Validating a new in-situ soil bulk density sensor

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Background

Soil bulk density is gaining in importance as soil parameter. For soil compaction, water infiltration, retention and rootability properties related to food production and climate change adaptation, but also as input to soil carbon content calculations and pedotransfer functions. The standard measurement of soil bulk density with rings is labour intensive and therefore expensive; existing sensor approaches require extraction of the soil core and are not widely used. As a possible solution to this challenge to measure bulk density in situ, a sensor is developed that measures the soil bulk density of a full soil profile.

Objectives

- Validate the soil bulk density sensor measurements for field and dry soil bulk density and moisture measurements, derive accuracy.
- Test performance on other soil types.

Methods

After a first validation study over a limited soil bulk density range in different soil types in the Netherlands with promising results (good accuracy, but with low precision) a validation study on one field with a clay (29%) on sand profile is set up with 9 soil pits, 3 profiles per pit. Per profile a 100 cc ring is taken every 10 cm up to 60 cm and a sensor profile is measured. Rings are weighed first, then dried for dry bulk density and moisture contents in the lab. The sensor provides field and dry bulk density measurements every 5 cm.

Results

Results are displayed in table 1, figure 1, 2, 4. Data is corrected for an observed 1.1 offset factor. Further research needs to show if this is field, soil type or sensor specific. Mechanical outliers in the rings were removed, for the sensor data this was not possible.

Table 1. Reported metrics of sensor and rings

Measurement	Avg. Stdev per measurement	RMSE ct rings	R^2
Rings	0.06		
MS-RhoC4 Dry bulk density (mean)	0.10	0.13	0.75
MS-RhoC4 Field bulk density (mean)	0.13	0.10	0.73

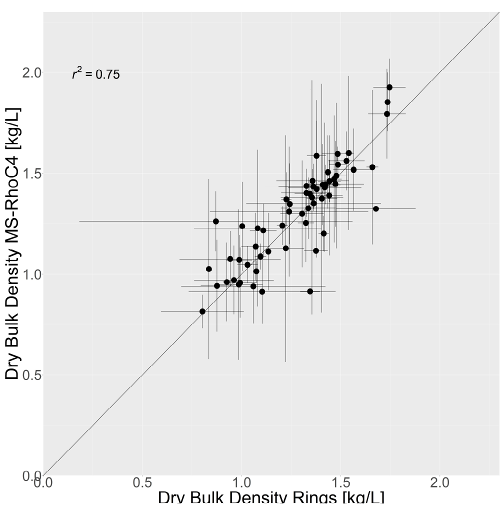

Figure 1. Dry bulk density averages per depth per location of sensor and ring (reference) data. Error bars are 2 times the standard deviation.

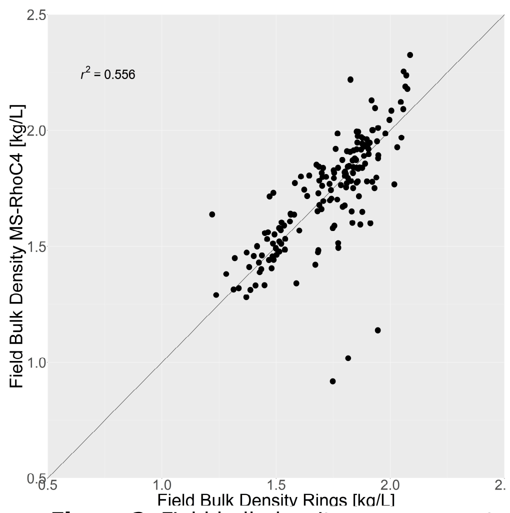

Figure 2. Field bulk density measurements with sensor and rings, not averaged per depth

Sensor

The MS-RhoC4 is designed for easy operation in the field and measures the backscatter of gamma radiation to get a measure of mass in a known volume. The sensor can measure up to 100 cm deep at any depth, creating a soil bulk density profile measurement. It needs a hole of 30 mm diameter by a hand auger. The sensor is placed in the hole up to the preferred depth. A measurement is started from the app, and within 30 seconds, an accuracy of ~0.01g/cm3 can be achieved and the result is displayed immediately. A shorter measurement period is possible, but will result in a lower accuracy. For correction to dry bulk density values, a model is used that incorporates moisture measurements from an internal capacitance-based moisture sensor. For each measurement location, the position is stored automatically using the GPS of the phone or tablet. Typically a full profile measurement takes 15 minutes to complete, allowing the soil scientist to gather more information in the vertical, as well as the horizontal scale.

Figure 3. Picture of the MS-RhoC4 bulk density sensor

Next steps

Measurements have been performed on the other soil types of the Netherlands (figure 5). Data analysis is ongoing. This will indicate correspondence and accuracy on other soil types and shows if soil specific corrections are needed for this sensor.

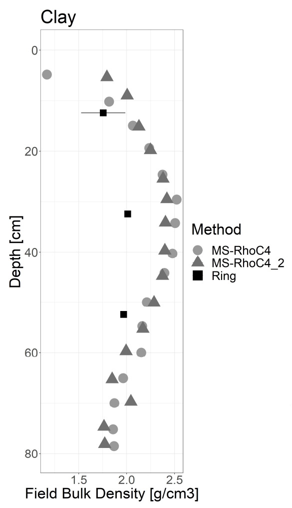

Figure 4. Field bulk density profile measurements

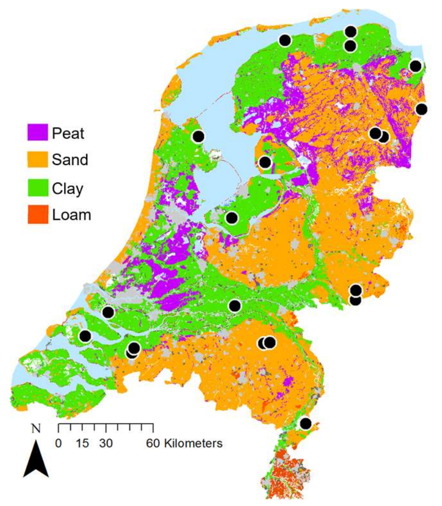

Figure 5. Measurements performed on other soil types of the Netherlands

Conclusions

- Validation results of the MS-RhoC4 soil bulk density sensor on one field show that measurements correspond well with the reference ring method with accuracies of RMSE 0.13 and 0.10 g/cm³ for dry and field bulk density values compared to rings.
- The results show a slightly lower precision than rings (0.10-0.13 compared to 0.06 g/cm³).
- A soil bulk density sensor as the MS-RhoC4 is able to provide an accurate and useable profile measure of soil bulk density directly in field, providing more insight in changes in depth in less time than the traditional method.

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