Validation of a new soil bulk density sensor

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Bulk density is key to

- Assess soil compaction and its effects on soil health
- Understand soil water infiltration and retention characteristics
- Assess and calculate soil (organic) carbon stocks

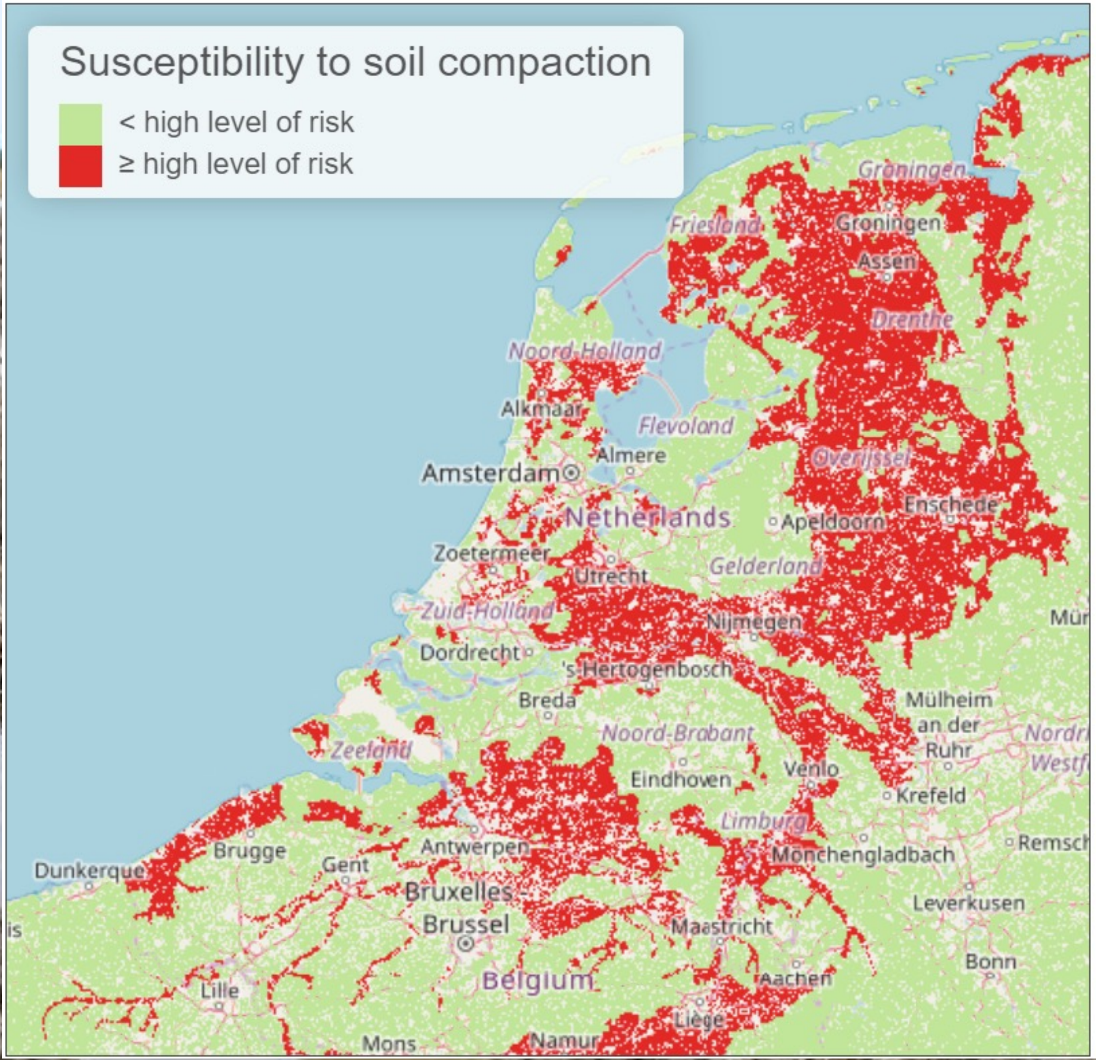
concentration x mass/volume (g/kg) = content

↓

bulk density

Causes of subsoil compaction

High risk for subsoil compaction in the Netherlands.



EU Soil Observatory,
https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/

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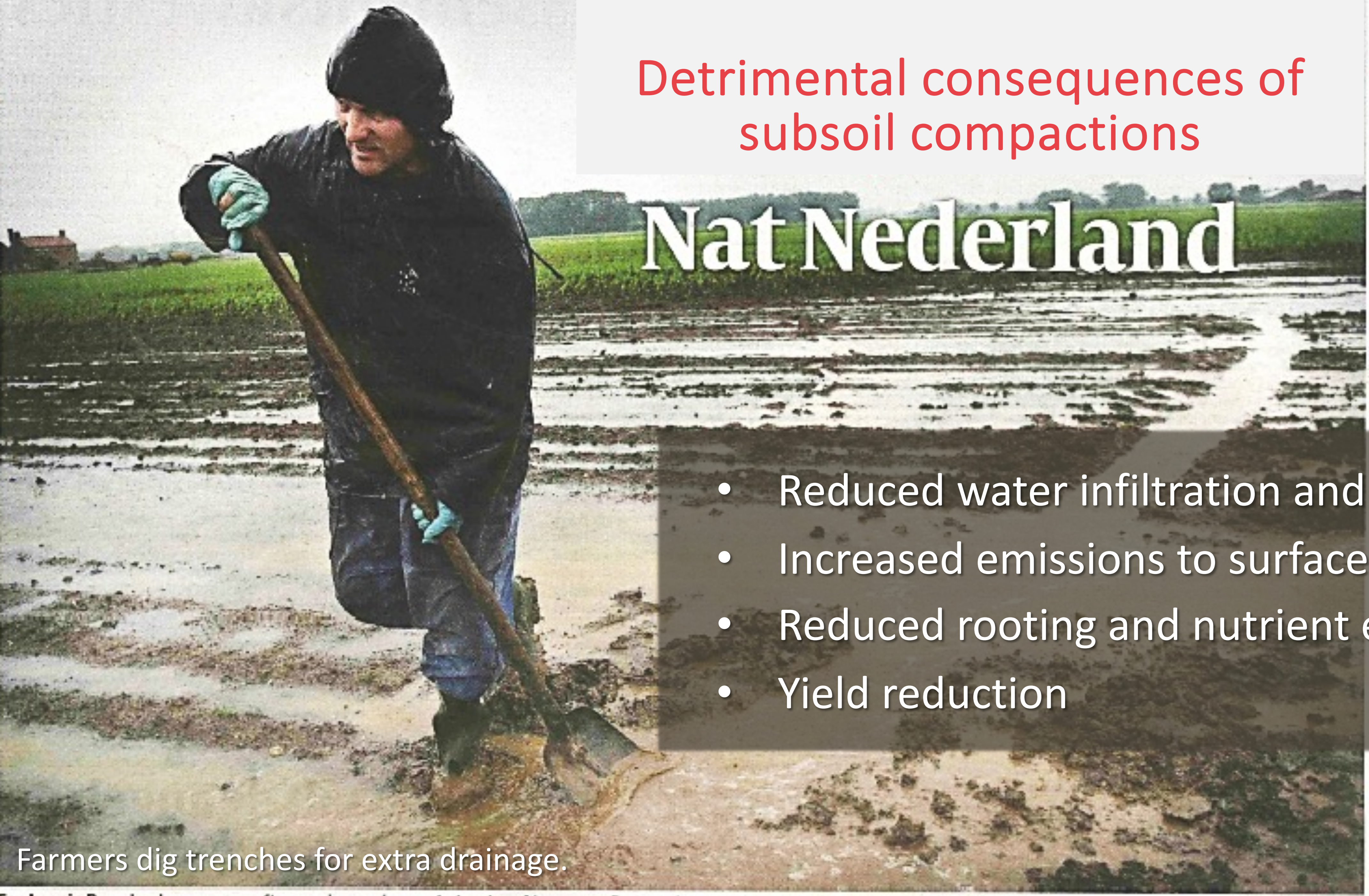
Detrimental consequences of subsoil compactions



- Reduced water infiltration and retention
- Increased emissions to surface water
- Reduced rooting and nutrient efficiency
- Yield reduction

Farmers dig trenches for extra drainage.

Een boer in Beneden-Leeuwen graaft maandag geulen om het water af te voeren. De grond waarop hij staat is al verloren gegaan. Foto Marcel van den Bergh / de Volkskrant

Awareness is essential for changes in soil management

Impediments to changes:

- Farmers are often unaware of the compaction in their fields
- Gradual build-up of compaction over the years
- Flooding after rainfall and reduced crop development are *non*-specific indicators

Therefore, it is important to measure subsoil compaction, but is not easy to quantify.

Conventional methods for diagnosing subsoil compaction

- Profile pit assessment:
  - Visual estimate
  - Qualitative, subjective
- Penetrometer:
  - Penetration resistance
  - Highly moisture dependent
- Kopecky rings:
  - Dry bulk density
  - Labour intensive, lab facility, time consuming (up to 5 h/profile)

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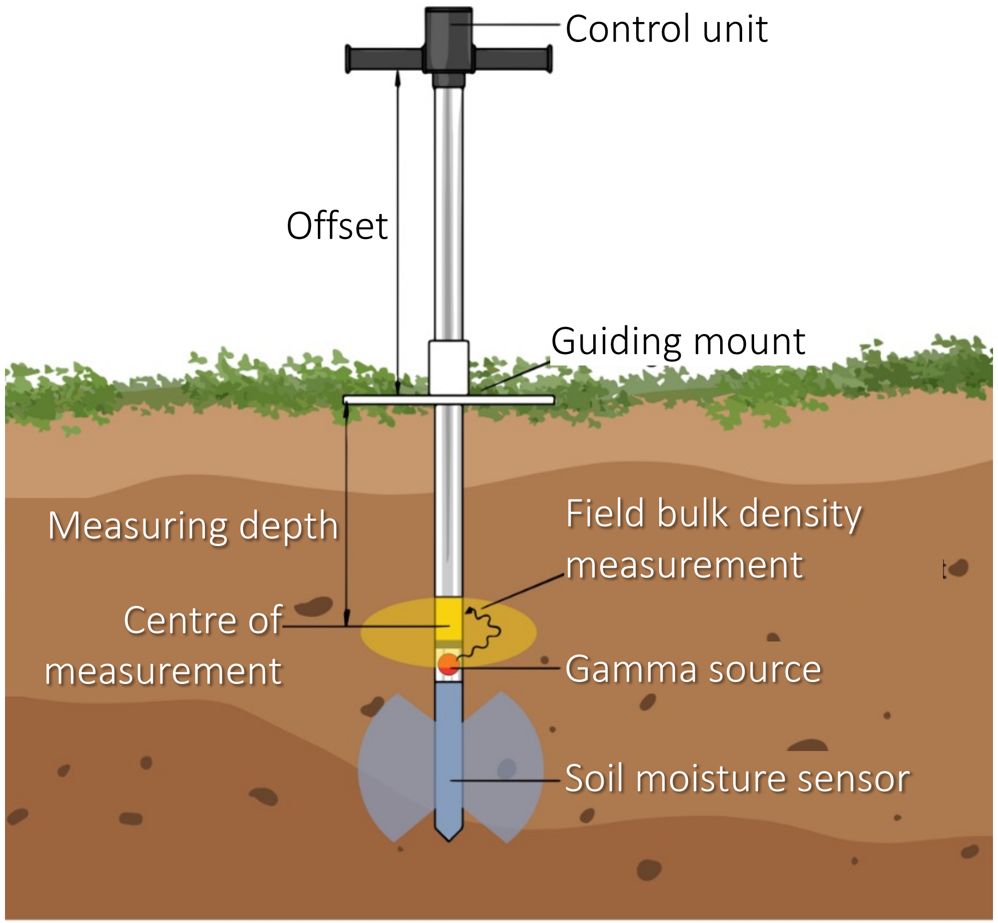
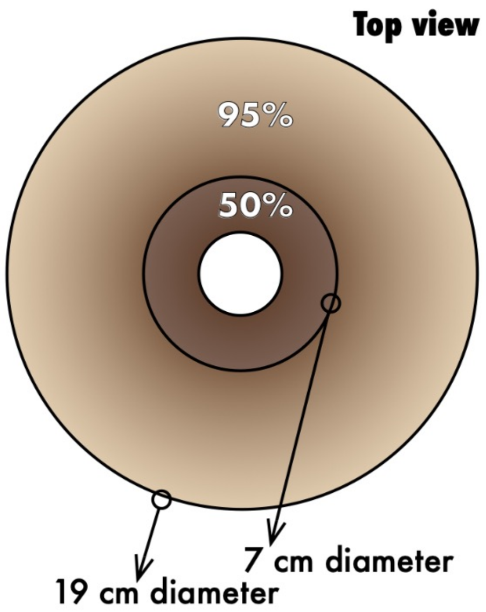
RhoC-sensor for *in situ* dry bulk density measurements

- ➢ Dry bulk density profile 0-100 cm deep in less than 10 minutes





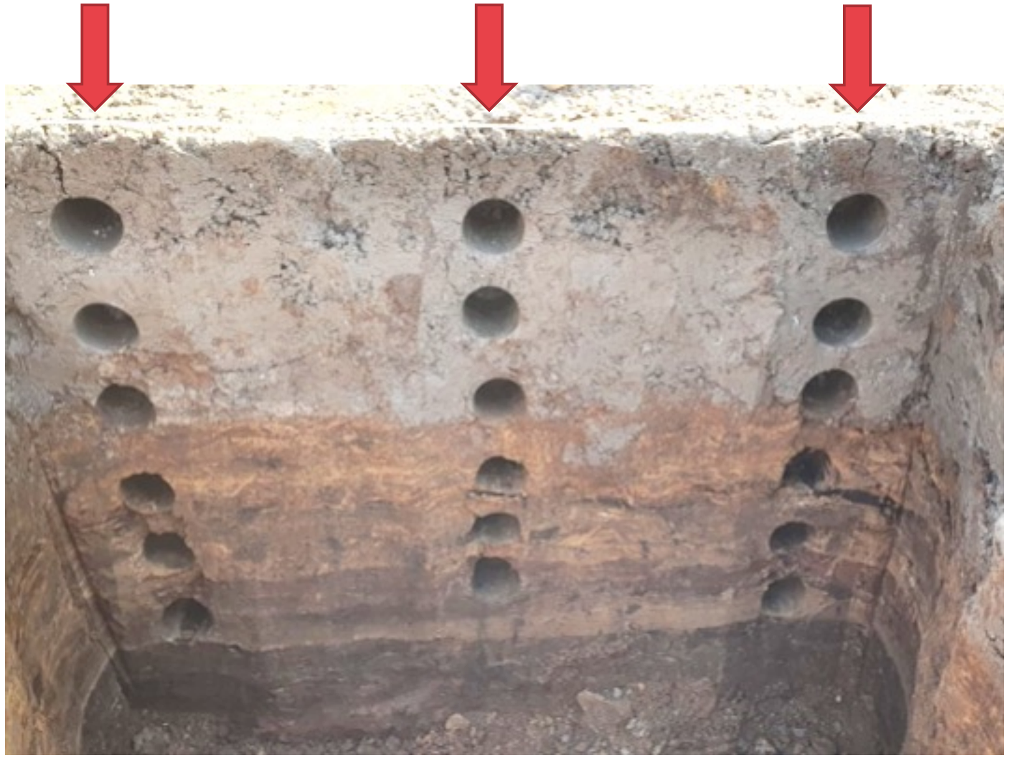
- ➢ Validation in two soil types: loam and sand

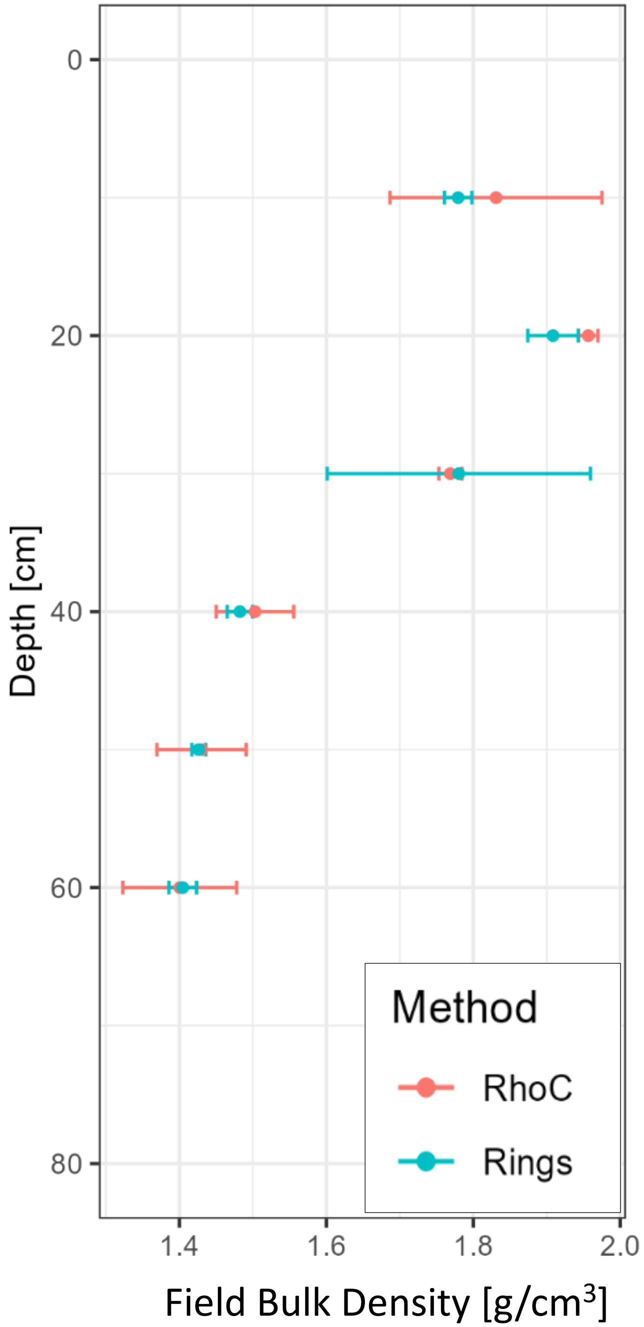
RhoC-sensor for *in situ* dry bulk density measurements

Measurement / sampling:

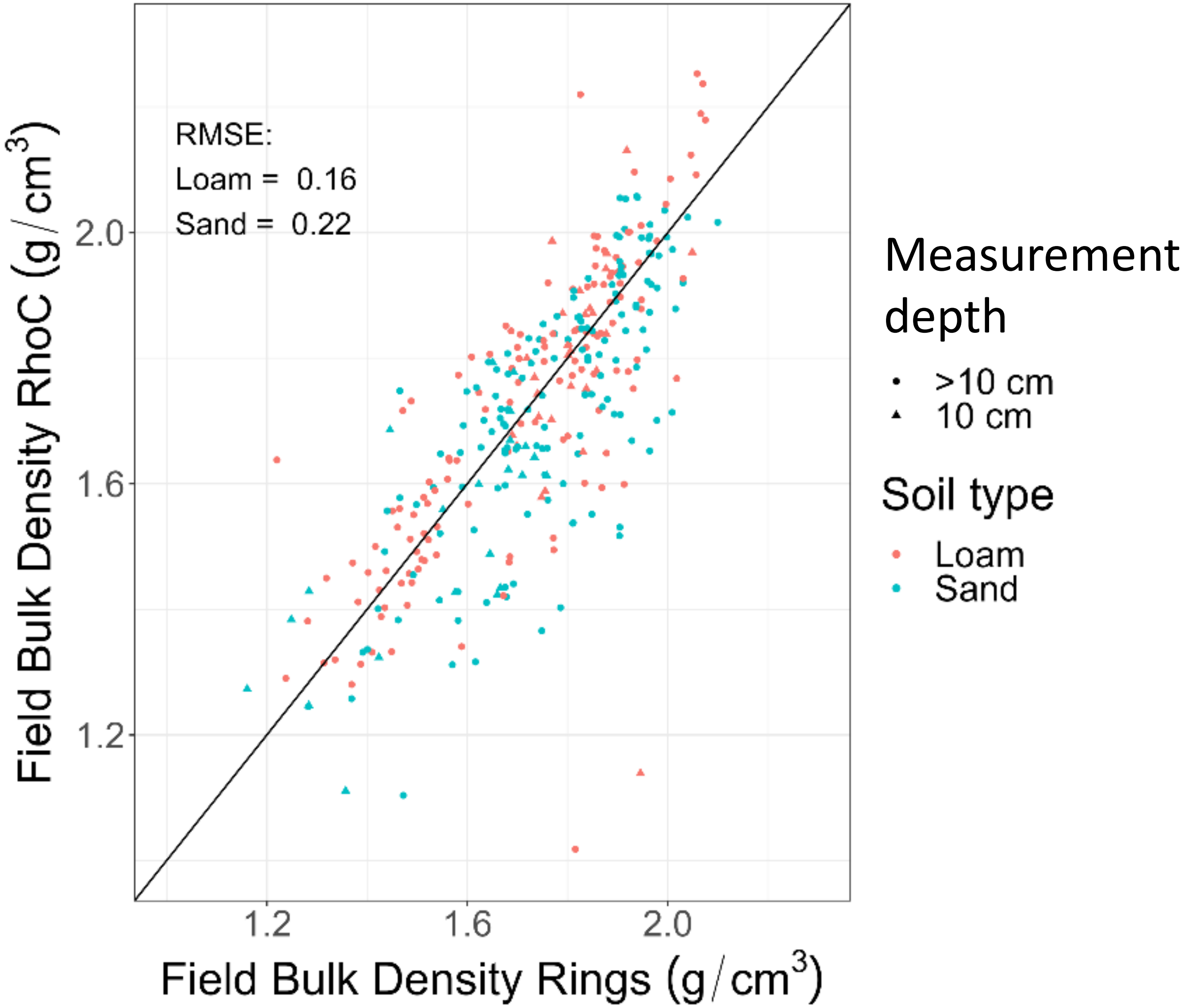
- 2 fields: loam and sand
- 10 soil pits per field
- Per 10 cm soil layer:
  - 3 x RhoC-sensor
  - 3 x Kopecky rings

RhoC-sensor measurement locations





Field bulk density correlation

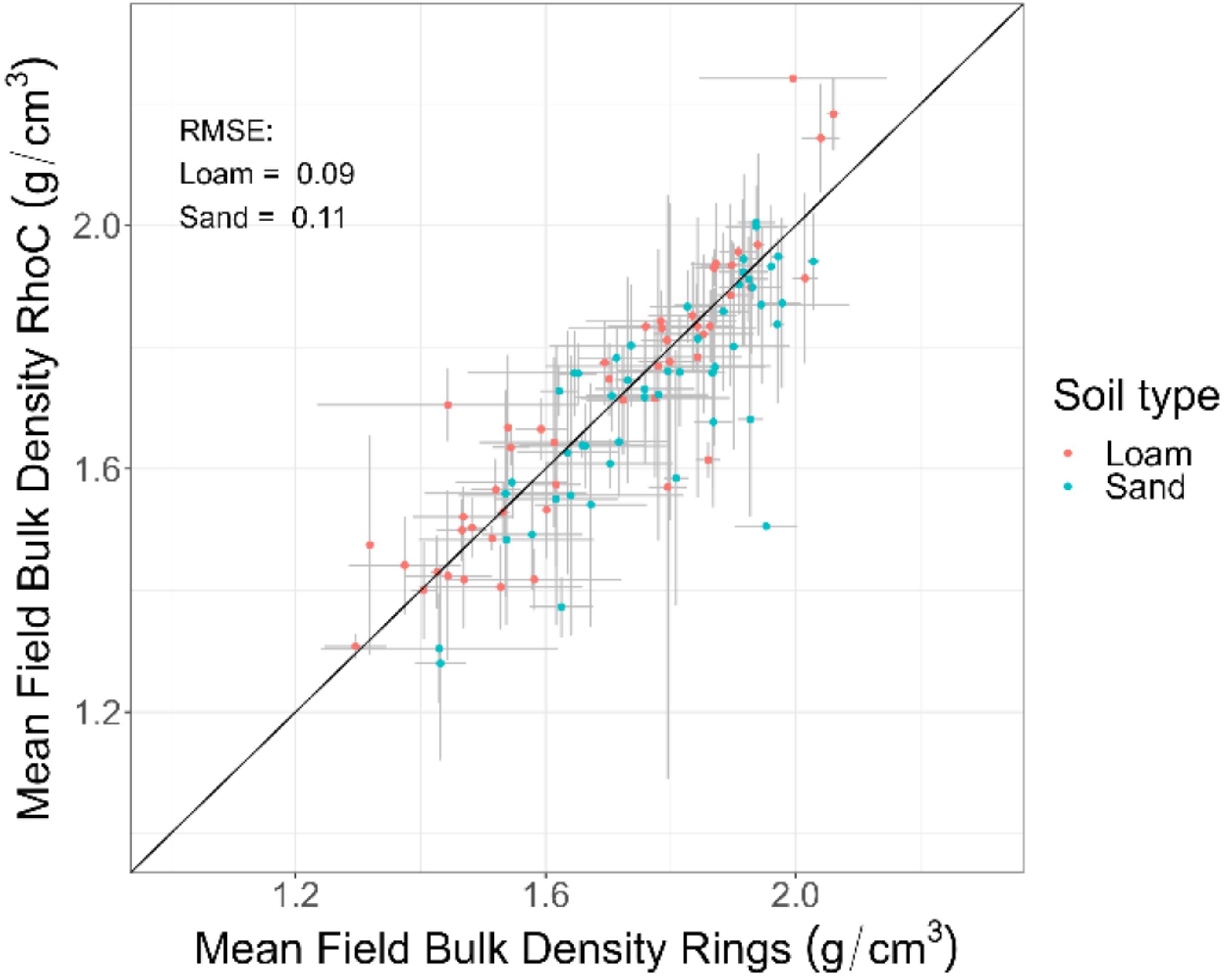


- Outliers are mainly measurements of 0-10 cm depth.

  This is probably due to very loosely packed soil.

  These data are excluded in the correlation analyses.

Mean field bulk density



- Strong correlation for both soil types.
- Error bars in two directions
- Errors reflect soil heterogenity between the 3 profiles + uncertainty in measuring methods

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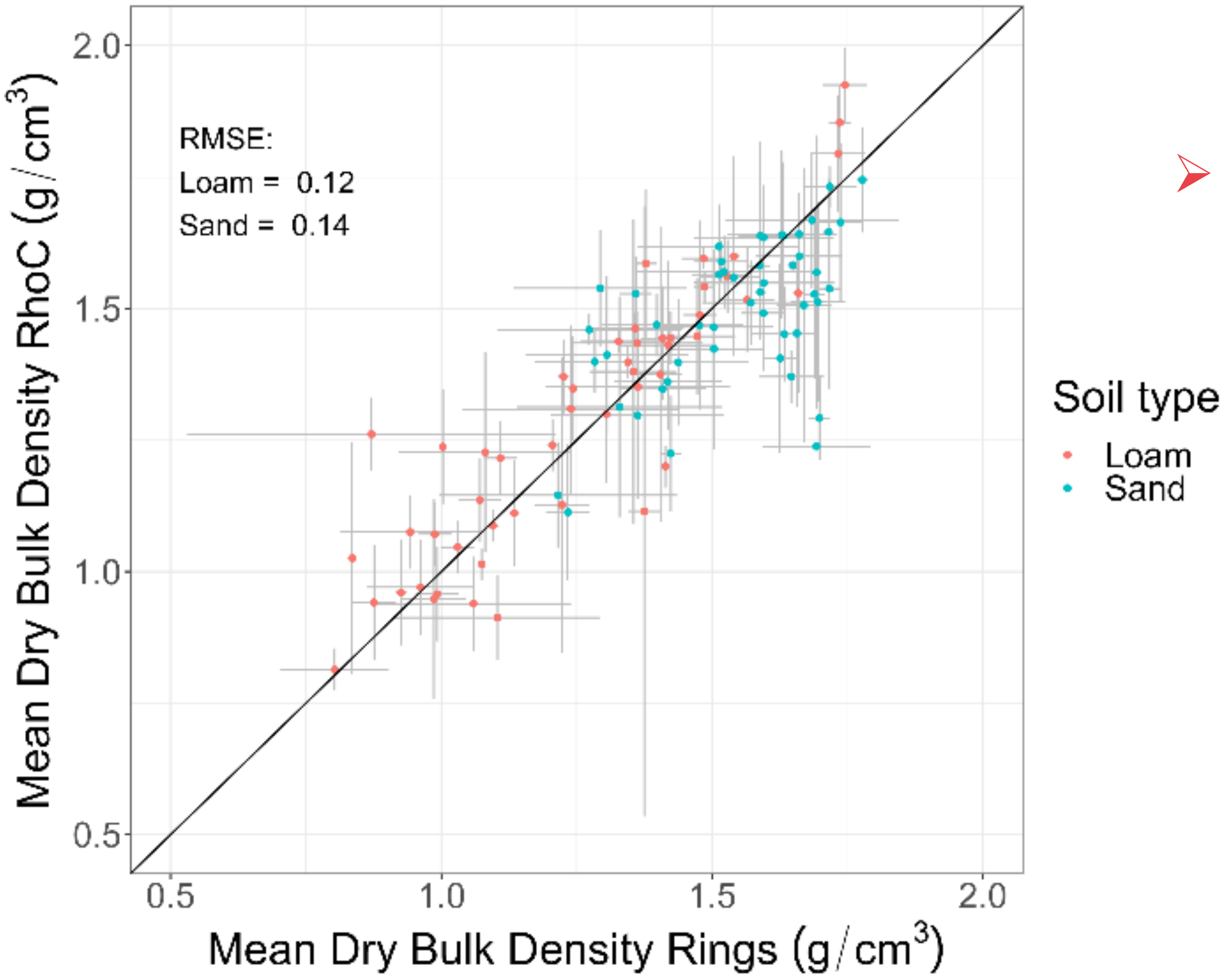
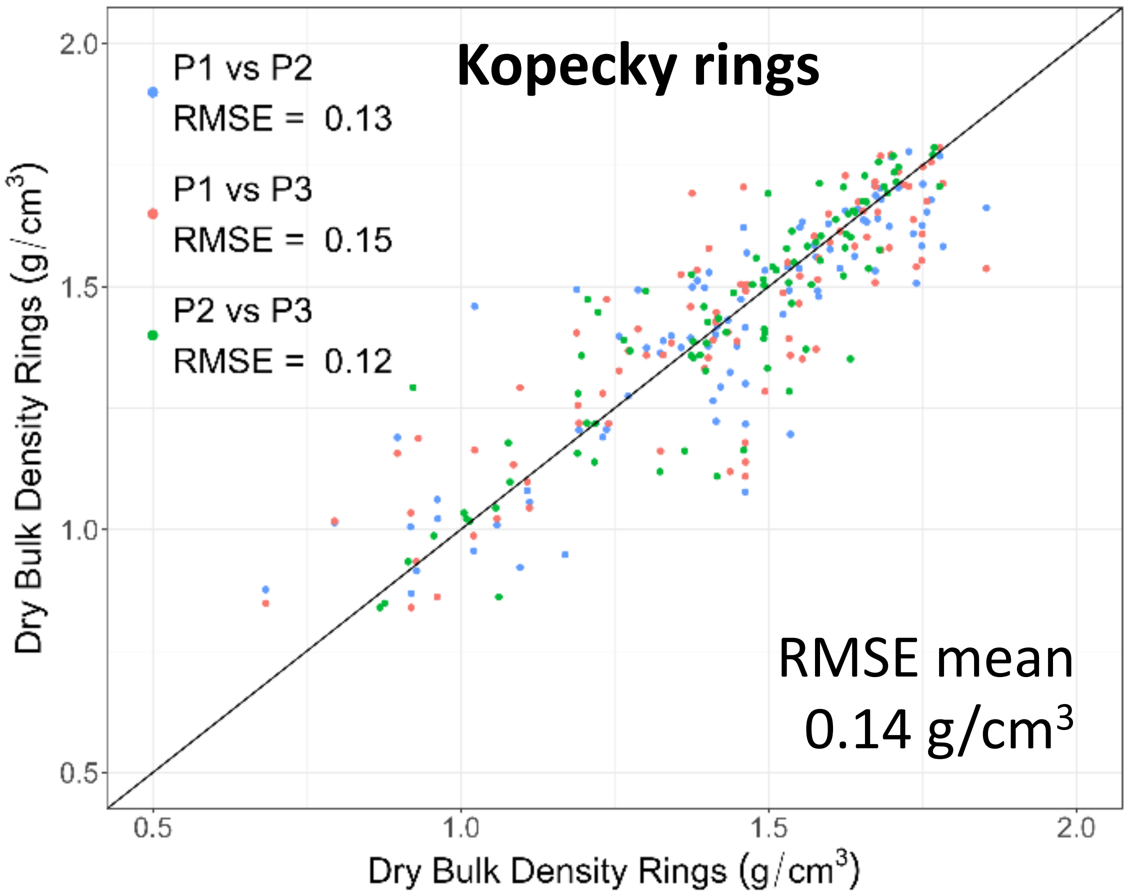
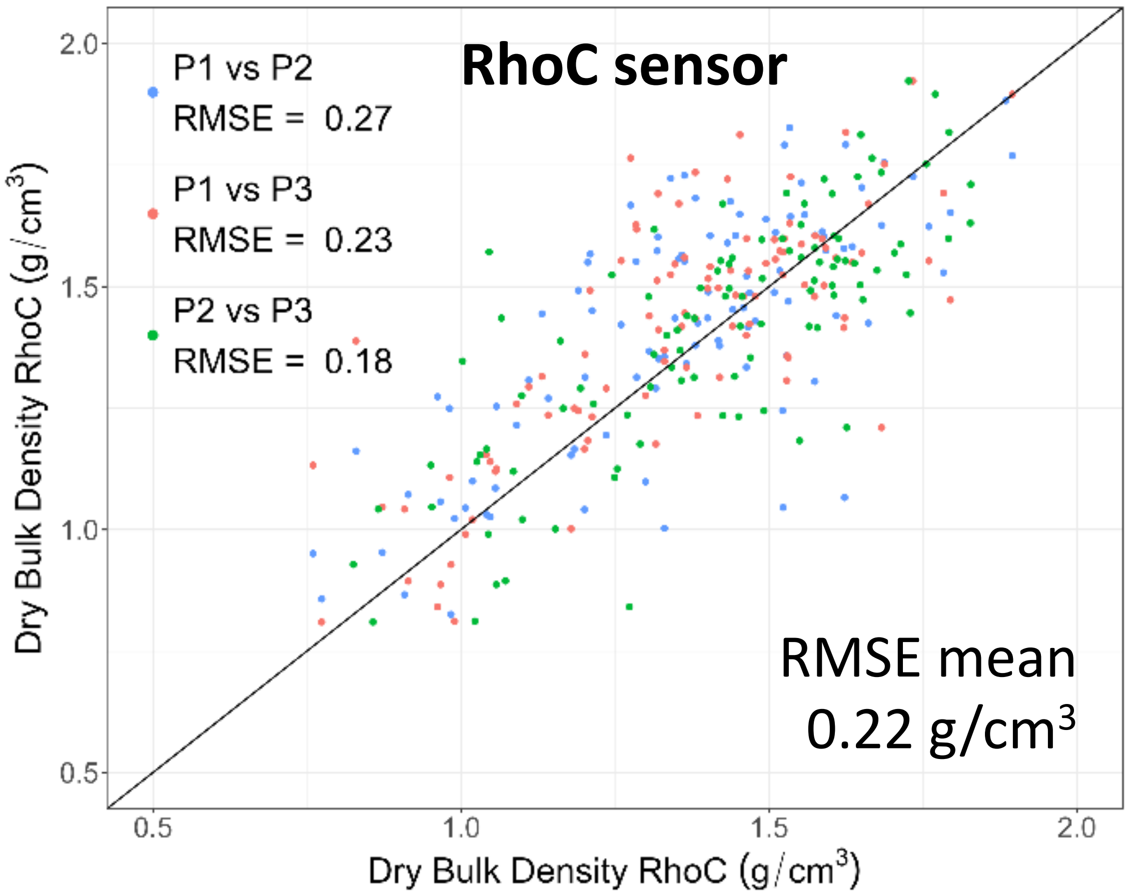
Mean *dry* bulk density correlation



- After correction for water content still strong correlation

Correlation analyses Kopecky ring method and RhoC method





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Conclusions

- Validation results show good correlation between RhoC sensor and the reference ring method for dry soil bulk density measurements.

Method	Average RMSE bulk density	Relative uncertainty	Measurement time	
			per location	per sample
Kopecky rings	0.14 g/cm^3	9%	~ 5 hours (incl. digging and lab)	~ 1 hour (incl. digging and lab)
RhoC sensor	0.22 g/cm^3	15%	< 10 minutes	< 3 minutes

- This provides the much-needed possibility for large scale assessment of soil bulk density in relation to soil health, water management, carbon stock calculations and crop production.

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