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Supplement of

How well does digital soil mapping represent soil geography? An investigation from the USA

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Contents

1 Introduction

This is a supplement to the journal article "How well does Digital Soil Mapping represent soil geography? An investigation from the USA". The Digital Soil Mapping (DSM) products discussed are POLARIS soil properties (Chaney et al., 2019) (abbreviation PSP), SoilGrids v2.0 (abbreviation SG2) (Poggio et al., 2021), and Soil Properties and Class 100m Grids of the United States (abbreviation SPCG) (Ramcharan et al., 2018). The reference product is gSSURGO (NRCS Soils, 2022a), supplemented with gNATSGO (NRCS Soils, 2022b) where gSSURGO is not available.

2 Data sources

2.1 gSSURGO

gSSURGO is delivered as gridded coverages at 30 m horizontal resolution on an Albers Equal Area projection covering the CONUS, with standard parallels at 29.5° and 45.5° N and the central meridian at -96° E on the NAD83 datum, which uses the GRS80 ellipsoid. gNATSGO is a 90 m resolution generalization of this. Access to gSSURGO is via a Web Coverage Service (WCS) interface provided in the `soilDB` R package (Beaudette et al., 2021b). Each $1 \times 1°$ tile requires about 63 Mb for the 30 m gridded map and 610 Kb for the associated data tables. Aggregation to the chosen GlobalSoilMap depth slice is by weighted averaging over the horizons or layers in the slice using the `slab` function of the `aqp` "Algorithms for Quantitative Pedology" R package (Beaudette et al., 2013, 2021a). These are then combined over the map unit components by weighted averaging, using the estimated component proportions for the map unit which the grid cell represents. The resulting tile is about 12 Mb.

The transfer from unrectified photos to topographic base has not always been flawless, and in addition polygons may have been mis-drawn on the original survey. Figure S1 shows an example of such discrepancies on a map of Tompkins County, NY, design scale 1:24 000. SMU `Ab` (alluvial soils) includes the lower hillside and does not cover much of the alluvial plain. SMU `Ro` (rock outcrop) includes the alluvial area at the junction of two streams. SMU `MaB` (Mardin channery silt loam, 2–8% slopes) does not properly delimit this slope class. These map units are indeed the correct ones for the soil landscape, but for a given 30 or 250 m pixel the mapped soil may be incorrect.

Since gNATSGO and gSSURGO are compiled from diverse field surveys over many years, in some areas there are artefacts of that survey process. The left panel of Figure S2 shows a particularly egregious example: not only is the E-W State boundary between Missouri (N) and Arkansas (S) obvious, but also the survey of the eastmost Missouri county in this figure (Ripley) shows an abrupt, artificial soil boundary with Oregon county, to its west. Contrast this with the predictions by SG2 in the right panel of Figure S2, which because it is based on globally-consistent covariates does not show such artefacts. PSP (center panel of Figure S2) partly solves this problem by its harmonization algorithm.

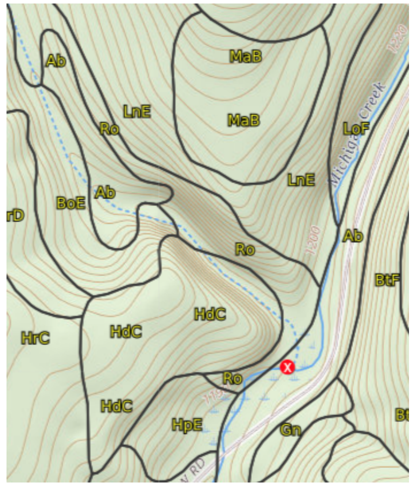

Figure S1. SoilWeb view of SSURGO map units. Point inquiry at $-76.4861°\mathrm{E}, 42.2986°\mathrm{N}$. Dimensions 660×720 m

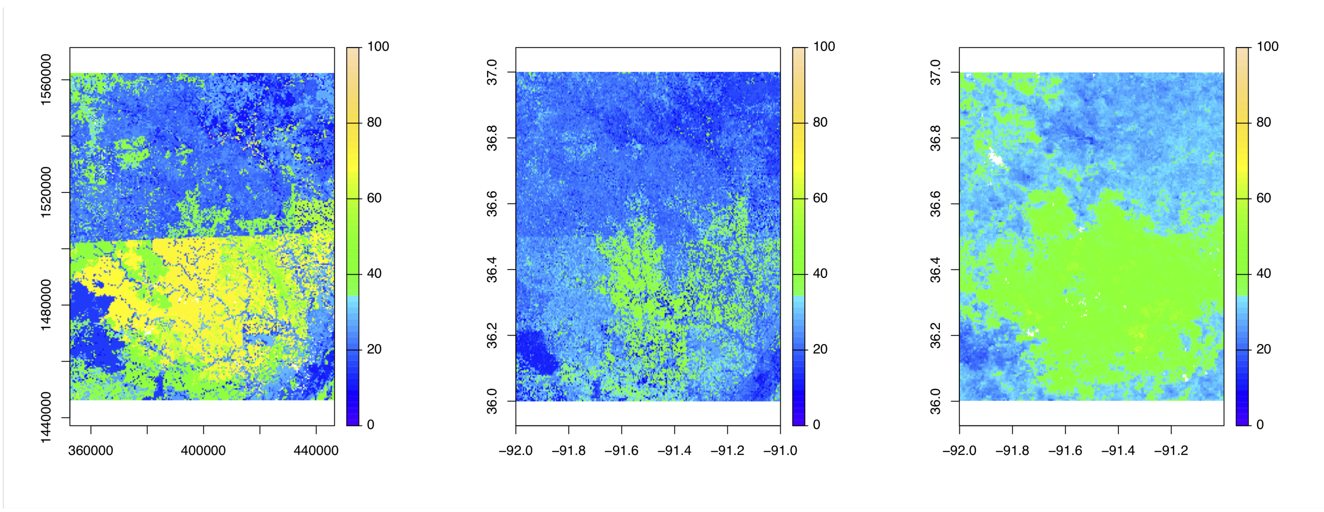

Figure S2. Maps of clay concentration % in the 30-60 cm depth slice, Missouri-Arkansas border; lower-right corner near Pocahontas AR. (left) gNATSGO; (center) PSP; (right) SG2

2.2 SoilGrids v2.0

SG2 (SoilGrids team, 2021b) predicts at 250 m resolution for the standard depth slices specified by GlobalSoilMap on an equal-area Interrupted Goode Homolosine (IGH) projection on the WGS84 datum (Moreira de Sousa et al., 2019). User-specified tiles for a property, depth slice, and quantile (5%, 50%, 95%, mean) are downloaded from the SoilGrids data store (SoilGrids team, 2021a) using the Web Distributed Authoring and Versioning (WebDAV) protocol, as a Virtual Raster Table (VRT) from the SG2, as explained by de Sousa (2020). This is then converted to the tile using the `gdal_translate` function of the `rgdal` R package (Bivand et al., 2021).

2.3 Soil Properties and Class 100m Grids of the United States

SPCG predicts at 100 m resolution for seven point depths (0, 5, 15, 30, 60, 100 and 200 cm) in the same projection as gSSURGO. Each property and depth is a separate grid covering the CONUS, about 370 Mb. These are downloaded from the ScholarSphere (PennState University Library) data repository (Ramcharan et al., 2017).

2.4 POLARIS

POLARIS is supplied as $1 \times 1°$ tiles, one for each property, GlobalSoilMap depth slice, and quantile (5%, 50%, 95%, mean). The grid is 1 arc-second of longitude and latitude resolution, i.e., 0.0002777778° on the WGS84 datum, equivalent to ≈ 32 m latitude, and proportionally smaller longitude depending on latitude. These are downloaded from the POLARIS repository (Chaney, 2019) and need no preprocessing. Each tile is 8–35 Mb, depending on the complexity of the spatial pattern.

3 Matching

The four maps are made compatible for regional comparison by (1) resampling to 250 m to match SoilGrids v2.0, using the `resample` function of the `terra` R package (Hijmans et al., 2021; Hijmans, 2021); (2) masking areas not predicted by one or more products (e.g., urban areas, water); (3) trimming to the minimum area covered by all the products.

For local comparison, both gSSURGO and POLARIS are already in nominal 30 m resolution, but in different coordinate reference systems. To make them compatible, gSSURGO is resampled into the POLARIS grid, and then both are resampled into the UTM projection covering the study area.

4 Environmental covariates and geographic scope

The three DSM products (SG2, PSP, and SPCG) use a large number of gridded GIS coverages as the basis of their Digital models, as explained in the respective papers.

SG2 uses the following global covariates, i.e., available over the entire area to be predicted.

- **Climate**: temperature, precipitation, snowfall, cloud cover, solar radiation, wind speed.
- **Ecology**: bioclimatic zones and ecophysiographic regions.
- **Geology**: soil and sedimentary thickness; rock types.
- **Land Use/Cover**: from sources such as ESA, NASA and USGS.
- **Elevation and terrain morphology**: including numerous morphology indexes and land form classes.
- **Vegetation Indexes**: NDVI, EVI and NPP. Raw bands from Landsat and Modis products
- **Hydrography**: global water table, inundation and glaciers extent and surface water change.

PSP uses a similar set, and also coarse-resolution (≈ 2 km) estimates of U, Th, and K γ-ray decay products. SPCG uses a similar set, but also parent material classes (87) and drainage classes (4) covering the CONUS. These are derived from the Official Series Descriptions of the dominant component of the SSURGO polygon at the grid cell centre.

5 Local spatial patterns

A second example of POLARIS disaggregation is shown in Figure S3. This is the predicted silt concentration within ≈ 3 ha field and some adjacent woodland, all within the Chenango series alluvial fan, south of the intersection of Robinson Hollow Road and NY State Route 79 in Tioga County. Values range from 37% (darkest red) to 55% (lightest red), a range with significant management implications. These values come from the constituents listed for this map unit. The named series Chenango is assigned 75% of the area, with a surface soil of 39.7% silt concentration. The other five inclusions have different predicted silt concentrations. However, in this field, there seems to be no justification to map any of these inclusions. For example, the Tioga series inclusion (5%) is found on higher positions of flood plains, and the Middlebury series inclusion (5%) is found in recent alluvium, but this field is all on the alluvial fan terrace. This disaggregation is clearly not based on land use, and there is no terrain or parent material differentiation in this almost flat field. There would be no basis for differential management of each $\approx 700\ m^2$ grid cell, as is implied by the fine resolution and strong differentiation within the field.

Figure S3. Ground overlay from PSP in the Chenango gravelly loam map unit, silt % 0–5 cm. Centre of image $-76^{\circ}17'03"\mathrm{E}, 42^{\circ}22'40"N$. Background from Google Earth

Author contributions. DGR conceptualized the approach, did most of the writing, wrote the R Markdown documents and performed the example case study. LP provided DSM expertise and detailed knowledge of SG2. DB and ZL provided USA-specific expertise, in particular about the NRCS and its products and services. All authors collaborated on the motivation, methods and conclusions.

Competing interests. There are no competing interests.

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