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Digital Soil Mapping

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The great explosion in computation and information technology has come vast amounts of data and tools in all fields of endeavor. Soil science is no exception, with the ongoing creation of regional, national, continental and worldwide databases. The challenge of understanding these large stores of data has led to the development of new tools in the field of statistics and spawned new areas such as data mining and machine learning (Hastie et al., 2001). In addition to this, in soil science, the increasing power of tools such as geographic information systems (GIS), GPS, remote and proximal sensors and data sources such as those provided by digital elevation models (DEMs) are suggesting new ways forward. Fortuitously, this comes at a time when there is a global clamour for soil data and information for environmental monitoring and modeling. Consequently, worldwide, organizations are investigating the possibility of applying the new spanners and screwdrivers of information technology and science to the old engine of soil survey. The principal manifestation is soil resource assessment using geographic information systems (GIS), i.e., the production of digital soil property and class maps with the constraint of limited relatively expensive fieldwork and subsequent laboratory analysis. The production of digital soil maps in to, as opposed to digitised (existing) soil maps, is moving inexorably from the research phase to production of maps for regions and catchments and whole countries. The map of the Murray–Darling basin of Australia (Bui and Moran, 2001, 2003) comprising some 19 million 250-250 m pixels or cells and the digital Soil Map of Hungary (Dobos et al., 2000) are the most notable examples to date. McBratney et al. (2000) reviewed Pedometrics methods for soil survey and suggested three resolutions of interest, namely >2 km, 20 m – 2 km and < 20 m corresponding to national to global, catchment to landscape and local extents. Table 1 provides a slightly more detailed overview with five resolutions of interest. The third one (D3) which deals with sub catchments, catchments and regions is the one which attracts the most attention. In the language of digital soil map, different from that of conventional cartography, scale is a difficult concept, and is better replaced by resolution and spacing. D3 surveys, which in conventional terms, have a scale of 1:20,000 down to 1:200,000, have a block or cell size from 20 to 200 m, a spacing also of 20 – 200 m and a nominal spatial resolution of 40– 400 m (see Table 1). The Netherlands has complete coverage at a nominal spatial resolution of 100 m. In France, on the other hand, a highly developed western economy, but with a large land area, only 26% of the country is covered at a nominal spatial resolution of 500 m and 13% at a nominal spatial resolution of 200 m (King et al., 1999). One-third of Germany is covered with soil maps at a nominal spatial resolution of 10 m (1:5000), but most of these are not yet digital (Lo¨sel, 2003).

Soil Mapping, Soil Survey and the value of Spatial Soil Information

Pedology, Hydropedology and Pedometrics Hydropedology: IS an integrative field of soil science, which incorporates the concepts of Pedology, soil physics, and hydrology to understand soil–water interactions at various scales (Lin, 2003; Lin et al., 2005, 2006). Another integrative field that is rooted in Pedology is pedometrics, which by contrast incorporates soil science, geographic information science, and statistics (Grunwald, 2006). Defined as "the application of mathematical and statistical methods for the study of the distribution and genesis of soils" pedometrics is concerned with quantifying soil variation in terms of its deterministic, stochastic, and semantic components. A subset of pedometrics is digital soil mapping (DSM), also referred to as predictive soil modeling (Scull et al., 2003) and quantitative soil survey has defined DSM as "the creation and population of spatial soil information systems by numerical models inferring the spatial and temporal variations of soil types and soil properties from soil observations and knowledge and from related environmental variables." The explicit geographic nature of DSM aligns it with hydropedology because hydropedology has been advocated as a means to study the relationships between soils, landscapes, and hydrology (Lin et al., 2006). Therefore, DSM can provide effective linkages for the integration of Pedology and hydrology. Lin (2011) referred to the development of such linkages between hydropedology and digital soil mapping as "an exciting research area, which can improve the connection between spatial soil mapping and process-based modeling.

Spatial Soil Information and Soil Survey: The perceived need for, as well as the demand for, spatial soil information is growing (McBratney et al., 2003, 2006; Lagacherie and McBratney, 2007; increasingly, detailed soil data from multiple counties and states are being viewed and analyzed together. To address resource issues ranging from local to global scales, environmental scientists and policymakers are seeking soil information that is more specific (soil properties) and more detailed (spatially explicit). These user's needs represent a challenge for soil scientists to provide new spatial soil information, particularly in a digital format that is readily incorporated into geographic information systems (GIS) and can be analyzed with other spatial data Lagacherie and McBratney, 2007).

The Case for DSM: While digitized soil maps are available for most of the world (Grunwald et al., 2011); for many areas those data are at a very small scale (1:1 million or coarser) and do not adequately represent soil variability in a format that is useful to non pedologists (Sanchez et al., 2009). The majority of currently available digital soil maps are actually compilations of multiple legacy soil maps, which were initially produced as hard-copy maps and subsequently digitized (Grunwald et al., 2011). For example, although SSURGO and STATSGO are digital products, they are based on paper maps that were later converted to vector-based polygon maps. For SSURGO, the soil maps were originally produced as part of approximately 3,000 independent soil surveys, and these individual maps are of different vintages and different scales, they were created using different mapping concepts, and they often use different soil components and different estimated property data to represent the same soil–landscape features. Consequently, there are frequently artificial boundaries in the data associated with geopolitical boundaries caused by discontinuities in map unit composition and in estimated soil property data, which produce discontinuities in mapped soil properties and in soil use and management interpretations. All these emphasize the point that digitizing existing paper maps not DSM.

The following limitations of most existing digitized soil survey maps

i. They are static,
ii. They aggregate soil information into soil classes that are not readily compatible with quantitative applications,
iii. The information content has been overly generalized relative to the information on the regional soil resources that was collected to create the soil survey,
iv. They are improperly scaled, and

v. They represent the information as polygons that are not as readily combined with most other natural resource data, which are raster-based. Similarly, Zhu (2006) emphasized that the spatial and attribute generalization of soil spatial variation into discrete classes makes soil survey information incompatible with other forms of continuous spatial data for environmental modeling. All things considered, there is a tremendous potential for the DSM community to capitalize on the demand for better soil information by improving the quality of existing digital soil maps and directly creating raster-based soil data of functional soil properties for hydropedology investigations and hydrologic modeling.

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