Assessment of modelling approaches for soil compaction risk based on wheeling experiments

Julius J. Weimper[1], Raimund Schneider[1], Judith Koschorke[2], Lukas Wald[3], Matthias Trapp[4], Markus Casper[5] and Christoph Emmerling[1]

[1]Department of Soil Science, Trier University, Trier, Germany (weimper@uni-trier.de); [2]Soil Science and Geomorphology, Eberhard Karls University, Tübingen, Germany; [3]Dienstleistungszentrum Ländlicher Raum Bad Kreuznach, Germany; [4]RLP Agroscience GmbH, Neustadt an der Weinstraße, Germany; [5]Department of Physical Geography, Trier University, Trier, Germany

EGU22-7914, EGU General Assembly 2022, Session SSS6.6 „Soil structure, its dynamics and its relevance to soil functions“

Introduction

Main strategies to avoid compaction risks in agricultural practice

- Avoiding field traffic on soils with high soil moisture
- Adapting machinery to current compaction susceptibility

Objective: Finding suitable modelling approach for decision support system

Further goal of SoFI-project: Web-based application for farmers

Model selection

Pre-selection from published approaches

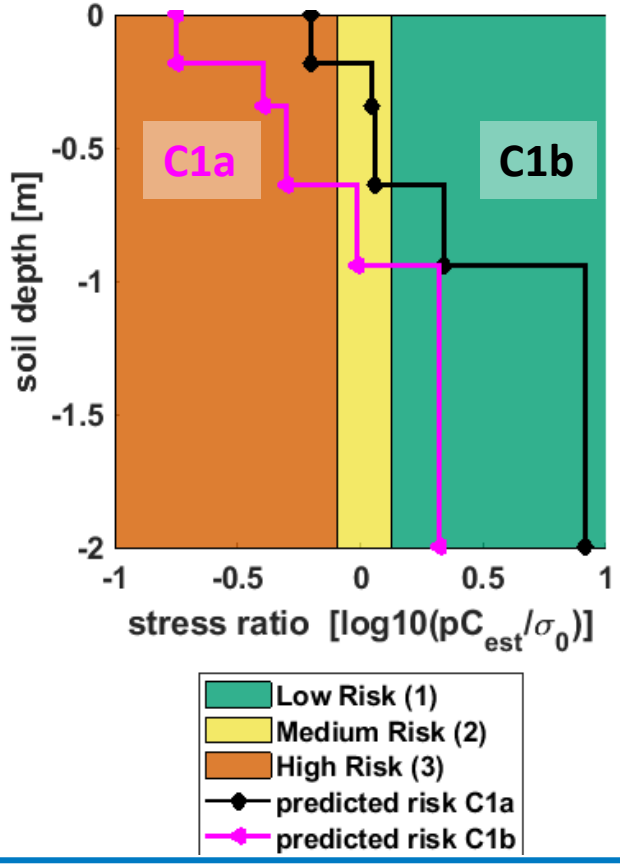
- **Semi-physical approach: Model C1a and Model C1b**
  - Modelled precompression stress versus analytically calculated stress in soil
  - C1a and C1b mainly differ in the calculation methods
    - Model C1a: Uniform stress distribution and transmission
      (Horn & Fleige, 2003)
    - Model C1b: Distributed stress distribution and transmission
      (Keller et al., 2007)
- **Conceptual approach: Model C2**
  - Classes for compaction susceptibility and stress by machinery
  - Decision-matrix for risk classification
    (Lorenz et al., 2016; Ledermüller et al., 2018)

Wheeling experiments

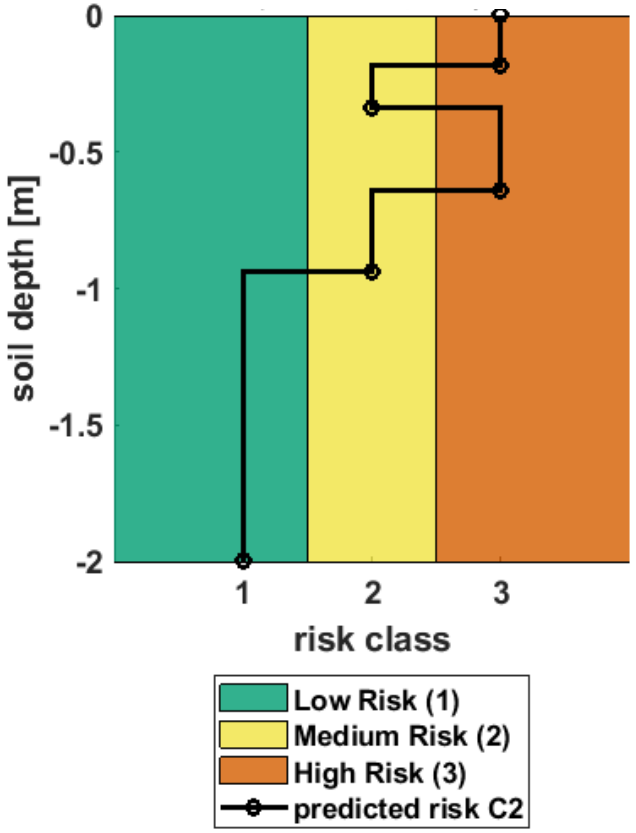
	E1 Sponheim 2019	E2 Sponheim 2021	E3 Trier 2020
Texture	**Sandy loam**	**Sandy loam**	**Clayey loam**
Soil moisture (% field capacity)	**91**	**84**	**93**
Max. wheel load (tons)	**3.63**	**7.34**	**3.20**
Max. inflation pressure (bar)	**1.2**	**4.0**	**1.2**

Exemplary modelling results

Semi-physical: Models C1a and C1b



Conceptual Model C2



Example: Results for E2

Application of all models to

- All experiments
- All sampled depths

Validation of risk-classes

Thresholds for soil physical parameters

- Air capacity < 5 v%/< 8 v% (topsoil)
- Saturated water conductivity < 10 cm/d
- Air permeability < 10 µm^2

Risk classes derived from measurements

No parameter : Class 1
1 parameter : Class 2
2 or 3 parameters: Class 3

Model-predicted risk classes

Low risk: Class 1
Medium risk : Class 2
High risk: Class 3

Statistics: Cohen‘s κ

agreement between modelled an measured classes

Model	Cohen‘s κ
C1a	0.09
C1b	**0.18**
C2	0.04

Range:
κ = 1: full agreement
κ = 0: only random agreement

Validation of risk-classes

Thresholds for soil physical parameters

- Air capacity < 5 v%/< 8 v% (topsoil)
- Saturated water conductivity < 10 cm/d
- Air permeability < 10 µm^2

Risk classes derived from measurements

No parameter : Class 1
1 parameter : Class 2
2 or 3 parameters: Class 3

Model-predicted risk classes

Low risk: Class 1
Medium risk : Class 2
High risk: Class 3

Statistics: Cohen‘s κ

agreement between modelled an measured classes

Model	Cohen‘s κ
C1a	0.09
C1b	**0.18**
C2	0.04

Range:
κ = 1: full agreement
κ = 0: only random agreement

Validation of risk-classes

Thresholds for soil physical parameters

- Air capacity < 5 v%/< 8 v% (topsoil)
- Saturated water conductivity < 10 cm/d
- Air permeability < 10 µm²

Risk classes derived from measurements

No parameter : Class 1
1 parameter : Class 2
2 or 3 parameters: Class 3

Model-predicted risk classes

Low risk: Class 1
Medium risk : Class 2
High risk: Class 3

Statistics: Cohen's κ

agreement between modelled an measured classes

Model	Cohen's κ
C1a	0.09
C1b	**0.18**
C2	0.04

Range:
κ = 1: full agreement
κ = 0: only random agreement

Conclusion

- **C1b currently most suitable**
- **Further development of C1b**

Thank you for your kind attention

…and thank you to everyone involved in the experiments!



Funding

Bundesministerium für Ernährung und Landwirtschaft

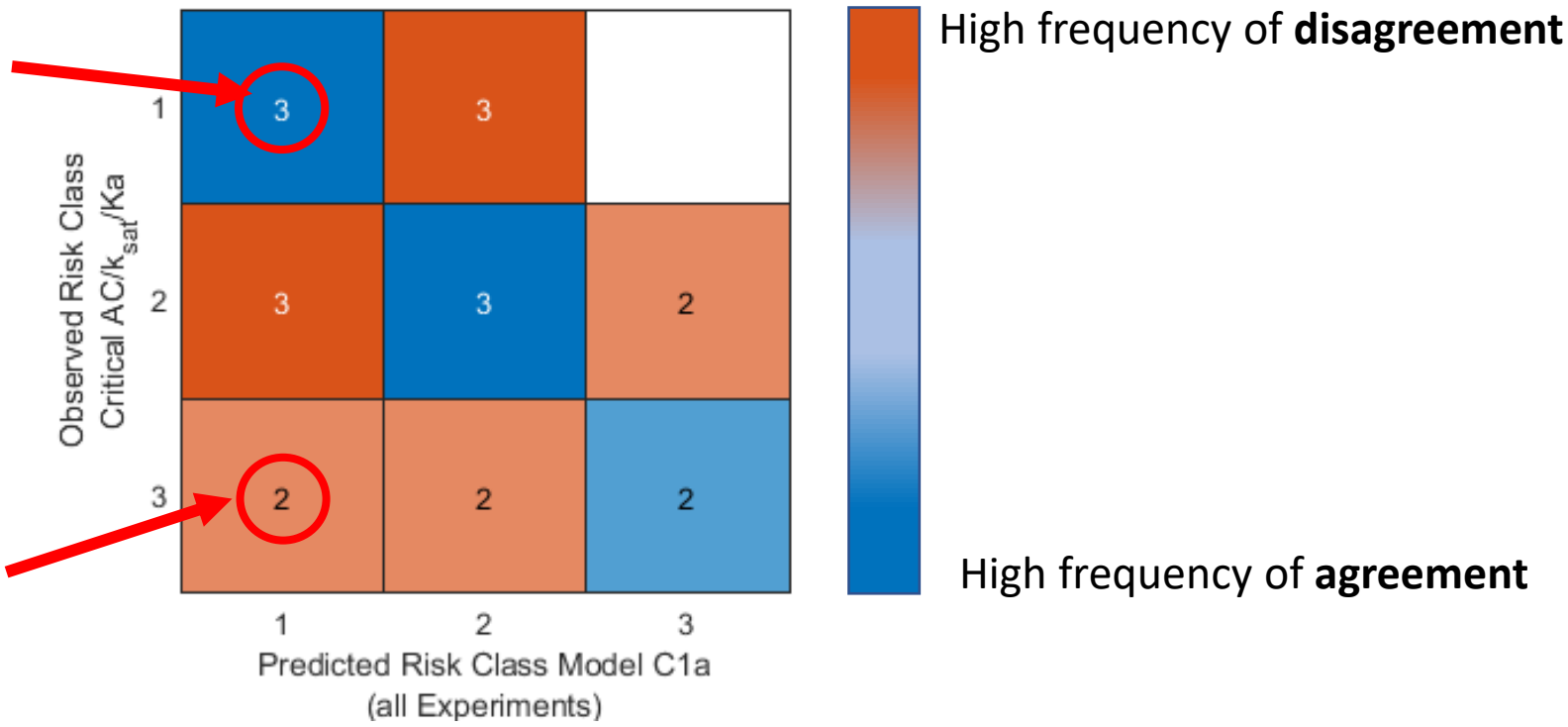
Projektträger Bundesanstalt für Landwirtschaft und Ernährung

Validation

Visualization of agreement between classes in confusion matrices

Example A:
Number of cases, where model predicts class 2 but measurements result in class 1

Example B:
Number of cases, where model predicts class 1 but measurements result in class 3



Validation

Thresholds for soil physical parameters

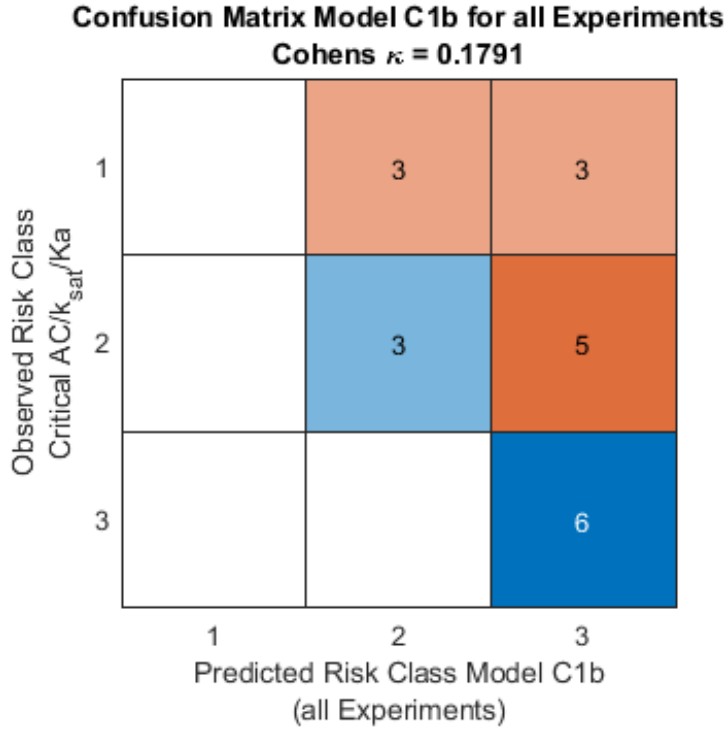
- Air capacity < 5 v%/< 8 v% (topsoil)
- Saturated water conductivity < 10 cm/d
- Air permeability < 10 µm^2

Risk classes derived from measurements

No parameter : Class 1
1 parameter : Class 2
2 or 3 parameters: Class 3

Predicted risk classes

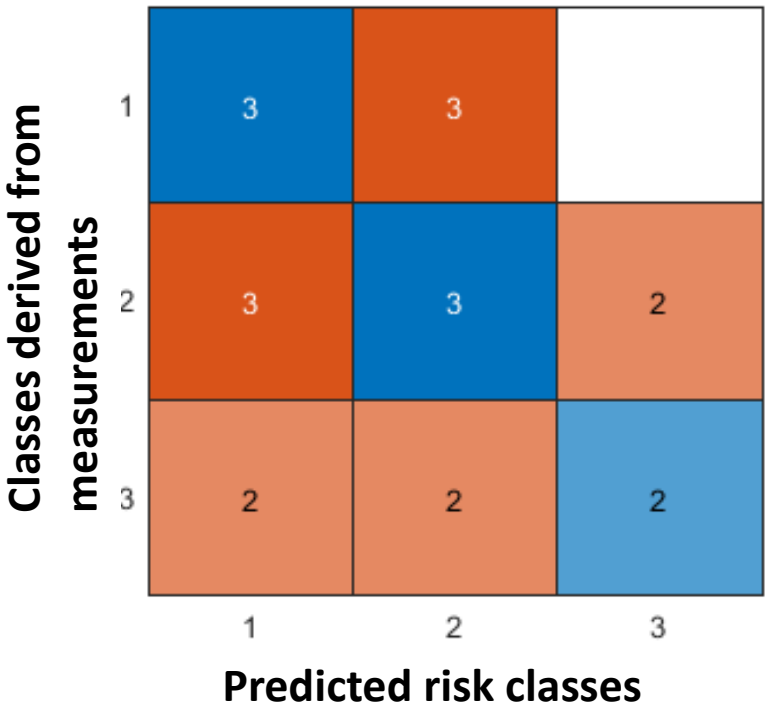
Low risk: Class 1
Medium risk : Class 2
High risk: Class 3



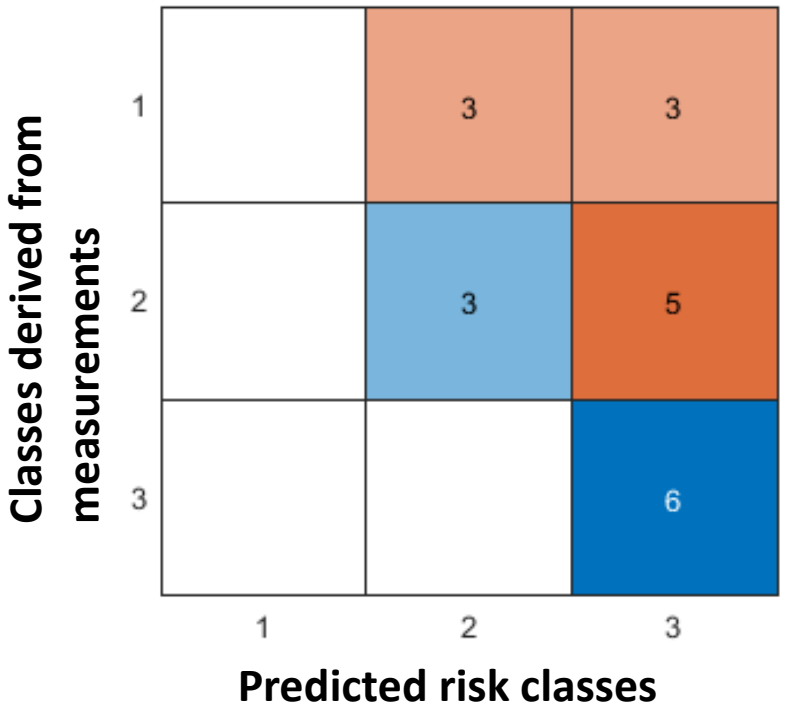
Validation

Visualization of agreement between classes in confusion matrices

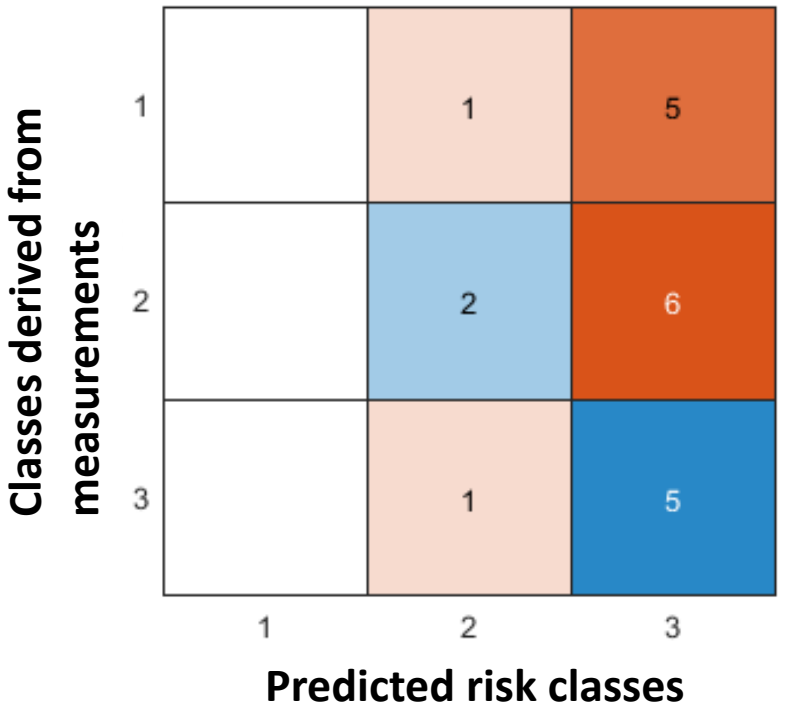
Semi-physical C1a



Semi-physical C1a



Conceptual C2



Cohen's K for class-based model assessment

- **Indicator:** Cohen's $\mathrm{K} = \frac{p0 - pc}{1 - pc}$ calculated from confusion matrix
  - *po*: observed agreement
  - *pc*: hypothetical agreement by chance
- Complete agreement: $K = 1$
- Agreement same as by chance: $K = 0$
- $K < 0$ indicates less agreement than expected by chance

Used as a relative score of model performance **between** selected modelling approaches

(Cohen, 1960; Jeness & Wynne, 2005; Landis & Koch, 1977; Castaldi et al., 2018)

Observed compaction effects

- **Thresholds** for key physical soil properties:
  - **air capacity:**
    - AC < 5 vol% (subsoil)
    - AC < 8 vol.% (topsoil)
  - **saturated water conductivity:** k_sat < 10 cm/d
  - **air permeability:** Ka < 10 µm^2

- **Classification after wheeling experiments (applied to median values)**
  - **No parameter** below threshold: **Class 1 (Low Risk of Compaction)**
  - **1 parameter** below threshold: **Class 2 (Medium Risk)**
  - **2 or 3 parameters** below threshold: **Class 3 (High Risk)**

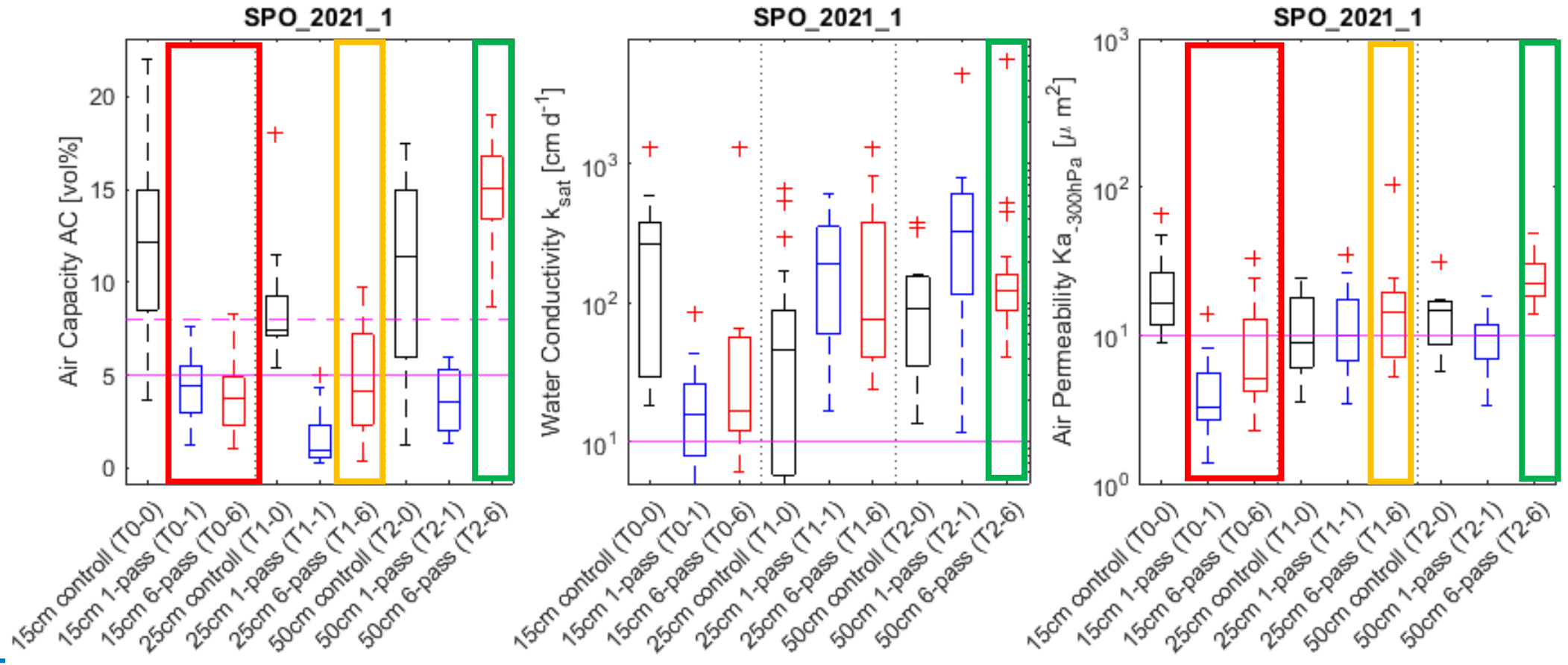
(Zink et al., 2016; Brunotte et al., 2015; Kmoch & Hanus, 1965; Lebert et al., 2004)

2 of 3 parameters < threshold

1 of 3 parameters < threshold

No Parameter < threshold

Measured data from E2



Selected modelling approaches

	C1a: semi-physical	C1b: semi-physical	C2: conceptual
Soil strength	**Precompression stress**, soil moisture dependent		**Classification of compaction susceptibility**
Soil stress/load of machinery	**Semi-analytical stress transmission** **uniform** stress at surface	**Semi-analytical stress stransmission** **distributed** stress at surface	**Classification of load-index of machinery**
Risk classification	**Ratio of stress/pV,** classified in three risk classes		**Combination of classes** for load and susceptibility
	(Lebert, 2010; Horn & Fleige, 2003; Rücknagel et al., 2012,2015; Newmark, 1942)	(Lebert, 2010; Rücknagel et al., 2012,2015; Söhne, 1953; Keller et al., 2003;)	(Lorenz et al., 2016; Ledermüller et al., 2018; Brunotte et al., 2015)