Editorial: Historical perspectives and future needs in soil mapping, classification, and pedologic modeling

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Soil mapping, classification, and modelling have been important drivers in the advancement of our understanding of soil from the earliest days of the scientific study of soils. Soil maps were desirable for purposes of land valuation for taxation, agronomic planning (Brevik and Hartemink, 2010; Miller and Schaetzl, 2014), and in military operations (Lark, 2008; Brevik et al., 2015a). Soil mapping required classification systems that would allow accurate and succinct communication of mapped information (Brevik and Hartemink, 2013), classification systems required understanding of the soil system (Marbut, 1922), and gaining that understanding included the creation of soil models (Wilding, 1994). Therefore, advancement in one of these highly interrelated areas tended to lead to corresponding advances in the others, and these relationships persist into the modern era. Furthermore, studying our field's history allows us to understand how we arrived at our current theories, including better understanding of both the strengths and weaknesses of those theories. Within this special issue (SI), historical aspects of soil mapping, classification, and/or pedogenic models are emphasized in papers by Brevik et al. (2015b), Calzolari and Filippi (2015), Miller and Schaetzl (2015), and Minasny and McBratney (2015)

Soil mapping has a long history. The earliest written attempts to link soil attributes to ownership documents date to around 300 CE (Miller and Schaetzl, 2014). By the early 1700s and 1800s soil attributes were being mapped by scientists in Europe and the USA, respectively (Brevik and Hartemink, 2010; Landa and Brevik, 2015). Nationally-organized soil survey programs began in many parts of the world in the early 1900s (Simonson, 1989; Gonzalez et al., 2010; Calzolari, 2013; Hartemink and Sonneveld, 2013). Soil survey activities were relatively well-funded through much of the mid part of the 20th century, including international aid for surveys in developing countries (Brevik and Hartemink, 2010). However, funding was reduced and soil survey activities declined in many parts of the world in the 1980s (Hartemink and McBratney, 2008), with soil survey activities ceasing completely even in some developed countries (Krasilnikov et al., 2009). Many soil maps today are available in digital format, but most were created by digitizing legacy paper maps and they retain the limitations of their source maps (Jones et al., 2005). Future soil mapping would benefit from better consistency between mappers (Hudson, 1992), measures of data uncertainty and improved quantification of soil properties (Gessler et al., 1995; Miller, 2012), and a better understanding of the spatial and temporal variability of soil properties (Ibáñez et al., 2005; Ibáñez et al., 2015). Applications of soil mapping are discussed in papers by Baruck et al. (2015), Brevik et al. (2015b), Calzolari and Filippi (2015), Miller and Schaetzl (2015), Minasny and McBratney (2015), and Wahren et al. (2015) in this SI.

Similar to mapping, soil classification has a long history. The first Chinese soil classification system was developed approximately 4,000 BP, in Europe the Greek philosopher Theophrastus (c. 371 – c. 287 BC) developed a classification for soils, and in the Americas the Aztecs developed a soil classification system used during the height of their civilization from the 14th to 16th centuries (Brevik and Hartemink, 2010). As national soil mapping programs became common around the world in the early part of the 20th Century (Brevik et al., 2015b), a wide range of national soil classification systems also developed (Krasilnikov et al., 2009). This profusion of classification systems led to difficulties communicating soil information internationally. The Legend of the Soil Map of the World (FAO-UNESCO, 1974) and the Revised Legend of the Soil Map of the World (FAO, 1988), followed by the creation of the World Reference Base for Soil Resources (WRB; IUSS Working Group WRB, 2014), were intended to provide correlations between all these disparate systems. Two classification systems have emerged to have wide-spread international use in modern soil science, WRB and Soil Taxonomy (Soil Survey Staff, 1999); however, there are still many national systems that are also in use. Efforts recently began to develop a universal soil classification system that may gain wide international acceptance and facilitate the communication of soil information between scientists from different countries (Hempel et al., 2013).

Papers that address soil classification needs in this SI include Baruck et al. (2015), Brevik et al. (2015b), Juilleret et al. (2015), and Michéli et al. (2015).

The earliest models of soil formation were probably those that viewed soils as a function of the geologic material they formed in (Brevik and Hartemink, 2013), but a major milestone in the development of soil science as an independent, scientific field of study was the development of Dokuchaev's functional–factoral model, which became a major driving force in the mapping and classification of soils internationally within 50 years of its introduction (Brevik et al., 2015b). Other major milestones in the development of pedogenic models include Jenny's (1941) casting of the five soil forming factors into state factors in a theoretically solvable equation, Simonson's (1959) process-systems model, Runge's (1973) energy transfer model, and Johnson and Watson-Stegner's (1987) evolutionary model. Soil landscape models introduced and refined by Milne (1935), Bushnell (1943), Ruhe and Walker (1968), Huggett (1975), and Wysocki et al. (2000) have been critical in guiding soil mapping efforts. In more recent years mathematical models have been developed based on remote (Mulder et al., 2011; Naveen et al., 2014) and proximal (Viscarra-Rossel et al., 2006; Doolittle and Brevik, 2014) sensing methods. New techniques of data collection and spatial statistical analysis led to development of the Scorpan model (McBratney et al., 2003). To varying degrees each of these models has influenced our view of the soil system, including the way we map and/or classify soils. Future work in soil modelling needs to address data quality (Carre et al., 2007) and uncertainty (Nauman and Thompson, 2014), reduction of errors (Adhikari et al., 2014), improved calibration and validation (Malone et al., 2011), ways that sampling techniques influence results (Parras-Alcántara et al., 2015), and discovery of covariates that provide better prediction of the soil formation factors (Hengl et al., 2014; Miller et al., 2015). Within this SI various aspects of pedogenic modeling are presented by Brevik et al. (2015b), Haslmayr et al. (2015), Minasny and McBratney (2015), Wahren et al. (2015), and Waroszewski et al. (2015).

Although many advances have been made in our understanding of the soil system since the late 1800s, when soil science blossomed into a scientific discipline in its own right, there are still many unanswered questions and additional needs in soil mapping, classification, and modelling. New technologies including GPS, GIS, remote sensing, and on-site geophysical instrumentation (EMI, GPR, PXRF, TDR, etc.) with associated data loggers and the development of geostatistical and other spatial statistical techniques have greatly increased our ability to collect, map, and analyse spatial information related to soils. However, linking all of this new information to soil properties and processes can still be a challenge and enhanced models are needed. The expansion of the use of soil knowledge to address issues beyond agronomic production, such as land use planning, environmental concerns, food security, energy security, water security, and human health requires new ways to communicate what we know about the soils we map as well as bringing forth research questions that were not widely considered in earlier soils studies. At present this information is communicated using dozens of national soil classification systems as well as WRB, but a more universal soil classification system would facilitate international communication of soils information. There are still many significant research needs in the area of soil mapping, classification, and modelling going into the future. Therefore, this special issue was developed to 1) document the history, 2) present some of the latest research, and 3) provide some perspectives on future needs in these areas. This has been accomplished by providing a mix of review papers and original research articles.

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