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From spatial-continuous electrical resistivity measurements to the soil hydraulic functioning at the field scale

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Abstract

The aim of this article is to present a strategy to interpret the hydraulic functioning of a small field area by using measurements of the soil electrical resistivity. The spatial soil electrical resistivity was recorded at a high resolution on a 2 ha area by the MultiContinous Electrical Profiling (MuCEP) device at two dates. These apparent electrical resistivity measurements were firstly interpreted in terms of local electrical resistivity by 1D inverse modelling to estimate the real resistivity of the soil. These interpreted electrical resistivity data were then transformed into soil water content values and soil water potential values by the use of independent punctual data of water content and the use of the water retention curve determined by laboratory data. Our analysis has permitted us to describe the spatial variability and temporal evolution of the hydraulic functioning at high resolution from electrical resistivity data. The interpretation of the water content and matric potential maps demonstrated that some soil hydraulic processes, such as lateral overland flow, can occur in the studied zone. They would never have been detected by local measurements of soil characteristics or by the use of the soil map. ***To cite this article: I. Cousin et al., C. R. Geoscience 341 (2009).***

Résumé

Depuis la mesure spatialisée en continu de la résistivité électrique du sol jusqu'au fonctionnement hydrodynamique in situ. Ces travaux ont pour objectif de proposer une stratégie permettant de discuter du fonctionnement hydrodynamique des sols à l'échelle parcellaire, à partir de mesures spatiales de la résistivité électrique. Celle-ci a été mesurée à deux dates, sur une parcelle de 2 ha, à l'aide du MultiContinous Electrical Profiling (MuCEP). Ces mesures électriques ont été analysées localement par un modèle 1D, de façon à estimer la résistivité vraie du sol, puis les données de résistivité vraie ont été interprétées en termes de teneur en eau et de potentiel matriciel, à l'aide de mesures ponctuelles de teneur en eau et de la courbe de rétention des sols étudiés, déterminée de façon indépendante au laboratoire. Cette analyse a permis de décrire la distribution spatiale et l'évolution temporelle de la teneur en eau du sol à haute résolution. L'interprétation des cartes de teneur en eau et de potentiel matriciel met en évidence certains processus hydrodynamiques, tels que des écoulements latéraux hypodermiques. Ceux-ci n'auraient pu être détectés par des mesures

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ponctuelles de teneur en eau et n'auraient pu être inférés à partir de la carte des sols de la parcelle. ***Pour citer cet article : I. Cousin et al., C. R. Geoscience 341 (2009).***

Keywords: Digital soil functioning mapping; Field scale; Soil water content; Soil water potential; DC geophysical method

Mots clés : Cartographie numérique de fonctionnement du sol ; Étude in situ ; Teneur en eau du sol ; Potentiel en eau du sol ; Méthode géophysique en courant continu

1. Introduction

In the context of precision agriculture, the understanding of the soil hydraulic functioning at a high spatial resolution is required to adapt the water supplies to plant demand, whatever its position in the field. To describe the spatial hydraulic functioning, one can analyse the temporal evolution of the spatial distribution of the water content, or, better, of the water potential. The initial problem is then to provide a way of producing a map of the water content.

One way is to use point measurements of the water content, which are then interpolated. The quality of the estimated map depends on the sampling density of the water content measurements. Usually, the latter are scarce because they are destructive and time-consuming.

A second way is to use ancillary data to provide information on the soil properties. Such data include yield from yield monitors, digital information from aerial photographs, electromagnetic induction data, elevation, and so on [3–5,7,17,18,23,24]. They are usually more intensive, and less expensive to obtain than the soil properties. Among these ancillary data, we focus here on the measurements from electrical resistivity sensors whose use is becoming more widespread in surveys for land management. The apparent electrical resistivity of the soil is related to several soil physical properties, and especially the moisture content: a wetter soil is more electrically conductive than a drier soil [11,16]. Previous studies have shown the value of using the electrical resistivity to assess the soil water content [6,21]. Thanks to the MultiContinuous Electrical Profiling (MuCEP) device, exhaustive spatial measurements of the electrical resistivity can be recorded with a high resolution [8]. A map of the electrical resistivity can then be used as an external drift in the kriging procedure to map water content from punctual measurements. Bourennane et al. [6] showed that the estimated map of water content is of better quality than the one produced without the use of the electrical resistivity.

A third way to analyse the spatial hydraulic functioning of soil is to describe the temporal variability of the electrical resistivity between several maps taken at different dates. If the maps have been corrected for the effects of temperature – which strongly influences the electrical resistivity measurements – the differences between these maps can only result from the evolution of the water content, once we have checked that the composition of the soil solution is not a first-order parameter that influences the electrical resistivity. Using this procedure, Besson et al. [2] showed that the temporal evolution of the water content at the field scale can be predicted by analysing the temporal evolution of electrical resistivity data.

A fourth way to use the information on water content included in the electrical resistivity signal, would be to interpret the apparent resistivity data into real resistivity data and to determine the water content by using a model of the relationship between the real resistivity and the water content. The latter could then be interpreted in terms of matric potential if we know the water retention curve of the studied soil horizon. This paper aims at testing this method of providing maps of the soil water content and soil matric potential by using scarce measurements of the water content and maps of the apparent electrical resistivity.

2. Material and methods

2.1. General outline of the study

From the spatial electrical resistivity measurements to the spatial estimation of the water potential, our study consisted of four steps (Fig. 1):

1. the apparent electrical resistivity was measured at three pseudo-depths by the MuCEP device at the field scale at two dates during the year 2006 (see section 2.3);
2. the apparent resistivity data were modelled by 1D inverse modelling to produce a true resistivity map that represents the spatial distribution of the resistivity of a specific soil layer (see section 2.4). The interpreted resistivity data were then corrected for the temperature effect by the Keller and Frischknecht equation [12], so that the resistivity