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A two-point method for determining the soil water characteristic of typical northern temperate boreal soils

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ABSTRACT

Data from Scottish soils were used to test a method to estimate the soil water characteristic from just two measured soil water retention points plus a measure of the water content at saturation. The method produced a good approximation of the measured soil water characteristic for the majority of the samples analysed ($R^2 = 0.947$; mean absolute error 0.019 $m^2\ m^{-2}$). However it was found that the method was not readily transferable to a group of soils that are very porous due to cryoturbation and have soil water characteristics not well approximated by a power function. It is concluded that the method has value in improving the cost effectiveness of obtaining soil water characteristic data. The assessments of the method, which now span a wide range of different soil materials, give sufficient indication of expected accuracy and precision to enable users to assess if the method is suitable for their particular applications.

1. Introduction

The soil water characteristic contains fundamental information on the condition and behaviour of soil but is time-consuming to measure. Researchers often seek to estimate the drained upper limit (field capacity) and the lower limit (wilting point) from laboratory measured soil water retention and therefore measure water content at just two matric potentials, −1.0 m (or −3.3 m, or −0.50 m), and −150 m. Cresswell and Paydar (1996) proposed a method of determining the soil water characteristic using two measured water retention points plus a measure of the water content at saturation (which can be estimated from bulk density) and demonstrated the accuracy of the method using a large set of Australian soils (Geeves et al.'s (1995) data set; mean R^2 of 0.959 and 0.970 for measured and predicted soil water retention data points for A horizon and B horizon samples respectively). The two-point method is not empirically based and should work consistently well across different soil water retention data sets providing that they are well described by the Campbell (1974) soil water characteristic equation. The transferability of the two-point method was tested on 144 soil horizons in France by Cresswell et al. (2006) who showed good soil water characteristic prediction (mean R^2 of 0.948).

The objective of this study was to apply the two-point method to soils from Scotland which contrast markedly to those used in previous testing of the method, including in clay percentage, bulk density and organic carbon content. The accuracy of the method is evaluated and limits to the transferability of the method discussed. Evaluations of the performance and transferability of methods to predict soil hydraulic properties contribute to the design of workable strategies for soil hydraulic characterization. Description of the functional attributes of our soils and landscapes will ultimately contribute to improved management of land and water resources.

2. Materials and methods

2.1. Scottish soil hydrological data

Mainland Scotland lies at a latitude of between approximately 55 and 59° north and between 2 and 6° west. It varies in altitude from sea level to 1344 m which means that the climate varies from temperate maritime, through boreal to subarctic. The soil hydrological data used in this study are a subset of the Scottish Soil Hydrological database held by the James Hutton Institute (formerly, the Macaulay Institute). The majority of the data were Stagnosols or stagnic Cambisols (IUSS Working Group WRB, 2007, 2010) developed on glacial lodgement till (Lilly, 1995, 1999) with some fragic Cambisols under grassland pastures. The soils from lowland sites in the Midland Valley and in the north-east of the mainland had a cultivated (anthric) topsoil with the land use varying from intensive arable agriculture to long term grass pastures. In addition, a number of samples were collected to characterise the hydrological properties of uncultivated upland mountain soils (Podzols and Umbrisols) with semi-natural vegetation. These soils are representative of around 15% of the land area above a latitude of 50° North (Jones et al., 2009) and were strongly influenced by freeze/thaw during the cold winter months. The distribution of sample sites and the topography of Scotland are shown in Fig. 1.

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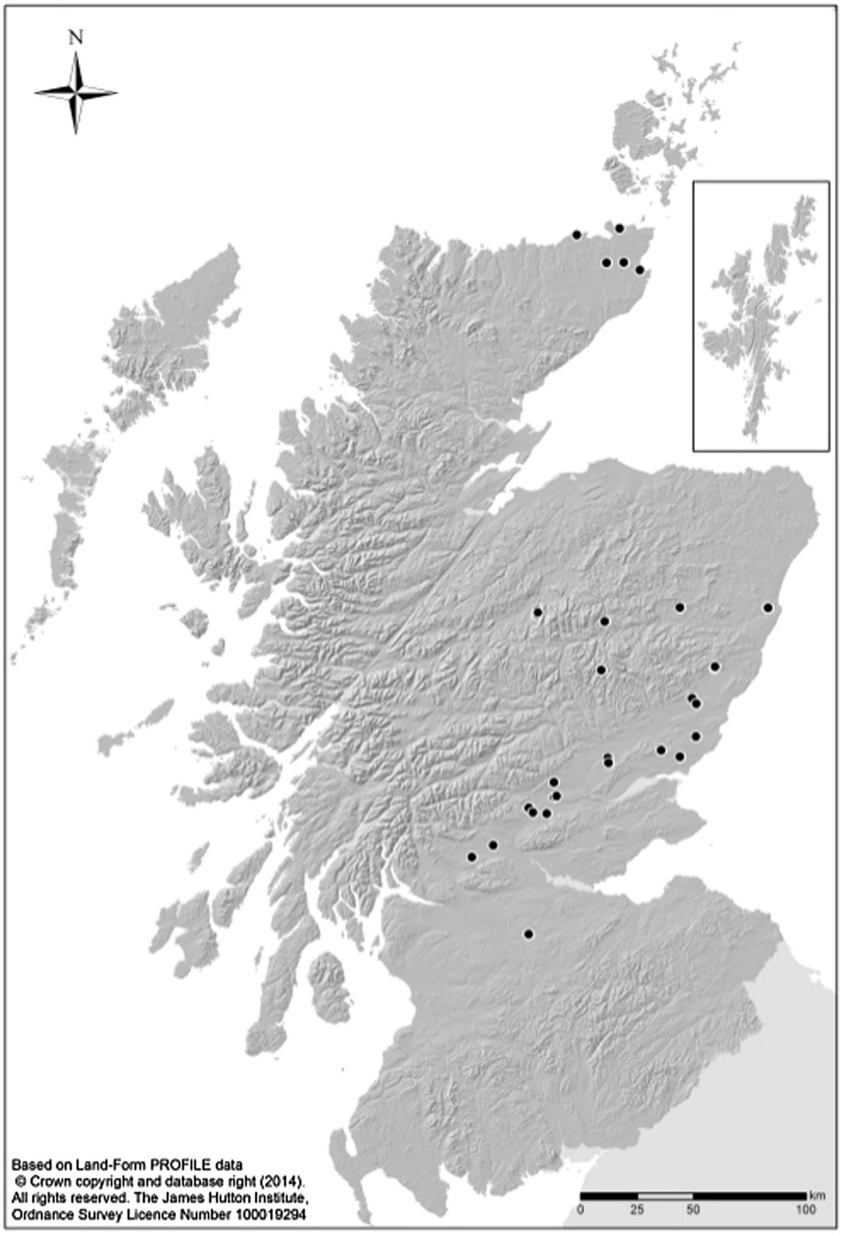

Fig. 1. Map of Scotland showing the distribution of the sites that were sampled.

The data are from 41 soil profiles of which 92 soil horizons met the selection criteria whereby the particle size distribution, organic carbon content and dry bulk density were measured, where there was a full monotonic water retention curve from saturation to −150 m matric potential and where the calculated porosity (from particle and bulk density) was greater than the measured saturated water content. Of the 92 soil horizons used in this study, 23 were cultivated topsoils (Ap), 49 were stagnic Bg or Cg horizons, and the remainder were fragic or cambic subsoil horizons or organic-rich A, E or podzolic B horizons from soils (Podzols and Umbrisols, IUSS Working Group WRB, 2010) that are subject to cryoturbation.

2.2. Measured soil properties and methods

2.2.1. Sampling methods

A soil profile pit was excavated at each site and the soil horizons were identified and described according to the Soil Survey of Scotland protocols (for example, Lilly et al., 2010). Core samples were collected from a horizontal plane exposed by excavating each horizon sequentially from the surface. Three stainless steel rings (5 cm high and 7.3 cm internal diameter giving a volume of approximately 210 cm^3) and three small rings of approximately 9.25 cm^3 (1.5 cm high and 2.8 cm diameter) were carefully carved into the soil from above. The cores were then excavated, trimmed and any projecting stones removed. Any resulting gaps were filled with soil packed to the same bulk density. The samples were sealed in plastic bags to prevent desiccation and then transported to the laboratory for determination of the soil moisture characteristic and bulk density.

2.2.2. Soil water retention

The soil water retention curve was determined by applying a series of known pressures to the saturated soil cores. Hanging water column methods were used to establish an equilibrium at −0.10, −0.50 and −1.0 m matric potential (some samples were also equilibrated at −1.50 m). Pressure plate apparatus was used to equilibrate soils at −5.0 and −20.0 m, while pressure membrane apparatus was used to establish the water retained at −150 m.