IOP Conf. Series: Earth and Environmental Science **25** (2015) 012020 doi:10.1088/1755-1315/25/1/012020

Delivering solutions to questions regarding soil change—examples from USDA and the National Cooperative Soil Survey

Maxine J Levin[1], Susan Andrews[2], Michael Robotham[3], Joel Brown[4], Lenore Vasilas[5] and David Hoover[6]

[1, 5] USDA Natural Resources Conservation Service, 5601 Sunnyside Avenue, Beltsville, MD, USA

[2, 3, 6] USDA Natural Resources Conservation Service, 100 Centennial Mall North, Room 152, Lincoln, NE, USA

[4] USDA Natural Resources Conservation Service, Jornada Experimental Range, MSC 3JER, New Mexico State University, Box 30003, Las Cruces, NM, USA

E-mail: maxine.levin@wdc.usda.gov

Abstract. The US National Cooperative Soil Survey (NCSS) has been investigating Soil Change within the Interpretations Conference Committees and within the USDA-Natural Resources Conservation Service (NRCS), Soil Science Division since the early 1990's. Historically, the National Cooperative Soil Survey worked on building a national map that would deliver information on land use and soil management. Soil Mapping, Soil Classification and Soil Taxonomy focused on the static qualities of the soil profile, attempting to make estimates and predictions of soil groupings based on soil characteristics that were stable beyond a 5 to 20 year cycle of use and management and potential anthropogenic change. The National cooperative Soil Survey continues to seek new ways to interpret soils and to make that information more easily accessible. Practice-specific soil interpretations are being explored to support NRCS conservation planning and practice implementation. Other areas of focus include the development of real-time interpretation systems that allow incorporation of site-specific information and interpretation systems that will allow users to incorporate other spatially-referenced data sets including climate and land use to develop accurate and site-specific interpretive information products.

1. Introduction

The US National Cooperative Soil Survey has been investigating Soil Change within the Interpretations Conference Committees and within the USDA-Natural Resources Conservation Service (NRCS), Soil Science Division since the early 1990's. Historically, the US Soil Survey worked on building a national map that would deliver information on land use and soil management. In the US, all these assessments of the potential uses of soils, from agricultural production to engineering properties, have become consolidated under the overarching category of Soil Interpretations. Soil Mapping, Soil Classification and Soil Taxonomy focused on the static qualities of the soil profile, attempting to make estimates and predictions of soil groupings based on soil characteristics that were stable beyond a 5 to 20 year cycle of use and management and potential anthropogenic change.

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From the early years of the soil survey through the development of computer databases in the 1970s, soil interpretations were based on written guides that were used by the soil surveyors to develop the interpretation tables contained in soil survey manuscripts published by the National Cooperative Soil Survey. Tables contained use and management interpretations by map unit or component. Interpretive results for a tract of land could be determined by cross referencing the hard copy soil map and the interpretive table(s). Examples of common interpretations provided in soils surveys include: crop, forage and range suitability groups, and use limitations for recreation, building site development, and engineering uses. The question of soil change focussing on the potential for erosion, salinity and sodicity, soil properties of wetlands, drainage phases and soil contamination has been the realm of soil interpretations and tying the map unit and individual soil characteristics to suitability or vulnerability indexes in separate tables or maps.

In the mid 1980’s through 2000 the National Cooperative Soil Survey started to explore how we might map the soil survey information to display more information by soil function and the capacity to recover from various anthropogenic forces. Farm and rangeland areas with drastic soil disturbances from native landscape were being mapped and classified within US Soil Taxonomy protocols but did not describe soil changes enough to categorize for interpretations or document changes from original material to inform management practices. The National Cooperative Soil Survey also started mapping urban areas where all the soils in the survey area had anthropogenic characteristics that needed to be described, classified and interpreted for management purposes. Soil change issues within policy forced us to build new systems of classification and description.

2. Delivering solutions with integration of policy and science

A prime example of the integration of policy and science in the National Cooperative Soil Survey was hydric soil indicators for wetland delineation as part of the Food Security Act and Clean Water Act. Disturbed functioning wetlands and drained systems were being considered for regulation by the Environmental Protection Agency (EPA) and Army Corp of Engineers as “Waters of the US.” Functioning wetlands needed to be delineated and documented. Wetland classes needed to be interpreted from existing soil maps and historical aerial photography. There was extensive analysis of a five-year history of historical compliance imagery. Policy required the identification of both functional hydric soils for jurisdictional wetland determinations and drained or non-functional hydric soils for wetland restoration practices for programs such as the wetland reserve program. The National Cooperative Soil Survey partnership worked with other agencies and scientists, building from the established soil and flooding hazard maps, to create “ high potential” wetland maps to inform the public.

Hydric soil lists were established by National Cooperative Soil Survey teams and published for public record but were not used as definitive information for wetland delineation. Onsite examination of hydric soil indicators to confirm active function of wetlands for policy management and regulatory statutes became the gold standard to delineate wetlands and document wet conditions. Traditional Soil Surveys mapped hydric soils based on their classification but on-site determinations using the field indicators are now needed to identify those areas that continue to function as a hydric soil (Figure 1) [1] from those that (through changes in soil and hydrologic characteristics) are no longer functional hydric soils.

Figure 1. Online and published guide-- Field Indicators of Hydric Soils in the United States. A Guide for Identifying and Delineating Hydric soils, Version 7.0, 2010. National Interagency committee for Hydric Soils collaboratively directed compilation of indicators to reflect wetland soil change and address national policy needs to identify active wetlands by soil characteristics.

In addition to the example of hydric soil policy implementation, there have been other programs (highly erodible land with wind or water soil erosion potential; salinity vulnerability and reclamation; and subsidence vulnerability) that have been providing guidance for conservation protection and yet allowed some flexibility for the science community to continue research for refinement and improved definition of terms and outcomes. The science community can learn from the example of hydric soil indicators development in the late 1980's through early 2000's on how to approach the relationships between policy formulation, science and regulation. There needs to be a balance between continual collection and validation of new information on soil change and the push of climate change adaptation policy progress.

The National Cooperative Soil Survey continues to identify ways to improve existing products and develop new products. The US Soil Survey has been transitioning from data collection and summary for empirical modeling and estimated values to point data summary for process modeling which could produce values and outcomes useful to climate change adaptation policy. The idea that specific measured or estimated point data can be spatially extrapolated through process modelling to predict outcomes of climate change is only now being explored in government sponsored environmental monitoring communities. As we complete initial US Soil Survey inventory projects, we are allowing for more resources to do on-site characterization specifically for process modelling of conservation practices on soil function, nitrate leaching, soil erosion and potential commodity crop yields. Conservation Effects Assessment Project (CEAP) is an interagency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Using the US Soil Survey as a base data resource for spatial analysis and additional project sampling for validation, assessments in CEAP are carried out through process modelling at national, regional and watershed scales on cropland, grazing lands, wetlands and for wildlife. The three principal components of CEAP—the national assessments, the watershed assessment studies, and the bibliographies and literature reviews—contribute to building the science base for conservation. That process includes research, modeling, assessment, monitoring and data collection, outreach, and extension education. CEAP findings are being used to guide USDA conservation policy and program development and help conservationists, farmers and ranchers make more informed conservation decisions [1].

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Next steps for further work will also be an increased focus on soil monitoring through the US National Resource Inventory (NRI) and the Ecological Site Inventory [1]. Soil survey mapping data technology and modeling teams are working together to identify soil change and vulnerable landscapes. In addition, the modeling effort through collection of long term monitoring with NRI tied to the spatial soil data base has created an opportunity to analyze conservation effects of management to land resources. Capacity for natural resource assessment and analysis has been developed through Conservation Effects Assessment Program (CEAP) by integrating investments such as the National Resources Inventory (NRI), Soil Survey base data through Gridded Soil Survey Geographic (gSSURGO) geospatial databases (Figure 2) [2], conservation practice implementation data, and partner monitoring data—with powerful and improved analytical models and methods [3]. In the last 5 years, the National Cooperative Soil Survey soil change dialog and the USDA NRCS Soil Science and Resource Assessment Deputy Area have aligned priorities to build on research progress, monitoring programs and modeling capacity. Modeling teams within the US National Cooperative Soil Survey are now forming at the regional level to build capacity for further development and integration.

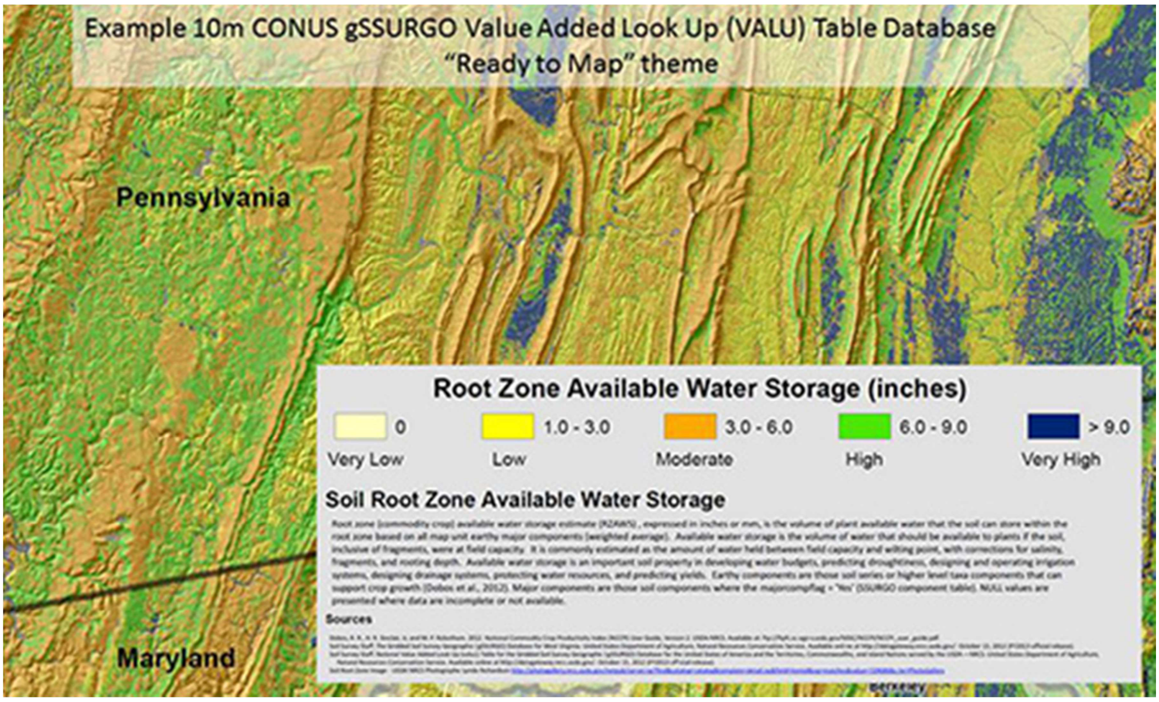

Figure 2. FY2014 Gridded Soil Survey Geographic (gSSURGO) Database is derived from a January 15th, 2014 snapshot of the Soil Data Mart database. These new data are available in both state-wide tiles and the Conterminous U.S. (CONUS) [2].

The USDA-Natural Resources Conservation Service (NRCS), National Soil Survey Center, Lincoln, Nebraska, leads a group that coordinates studies in Soil Quality and Ecosystem Dynamics. The group focuses on the development of useful tools for measurement and applications for policy related to Soil Change, Resistance, Resilience, State and Transition Models (STMs) and Dynamic Soil Properties (DSPs). The National Cooperative Soil Survey started committees in 2010 which have been consolidating research and evaluating inventory techniques and data to push forward a practical and scientifically robust approach to mapping and applying soil change properties to spatial soils data. This entails teams addressing topics such as onsite assessment indicators, sampling protocols, and developing data models for data storage within the National Soil Information System (NASIS). The committees and Dynamic Soil Property Team at the National Soil Survey Center in Lincoln NE have developed assessment protocols and a 3 year plan for sampling and research starting in 2014.

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Priorities for the committees are documented and are summarized as follows: (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/partnership/?cid=nrcs142p2_053534#ecosystem) [1]

1. Identify criteria for a minimum datasets for DSP and ecological sites (ESs), especially for new land types.
2. Develop and support a database that contains the correct data elements to relate vegetation composition to DSPs and vice versa. Allow data retrieval and queries.
3. Develop partnerships to share data in a format that is compatible, linked to soils, and at a useable scale. Review current pathways for NRCS agency and other users to access completed ESDs.
4. Use data analysis tools and skills to analyze data for ESD and DSP interpretations as drivers of ecosystem change. Support standardization of properties and protocols for ESs and DSP data collection
5. Report criteria that are being used to differentiate sites and states for various land types
6. Explore the adaptation of ESs for use on croplands
7. Discuss how dynamic soil properties can be effectively integrated into all ESs

The National Ecological Site Description Initiative, (now led by Joel Brown, USDA-NRCS and Agricultural Research Service (ARS) at Jornada Experimental Range in Las Cruces, New Mexico), is providing technical support to teams throughout the US to develop Ecological Site Descriptions that describe impacts of management or climate change on the landscape. The ARS Jornada has been partnering for many years through the National Cooperative Soil Survey to build a framework for the National Ecological Site Inventory. Ecological sites are conceptual divisions of the landscape based on soil map unit components as defined and mapped by the National Cooperative Soil Survey. Recurring soil, landform, geological, and climate characteristics are grouped together based on their dynamic responses to disturbance, whether natural or anthropogenic. The differing soil: plant communities determine ecosystem services that may be derived from land and management interactions. Each ecological site may exhibit multiple stable plant communities (states) and dynamic patterns of change (transitions). State and Transition models (*sensu* [4]) are graphic and textual models of changes in plant communities and associated dynamic soil properties that can occur on an ecological site. The causes of change, the constraints to reversibility of the change, and the management interventions needed to prevent or initiate change are described qualitatively. Together, ecological sites and state and transition models provide spatially-explicit information about multiple potential soil:plant communities and the descriptions of soil change for landowners and agencies to help guide land management decisions (Figure 3) [1,5]. A good overview of Ecological Site history, concepts, applications and protocols is in *Rangelands* December, 2010 [6].

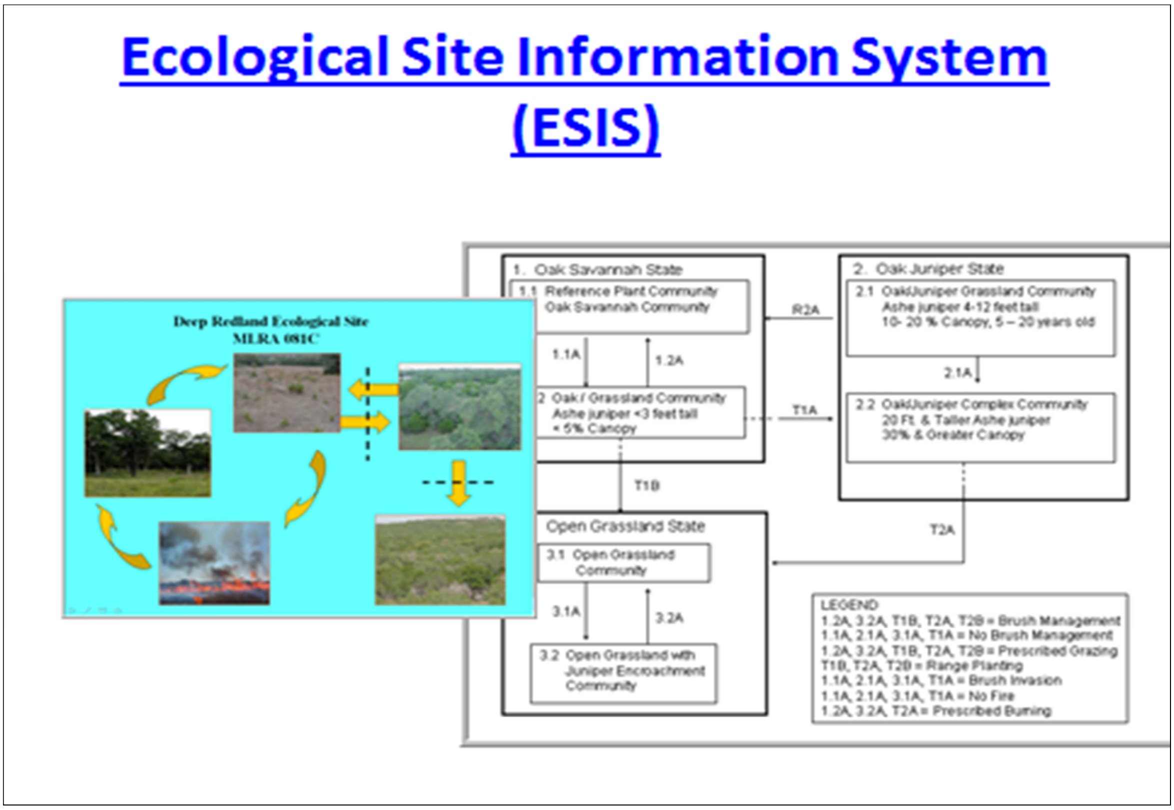

Figure 3. Ecological Site Information (ESIS) is the NRCS repository for ecological site descriptions and for information associated with the collection of forestland and rangeland plot data. ESIS is organized into two applications and associated databases; the Ecological Site Description (ESD) application and the Ecological Site Inventory (ESI) application [1].

There are two National Handbooks on the mapping and documentation of Ecological Sites that were released in 2013 and early 2014 [1]. The first, the Interagency Ecological Site Handbook for Rangelands, was released in early 2013 by the USDA Natural Resources Conservation Service, Bureau of Land Management, and the US Forest Service. The publication of the handbook in 2013 effectively links a unified set ecological concepts and methodological approaches to the land management activities in rangelands for the three major federal agencies. This was a response, in part, to direction from Congress in the Department of the Interior and Related Agencies Appropriations Act of 2002. In that Appropriations Act, Congress expected the Secretary of Agriculture and the Secretary of the Interior to prepare a coordinated plan and budget that would identify the cost of completing standardized soil surveys and ecological classification on all rangeland for use at local management levels. Following the release of the first Rangeland Ecological Site Handbook, the National committees pressed on to finish the editing and vetting of the 2nd more comprehensive Handbook for all of the US, the National Ecological Site Handbook. It has now been released for immediate adoption in early 2014. The Handbooks describe most accepted and vetted definitions as they now stand of Ecological Site Inventory terms, approaches to data collection and standardized analysis nationwide [3].

3. Integration of policy and science with Soil Survey Interpretations

By building on its long history and record of success in interpreting soils information to meet user needs and incorporating new ideas and technology, the Soil Science Division, the NRCS and the National Cooperative Soil Survey partnership are well positioned to continue to deliver interpretive information that meets customer needs now and on into the future. Ongoing activities within the

National Cooperative Soil Survey include improving the consistency of the soils data that underpins interpretations across political boundaries and developing a “minimum data set” of commonly used interpretations to include in digital soils data [3]. Soil Scientists in the field are working with local cooperators to assess and improve existing interpretations, particularly in the context of soil change and climate change adaptation. The National Cooperative Soil Survey continues to seek new ways to interpret soils and to make that information more easily accessible. As an example, practice-specific soil interpretations are being explored to support NRCS conservation planning and practice implementation. Other areas of focus include the development of real-time interpretation systems that allow incorporation of site-specific information and interpretation systems that will allow users to incorporate other spatially-referenced data sets including climate and land use to develop accurate and site-specific interpretive information products. On the distribution side, efforts are underway to look at how interpretive information can be effectively delivered through other avenues including via smart phones and tablets. This will lead to more effective sampling, data collection and interpretation of soil information to support monitoring and soil change attributes.

Soil Change, as a scientific directive and focus, is a new step in the history of the National Cooperative Soil Survey in the United States. Redirecting resources of the soil survey community to linkages with soil characterization, pedo-transfer functions and modeling of processes for yield and erosion outcomes has been useful to better understand soil change. It has put us on a path to acknowledge soil change as a soil property that can be characterized and potentially mapped. Costs of time and money are still involved for monitoring but the framework of state and transition models offers some relief from multi-year projects involving the whole country or a region. Exchange of “space for time” in dynamic soil properties (DSP) monitoring projects with state and transition models [5] has opened up the possibility of predicting and spatially illustrating use and management effects on soil properties. Though extensive “space for time” projects are still several years away in the planning stages for many regions of the United States, the potential payback for a quick turnaround of science-based information in soil change is promising. Spatially armed with models and maps, a farmer, land user or policy maker could be able to make better decisions in the face of food security issues and climate change with these tools in hand.

References

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