Gamma and Electro Magnetics: a multi-sensor approach for the mapping of water related soil properties

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Abstract

For the mapping of subsoil water related soil properties a multi-sensor approach was chosen in order to obtain high resolution input for a decision support system. The gamma ray sensor the Mole was applied for top soil mapping, an EM38 for the mapping of soil profiles. Calibration of both sensor system for the different soil layers went well in practice. Statistical analysis shows that both sensors provide independent data from top soil and subsoil. It is concluded that a multi-sensor approach is appropriate with soil conditions as described.

Keywords: gamma ray, EM38, multi-sensor approach, soil mapping.

Introduction

In 2008 and 2009 two water related sensor projects were set up in the north-eastern part of the Netherlands. In these projects the local water board

High resolution digital water related soil maps of the top soil and subsoil were required as input for the water models in the DSS. This was a novel approach, as the water board tends to focus on water in the substrata. The soil maps were used to pinpoint appropriate locations for the water probes. In this study 15 fields are selected for analysis.

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he top soil differs significantly from the subsoil in most cases, with parent material starting at 30 to 80 centimetres. Within the top soil the organic matter content can vary significantly over short distance. The gamma ray soil sensor the Mole was applied for the quantitative mapping of the top soil (Egmond et al, 2008) and the EM38 for the qualitative mapping of the subsoil soil profiles (Geonics). In a number of surveys both sensors were conducted in one run, both attached to the same vehicle as depicted below.

Figure 1. The gamma ray sensor the Mole in the lift of the tractor and the EM38 towed at the same time.

In other cases the survey of the EM and gamma ray sensor was done in two separate runs. The sensors were moved with a speed of approximately 6 km/hr at tram lines of 15 meter. Data was logged every second, resulting in dense coverage of the fields. In addition, in all fields the compaction was mapped with a penetrometer in a 20 meter grid.

In each field 4 to 6 samples were taken from the top soil for calibration purposes of the gamma ray data. The soil properties organic matter, clay content (2 µm), loam content (50 µm) and grain size M50 were modelled by multi linear regression. This was done on a field scale or on a regional scale for similar soil types (Loonstra, 2008). The resulting soil maps were input for the mapping of continuous pedotransfer functions for water retention, field capacity and hydraulic saturated capacity (Wösten et al, 2001). For the calibration of the EM data, management zones were identified based on comparison of the collected EM38 and gamma ray data, and consequently soil profile samples were taken and described for each significant zone. The standard Dutch soil classification method (Stiboka) was applied for describing the soil profile characteristics. Examples of the soil maps are depicted below.

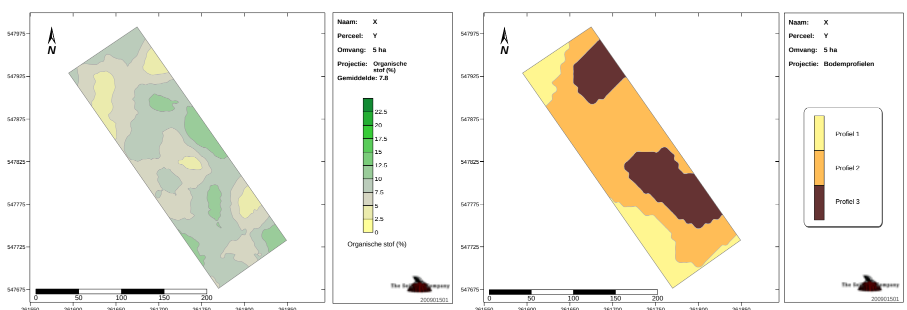

Figure 2. Organic matter content map of top soil and soil profile map of subsoil.

Results

The outcome of the soil samples of the 15 fields confirmed the expected variance of soil properties. The organic matter content is the property that differs greatly, also within fields, followed by variance in loam content. Grain size and clay content show little variation.

Table 1. Variance of top soil properties

	Organic matter	pH	clay	loam	Grain size
Minimum	3.7%	4.0	1.6%	6.5%	116 µm
Maximum	40.6%	5.6	8.0%	27.8%	144 µm
Average	12,2%	4.9	3.1%	12.8%	127 µm

The correlation of the top soil properties with the gamma ray nuclides can be qualified as good, with an R^2 ranging between 0.7 and 0.9.

Table 2. Calibration models for top soil properties with radioactive nuclides

Soil property	Main nuclides	General model
Organic matter	^{137}Cs, ^{40}K	OM = a + b x Cs – c x K
pH	^{238}U	pH = a + b x U
Clay content	^{232}Th	Clay = a + b x Th
Loam content	^{232}Th, ^{238}U	Loam = a + b x (Th + U)

The calibration of EM data for soil profiles was done on a field scale. Again, 4 to 6 sample locations were identified, where soil profiles were described. In most cases it was possible to identify differences in soil type and layer thickness in line with the observed EM zones. However, as the final soil profile map is qualitative by nature the within-field boundaries remain arbitrary.

The suitability of the multi-sensor approach was analysed by comparison of the raw data of both sensors. The correlation between the radioactive elements and the EM38 data was examined for the 15 fields. No significant correlation was found between the output of both sensors for any of the fields. An overview of the outcome of the analysis is shown in the table below.

Table 3. Regression coefficient of Mole radioactive nuclides and EM38 data

R^2	^{40}K-EM	^{238}U-EM	^{232}Th-EM	^{137}Cs-EM	Total Counts-EM
Minimum	0.001	0.000	0.000	0.000	0.000
Maximum	0.158	0.230	0.169	0.163	0.314
Average	0.035	0.045	0.023	0.030	0.073

The final high resolution water related soil maps of both sensors were constructed with a 5 meter grid size. This meets the needs of the water models that are based on 20 meter grid data or larger. The level of detail of the soil maps was also suitable for the models. The presented classes were finer compared to the classes used in the water models.

This study shows that a multi-sensor approach can be useful in mapping soil properties for the complete subsoil. Under the described circumstances where top soil differs in composition from the subsoil, gamma ray sensors and EM sensors will provide differentiated sets of data that can be calibrated individually for the purpose of soil mapping. Calibration of gamma ray nuclides can be performed on a field for chemical properties and on a regional scale for physical soil properties from the same soil type. The calibration of EM data with soil properties was conducted on a field scale, although it is believed that a regional approach could have been applicable as well. The high resolution soil maps from both sensors have sufficient detail to serve as input for the water models in the DSS.

References

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