Geoderma 230–231 (2014) 329–339

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

The historical role of base maps in soil geography

B.A. Miller [a], R.J. Schaetzl [b]

[a] Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V., Institute of Soil Landscape Research, Eberswalder Str. 84, 15374 Müncheberg, Germany
[b] Michigan State University, Dept. of Geography, 673 Auditorium Rd., East Lansing, MI 48912, USA

ARTICLE INFO

Article history:
Received 7 March 2014
Received in revised form 8 April 2014
Accepted 16 April 2014
Available online 11 May 2014

Keywords:
Soil mapping
Geographic technology
History
Environmental correlation
Model parameters
History of mapping

ABSTRACT

Soil mapping is a major goal of soil science. Soil maps rely upon accurate base maps, both for positional reference and to provide environmental data that can assist in the prediction of soil properties. This paper reviews the historical development of base maps used for soil mapping, and evaluates the dependence of soil mapping on base maps. The availability of geographic technology for producing base maps has both constrained and directed the geographic study of soil. The lack of accurate methods for determining location limited early geographic descriptions of soils to narratives, or to listings of attributes for property-based map units. The first real base maps available for soil mapping were outline maps produced in the late 18th century, fueled by governments' interests in documenting national boundaries and popular interest in world atlases. These early soil maps primarily used outline maps as a positional reference onto which soil-related thematic detail was added. Eventually, additional spatial information, in the form of topographic maps and later aerial photographs, increased the predictive role of base maps in soil mapping. In the current digital, geospatial revolution, global positioning systems and geographic information systems have nearly replaced the positional reference function of base maps. Today, base maps are more likely to be used as parameters in soil-landscape models for predicting the spatial distribution of soil properties and classes. Formerly, as a reference for spatial position, paper base maps controlled the cartographic scale of soil maps. However, this relationship is no longer true in geographic information systems. Today, as parameters for digital soil maps, base maps constitute the library of predictive variables and constrain the supported resolution of the soil map.

Contents

E-mail addresses: miller@zalf.de (B.A. Miller), soils@msu.edu (R.J. Schaetzl).

http://dx.doi.org/10.1016/j.geoderma.2014.04.020
0016-7061/

1. Introduction

Soil geography and mapping are indispensable components of soil science, because soils are inherently spatial (Arnold, 1994; Campbell and Edmonds, 1984; Fridland, 1974; Goryachkin, 2005; Hole, 1953, 1978; Hudson, 1992). The processes for creating soil maps, with uses ranging from scientific study of soil pattern to applied use and management decisions, are firmly rooted in the concepts and methodologies of geography (Bushnell, 1929; Florinsky, 2012; Helms et al., 2002). Therefore, it can be beneficial to review the historical development of soil mapping, as it relates to evolving concepts in geography.

The on-line Dictionary of Cartography (2014) defines a base map as a "map on which information may be placed for purposes of comparison or geographical correlation." From the beginning of accurate surveying techniques (17th century), until the widespread completion of topographic maps, base maps were often limited to outline maps, which provide only positional reference. Outline maps tended to consist mainly of political borders, because these were of greatest interest to the governments who funded their compilation (Harley, 1988). Early soil maps used these base maps because the mapper needed a positional reference on which to plot observations, and these base maps were the only ones available. When other kinds of base maps - containing information useful beyond positional reference - became available for soil mapping, the additional information in them could be used to predict known soil patterns (Dokuchaev, 1883/1967; Florinsky, 2012; Hole and Campbell, 1985; Milne, 1935). Thus, historically, the base map has served as both a positional reference and a source of soil-landscape model parameters for the production of soil maps.

Although positional reference is a key function of all maps, recent developments in global positioning systems (GPS) and geographic information systems (GIS) have nearly replaced the need for separate maps to provide positional reference. Because of the heavy reliance on base maps for positional reference in the past, these new geographic technologies may lead some to consider the term 'base map' as outdated. However, base maps still have use in "geographic correlation."

In the modern definition of base maps, geography is recognizing the continuing role of base maps for spatial association. Indeed, GPS data do not actually replace base maps, because GPS only provides information on location. In contrast, base maps provide more information than location alone; they include spatially associated attributes and context (Abler, 1993). Base maps' significance to soil mapping has, in fact, grown over the past century, as new technologies have provided new and more data-rich base maps with critical information about the soil environment. In digital soil mapping applications, base maps with these kinds of data have been commonly referred to by terms such as 'parameters', 'covariates', or 'input variables' (e.g. Behrens and Scholten, 2006; Grunwald, 2009; McBratney et al., 2003). These terms have been carried over from non-spatial modelling applications. However, maps used as input variables are a special kind of parameter used in soil-landscape modelling (Dobos et al., 2000; Levi and Rasmussen, 2014), with important spatial characteristics. Therefore, the continuing influence of base map properties on soil geography and soil mapping needs to be clarified, explained and hence, appreciated. Acknowledgment of base maps' role in GIS-based methods of soil mapping provides a key link between traditional soil mapping endeavors of the past, and the new wave of digital soil mapping (McKenzie and Ryan, 1999). Thus, in this paper we examine the changing role of the base map in the creation of soil maps throughout history, guiding this discussion within the context of geographic technology's evolution over time.

2. Early soil geography

2.1. Background

Ever since early peoples began sowing crops, and perhaps before, humans have had a vested interest in the geography of soil. Dating back to 3,000–2,000 BCE in central India, archeologists have found evidence of farming on the fertile, black soils formed in the Deccan basalt, but not in areas to the north where these soils are absent (Shchetenko, 1968). Around the same time, the people of Mesopotamia were adjusting cropping patterns in response to observed differences in soil fertility (Brevik and Hartemink, 2010; Krupenikov, 1993). In eastern Sweden, where farming systems date back to 500 BCE, patterns of settlements, fields, meadows, and pastures are correlated to soil type (Widgren, 1979). Similarly, archeological sites in the United States (U.S.) have been shown to be preferentially located on well-drained soils (Almy, 1978). In each of these cases, a mental map of where certain soil characteristics existed was likely used in deciding where to live, settle, and plant. Although such information about soils was probably gathered by trial and error, eventually some rational patterning must have emerged so that numerous excavations were no longer required – if at all. Early peoples most likely used information observable from the surface, e.g., plants, slope, wetness, etc., as reference data with which to build their mental map of desired soil properties.

The Greeks of the Hellenistic Period were particularly astute at observation. Among these observations, they were the first to recognize the information that could be gained from examining a soil profile, which led to improved ideas related to pedogenesis (Krupenikov, 1993). Beginning with Parmenides and Eudoxus (ca. 540–470 BCE), they also recognized the connections among similar soils, vegetation, and climates on large scales - in belts on the Earth (Isachenko, 1971; Krupenikov, 1993). Theophrastus (ca. 371–287 BCE) observed that different soils react differently to the vagaries of weather, and that different crops were better suited for different soils (Theophrastus, 1916). Extending the soil geography of Theophrastus to predictive indicators, Marcus Cato (ca. 234–149 BCE) recalled a point made by Diophanes of Bithynia that, "you can judge whether land is fit for cultivation or not, either from the soil itself or from the vegetation growing on it" (p. 205, Cato, 1934). Even though the concepts of spatial and functional association were in place at this time, an actual soil map was still missing.

Many of the techniques for making the kind of paper map we know today began to appear after 600 BCE (Eratosthenes, 2010). However, the preferred method for describing soil geography remained the written narrative. There are two primary reasons for the lack of interest in producing a physical soil map at this point in history: (1) knowledge of soil was minimal and generalized, and (2) base maps of any kind were extremely crude. To be sure, the manual measurement of distance across land was relatively reliable. However, because a large amount of the geographic data was based on the narrative descriptions of explorers, assembling locations together on a two-dimensional format, i.e. the map, was not as reliable. For example, Herodotus (ca. 484–425 BCE) was highly critical of maps, because of their potential to be misleading. He believed that a map showing Persia far away from Lacedaemon (modern Greece) convinced the Spartans not to assist in the Ionian Revolt. In place of maps, he felt that his table of distances provided more accurate information (Eratosthenes, 2010). Of course, the potential for maps to be misleading still exists today (Monmonier, 1996), but the primary problem with maps of any kind during this early time was accurately representing the position of all features consistently.

Due to the difficulty of accurately measuring position on the Earth, map scale was very inconsistent on early maps. Even though early maps essentially did not have a cartographic scale, their relationship between extent and generalization remain consistent with the modern use of map scale terms. Specifically, for a given size of media (i.e. paper), the map could either include more detail about a small extent or it could be more generalized for covering a larger extent.

Because of the limitations in geographic technology, maps before 1500 CE were either theoretical maps about the Earth with a small cartographic scale, or maps created for civil purposes with a large cartographic scale. Small cartographic scale maps were popular with natural philosophers for the purpose of illustrating conceptualizations about the known world (Fig. 1). Large cartographic scale maps were