization, aggregation, and classification of soil profile collections. In addition, we sought to advance the study of numerical soil classification by building on previously published methods within an extensible and open source framework. Functions in the aqp package have been successfully applied to studies involving several thousand soil profiles. The stable version of the aqp package is hosted by CRAN (http://cran.r-project.org/web/packages/aqp), and the development version is hosted by R-Forge (http://aqp.r-forge.r-project.org).
http://www.sciencedirect.com/science/article/pii/S009830041200369X

Láng, V., Fuchs, M., Waltner, I., Michéli, E. 2013. Soil taxonomic distance, a tool for correlation: As exemplified by the hungarian brown forest soils and related WRB reference soil groups. Geoderma, 192 (1), pp. 269-276.
This paper discusses the application of taxonomic distance calculations for the correlation of soil units from different soil classification systems. Conceptual and centroid-based methods were tested on the brown forest soil types of the Hungarian Soil Classification System, correlated with the Reference Soil Groups of the World Reference Base for Soil Resources. The results of the distance calculations were compared and evaluated with previous expert based correlation studies. Earlier studies to derive taxonomic distances between soil taxa based on their dominant identifiers were further developed with the introduction of finer coding, and the application for correlation purposes. For the centroid-based approach, values were calculated from legacy laboratory data of different soil properties of the studied soil classes to derive the taxonomic distances. The results of the three different approaches are concordant, but as each method studied has its own limitations,

we recommend their joint application. Therefore the methods complement each other and provide a good tool to assist correlation tasks. We found this study very helpful in identifying the shortcomings of certain definitions and the conceptual conflicts within and between systems. The numerical approaches should be applied in the evaluation of current systems in the efforts toward a Universal Soil Classification System.
http://www.sciencedirect.com/science/article/pii/S0016706112002935

There was a new proposal (after those developed by Freddy Nachtergaele and Gabriella Broll et al.) for including humus forms in the WRB:

Jabiol, B., Zanella, A., Ponge, J.-F., Sartori, G., Englisch, M., van Delft, B., de Waal, R., Le Bayon, R.-C. 2013. A proposal for including humus forms in the World Reference Base for Soil Resources (WRB-FAO). Geoderma, 192 (1), pp. 286-294.
The morpho-functional classification of humus forms proposed in a previous issue by Zanella and collaborators for Europe has been extended and modified, without any change in diagnostic horizons, in order to embrace a wide array of humus forms at worldwide level and to complete and make more effective the World Reference Base for Soil Resources. For that purpose 31 Humus Form Reference Groups (HFRGs) and a set of prefix and suffix qualifiers are proposed, following the rules erected for the WRB. An exhaustive classification key, respecting the principles of WRB, is suggested and examples of classification are given for some already well known humus forms.
http://www.sciencedirect.com/science/article/pii/S0016706112002972

Several papers discussed the use of Soil Taxonomy and WRB and their correlation.

Morand, D.T. 2013. The world reference base for soils (WRB) and Soil Taxonomy: An appraisal of their application to the soils of the Northern Rivers of New South Wales. Soil Research, 51 (3), pp. 167-181.
Few soil surveys in New South Wales have utilised international soil classifications. Extensive morphological and laboratory data collected during soil surveys in the Northern Rivers region provided a strong basis for correlation with the World Reference Base for Soil Resources (WRB), Soil Taxonomy (ST), and the Australian Soil Classification (ASC). Of the 32 reference soil groups comprising the WRB, 20 were present locally; nine of the 12 ST orders were present. After re-classification of soils, correlation of the ASC with the WRB and ST was undertaken. Soils not requiring extensive laboratory analysis for classification and sharing similar central concepts were the more straightforward to correlate. Several ASC orders have unique central concepts and were therefore difficult to correlate with any one WRB reference soil group or ST order/suborder. Other soils were difficult to correlate due to differences in definitions of similar diagnostic criteria. This is most applicable to soils with strong texture-contrast and those with natric conditions. Such soils are not adequately differentiated to suit the Northern Rivers conditions. Of the two international schemes, the WRB was easier to apply locally due to the relative simplicity of the scheme. Considering certain aspects of Australian soils would improve the applicability of the WRB as a truly international framework for soil classification and correlation. Amendments to both the ASC and WRB are suggested.
http://www.publish.csiro.au/?paper=SR12144

Esfandiarpour, I., Salehi, M.H., Karimi, A., Kamali, A. 2013. Correlation between Soil Taxonomy and World Reference Base for Soil Resources in classifying calcareous soils: (A case study of arid and semi-arid regions of Iran). Geoderma, 197-198, pp. 126-1136.

The two most widely used modern soil classification schemes are Soil Taxonomy (ST) and World Reference Base for Soil Resources (WRB). The purpose of this paper is to clarify the differences and highlight the similarities between ST and WRB in their current state, with special emphasis on calcareous soils in arid and semi-arid regions of Iran. Four study sites were selected from central, northeast, and southeast Iran, and four representative pedons were described and classified for each site. Then, soil units from WRB were compared to those obtained by using ST at the family level. The results demonstrated that WRB shows more accessory soil properties compared to ST; moreover, through the method of combining qualifiers, the WRB system is a better option for naming calcareous soils. Defining new great groups, including Natrisalids, Gypsisalids, Calcisalids, Gypsicalcids, and Calcixeralfs, and new subgroups consisting of the Calcic Natrisalids and Calcic Natrargids for ST, and the "Paralithic" qualifier for the WRB system, could increase the usefulness and correlation between these two soil classification systems. Moreover, the definition of some reference soil groups (such as Vertisols), diagnostic horizons (such as salic), and/or qualifiers (such as Luvic prefix) should be revised to harmonize the classification systems.

http://www.sciencedirect.com/science/article/pii/S0016706113000165

Finally, we list several unsorted publications related to soil classification issues.

Schimel J., Chadwick O. 2013. What's in a name? The importance of soil taxonomy for ecology and biogeochemistry. *Frontiers in Ecology and the Environment* 11: 405–406.

http://dx.doi.org/10.1890/13.WB.016

Duniway M.C., Miller M.E., Brown J., Toevs G. 2013. An alternative to soil taxonomy for describing key soil characteristics. *Frontiers in Ecology and the Environment* 11: 527–528.

http://dx.doi.org/10.1890/13.WB.020

Huq, S. I., Shoaib, J. U. M. 2013. Soil Classification. In *The Soils of Bangladesh* (pp. 71-82). Springer Netherlands.

http://link.springer.com/chapter/10.1007/978-94-007-1128-0_8

Fengrong, Z., Zhong, Z. 2013. The Reclamation Effects Should Be Considered for Saline Soil Criteria in Soil Classification System. In *Developments in Soil Salinity Assessment and Reclamation* (pp. 357-363). Springer Netherlands.

http://link.springer.com/chapter/10.1007/978-94-007-5684-7_24

The historical document is a paper by Roy Simonson published in the Soil Science Society of America Proceedings in 1959, vol. 23, No. 2, pp. 152-156. Though it does not address soil classification directly, we decided to include it because of its importance of pedogenesis/classification links.

Outline of a Generalized Theory of Soil Genesis[1]

ROY W. SIMONSON[2]

ABSTRACT

Processes of soil formation have been related to prominent great soil groups by means of names such as podzolization, laterization, and solonization. A change from this point of view seems necessary when soils of the world are considered as a continuum with a number of properties in common. It is therefore proposed that soil genesis be considered as two overlapping steps; viz, the accumulation of parent materials and the differentiation of horizons in the profile. Of these two steps, the second is of more immediate concern to soil scientists.

Horizon differentiation is ascribed to additions, removals, transfers, and transformations within the soil system. Examples of important changes that contribute to development of horizons are additions of organic matter, removals of soluble salts and carbonates, transfers of humus and sesquioxides, and transformations of primary minerals into secondary minerals. It is postulated that these kinds of changes, as well as others, proceed simultaneously in all soils. It is further suggested that the balance within the combination of changes governs the ultimate nature of the soil profile. If this point of view is valid, the same kinds of changes occur in horizon differentiation in soils as unlike as Chernozems and Latosols, but the balance among the processes is not the same.

THEORIES OF SOIL GENESIS reflect the state of knowledge in the soil science of their day. This state of knowledge includes the extent to which soil properties are known and understood. It includes the relative prominence given to various soils in the classification system in use. It includes the very concept of soil itself. As knowledge of soils has grown over the years, there have been a number of changes in concept of soil. These have been followed in turn by changes in theories of genesis. Review of a few theories widely held in the past will bear out these observations. Furthermore, changes in theories of genesis are part of a continuing process which will not stop in our time. Concepts in soil genesis need continuing scrutiny and modification. This paper is an effort to sketch the outlines of a theory of soil genesis consistent with a concept of soil widely held at the present time.

Past Concepts of Soil

Most scientists concerned with soil a century ago, and even a half century ago, thought of it as disintegrated rock mixed with some decaying organic matter. This is evident from published reports (4, 10). If soil is considered to be disintegrated rock, weathering alone provides an adequate explanation for its formation. Nothing further is necessary to provide a satisfactory theory of soil genesis.

This early concept was replaced first in Russia (5) and later in other countries by the idea that soils were more than weathered rock and that they had profiles consisting of genetically related horizons. After this concept was developed, weathering alone was no longer an adequate theory of soil formation. A modified theory was required to explain the evolution of the profile with its related horizons. As a consequence, soil genesis was considered to be a combination of weathering and certain additional changes due to interactions between living organisms and weathered rock. In the early Russian studies (5, 11), much stress was placed on climate and vegetation as factors of soil formation though parent materials, relief, and time were also considered. Functional relationships between soils and their environment were recognized in these studies.

The studies of Dokuchaeiv and his colleagues were centered on soils with marked horizonation, such as the Chernozems and Podzols (11). These and parallel groups have continued to receive much attention in soil science. In this country, processes of soil formation have been related directly to prominent great soil groups by names such as podzolization, laterization, and solonization (7). These processes have been thought to differ from one another in a number of essentials. In fact, some pairs of processes such as podzolization and laterization have been considered to be opposites in large measure.

A number of shifts in theories of soil genesis have occurred since attention was first focused on the profile and on multiple factors of soil formation in Russia some 75 years ago. One point of view developed in that country holds soil evolution to be a continuous process (11, 12). According to this view, all kinds of soils existing on the earth at any given time are temporary stages. Each kind represents one stage which may disappear, recur, disappear, and recur again. Each stage is succeeded by some other stage in the process of continuing evolution. Thus, the patterns of distribution of soils can change over the face of the earth even though, collectively, the kinds of soils remain the same.

Present Concept of Soil

A concept of soil widely held in this country at the present time is a further modification of earlier ones. According to this concept, soils are natural bodies formed on the land surface, occupying space, and having unique morphology. The character of the soil profile remains important though it must share place with other features of the soil. Looking upon soils as geographic bodies entails certain consequences which do not follow as long as attention is focused exclusively on the profile.

First of all, each body of soil occupies volume or space. It is an entity with three dimensions; namely, length, breadth, and depth. Each soil body has a distinct upper boundary where it meets the atmosphere. Each has a less distinct perimeter where it meets other soils. Each has an indefinite lower boundary where it grades into weathered rock. This idea is illustrated diagramatically in figure 1, which also shows the relationship of the soil profile to the soil body (17).

Individual bodies of soils are seldom set apart from their neighbors by sharp boundaries. Adjacent bodies commonly grade into one another. The normal gradation between adjacent soil bodies is well known to every man who has helped make a soil survey. Thus, the soils of the world form a continuum or a continuous mantle over most of the land surface.

Every soil type comprises a number of separate geo-

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[1] Contribution from the Soil Survey, Soil Conservation Service, U. S. Department of Agriculture. Presented before Div. V, Soil Science Society of America, Atlanta, Ga., Nov. 18, 1957. Received Feb. 17, 1958. Approved May 27, 1958.

[2] Director, Soil Classification and Correlation.

graphic bodies or segments of the soil continuum. For the most part, the individual bodies are small so that several occur within a limited area, such as 10 acres. For example, bodies of Fullerton, Dewey, and Emory soils occur in a single small field in east Tennessee. Comparable illustrations can be drawn from any other section of the country. The pattern of small individual soil bodies thus introduces local differences into the soil continuum.

Every soil type has a characteristic region of occurrence. It occurs as a number of separate bodies or segments of the continuum within a certain geographic region or regions. Most soil types commonly occupy characteristic positions in a given landscape. The occurrence of specific soil types in definite geographic regions is reflected in regional differences in the soil mantle of the earth. Thus, there are differences of importance between soils of central Maine and soils of central Arizona, normally greater than local differences in either place.

Although the soil continuum varies both locally and regionally, all soils are alike in some ways. All are three-phase systems; i.e., solid, liquid, and gas. All or nearly all consist of the same major components; i.e., mineral matter, organic matter, water, and air. The proportions of these major components vary widely. All soils have profiles of some kind, and all occupy space. In other words, all form small segments of the surface mantle of the earth. Common to all soils, these features are of consequence to theories of genesis.

To be adequate, a theory of soil genesis must be consistent with the similarities and differences known to exist among the soils of the world. This seems almost too obvious to be worthy of mention but it does deserve emphasis. A theory of soil genesis should be consistent with the existence of soils of the world as a continuum, of features common to all soils, of the normal gradations from one soil to its neighbors, and of differences expressed to various degrees among soils.

Steps and Processes in Soil Genesis

Soil genesis can be viewed as consisting of two steps; viz, (*a*) the accumulation of parent materials, and (*b*) the differentiation of horizons in the profile. It is not suggested that these steps are clear-cut and distinct or that they lead only in one direction. The two merge and overlap so that it is impossible to tell where one begins and the other ends. For purposes of discussion, however, it is convenient to subdivide the broad and complex topic of soil genesis, as has been done in many earlier discussions. Examples are (*a*) the reference to combined effects of weathering and of living organisms by Dokuchaeiv (11); (*b*) the outlining of destructional activities of weathering and of constructional biological activities by Kellogg (7); (*c*) the distinctions between weathering and soil evolution made by Nikiforoff (13); and (*d*) the subdivision of soil formation into soil wasting, the organic cycle, and the inorganic cycle by Taylor and Cox (19).

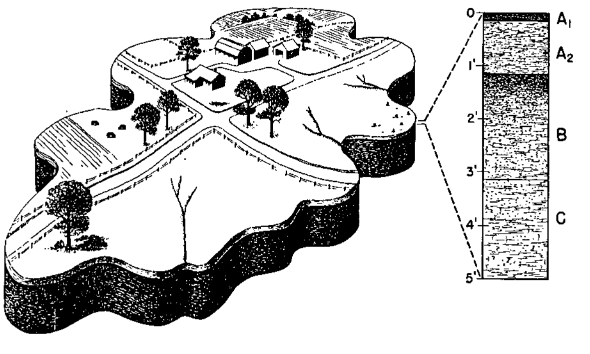

Figure 1—Sketch to illustrate a single body of soil as it occurs together with a diagrammatic soil profile. This body would be shown as one delineation on a detailed soil map.

Subsequent discussions in this paper are focused on horizon differentiation. This is not intended to imply that the accumulation of parent material is unimportant. The nature of the regolith in which horizon differentiation proceeds does affect the rate and direction of changes immensely. Lack of space, however, precludes full discussion of either of the two steps. Furthermore, the theory of soil genesis outlined in this paper is more directly concerned with the second step.

Horizon differentiation in soils is considered due to four basic kinds of changes. These are additions, removals, transfers, and transformations in the soil system. These four kinds of changes cover a wide range of processes. In his lectures 30 years ago, Marbut (9) observed that processes of soil development did a "good many things" in making soils from parent materials. His examples included decomposition of minerals, accumulation and assimilation of organic matter, removal of substances, translocations of substances, and development of structure.

Each of the four kinds of changes affects many substances comprising soil. For example, there may be additions, removals, transfers, or transformations of organic matter, soluble salts, carbonates, sesquioxides, or silicate clay minerals. Organic matter is added to the soil in the form of fresh residues. It is transformed and lost through decay. It may be transferred from one horizon to another. Rapid and continuing changes thus affect the organic matter in soils, accompanied by much slower alterations of the mineral fraction. Soluble salts may be lost from the profile or moved from one part to another. Silicate clay minerals may be formed by the transformation of primary minerals, or they may be lost by weathering. They may also be moved from the upper to the lower horizons. Transfers of substances from one horizon to another operate in many soils. Transformations of substances from one form to another proceed in all horizons. Considering the soil as a whole, all of these changes, and others, may contribute to differentiation of horizons.

The additions, removals, transfers, and transformations in soils do not necessarily promote horizon differentiation. Some tend to offset or retard it. For example, the materials transferred from one horizon to another by animal activity (20) or by the cracking and churning of certain clays (16) may retard or offset the differentiation of horizons. Similarly, the mixing of soil by windthrow in the northeastern United States (3) also retards the evolution of horizons in a profile. The uptake of nutrient elements from the deeper profile by growing plants is another example of transfer which does not necessarily contribute to horizon differentiation. Thus, the additions, removals, transfers, and transformations may act to promote or retard the development of horizons. Some changes operate in one direction and some in the other. The various processes operating at the same time in the same profile may be in conflict to some degree.

Role of Organic Matter

Additions, removals, transfers, and transformations in organic matter during horizon differentiation are discussed briefly in this section of the paper. The purpose is to illustrate the kinds of changes that do occur. Organic matter has been chosen for the discussion as one example of a major constituent, not necessarily the most important. Parallel discussions would be possible for silicate clays, sesquioxides, silica, or soluble salts and carbonates. It should, therefore, be stressed that the discussion of organic matter is simply meant to illustrate what can happen through gains, losses, transfers, and transformations. Lack of space precludes discussion of other substances rather than any lack of importance in soil genesis. The discussion in this section is focused mainly on mineral soils. Organic matter regimes in soils have been considered at length by Jenny (6) in his discussion of the functions of living organisms in soil formation.

Additions of organic matter are an early step in horizon differentiation in most soils. The additions of organic matter to the upper part of the regolith commonly exceed the rate of decay for a time after soil development begins. For example, a borrow pit used in the construction of a railroad in North Dakota about 50 years ago is now marked by a darkened A_1 horizon approximately 6 inches thick. Crocker and Dickson (2) found appreciable accumulation of organic matter in soils being formed from fresh glacial drift in Alaska within a matter of decades. After a period estimated to be 150 years, soils on this glacial drift were as high in organic matter as are most of those in the eastern part of the United States. Thus, gains in organic matter seem to be greater than losses for a time after horizon differentiation begins.

For most soils, the balance between gains and losses in organic matter seems to shift as horizon differentiation moves out of the earliest stages. The rates of loss through decay and transfer increase until they equal those of gain from plant and animal residues. Under a given set of conditions, the gains and losses tend to become equal after a time. Thus, the quantity of organic matter in a soil stabilizes and remains fairly constant even though additions continue.

The nature and amount of organic matter in each horizon of a soil depends upon the additions, transformations, and transfers in the past and present. These are in turn governed by climate, the nature of flora and fauna, the age of the soil, and the like. For example, the additions of organic matter are small in Desert soils. So are losses. The rates of additions and decay are both higher in Chernozems. They are still higher in many Latosols. The points of balance between additions and losses differ among these three groups of soils. Quantities of organic matter are low in Desert soils and relatively high in Chernozems and many Latosols.

Gains in organic matter have been of special importance in the differentiation of horizons in the soils of grasslands in temperate zones. The prominent A_1 horizons of Chernozems, Brunizems, Chestnut soils, and Humic-Gley soils[3] are due largely to additions of organic matter in the past. Other changes have also occurred but the additions of organic matter have been of special importance in setting apart the prominent A_1 horizons.

Relatively rapid turnover in organic matter is the rule in most soils. The soil is simply a way-station for organic matter moving in a larger cycle. Additions of fresh residues are made periodically. Transformations of organic matter through decay proceed all the while. Losses through decay and transfers also continue. The bulk of the organic matter added as fresh residues during a single growing season decays and disappears before the next arrives. Some indication of the rate of change is given by radiocarbon data for A horizons of certain soils formed under grass in the Midwest. Samples were obtained from the deeper part of the A horizon in uncultivated areas, except in the one instance. The data (1) for these samples are as follows:

Barnes	350 years ± 120
Clarion	440 years ± 120
Cresco-Kenyon intergrade	210 years ± 120
Cresco-Kenyon intergrade (plowed)	< 100 years
Webster	270 years ± 120

The above data indicate that a small part of the organic matter added to the soils in grasslands persists for a long while. At the same time, the implications of the data are consistent with other observations, which indicate that the bulk of the organic matter added to soils decomposes and disappears rapidly.

Transfers of organic matter within the profile contribute to horizon differentiation in many soils. Such transfers may be due to downward moving water, as in Podzols and solodized-Solonetz, or they may be due to the activities of animals.

Evidence of downward transfer of organic matter by water seems clear in Podzols. Narrow moving fronts which appear to be humus can sometimes be observed as water moves downward through the A_2 horizons of Podzol profiles. The marked accumulation of humus in the B_2 horizons of many Podzols is almost certainly due to downward transfer. This is indicated by position of the humus B horizon in relation to the water table in Ground-Water Podzols in Florida and Holland. The depth at which the humus B horizon occurs may vary widely, depending upon the position of the water table. Downward movement is also indicated by the nature of organic matter in certain Podzol profiles in Michigan. According to data of Norman and Bartholomew (14), approximately twice as much of the organic carbon is in the form of uronides in the B horizon as in the A horizon. Downward transfer of organic matter high in uronides seems essential to explain this difference in composition.

Downward movement of humus by water is also indicated in the profiles of solodized-Solonetz and Planosols. The faces of prisms or columns in B_2 horizons of many solodized-Solonetz profiles have dark coatings. These have been found to be higher in organic matter than the interiors or caps of the prisms or columns (15). The distribution of the coatings on the vertical faces of the peds and their association with clay films indicate that the humus was transferred downward into the B horizon.

The transfer of organic matter from the A to the B horizon also seems to have occurred in a number of Planosols. For example, the distribution curve for organic matter against depth has two maxima in a profile of Edina silt loam from Lucas County, Iowa. The first and most important is in the A_1 horizon (4.41%) and the second smaller one is in the B_2 horizon (1.47%). The A_2 horizon has the first minimum of 0.90% and the C horizon the second minimum of 0.32%. These differences in amounts of organic matter are not large, but they suggest transfers of organic matter.

Losses of organic matter are apparent in the deeper A horizons of Brunizems which have been occupied by forest and are gradually being changed to Gray-Brown Podzolic soils. The appearance and gradual expansion of light-colored A_2 horizons in the profile are accompanied by parallel decreases in organic matter (22). Dark coatings on the peds in the underlying B horizons also suggest that organic matter is being transferred downward from the A horizons.

Organic matter is transferred by animals from one horizon to another in many soils. Burrowing animals move soil materials low in organic matter from the deeper horizons to the surface and vice versa in many places (20). For example, the author has observed as many as four crotovinas per square foot of horizontal cross-section in the upper C horizon of Webster profiles in north central Iowa. That number is unusual but 1 per square foot is common. Earthworms mix organic matter with the mineral fraction and move it in many soils. In soils such as Oak Lake silt loam in Brookings County, South Dakota, earthworms have

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[3] Concepts of these great soil groups and others referred to later are those given by Thorp and Smith (21), except for Brunizems, defined by Simonson et al. (18), and Latosols, defined by Kellogg (8).

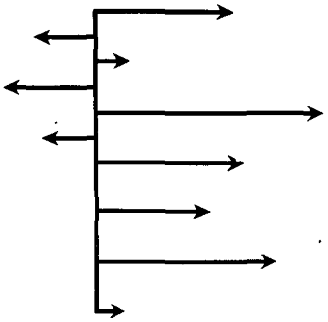

Figure 2—Diagram illustrating a combination of processes of differing importance in horizon differentiation.

completely mixed upper horizons to a depth of 2 feet or more, transferring organic matter down in the process. Earthworms transfer organic matter downward and mix it with the mineral fraction in profiles of Brown Forest soils in New York. These are a few examples which indicate transfers of organic matter by animals from one horizon to another. Collectively, for all soils, the magnitude of such transfer is substantial.

For the most part, the evidence of transfer of organic matter is not clear cut. It seems probable, nevertheless, that there is some transfer of organic matter from upper horizons to deeper ones in most soils, if not in all of them. The relative importance in horizon differentiation of such transfers may be either large or small.

The preceding discussion of organic matter is meant to illustrate the kinds of changes which affect one major soil constituent as horizons are developed. As emphasized in the first part of this section, parallel discussions could be prepared for other substances. Other illustrations could also be drawn of additions, removals, transfers, and transformations. Though not complete, the discussion still suggests the variety and complexity of changes that affect a single major constituent. The discussion also suggests differences in relative importance among the several basic kinds of processes from one soil to another.

Combinations of Processes

It is postulated that additions, removals, transfers, and transformations of the same constituents proceed in horizon differentiation in most if not all soils. Thus, the processes in horizon differentiation in Podzols would be the same as those in Latosols, Chernozems, or Desert soils. Following this line of thought, there would be some solution and transfer of sesquioxides in all of these soils, though not necessarily the same amounts. There would also be additions of organic matter, transfers of humus within the profile, and losses through decay in all of the soils. There would be one or more of additions, removals, transfers, or transformations of silicate clay minerals. The same combinations of processes would be operating in horizon differentiation in all of these soils.

It is further postulated that the relative importance of each process operating in horizon differentiation is not uniform for all soils. The relative importance of the several processes differs from one soil to another. The relative importance may also change with time in a single profile. For example, the solution and transfer of sesquioxides is far more important in the differentiation of horizons in Podzols than in Chernozems. Additions of organic matter are important in the development of A horizons in Humic-Gley soils and much less important in Red-Yellow Podzolic soils. Differences in relative importance of any process in the full combination are small when two similar soils are compared. The differences are much larger between soils that are themselves unlike in many ways.

The combination of processes operating in horizon differentiation and the balance among them may be illustrated by a diagram consisting of arrows of different lengths, as in figure 2. The length of each arrow indicates the importance of a single process. The balance among the several processes is suggested by the relative lengths of the arrows. This balance can be altered by changes in the length of any one arrow or by changing the lengths of several simultaneously. Similarly, the relative importance among the processes may be altered by changes in one or more of those processes. It should further be recognized that in certain combinations some processes may be of little importance. By and large, however, the full variety of processes seems to leave its imprint on soil character.

Further examples as applied to a few specimen groups of soils may be helpful. In Desert soils, there are small losses of soluble salts and carbonates from the profile, downward transfers of salts and carbonates into deeper horizons, small additions of organic matter, limited transfers and transformations of clay minerals, and limited transfers of sesquioxides. In Podzols, there is much greater removal of salts and carbonates, appreciable gains in organic matter, marked transfers of sesquioxides and organic matter, limited losses of sesquioxides and clay minerals, and some loss of silica. In Latosols, there are marked removals of salts and carbonates, appreciable additions of organic matter, some losses of sesquioxides, marked losses of silica, and transformations and losses of clay minerals.

The balance among individual processes in a given combination thus becomes the key to the nature of a soil. The relative importance of each process in the combination is reflected in the ultimate character of the soil itself. Additions of organic matter are of little importance in the combination of processes that differentiate horizons in Desert soils. Removals and transfers of sesquioxides are also of little importance. On the other hand, these same processes are of great importance in horizon differentiation in Latosols. This further illustrates the importance of the balance among processes in any given combination.

The variety of changes proceeding during the differentiation of horizons in a profile depend themselves upon a host of simpler processes such as hydration, oxidation, solution, leaching, precipitation, and mixing. These simpler and more basic reactions proceed in all soils. They are controlled in their turn by factors such as climate, living organisms, parent materials, and topography.

Thus, the theory of soil genesis outlined in the preceding discussions requires a shift in emphasis from theories of soil formation held in the past. The theory does not so much discard ideas held earlier as modify them and place them in a different setting. Primary emphasis is placed upon the operation of processes in combinations, with some processes promoting and others offsetting or retarding horizon differentiation. Major emphasis is also placed upon the balance among processes in any combination. It is further suggested that shifts in balance among combinations of processes are responsible for soil differences rather than the operation of markedly different genetic processes. The emphasis on widespread operation of the same kinds of changes in horizon differentiation seems consistent with the existence of the soils of the world as a continuum over the land surface. It is also consistent with the common lack of sharp boundaries between one soil and the next. It can accommodate the existence of both local and regional differences among soils. Finally, it is consistent with the sharing of some properties by all soils.

LITERATURE CITED

1. Broecker, W. S., Kulp, J. L., and Tucek, C. S. Lamont natural radiocarbon measurements: III. Science 124:162. 1956.

2. Crocker, R. L., and Dickson, B. A. Soil development on the recessional moraines of the Herbert and Mendenhall glaciers, southeastern Alaska. J. Ecol. 43:427-448. 1955.
3. Denny, C. S. Surficial geology and geomorphology of Potter County, Pennsylvania. U. S. Geological Survey Prof. Paper 288. pp. 55-66. 1956.
4. Fallou, Fr. Alb. Pedologie oder allgemeine und besondere Bodenkunde. Dresden. pp. 180-182. 1862.
5. Glinka, K. D. Dokuchaeiv's ideas in the development of pedology and cognate sciences. Russian Pedological Invest.; Acad. Sci. U.S.S.R. 32 pp. 1927.
6. Jenny, Hans. Factors of Soil Formation. McGraw-Hill, New York. pp. 197-260. 1941.
7. Kellogg, C. E. Development and significance of the great soil groups of the United States. USDA Misc. Publ. 229. 40 pp. 1936.
8. ————. Tropical soils. Trans. Inter. Congr. Soil Sci. 4th. Congr. Amsterdam. 1:266-276. 1950.
9. Marbut, C. F. Soils: Their Genesis and Classification. Soil Sci. Soc. Am., Madison. p. 25. 1951.
10. Merrill, G. P. A Treatise of Rocks, Rock Weathering, and Soils. The MacMillan Co., New York. 1906.
11. Neustruev, S. S. Genesis of soils. Russian Pedological Invest.; Acad. Sci. U.S.S.R. 98 pp. 1927.
12. Nikiforoff, C. C. Fundamental formula of soil formation. Am. J. Sci. 240:847-866. 1942.
13. ————. Weathering and soil evolution. Soil Sci. 67: 219-230. 1949.
14. Norman, A. G., and Bartholomew, W. V. The chemistry of soil organic matter: I. Distribution of uronic carbon in some soil profiles. Soil Sci. 56:143-150. 1943.
15. Retzer, J. L., and Simonson, R. W. Distribution of carbon in morphological units from the B horizons of Solonetz-like soils. J. Am. Soc. Agron. 33:1009-1013. 1941.
16. Simonson, R. W. Morphology and classification of the Regur soils of India. J. Soil Sci. 5:275-288. 1954.
17. ————. What soils are. In USDA Yearbook of Agr. Soil. U. S. Government Printing Office, Washington, D. C. pp. 17-31. 1957.
18. ————, Riecken, F. F., and Smith, G. D. Understanding Iowa soils. Wm. C. Brown Co., Dubuque. p. 23. 1952.
19. Taylor, N. H., and Cox, J. E. The soil pattern of New Zealand. New Zealand Soil Bureau Publ. 113. 1956.
20. Thorp, J. Effects of certain animals that live in soils. Sci. Monthly 48:180-191. 1949.
21. ————, and Smith, G. D. Higher categories of soil classification: Order, suborder, and great soil group. Soil Sci. 67:117-126. 1949.
22. White, E. M., and Riecken, F. F. Brunizem–Gray-Brown Podzolic soil biosequences. Soil Sci. Soc. Am. Proc. 19: 504-508. 1955.