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Digital Soil Mapping

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Introduction

Digital Soil mapping (DSM) is an important branch of soil science which deals with computer-generated production of digital maps of soil types and soil properties. It is also known as 'predictive soil mapping' or 'pedometric mapping'. Generally, the process of soil mapping involves the creation and population of spatial soil information by the use of field and laboratory observational methods coupled with spatial and non-spatial soil inference systems.

The creation and the population of a geographically referenced soil database generated at a given resolution by using field and laboratory observation methods coupled with environmental data through quantitative relationships. Soil mapping involves locating and identifying the different soils that occur, collecting information about their location, nature, properties and potential use, and recording this information on maps and in supporting documents to show the spatial distribution of every soil.

Soil mapping is very important for the correct implementation of sustainable land use management. In recent decades, soil mapping methods and data availability have increased exponentially, improving the quality of the maps produced.

We have several techniques available to make maps that give us different layers of information about the soil. Traditionally works were made with open soil pits but now a days we can resort to much more advanced tools. The main ones are these:

Soil maps support many research fields including, but not limited to, pedology, soil classification, soil survey, landscape modeling, natural resources management, land use planning, carbon storage, land use/land cover change, and environmental risk assessment. Numerous assessments have defined and criticized current soil mapping techniques. DSM involves 3 main components: (1) input data (field and laboratory soil observations), (2) the process (building mathematical or statistical models to better fit the soil-environment relationships), and (3) output (continuous thematic or raster maps), and the associated uncertainties. The first recognized soil maps were produced in the mid-19th century to determine the suitability of land use for agricultural purposes. Vast growth occurred in this field in the 20th century due to the development of computers and information technology, including exponential development in geographic information systems (GIS), global positioning systems (GPS), remote sensing (RS), and geostatistics. The availability of satellite images, digital elevation models (DEMs), Light Detection and Ranging of Laser Imaging Detection and Ranging (LIDAR), and radio detection and ranging (RADAR) are key to understanding the increasing research on digital soil mapping. The utilization of proximity sensors such as portable X-ray fluorescence (PXRF) spectrometry, gamma-ray radiometry, UV-visible fluorescence measurements, and visible near-infrared reflectance (Vis-NIR) spectroscopy, as well as computational algorithms, represent new horizons to be explored.

- Soil nutrient properties are predicted using a land parcel-based DSM method.
- Land parcel are automatically extracted from GF-2 fusion image (0.8 m).
- Four models and two mapping units are compared in their performance.
- The land parcel-based digital soil maps include spatial prediction and uncertainty.
- The spatial variations and influence factors at land-parcel scale were analyzed.

Conceptual models for digital soil mapping

(1) The SCORPAN model

This model is a modified version of Jenny's soil formation CLORPT model (1941). The process of soil formation (pedogenesis) mainly involves processes like laterization, podsolization, calcification, salinization, gleization, decomposition, humification, acidification, pedoturbation etc. All of these processes are affected by climate, soil flora, soil fauna, relief, nature of parent material etc. of the particular geographical location. The scientific foundation of soil mapping is based on the conceptual model of soil formation (pedogenesis) by Jenny, in which the process of soil formation is influenced by five factors i.e., climate (cl), organisms (o), relief (r), nature of the parent material (p) and time (t):

$$\mathbf{S = f\,(cl, o, r, p, t)}$$

The Jenny's model is mostly used in conventional soil mapping systems.

(2) Digital elevation models (DEMs)

A digital elevation model is a three-dimensional representation of a terrain's surface of a geographical area created from the elevations data of the terrain. The digital elevation models are used mainly in

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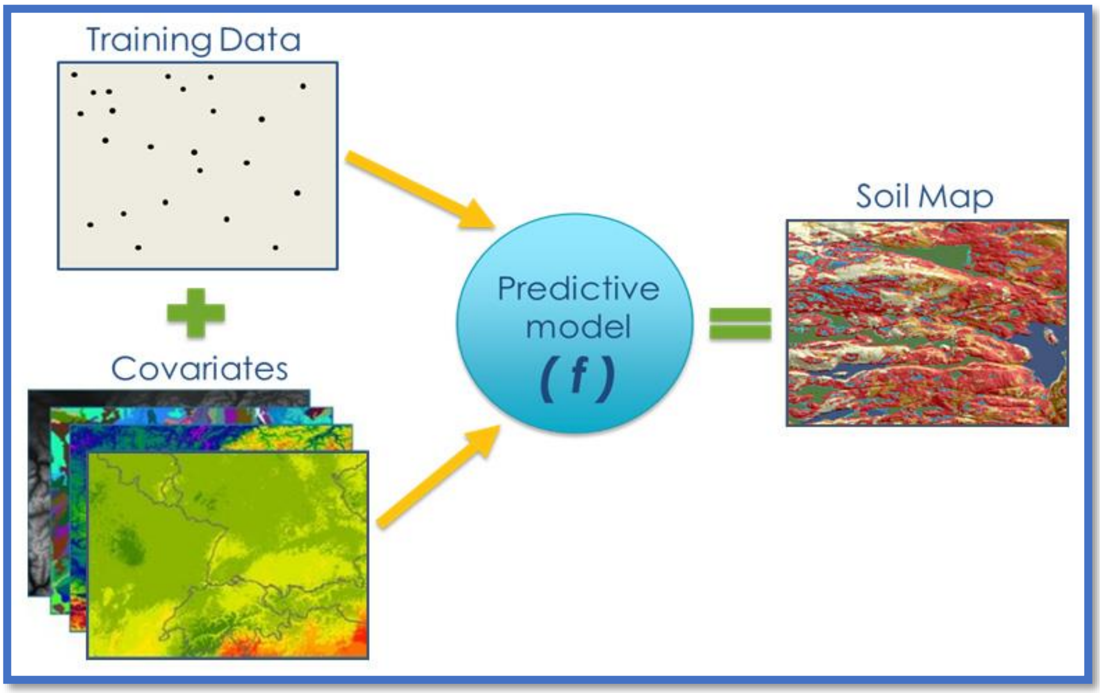
geographic information systems (GIS) and are the most common basis for production of digitalized relief maps. The DEMs consist of two types of models i.e., Digital Surface Model (DSM) and Digital Terrain Model (DTM). The digital surface models are helpful in landscape modeling, digital soil mapping and visualization implications. The digital terrain models are often needed for flood modeling, drainage modeling, land use studies and geographical applications. One of the major differences between the digital surface models and digital terrain models is that, the former includes buildings and other objects over the land area during modeling, while the later represents only the bare ground surface and excludes the plants, buildings etc. over the land area during the same. The digital elevation models are used as a generic term for digital surface models and digital terrain models.



(3) Universal transverse Mercator (UTM) coordinate system

The Universal Transverse Mercator (UTM) is a system for assigning coordinates to locations on the surface of the earth. This UTM coordinate system is very widely used in digital soil mapping. It is a horizontal position representation, which ignores the altitude and treats the earth as a perfect ellipsoid. It divides the earth into 60 zones and projects each to the plane as a basis for its coordinates. Basically, UTM coordinate system is a standard set of map projections with a central meridian for each six-degree wide UTM zone.

(4) Geostatistical modeling

Geostatistics is a branch of statistics focusing on spatial or spatiotemporal datasets with the help of geostatistical algorithms. In geostatistical modeling, several tools like kriging, splines, simulation, semivariance functions, variograms, etc. are used. In this type of modeling, different statistical methods are used to reduce and estimate the error of estimation of the unknown or missing datasets. Therefore, geostatistical modeling is of higher importance in digital soil mapping. The general model equation used to find out the unknown datasets in geostatistical modeling is:

$$\sigma 0^{2} = 1/3 (T0 - T1)^{2} + 1/3 (T0 - T2)^{2} + 1/3 (T0 - T3)^{2}$$

Where,

$\sigma 0$ 2 = Mean Square Error

T0 = unknown data set

T1, T2 and T3 = known datasets

(5) Global Soil Map.net' Project

A global consortium has been formed that aims to make a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution. The new global soil map will be supplemented by interpretation and functionality operations that aim to assist better decisions in a range of issues like agriculture, food production, climate change and environmental degradation. It is an initiative of the Digital Soil Mapping Working Group of the International Union of Soil Sciences (IUSS). This project considers six soil depth functions at six soil depths of the profile i.e. (0-5) cm, (5-15) cm, (15-30) cm, (30-60) cm, (60-100) cm. and (100-200) cm.

(7) 'R' Packages useful in digital soil mapping

The 'R-Studio' software package is downloaded from the Comprehensive R Archive Network (CRAN) website (https://cran.rproject.org) and is used to write codes required in digital soil mapping.

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All the important R packages needed to obtain digital soil maps and their auxiliary data are discussed in brief.

(7) Portable x-ray fluorescence spectrometer

It is an advanced portable soil sensor used in digital soil mapping in which the energy released by replacing of inner shell electrons by outer shell electrons (termed 'fluorescence') is quantified by a silicon drift detector in the aperture of the instrument. The scanning time per soil sample by this instrument is typically 60 to 90 seconds. This instrument is applied in the calculation of the soil pH, soil moisture content, soil organic carbon, electrical conductivity (EC), cation exchange capacity (CEC), the nutrient concentrations in soil like nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and other micronutrients, gypsum concentration, percentage of base saturation, the concentration of heavy metals, nature of parent material, profile horizonation, geochemistry etc. This instrument is portable to the fields with high accuracy of calculation of nutrients in the soil samples as well as plant samples.