USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Soil and Plant Science Division

Digital Soil Mapping Focus Team

Fiscal Year 2023

Introduction

Digital soil mapping (DSM) is the production of georeferenced soil databases based on the quantitative relationships between soil measurements made in the field or laboratory and environmental data and may be represented as either discrete classes or continuous soil properties. DSM products are raster-based soil map products where each raster cell represents either soil type (soil series or map unit) or a continuous soil property (such as pH or clay content). The flexible and quantitative approach of DSM allows the Soil and Plant Science Division (SPSD) to provide critical and relevant soils information for environmental assessments and decision support tools.

DSM activities within the National Cooperative Soil Survey (NCSS) are largely led and supported by the DSM Focus Team. The team currently has 23 members from NRCS, U.S. Forest Service, Agricultural Research Service, and universities. Within the SPSD, staff at every level are involved from soil survey offices, regional offices, the National Soil Survey Center, and National Headquarters. The mission of the team is to operationalize DSM methods in production soil mapping. The objective of the team is to continue to build the DSM framework of standards, training, support, and delivery of raster-based soil information products in the NCSS, as outlined in the team's charges:

1. Coordinate DSM activities across the SPSD
2. Identify training needs
3. Identify needs to update standards and propose solutions
4. Initiate annual field weeks to investigate soil-landscape relationships in selected DSM projects
5. Assemble existing data
6. Identify gaps
7. Produce raster-based soil data and information

The focus team is currently structured with three subteams: The Practitioner Subteam, which concentrates on local-scale projects and capacity building, the Properties Subteam, which emphasizes work on national-scale projects, and the Ecological Site Subteam, which focuses on products for ecological inventory (figure 1). Ad hoc members join the team's activities as their expertise is needed and during the focus team's quarterly meetings when all subteams report and discuss activities.

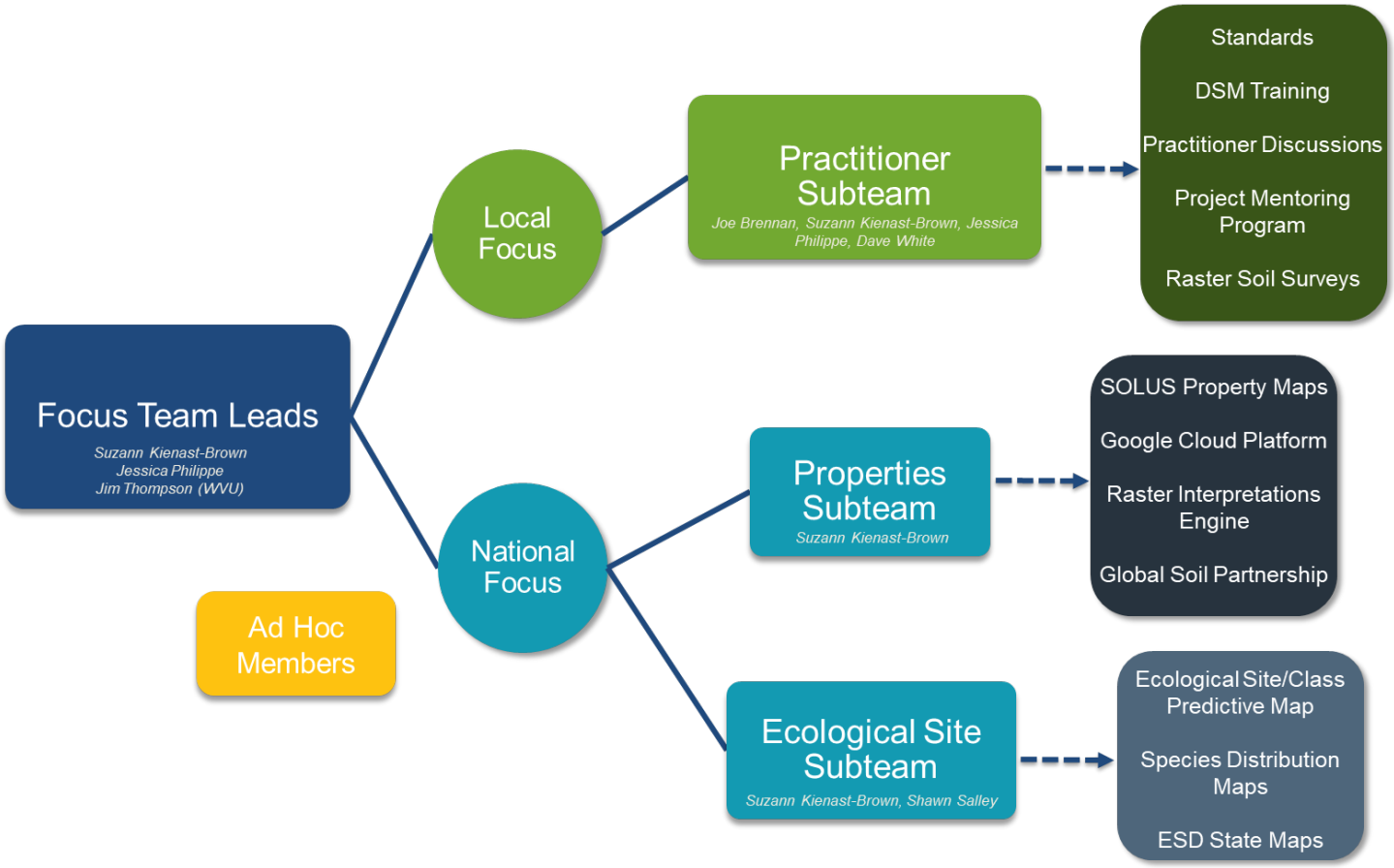

Figure 1.—DSM Focus Team structure with subteams and relevant activities.

Highlights

The DSM Focus Team is critical for building a framework within the NCSS and SPSD to support application of DSM methods in daily soil survey activities to provide meaningful results to users. In fiscal year 2023 (FY23), the team has accomplished several major goals:

- Completed maps and NCSS open comment and review period for Soil Landscapes of the United States (SOLUS) 100m property maps for 20 soil properties for the contiguous United States (CONUS)
- Provided project mentor support for eight Raster Soil Survey projects across the country covering 10 million acres of unmapped land
- Created an Ecological Site Subteam to explore creation of ecological resource inventory products using a DSM framework
- Delivered seven DSM training courses, including a customized course for Koya University (Iraq) faculty
- Completed and published major updates to National Soil Survey Handbook (NSSH) Part 648

The overarching goal of all these activities is to build capacity in DSM in the NCSS and SPSD to provide the best available data to conservation planners, land managers, decision makers, and other scientists to adequately assess natural resource concerns and solutions.

Soil and Plant Science Division Priorities

Inventory

The DSM Focus Team is involved in all aspects of inventory work in the SPSD. The team supports inventory work by training scientists to use DSM in their soil survey operations, providing guidance and project support through mentoring, generating new products, and developing standards to support DSM and raster products.

The team administers a mentoring program to provide project support to soil survey offices engaged in DSM activities in ongoing soil survey projects that will result in publication of Raster Soil Surveys. Members of the team are currently assisting 14 active projects across the Nation in both formal and informal mentoring roles and supporting soil survey crews to build capacity in DSM techniques and achieve their mapping goals. These projects occur on a mix of federally and privately owned lands. Collectively, these projects cover approximately 14 million acres of managed land and are goaled for completion by 2026.

Members of the DSM Focus Team are actively involved in supporting several Dynamic Soil Survey projects contributing to the goal of capturing and visualizing the variability and diversity of the soil landscape, as affected by management and land use encompassing area, depth, time, hydrology, or other temporal soil properties. A priority related to Dynamic Soil Survey and completed in FY23 was Soil Landscapes of the United States (SOLUS). SOLUS100 is a set of 20 continuous soil property maps for CONUS predicted at seven depths with uncertainty and accuracy estimates. The team facilitated an open comment period for the maps from June 1 to July 1, 2023, with review apps built in Google Earth Engine and Google Cloud Platform (figure 2). The feedback gained from the comment period will be used to improve future versions of SOLUS. The maps and a peer-reviewed scientific paper are expected to be published in the first half of FY24.

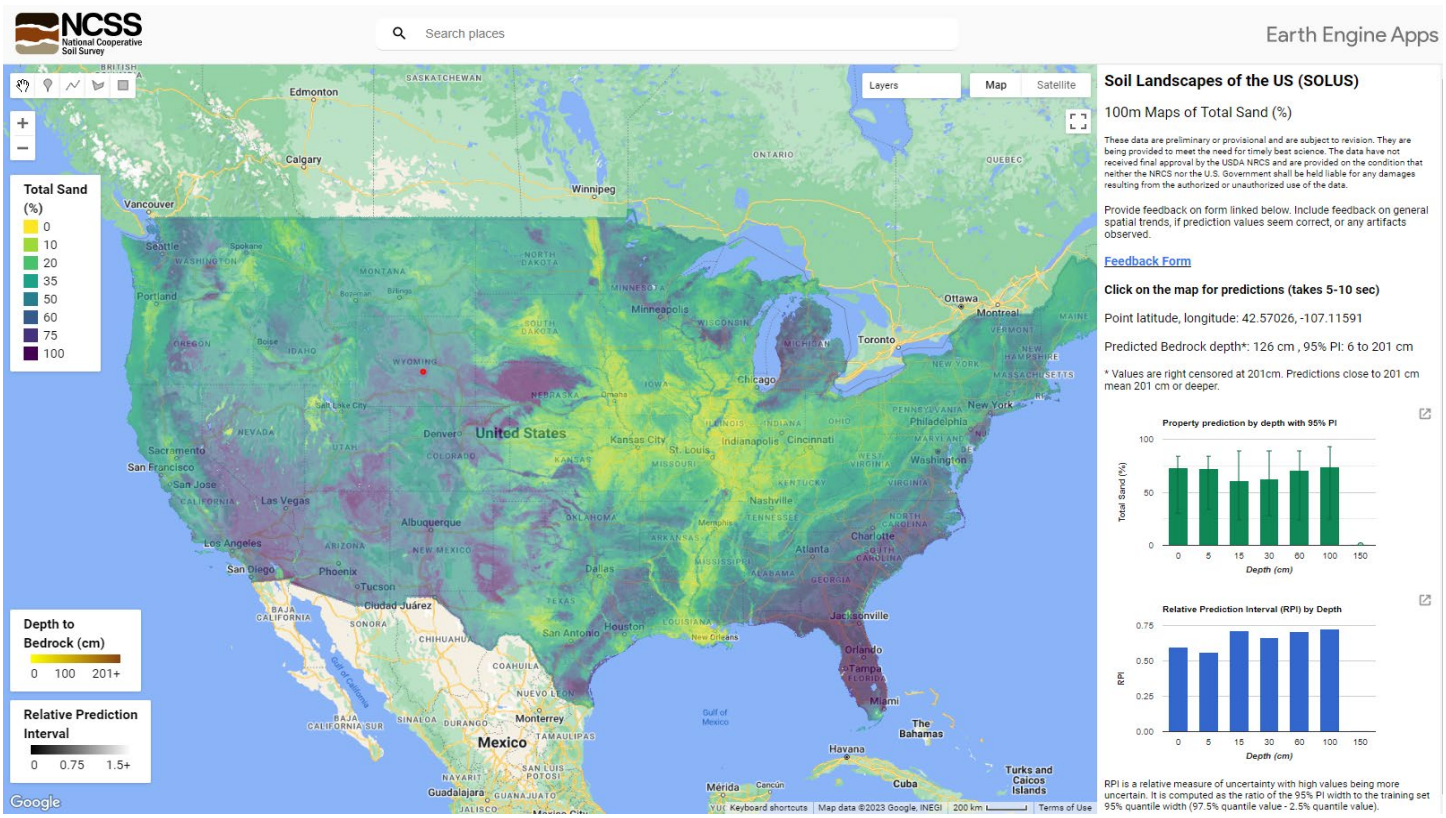

Figure 2.—SOLUS100 review app for total sand (0cm depth shown) built in Google Earth Engine and Google Cloud Platform to facilitate review and comment period.

The DSM Focus Team initiated an Ecological Site Subteam in FY23 to focus on development of Raster Ecological Survey products, such as maps of sites, groups, states, or species distribution using a DSM framework, and standards for Raster Ecological Survey products (figure 3). The team has started drafting a Raster Ecological Survey section for NSSH Part 648 that is planned for review and publication in FY24. The team is also working on a modeling workflow for ecological site groups using Google Cloud Platform computing resources. Raster Ecological Surveys in combination with Raster Soil Surveys and SOLUS maps will provide a foundation for Dynamic Soil Survey priorities such as interactive state-and-transition models and enhanced interpretations.

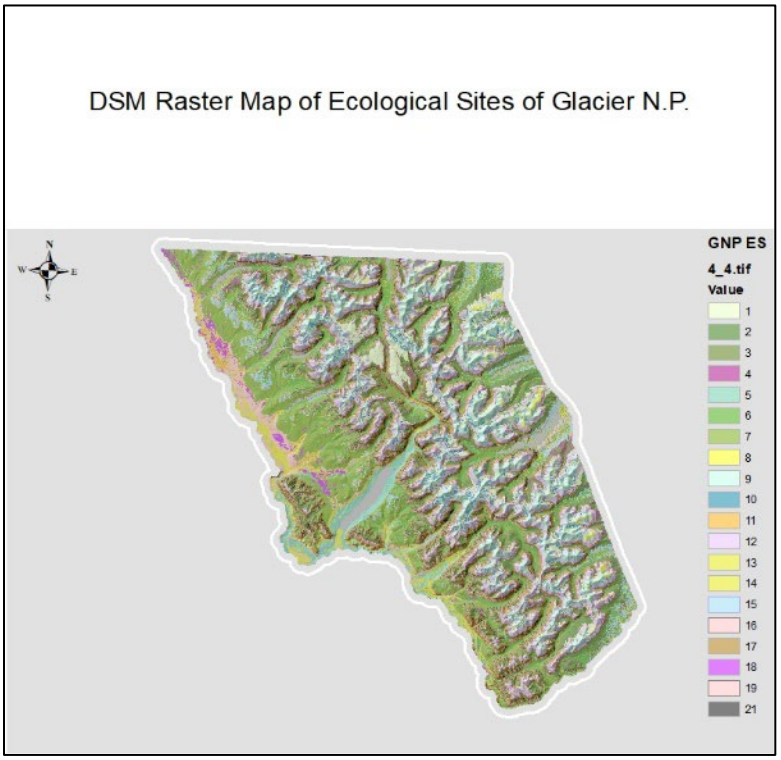

Figure 3.—Example of a Raster Ecological Survey created with a DSM framework for Glacier National Park in Montana.

Raster Soil Surveys and SOLUS property maps can be used to support Dynamic Soil Survey, precision conservation planning, development of ecological site descriptions, state-and-transition models, and decision support tools. In turn, these maps can help address important issues related to ecosystem services and climate change. Ecological sites and state-and-transition models are key to understanding how vegetation communities respond to disturbance or change. An essential component of these models is soil properties, both static and dynamic, and Dynamic Soil Survey will use the DSM framework to predict these. Nationwide, high resolution continuous soil property maps, such as SOLUS, will provide a foundation for modeling ecological sites and understanding how different landscapes and environments will respond to changes in land management or use, conservation practices, and climate. The ability to predict potential response to disturbance or land use change is critical to understanding and mitigating climate change.

SOLUS property maps will provide a complete, consistent, and current inventory of soil resources for the United States and will be updated annually to include improvements in data availability and modeling methods. A regular update cycle of a product with complete coverage of the United States, which does not follow county or State political boundaries or allow for different vintages of data to be combined in one product, means every acre of ground will have the same quality of data available to users. This type of soil map product will serve all communities equally in the ability to generate interpretations for management and use, support conservation programs and planning, and respond to environmental changes.

Soil Services and Information Delivery

The DSM Focus Team supported development, update, and delivery of seven Raster Soil Survey datasets in FY23. Raster Soil Survey is a reference to the products of soil survey work completed using DSM methodologies for production of soil type maps. These datasets are delivered as raster products with tabular data in a structure that mimics gridded Soil Survey Geographic Database (gSSURGO), so they can be used in all the same GIS tools for analysis and interpretation as the gSSURGO datasets (figure 4). They are delivered as individual State databases and as part of the gridded National Soil Survey Geographic Database (gNATSGO) through the NRCS Geospatial Data Gateway – Box site. Existing Raster Soil Surveys in Minnesota, North Carolina, North Dakota, Tennessee, Vermont, and Wisconsin were updated for current interpretations to support use of the data for land management decisions. Raster Soil Surveys were officially part of the Annual Soils Refresh for the first time in FY22. The Raster Soil Survey section of the Annual Soils Refresh instructions and the "Build Raster Soil Survey Database" GIS toolbox instructions were significantly updated in FY23 to support States and soil survey regions. Current operating procedures will allow update and publication of Raster Soil Surveys annually.

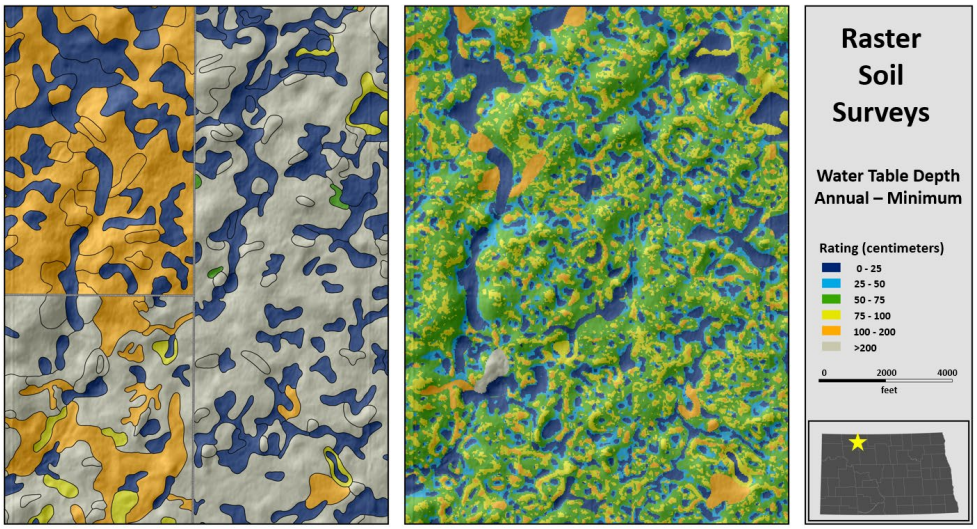

Figure 4.—SSURGO (left) compared to updated Raster Soil Survey (right) for water table depth for an area in North Dakota.

The DSM Focus Team completed SOLUS100 maps and are currently preparing them for publication. However, the preliminary maps are being used internally to test the utility of combining SSURGO and SOLUS data in resource assessment models that support conservation planning. The model includes the parameters water table depth and type, taxon group, Hydrologic Soil Group (HSG), K factor, coarse fragment volume, and slope. The water table parameters, taxon group, and K factor were all derived from gSSURGO. SOLUS was used for coarse fragment volume and HSG inputs, including various soil properties and saturated hydraulic conductivity derived from a pedotransfer function (figure 5). Initial results show promise for combining multiple sources of the best available soil survey data to support the conservation planning process by potentially providing more spatially explicit information.

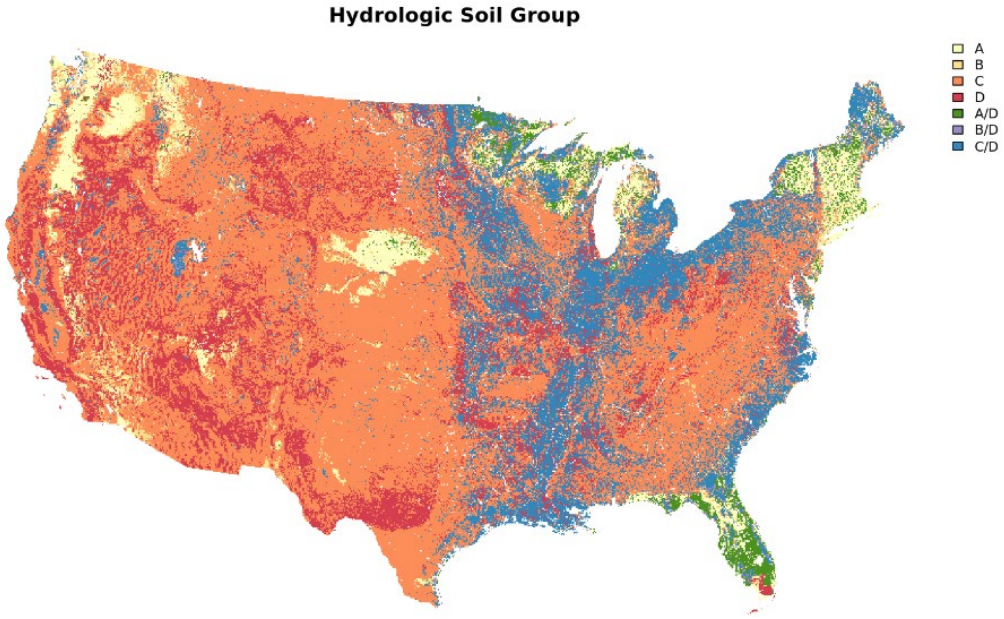

Figure 5.—HSG derived from a combination of gSSURGO and SOLUS inputs.

FY23 was the first year since FY19 that all six formal training courses in the DSM curriculum were delivered. Spatial Analysis Workshop, Statistics for Soil Survey – Part 1, Introduction to Digital Soil Mapping, Digital Soil Mapping with ArcSIE, Statistics for Soil Survey – Part 2, and Remote Sensing for Soil Survey Applications were taught to approximately 150 participants. Updates to three of the core courses were completed to ensure delivery of the most relevant information and use of current software versions to best prepare SPSD staff to accomplish DSM tasks in their inventory work, including updating Digital Soil Mapping for ArcSIE to the ArcGIS Pro version of the tool. Remote Sensing for Soil Survey Applications will undergo a major update in FY24. The team also hosted monthly DSM Practitioner's Discussions that cover a wide range of topics related to DSM. The discussions are open to the NCSS include around 80 participants from NRCS, other federal agencies, universities, and the private sector. The team also designed a custom DSM training course to meet the needs of faculty from Koya University in Iraq, expanding their ability to map soils and generate interpretations for food security concerns in their country (figure 6).


Figure 6.—Suzann Kienast-Brown and Tiffany Allen deliver DSM training to Koya University faculty.

One key activity for the DSM Focus Team is the development and update of standards to support DSM activities and products within the NCSS. In FY23, the team incorporated comments collected through an open comment period and completed major updates to the NSSH Part 648: Digital Soil Mapping – Raster Products for Soil Survey. The revisions and additional content were based on four years of experience gained by the team through completing and mentoring DSM projects across the country and will provide significant improvement to the definition, purpose, and requirements of both Raster Soil Survey and SOLUS products. The new version of NSSH Part 648 was made available in July 2023.

SOLUS property maps, Raster Soil Surveys, and SSURGO can be combined and used to support Dynamic Soil Survey, conservation planning, and decision support tools. DSM products, such as SOLUS and Raster Soil Surveys, will provide a foundation for resource assessment and insight to how different landscapes and environments will respond to changes in land management or use, conservation practices, and climate. The ability to assess, quantify, and model potential response to disturbance or land use change is critical to understanding and mitigating climate change.

Training and standards to support the development and publication of DSM products form the groundwork for DSM to be applied to soil mapping in all areas, including local, regional, and national scales, and unique project areas like urban or coastal zone environments. Nationwide products, like SOLUS property maps, will provide a consistent and current inventory for the entire United States, which means every acre of ground will have the same quality of data available to users. This type of soil map product will serve all communities equally in the ability to generate interpretations for management and use, support conservation programs and planning, and respond to environmental changes.

National Cooperative Soil Survey

The DSM Focus Team has wide representation from the NCSS including NRCS, U.S. Forest Service, ARS, and multiple universities. All projects within the team are collaborative and involve multiple NCSS members. These projects include the SOLUS property map project, which provides property maps for almost two dozen key soil properties at seven depths to support Dynamic Soil Survey. The team presented results from this project at the Soil Science Society of America meeting in November

2022, the 2nd Joint Workshop of the IUSS Working Groups for Digital Soil Mapping and Global Soil Map in February 2023 (figure 7), and the national NCSS conference in July 2023. The team is actively engaged with NCSS partners on Dynamic Soil Survey projects in North Carolina, New Hampshire, West Virginia, Massachusetts, Maine, and Ohio where exchange of data and technical expertise are being combined to explore potential methods and products to support incorporation of temporal and dynamic properties into soil survey to better support land management decisions. Many of the team's mentoring projects are in collaboration with NCSS partners from other federal land management agencies such as U.S. Forest Service, Bureau of Land Management, and National Park Service. Support of the Soils2026 Initiative for CONUS allows the team to interact with NCSS partners from federal agencies and universities to find creative ways to meet the goals of the initiative.

Figure 7.—DSM Focus Team members, Suzann Kienast-Brown (NRCS, left) and Dr. Colby Brungard (New Mexico State University, right) present at the 2nd Joint Workshop of the IUSS Working Groups for Digital Soil Mapping and Global Soil Map, Orléans, France.

NCSS activities are critical to progressing the application of DSM in soil and ecological mapping to support creation of relevant inventory products, like SOLUS property maps and completion of the Soils2026 initiative. Research combined with production activities in the NCSS that result in nationwide data products can build and support Dynamic Soil Survey and contribute to understanding how different landscapes and environments will respond to changes in land management or use, conservation practices, and climate. This is critical to understanding and mitigating climate change for all areas and communities of the United States.

Looking Forward

DSM is an active field of research in the scientific community. Techniques are constantly evolving, and soil and ecological scientists must remain curious and flexible in learning and application to provide the best available data to customers. The DSM Focus Team is committed to pursuing projects and work FY24 to provide the best available data about soil science to both internal and external customers.

SOLUS Property Maps

Publication of SOLUS100 maps and a peer-reviewed scientific journal paper are the first priorities for FY24. Once those tasks are complete, modeling for SOLUS30 (30m resolution property maps for CONUS) will begin. The team will continue to work on exploring the utility of combining SSURGO and SOLUS in models to support conservation planning. Results will be shared with conservation planners to demonstrate new soil information products and collect feedback to improve the customer experience.

Raster Ecological Surveys

The Ecological Site Subteam will work toward predicting ecological site groups at a regional scale in FY24. The team hopes to collaborate with a detailee on the Ecological Site staff to complete a project predicting ecological sites at a local scale. Projects completed on a local and regional scale will provide a foundation for development of a workflow that can be applied on a national scale.

Mentoring

The team aims to make significant progress on critical mentoring projects such as the Idaho Soils2026 project, which covers 9 million acres of unmapped land.

Training

The Remote Sensing for Soil Survey Applications course will be extensively updated in FY24 to include relevant data sources, techniques, and software. Other courses will be updated as needed with a goal of delivering all courses in the DSM curriculum in FY24, including a DSM Field Week in either Missouri or Puerto Rico.

Standards

The Practitioner and Ecological Site Subteams will continue working on improvements and additions to NSSH Part 648 to address needs for Raster Soil Surveys, SOLUS, and Raster Ecological Surveys. The goal for FY24 is to publish the new section on Raster Ecological Surveys.

Raster Interpretations Engine

The team completed a solid start to a Raster Interpretations Engine in R in FY21 and would like to focus resources, such as a detailee, on further development and refinement of the R package to include more standard interpretations.

Dynamic Soil Survey

The team will continue to support Raster Soil Survey development for ongoing and new Dynamic Soil Survey projects and keep progressing on SOLUS, Raster Soil Surveys, Raster Ecological Surveys, and the Raster Interpretations Engine to support Dynamic Soil Survey.