Annotated bibliography of Digital Soil Mapping publications with NRCS participation

December 20, 2012

This is a compilation of publications related to digital soil mapping activities the NRCS has been involved with through funded projects or in-kind cooperation with university collaborators.

General overview

Boettinger, J. L., Howell, D. W., Moore, A. C., Hartemink, A. E., & Kienast-Brown, S. (Eds.). (2010). Digital soil mapping: Bridging research, environmental application, and operation (Vol. 2). Springer.

> This book is a compilation of selected papers presented at the 3rd Global Workshop on Digital Soil Mapping, held in 2008, Logan, Utah.

Hempel, J. W., Hammer, R. D., Moore, A. C., Bell, J. C., Thompson, J. A., & Golden, M. L. (2008). Challenges to digital soil mapping. Digital Soil Mapping with Limited Data, Springer Science, Australia, 81-90.

> The position calls for moving digital soil mapping to an operational level for soil scientists and discusses the challenges of adopting these methods.

Moore, A.C., D.W. Howell, C.A. Hadyu-Houdeshell, C. Blinn, J. Hempel and D. Smith. 2010. Building digital soil mapping capacity in the natural resources conservation service: Mojave Desert operational initiative. In Boettinger, Janis L., Howell, David W., Moore, Amanda C., Hartemink, Alfred E., Kienast-Brown, Suzann(Eds.), Digital Soil Mapping: Bridging Research, Production, and Environmental Application (pp. 357-367). Springer.

> Discussion of the initial digital soil mapping activities in the Mojave Desert. Elevation data from IFSAR and ASTER and Landsat imagery were used to develop derivatives. Results were under evaluation at the time of publication.

Roecker, S.M., D.W. Howell, C.A. Haydu-Houdeshell and C. Blinn. 2010. A qualitative comparison of conventional soil survey and digital soil mapping approaches. In Boettinger, Janis L., Howell, David W., Moore, Amanda C., Hartemink, Alfred E., Kienast-Brown, Suzann(Eds.), Digital Soil Mapping: Bridging Research, Production, and Environmental Application (pp. 369-384). Springer.

> A conventionally produced soil map was compared to one developed using the random forest statistical model for an area in the Mojave Desert of California. Soils were classed to the subgroup level of Soil Taxonomy. Subgroups associated with fan remnants were underrepresented with the predictive model. The conventionally mapped area in the mountains underrepresented the number of subgroups and the composition of subgroups. The outputs of digital soil mapping products are suggested for use in understanding map unit composition and design.

Shi, X., Long, R., Dekett, R., & Philippe, J. (2009). Integrating different types of knowledge for digital soil mapping. Soil Science Society of America Journal, *73*(5), 1682-1692.

> The concept of global and local knowledge were explored within the context of rule-based and case-based reasoning. A framework is suggested and explored to proceed from legend development, data development, globally applied rules or cases and refinement with local cases based on increased knowledge from field work.

DEM analysis

Klingebiel, A.A., E.H. Horvath, W.U. Reybold, D.G. Moore, E.A. Fosnight and T.R. Loveland. (1988). A guide for the use of digital elevation model data for making soil surveys. USGS, Open-file report 88-102.

> An early document describing DEM processing to produce slope and aspect maps for use in a soil survey pre-map in the western USA.

Roecker, S. M., & Thompson, J. A. (2010). Scale effects on terrain attribute calculation and their use as environmental covariates for digital soil mapping. p55-66. In: J.L. Boettinger, D.W. Howell, A.C. Moore, A.E. Hartemink, and S. Kienast-Brown (eds.) Digital soil mapping: Bridging research, environmental application, and operation. Springer Science+Business Media, Dordrecht.

> The effect of grid resolution and neighborhood size on terrain derivatives was investigated on two sites in West Virginia. The ability to vary neighborhood size when developing derivatives was noted as an improved option beyond changing grid resolution. Selection of appropriate neighborhood size is dependent on the nature and size of landforms in project area.

Shi, X., Girod, L., Long, R., DeKett, R., Philippe, J., & Burke, T. (2012). A comparison of LiDAR-based DEMs and USGS-sourced DEMs in terrain analysis for knowledge-based digital soil mapping. *Geoderma*, *170*, 217-226.

> DEMs derived from LiDAR were more accurate than USGS 10m DEM using slope gradient as a benchmark. A 5m DEM, derived by resampling the 1m DEM, produced results comparable to the 1m DEM. A call for further investigation on the effect of neighborhood size is warranted.

Rule-based

Cole, N.J., and J.L. Boettinger. 2007. A pedogenic understanding raster classification methodology for mapping soils, Powder River Basin, Wyoming, USA.p. 377-388. In: P. Lagacherie, A.B. McBratney, and M. Voltz (eds.) Digital Soil Mapping: An introductory perspective. Developments in Soil Science Vol. 31, Elsevier, Amsterdam.

> Unsupervised, supervised and knowledge-based classifications were used to develop soil maps for all phases of a soil survey project; pre-mapping, model development, refinement and map compilation for the project area in north-central Wyoming. Knowledge-based models provided the best fit for predicting soil-landform relationships, however unsupervised and supervised classifications provide data driven techniques to explore relationship between data and soil-landscape.

D Avello, T. P., Indorante, S. J., Bathgate, J. D., Fitch, B. C., McCauley, W. M., Williams, D. R., & Wilson, M. A. (2008). Application of SoLIM for a High-Intensity Soil Survey: A Southern Illinois Example. SOIL SURVEY HORIZONS, 49(1), 3.

Rule-based, fuzzy classification was used to develop an Order 1 soil map on a small watershed in support of a hydropedology project. Overall accuracy assessment of 72% was achieved.

Frazier, B. E., Rodgers, T. M., Briggs, C. A., & Rupp, R. A. (2009). Remote area soil proxy modeling technique. Soil Survey Horizons, 50(2), 62-67. *In addition, available from this and related work: Rodgers, T.M. 2000. Modeling soils in the Sawtooth and Pasayten wilderness areas with GIS. MS Thesis. Washington State Univ., Pullman. Briggs, C.A.D. 2004. GIS-Based mapping of soil distribution in Thunder Creek Watershed, North Cascades National Park, Washington. Washington State University M.S. Thesis.*

ArcGIS was used to implement a rule-based classification for a watershed in a remote area of north-central Washington state. 22 soil map units were predicted and 75% of sampled sites were correctly classified.

Kienast, S. 2002. Soil survey using traditional and landscape analysis methods – Grand Staircase-Escalante National Monument, Utah. M.S. thesis. Utah State University, Logan.

A soil survey of the Circle Cliffs area was completed using traditional soil survey methods, and then enhanced using GIS-based methods. GIS was useful for quantifying and validating map unit concepts and accelerating the soil survey, and may be applicable in other remote areas for examining soil-landscape relationships.

Libohova, Z., Winzeler, E. H., & Owens, P. R. (2010). Developing Methods for a Terrain Attribute Derived Soil Map. Soil survey horizons, 51(2), 37. *In addition: Libohova, Z. (2010). Terrain attribute soil mapping for predictive continuous soil property maps. PhD Dissertation, Purdue Univ.*

Knowledge-based approach using fuzzy classification to map soil classes in a loess covered, southern Indiana watershed. A predictive map of depth to lithic/paralithic was generated from the fuzzy membership soil class maps. Results indicate the modeled depths were within 25cm of measured depths, while SSURGO relative depths were within 60cm of measured depths.

Loomis, L., Young, F.J. (2008, October). Digital Modeling of Soils in a Production Soil Survey on the Culberson Gypsum Plain, West Texas. In *2008 Joint Meeting of The Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM*.

A knowledge-based mapping process in a production soil survey in west Texas soil survey is discussed. The environmental setting for soil components to be mapped is defined and managed within the software and the resulting raster maps reflect the soil scientist's best understanding of soil landscape relationships. Time and energy can be focused on validating and documenting soil-landscape models, rather than laboriously translating their mental constructs into maps.

McKay, J., Grunwald, S., Shi, X., & Long, R. F. (2010). Evaluation of the Transferability of a Knowledge-Based Soil-Landscape Model. 165-178. In: J.L. Boettinger, D.W. Howell, A.C. Moore, A.E. Hartemink, and S. Kienast-Brown (eds.) Digital soil mapping: Bridging research, environmental application, and operation. Springer Science+Business Media, Dordrecht.

The applicability of a rule-set developed in one project area was tested in a different project area with similar soil forming factors in northeastern Vermont. Results based on accuracy assessment were comparable, indicating the validity of extending a rule-set when predicting soil classes, provided the environmental factors are common between areas.

Prescott,T.M., J. A. Thompson, W. J. Waltman, and T. A. Craul. (2008). Thinking inside the (Tool) Box Geomorphometric Analysis for the Soil Survey Update of Potter County, Pennsylvania. Soil survey horizons 49:68-74.

Rule-based procedures were used with terrain derivatives and a modeled soil temperature surface to better define the distribution of two soil series mapped in north-central Pennsylvania. Modeled results verified the mapping of one series and indicated over-mapping of the other series.

Winzeler, H. E., Owens, P., Norwood, K., & Libohova, Z. (2008, October). Terrain Attributes Aid Soil Mapping on Low-Relief Indiana Landscapes. In *2008 Joint Meeting of The Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM*.

A model using fuzzy logic and knowledge mining from existing soil survey data supplements the work and helps to establish terrain-soil relationships. In this fairly flat landscape Topographical Wetness Index and Altitude Above Channel Network were useful in distinguishing Mollisols from Alfisols and soils in neighboring major drainage networks respectively.

Zhu,A.X., B. Hudson, J. E. Burt, and K. Lubich, 2001. "Soil mapping using GIS, expert knowledge and fuzzy logic," Soil Science Society of America Journal, Vol. 65, pp. 1463-1472.

Fuzzy soil inference software was used to map soils in project areas in Montana and Wisconsin. The fuzzy membership/similarity representation of data is described. Results from the prototype projects indicate production of an accurate soil map. However, the results are contingent on accurate environmental data of sufficient resolution, and a good understanding of the soil-landscape relationships.

Case-based

Shi, X., Zhu, A. X., Burt, J. E., Qi, F., & Simonson, D. (2004). A case-based reasoning approach to fuzzy soil mapping. *Soil Science Society of America Journal*, *68*(3), 885-894.

Case-based reasoning is introduced as an alternate method to strict rule-based reasoning. Rule-based methods require explicit knowledge of soil-landscape relationships as they relate to environmental covariates. Case-based reasoning allows soil scientists to select typical locations where particular soils occur. The inference engine computes the similarity of areas for the provided cases based on the set of environmental data (layers) that are treated as "predictors" or proxies. The study demonstrates the effectiveness of this method for a soil scientist to express their knowledge.

Classification and regression tree

Brown, R. A., McDaniel, P., & Gessler, P. E. (2012). Terrain Attribute Modeling of Volcanic Ash Distributions in Northern Idaho. *Soil Science Society of America Journal*, *76*(1), 179-187. *In addition: Brown, R. 2008. Volcanic ash in a mountainous landscape of northern Idaho: Digital modeling and mapping. M.S. thesis, Univ. of Idaho, Moscow.*

Terrain attributes derived from these DEMs were used to model volcanic ash mantle presence or absence, thickness, and degree of mixing using classification and regression trees. Elevation was the single variable most related to the presence or absence, degree of mixing, and thickness of a volcanic ash mantle; other terrain attributes had less predictive value. The 30-m grid resolution provided the best model of ash presence or absence, with 78% accuracy, indicating good promise for digitally mapping Andisols and related soils across the region.

Hash, S. J., & Noller, J. S. (2009). Incorporating predictive mapping to advance initial soil survey: an example from Malheur County, Oregon. Soil Survey Horizons, 50(4), 111-115. *In addition: Hash, S. J. (2008). Use of decision tree analysis for predictive soils mapping and implementation on the Malheur County, Oregon initial soil survey. MS Thesis, Oregon State University.*

Decision tree analysis was used to map several 7.5' quadrangles in south-eastern Oregon. Conventional soil maps were used as training sets for the model. Various techniques were investigated for mapping the unmapped areas. The most successful result was obtained when predicting inward from a mapped surrounding area. Accuracy was near 80% at the subgroup level, suggesting use of a checkerboard approach for mapping using this approach. The challenge of adopting the technology as well as the required expertise of a soil scientist was noted for making these techniques operational.

Saunders, A.M. , and J.L. Boettinger. 2007. Incorporating classification trees into a pedogenic understanding raster classification methodology, Green River Basin, Wyoming, USA p. 389-399. In: P. Lagacherie, A.B. McBratney, and M. Voltz (eds.) Digital SoilMapping: An introductory perspective. Developments in Soil Science Vol. 31, Elsevier, Amsterdam. *In addition: Amy M. Saunders. 2005. Incorporating classification tree analysis into the pedogenic understanding raster classification methodology.MS Thesis, Utah State Univ.*

Knowledge-based and classification tree methods were used to develop predictive maps in southwestern Wyoming. Data inputs included Landsat imagery and terrain derivatives from USGS DEMs. Unsupervised classification was performed to define preliminary classes. Resulting maps from the knowledge-based and classification tree methods were similar and satisfactorily represented the soil-landscape relationships according to local soil scientists. The classification tree procedure was less time-consuming than the knowledge-based method.

Remote sensing

Bodily, J. M. (2006). Developing a digital soil survey update protocol at the Golden Spike National Historic Site. MS Thesis, Utah State Univ.

Landsat imagery and USGS DEMs were used in a soil survey update and refinement of ecological sites. Slope classes were verified from DEMs. Rock outcrops were mapped using image derivatives and slope, achieving overall accuracy of 87%.

Boettinger, J. L., Ramsey, R. D., Bodily, J. M., Cole, N. J., Kienast-Brown, S., Nield, S. J., Saunders, A.M. & Stum, A. K. (2008). Landsat spectral data for digital soil mapping. *Digital Soil Mapping with Limited Data*, 193-202.

Availability and access of Landsat data and derivatives related to vegetation, parent material, land cover and relationship to soil classes and properties are discussed.

Kienast-Brown, S. and J.L. Boettinger. 2010. Applying the optimum index factor to multiple data types for soil survey. p. 385-398. In: J.L. Boettinger, D.W. Howell, A.C. Moore, A.E. Hartemink, and S. Kienast-Brown (eds.) Digital soil mapping: Bridging research, environmental application, and operation. Springer Science+Business Media, Dordrecht.

The optimal index factor was used with imagery and terrain data sets to determine the data layers maximizing variability within a project area in northeast Utah. A combination of unsupervised and supervised classification was used with the selected layers to produce a 10 class map used for pre-mapping activities.

Kienast-Brown, S., and J.L. Boettinger. 2007. Land cover classification from Landsat imagery for mapping dynamic wet and saline soils. p. 235-244. In: P. Lagacherie, A.B. McBratney, and M. Voltz (eds.) Digital SoilMapping: An introductory perspective. Developments in Soil Science Vol. 31, Elsevier, Amsterdam.

Landsat imagery was used to update the East Shore Area of the Great Salt Lake soil survey. Supervised classification was used to develop 14 land cover classes. Overall accuracy of the land cover mapping was 88%. The results were used to refine the original soil maps, improve map unit composition estimates and gain an understanding of soil-land cover relationships.

Moore, C. A., Hoffmann, G. A., & Glenn, N. F. (2007). Quantifying Basalt Rock Outcrops in NRCS Soil Map Units Using Landsat-5 Data. *Soil Survey Horizons*, *48*(3), 59.

Landsat, NAIP, NAPP and USGS DEMs were used to map basalt outcrops for an area in eastern Idaho. A very limited ground-truth indicated 82% accuracy level. It was noted that rock outcrops were over estimated for this project and additional work would be required to improve the classification.

Nauman, T. (2009). Digital soil-landscape classification for soil survey using ASTER satellite and digital elevation data in Organ Pipe Cactus National Monument, Arizona. ProQuest.MS Thesis. University of Arizona.

A combination of unsupervised and supervised classification techniques along with image segmentation were employed to define soil landscape units in southern Arizona. ASTER imagery and terrain derivatives developed from USGS 30m DEMs served as proxies for soil forming factors. Predicted map identified fluvial soils sourced from different lithologies and unique mountain areas not delineated by the original survey. The methods demonstrate potential for soil pre-mapping, and sampling design efforts for soil survey and survey updates.

Nield*, S.J., J.L. Boettinger, and R.D. Ramsey. 2007. Digitally Mapping Gypsic and Natric Soil Areas Using Landsat ETM Data.Soil Science Society of America Journal 71:245-252. *In addition: Shawn J. Nield. 2004. Geographic information systems and remote-sensing to assess potential salinity contributions to the upper San Rafael River, UT. MS Thesis, Utah State Univ.*

Landsat data was used to map gypsic and natric soils in central Utah. A normalized difference ratio of bands 5 and 7 were used to identify gypsic areas, while natric areas were identified with a normalized difference ratio of bands 5 and 4. Accuracy assessment indicated user accuracy of 82% for the gypsic areas and 50% for the natric areas, demonstrating the difficulty in predicting natric soils. Transferability of the gypsic model is likely within the region.

Mapping soil properties

Howell, D., Kim, Y., Haydu-Houdeshell, C., Clemmer, P., Almaraz, R., & Ballmer, M. (2006). Fitting soil property spatial distribution models in the Mojave Desert for digital soil mapping. Developments in Soil Science, 31, 465-624.

> Depth to secondary carbonates, calcic horizon, argillic horizon, durinodes, duripan and presence/absence of these features was modeled, in addition to particle size class. The most reliable models were for particle size class and depth to secondary carbonates. Particle size class was estimated within one class 73% of the time. Depth to secondary carbonates was accurate within 20cm for 71% of observations. Results are promising and should be useful as a pre-mapping tool, a guide for fieldwork and a framework for visualizing soil-landform relationships.

Thompson, J. A., Perry, C., DeGloria, S., Prescott, T., & Moore, A. (2008, October). Soil Property Mapping using Legacy Data and Pedometric Techniques: A Case Study Approach. In *2008 Joint Meeting of The Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM*.

> Soil property predictions from SSURGO polygon data are generated using measure-and-multiply approaches and disaggregation techniques using environmental covariates. These two spatial predictions are combined to produce raster soil property maps.

Young, F., Myers, D.B., Kitchen, N.R. 2011. Knowledge-based soil inference modeling for estimating soil productivity and grain yield in north-central Missouri [abstract]. ASA-CSSA-SSSA Annual International Meeting, October 16-19, 2011, San Antonio, Texas. 264-9.

> Knowledge-based rules and ArcSIE was used to model soils for eight 12 digit watersheds in north-central Missouri. Missouri Productivity Index values were assigned to each modelled soil and a continuous-surface Productivity Index was developed. Comparisons were made for the SSURGO maps, the modelled soil maps and the continuous surface PI maps with yield data from combine-mounted yield monitors. Results indicate year to be the biggest predictor of yield, with soil-yield relationships being weak.

Zhu, A., Qi, F., Moore, A., & Burt, J. E. (2010). Prediction of soil properties using fuzzy membership values. *Geoderma*, *158*(3), 199-206.

> Soil properties were predicted using a fuzzy classifier and regression models for a watershed in southwestern Wisconsin. A-horizon sand and clay content, Bt1-horizon sand and clay content, depth to Bt1-horizon, loess thickness, and depth to weathered bedrock were the properties predicted. Comparisons between methods indicate regression performs well in gentle terrain. Predictions using regression on steeper terrain may require additional data management procedures. Predictions using weighted average of fuzzy membership values are promising based on computational ease and freedom from linearity requirements of statistically based models.

Soil climate

Beaudette, D. E. O'Geen, A. T. 2009. Quantifying the Aspect Effect: An Application of Solar Radiation Modeling for Soil Survey Soil Sci. Soc. Am. J. 2009 73: 1345–1352.

> A case is made for the use of solar radiation in modeling applications to eliminate the mathematical problems associated with cyclic data like aspect. Solar radiation serves as the driver for surface/near-surface soil forming processes. Upland Mollisol distribution was predicted using solar radiation and geology maps in a logistic regression with promising results.

Prescott, T. M., Thompson, J., Sencindiver, J., Waltman, W. J., Carpenter, S. G., & Waltman, S. W. (2006, July). Soil Climate Regimes of West Virginia. In *The 18th World Congress of Soil Science*.

> A terrain regression modeling approach in ArcGIS was coupled with the Newhall Simulation Model to generate surfaces of soil temperature and moisture regimes, soil biological windows, growing degree-days, frost-free period, and temperature minima. Previous work by Soil Survey Staff showed limited areas of frigid soil temperature regimes at the highest elevation in West Virginia. Our terrain regressions, based upon 1971 to 2000 normals, indicates more extensive areas of frigid temperatures and predicts cryic temperatures above elevations of 1378m.

Waltman, W. J., Ciolkosz, E. J., Mausbach, M. J., Svoboda, M. D., Miller, D. A., & Kolb, P. J. (1997). Soil climate regimes of Pennsylvania, bulletin no. 873. Pennsylvania State University Agricultural Experiment Station, University Park, PA.

> Climate parameters for Pennsylvania were modeled using five predictors; easting, northing, elevation, slope and aspect for the 1961-1990 period. Soil climate regimes were predicted in addition to agro-climate regions geared towards agronomic crop production. Frigid soil temperature regimes were modeled in the Allegheny Plateau, which were not previously recognized.

Disaggregation

Thompson, J. A., Prescott, T., Moore, A. C., Bell, J., Kautz, D., Hempel, J., Waltman, S. W., Perry, C. H. 2010. Regional approach to soil property mapping using legacy data and spatial disaggregation techniques. International Union of Soil Sciences (IUSS), c/o Institut für Bodenforschung, Universität für Bodenkultur. 17-20.

> Two map units of large extent in the southern portion of the Eastern Allegheny Plateau and Mountains provide an illustration of the disaggregation approach to produce raster-based, landscape-scale maps of soil organic carbon (SOC). The disaggregated data identifies locations of component soils within soil class map units, depicting the spatial distribution of soils with higher and lower SOC stocks instead of an average SOC value for the entire soil map unit polygon. The disaggregated data predicted 6% higher average SOC content compared to the published soil class map data in the study area.

GlobalSoilMap.net

Goodman, J. M., Owens, P. R., & Libohova, Z. 2012. Predicting soil organic carbon using mixed conceptual and geostatistical models. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (p. 155). CRC Press.

> The objective of this research was to take soil class information, in conjunction with terrain attribute data, and develop quantitative 5 m raster soil property predictions. Point coordinates were extracted from the centroid of each Soil Survey Geographic Database map unit with associated surface soil organic carbon estimate. Regression – kriging was then performed using terrain attributes as covariates with the predictor variable, SOC. Topographic Wetness Index was most strongly correlated with SSURGO SOC, R2= 0.33, and was utilized as an environmental covariate for the resulting RK map.

Hempel, J. W., Libohova, Z., Odgers, N. P., Thompson, J. M., Smith, S. S., & Lelyk, G. W. 2012. Versioning of GlobalSoilMap. net raster property maps for the North American Node. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (Vol. 1, No. 250,000, p. 429). CRC Press.

> The diversity of spatial and temporal scales and data content and completeness of existing soil polygon maps lead to the idea of versioning for development of raster soil property maps for Canada, United States and Mexico. Legacy data and digital mapping techniques are being used to meet the standards and specifications of the GlobalSoilMap.net project. Versions will successively utilize data of increased detail to produce information, with the final product being a fully modeled continuous digital soil map.

Libohova, Z., Wills, S., Hempel, J. W., Odgers, N. P., & Thompson, J. A. 2012. Using Pedotransfer functions for estimating soil pH and bulk density at regional scale. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (p. 313). CRC Press.

> The objectives of this study were to develop relationships for converting soil pH 1:1W/1:2Ca to 1:5W; assess the use of bulk density from STATSGO2 and lab data, and generate predictive maps of soil pH 1:5W and bulk density per global standards. Linear regression was adequate for prediction of pH 1:5W by depth class. The spline function does not estimate pH and bulk density in lower horizons when shallow soils are present.

Nauman, T. W., Thompson, J. A., Odgers, N. P., & Libohova, Z. 2012. Fuzzy disaggregation of conventional soil maps using database knowledge extraction to produce soil property maps. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (p. 203). CRC Press.

> In efforts to create more detailed raster soil maps in areas with sparse point data, legacy soil maps are often the main source of soil-landscape information. Expert rule sets and fuzzy membership methods were used to model components and transitions spatially to help model properties in a more continuous manner. Results in a 388,000 ha region of West Virginia, USA show that SSURGO disaggregation helped improve crisp boundaries in property maps and improved estimates of carbon storage at a watershed scale, but lacked the ability to predict soil properties at field scale mapping (~28-meter pixels).

Odgers, N. P., Thompson, J. A., Libohova, Z., & McBratney, A. B. 2012. Uncertainty estimation for weighted-means digital soil maps. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (p. 179). CRC Press.

> Many nations have legacy soil data in the form of polygon maps and soil profile descriptions. There is interest in developing soil property maps over large areas in order to support various modeling efforts using legacy data. Clay content was estimated for all soils by depth in MLRA 120B in southern Indiana. Measures of uncertainty were inconsistent. Improving point sample density or modeling at a coarser resolution may improve results.

Odgers, N. P., Libohova, Z., & Thompson, J. A. 2012. Equal-area spline functions applied to a legacy soil database to create weighted-means maps of soil organic carbon at a continental scale. *Geoderma*, *189*, 153-163.

> The equal-area spline function was applied to the soil components of STATSGO2 map units to obtain estimates of soil organic carbon content at the GlobalSoilMap standard depth increments. Weighted mean of soil organic carbon content was calculated for each STATSGO2 map unit at each depth increment and gridded at 100 m resolution for the contiguous United States. The result is a set of maps of soil organic carbon content for each GlobalSoilMap depth increment accompanied by an indication of the within-map unit variability.

Thompson, J. A., Nauman, T. W., Odgers, N. P., Libohova, Z., & Hempel, J. W. 2012. Harmonization of legacy soil maps in North America: Status, trends, and implications for digital soil mapping efforts. In *Digital Soil Assessments and Beyond: Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia* (p. 97). CRC Press.

> In the U.S., SSURGO was not designed to be a soil property map. As SSURGO is being modified to appear more seamless through the harmonization process, the following questions are discussed, with accompanying examples; how is the accuracy, precision, and uncertainty addressed in new maps? How can this data be used? Are there better digital soil mapping techniques out there for correcting these problems?