Geoderma 148 (2008) 107–112

Contents lists available at ScienceDirect

Geoderma

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

Upgrading a 1/20,000 soil map with an apparent electrical conductivity survey

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ARTICLE INFO

Article history:
Received 4 April 2008
Received in revised form 17 September 2008
Accepted 18 September 2008
Available online 21 October 2008

Keywords:
Soil map upgrading
Apparent electrical conductivity
EM38
Regression kriging

ABSTRACT

Despite their shortcomings, choropleth soil maps remain the most widespread source of information on soil resources. Since most nationwide soil surveys were conducted in the second half of the previous century, a need for upgrading emerges. We evaluated the potential of detailed observations made by a mobile, non-invasive proximal soil sensor to upgrade a part of the 1/20,000 choropleth soil map of Belgium. This study was conducted on a 14 ha area which had been mapped twice in the 1950s: first, during the national soil survey yielding a 1/20,000 soil map, and second, during a detailed investigation resulting in a 1/5000 map. The first map failed to identify the presence of a Tertiary clay substratum at variable depths, while the second map indicated this substratum to be present within 1.2 m below the soil surface for about a third of the area. A recent survey with the EM38DD soil sensor provided 9192 measurements of the apparent electrical conductivity (EC_a) within the study area. The depth of the substratum (D_{ts}) was noted at 60 calibration locations by augering and the relationship between EC_a and D_{ts} was modelled by an exponential curve with an R^2 of 0.80. This allowed the detailed mapping of D_{ts} by regression kriging. The predictions were validated using 46 independent observations of D_{ts} indicating a reasonable average error of 0.24 m and a very good correlation coefficient between observed and predicted values of 0.94. A map accuracy assessment indicated that even after classification, the D_{ts} classes were better predicted by the sensor data than the 1/5000 map which was based on many more auger observations. Finally an upgraded 1/20,000 soil map was presented, illustrating the potential of combining existing soil maps with proximal soil sensing technology.

1. Introduction

Choropleth, or polygon, soil maps are the traditional source of information for land suitability analysis (Beckett and Burrough, 1971; Rossiter, 1996). During the last century, most European countries conducted nationwide surveys resulting in soil maps published on scales between 1/20,000 (e.g. Belgium) and 1/100,000 (e.g. Denmark), mostly with the aim to support agricultural development. Nowadays, increased pressure on sustainable use of limited land resources demands for land use decisions at much smaller scales (e.g. precision agriculture) and for more diverse land uses. So different decision support tools, such as process-based land evaluation frameworks, soil quality assessment and simulation models require highly detailed spatial information about soil properties (Finke, 2007). Moreover, many land characteristics vary within the recorded mapping units and ignoring this variation strongly reduces the accuracy and the reliability of choropleth soil maps (Heuvelink and Webster, 2001). Nevertheless these shortcomings, polygon-based national soil maps remain the major source of soil information available in most countries. Therefore, Finke (2007) highlighted the need to upgrade the existing polygon-based soil maps by adding new or correcting wrong information.

The traditional way to upgrade a soil map was to conduct a new survey, either at a similar scale but focussing on other soil properties, or at a more detailed scale to obtain a better representation of the spatial variability of the mapped soil properties (Dent and Young, 1981). More recently, map upgrading attempts have been made by combining the predictions obtained by interpolating soil observations with predictions by soil polygon maps (Voltz and Webster, 1990; Van Meirvenne et al., 1994). But these invasive methods require large field survey efforts and thus they are often limited by the cost and time constraints associated with intensive field sampling and laboratory analysis (Oberthür et al., 1999). Recent developments in proximal non-invasive soil sensing techniques offer new opportunities to improve the soil map accuracy with considerable reductions in sampling effort (Adamchuk et al., 2004).

Our objective was to compare a more detailed soil map (scale 1/5000) with mobile measurements of the apparent electrical conductivity obtained with a georeferenced electromagnetic induction

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0016-7061/$ – see front matter
doi:10.1016/j.geoderma.2008.09.013

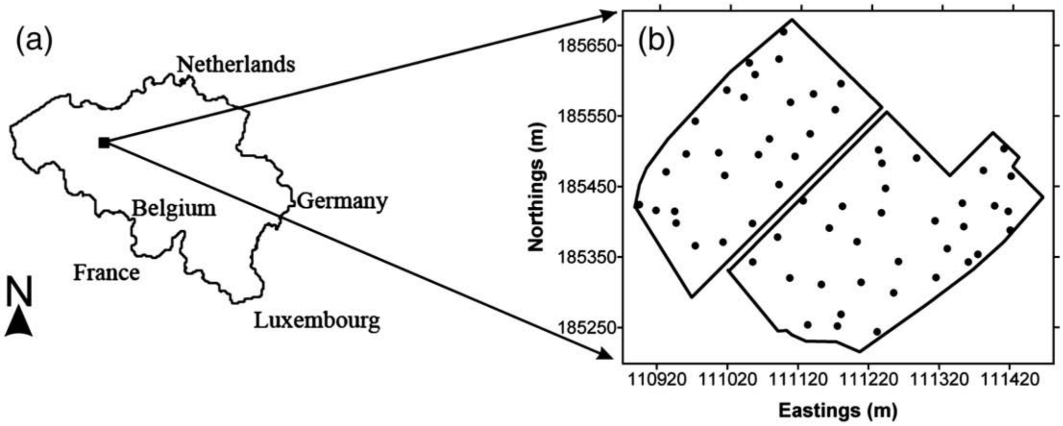

Fig. 1. (a) Localization of the study area in Belgium and (b) study area with observation points of the depth to the Tertiary clay substratum.

(EMI) soil sensor (the EM38DD) to upgrade an existing 1/20,000 soil map. This objective will be evaluated for a 14 ha area in Belgium, where the existing soil map needs to be upgraded with information on the depth to a Tertiary substratum.

2. Materials and methods

2.1. Study area

The 14 ha study area was located in Melle, Belgium, with central coordinates: 50° 58′ 42″ N and 3° 49′ 00″ E (Fig. 1). This area is a part of the Ghent University agricultural research farm and situated in the sandy silt (sandy loam to silt loam in the USDA textural classification) agro-pedological region of the country. During the Weichselian glacial stage of the Late Pleistocene (80 ka–10 ka), wind-blown loess was deposited over this area, covering the surfacing Tertiary layers. This loess cover can have a substantial thickness in the depressions (5–10 m), but it can diminish to some tens of centimetres on the ridges. The Tertiary substratum consists of sandy or clayey formations from the Early Eocene (55 Ma–49 Ma). The elevation of the study area declines gradually from 22 m above mean sea level in the western corner to 15 m in the eastern corner.

2.2. 1/20,000 soil map

The Belgian national soil survey was conducted between 1947 and 1973. It proceeded by taking soil auger observations, down to 1.25 m, at an average density of one observation per 0.7 to 1 ha. Within the study area this map indicated the presence of two soil series (see further Fig. 6b). Approximately two-third of the area belongs to series 'Ldc', which represents a sandy silt topsoil texture ('L') (according to Belgian soil textural triangle; Tavernier and Maréchal, 1962), moderately wet conditions (drainage class 'd') with a strongly degraded textural B-horizon (profile development type 'c'). The remaining part of the study area is characterized by the soil series 'Lcc', with a similar topsoil texture and profile development but with drier moisture conditions (drainage class 'c'). These soil types correspond to Albeluvisols according to the WRB classification system (FAO/ISRIC/ISSS, 1998). The Belgian soil map legend used a prefix to indicate the depth and nature of a shallow substratum observable within augering depth (a substratum represents a contrasting layer with a different texture). If a clayey substratum was encountered in the top 0.75 m, a prefix 'u' was added to the soil series. When this substratum was found between 0.75 and 1.25 m then the prefix was '(u)'. No prefix implicated that no substratum was observed within 1.25 m from the soil surface. The latter situation is the case in our study area, where according to the soil map there should be no substratum within the top 1.25 m (Fig. 2(a)).

2.3. 1/5000 soil map

Since our study area is a part of the experimental farm of the UGent, it was surveyed again in more detail in 1951. Therefore, an intensive survey was conducted with about 15 observations per ha, summing to approximately 210 augerings within the study area. This resulted in a choropleth soil map at a scale of 1/5000. For unclear reasons, the depth limits were slightly modified: 0.6 and 1.2 m instead

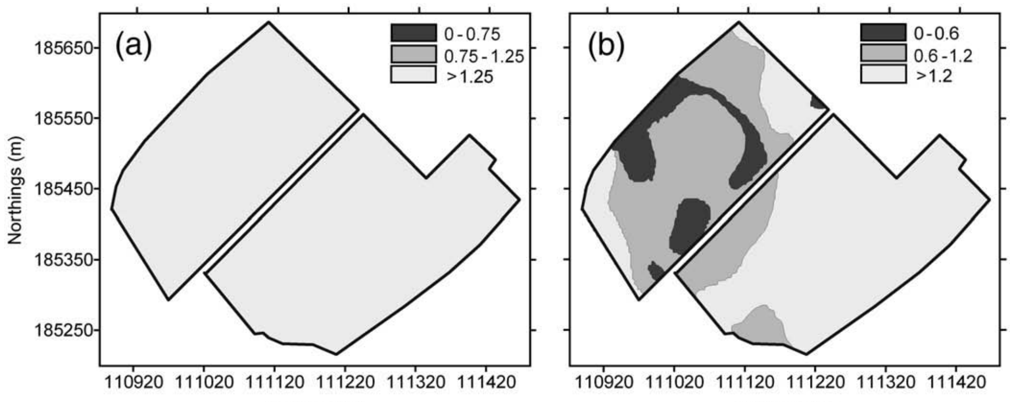

Fig. 2. Information about the depth to the clay substratum (D_{ts}) as provided by the two soil maps: (a) at a scale of 1/20,000 and (b) at a scale of 1/5000.