Agroecology and Environment Research Division
Agroscope

Describing effects of grazing on soil quality in LCA

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Agenda

1. Introduction
2. Methods
3. Data
4. Results
5. Discussion
6. Outlook

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Introduction – Pasture damage caused by grazing livestock

Introduction

- Share of grassland on AUU is high (West Europe: 40%, Switzerland: 70%)
- Number of cows 2016 in Switerland: 1.56 million cattle (700 thousand cows)
- Stress through hooves (claws) of cattle/ horses can be very high: static up to 200 kPa; moving up to 400 kPa (Tractor -> 30-150 kPa)
- Animal trampling: Damage on the soil structure (topsoil) (operations with heavy machinery: also subsoil)
- Compaction from cattle not regionally limited (passage of machines: lanes are locally concentrated)
- Compaction impacts (i.a.) on macropore volume and aggregate stability

Literature Research: Some key findings

- Little literature on the impact of animal treading on soil physical properties (mostly field studies)
- Risk of soil compaction due to grazing cattle
  - increases with stocking density and soil moisture
  - depends on soil structure, soil type, soil cover and topography
- Compaction affects the water cycle (decreasing infiltration capacity, enhanced surface runoff) and tends to decrease the yield.
- Overgrazing can also lead to excessive defoliation, erosion and water quality deterioation (eutrophication)

Method: SALCA-SQ

(**S**wiss **A**gricultural **L**ife **C**ycle **A**ssessment – **S**oil **Q**uality)

SALCA-SQ estimates soil quality on the basis of **9 indicators** (impact sub-classes); three of which are on **soil physics, soil chemistry** and **soil biology**.

Soil physics	**Soil chemistry**	**Soil biology**
Rooting depth	Organic carbon	Earthworm biomass
Macropore volume	Heavy metals	Microbial biomass
Aggregate stability	Organic pollutants	Microbial activity

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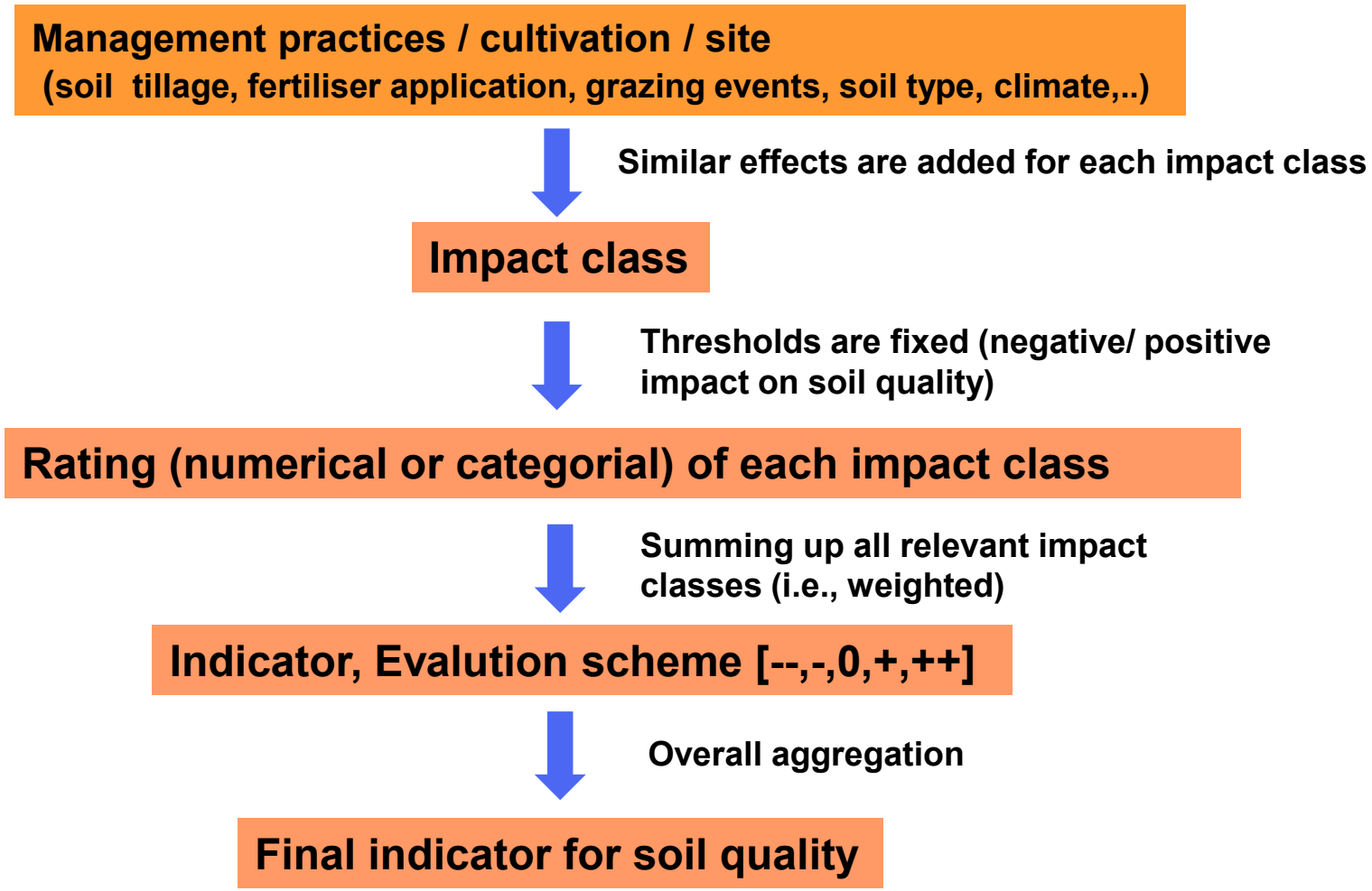
SALCA-Soil quality: Flow chart



SALCA-SQ – Changes of soil structure

Damage of soil structure

- **Risk of soil compaction by wheeling**
- **Risk of aggregate damage due to grazing**

Stabilisation of soil structure (formation of a more stable soil structure)

- **crop (root penetration) -> crop rotation**
- **Supply of $C_{organic}$ through fertilization**
- **Increase of pH-value by liming**

Macropore volume and Aggregate stability

➢ Study is constrained to a small section of the model SALCA-SQ :

Grazing Event → **Risk of aggregate damage due to grazing** → **Macropore volume**, **Aggregate stability**

Approach: «Overuse»

Concentration factor *K* serves as a proxy for soil structure damage through grazing

$$K_{pw} = K_o \times c_1 \times c_2 \times c_3 \times c_4$$

K_{pw} : Concentration factor of pasture *p* and grazing event *w*

K_o : Initial value: f (soil moisture und soil stability)

soil moisture = f (month, soil type)

$c_1, \ldots, c_4$: correction factors

K_{farm} = Sum up K_{pw} over all pastures and grazing events

Classify the risk of soil structure damage through trampling animals, using threshold values, into the classes «0» (no impact), «-» (unfavorable) and «- -» (very unfavorable).

Approach: «Overuse»

c_1: Overuse due to "too high" stocking density and duration -> Look-up table (intensity of browsing)

c_2 = 1.2, if standard yields of pasture is below the feed intake of the herd (otherwise c_2=1)

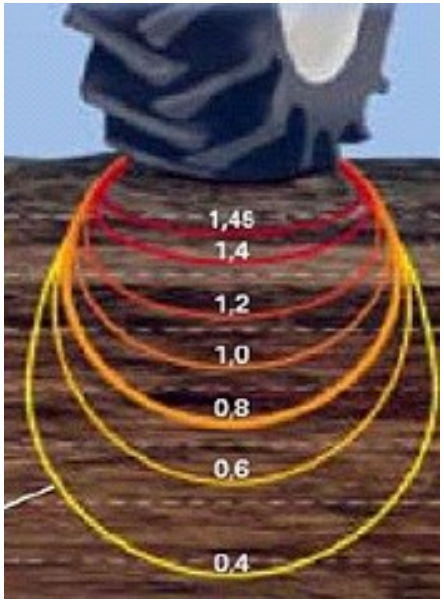
c_3: Bearing capacity of the pasture
c_3 = 0.8, if grass-rich
c_3 = 1.2, if rich of herbs and leguminous plants

c_4 = 0.8, if rotational grazing (otherwise c_4=1)

Approach: «Wheeling»

Assessment of the risk for a damage of soil structure

Idea: Treat animal hooves the same way as a tractor wheel



Damage in subsoil

Damage in topsoil only

Approach: «Wheeling»

Procedure for each single grazing event:

1. Determine concentration factor *K* from lookup-table (depending on soil stability and soil humidity)
2. Compute surface stress and treaded area
3. Estimate vertical soil stress at 10 cm soil depth
4. Classification based on a lookup-table (depending on vertical soil stress and percentage of trampled area)

	Vertical soil stress at 10cm soil depth [kPa]					
Percentage of trampled area [%]	<30	30-59	60-89	90-119	120-149	>=150
> 50	0	-1	-1	-2	-2	-2
26-50	0	0	-1	-1	-2	-2
10-25	0	0	0	-1	-1	-2
<10	0	0	0	0	-1	-1

Comparison: Tractor vs. Cattle

Variable	Tractor (Wheeling)	Cattle (trampling)
Stress (contact surface)	f(tyre width, wheel load)	f(hoof size, hoof load)
Soil moisture	f(soil type, time of operation)	f(soil type, time of grazing event)
Soil stability	grain size, soil structure, soil moisture)	
Stress propagation	f(soil stability) -> «Pressure pulb»	
Risk of compaction (at selective points)	Soil stability vs. ground contact pressure («Pressure pulb»)	
Area used	f(number of tyres, working width, number of operations,…)	f(stocking density, animal activity, duration of grazing,…)

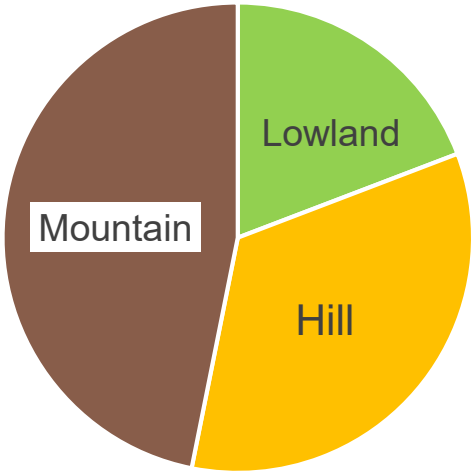
Assumption: Approach «Wheeling»

- **Size of claws** (both claws: ~90 cm^2, Bilotta et al., 2007, Mattern and Laser, 2007)
- **Mean weight of a cow** (assumption: 700 kg)
- **Stride length** (81 cm, Benz, 2003)
- **Activity** of cows:
  - 1-13 km daily [Krohn et al., 1992 und KTBL, 2009])
  - Dairy cows full pasture trial GEOGS (Posieux, 2013): Logging of movements by GPS-trackers (Felber et al., 2016, Biogeosciences)

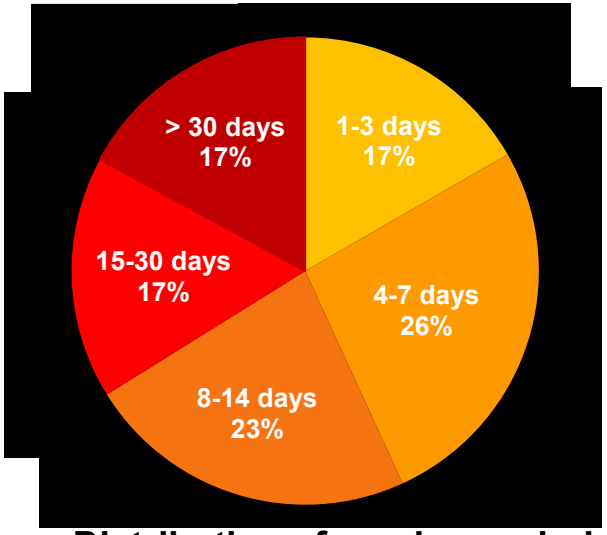
  => Daily walking distance on pasture : approx. 8 km

Dataset: SAEDN farm data

- ✓ Comprehensive dataset covering the period 2011-2014
- ✓ 254 (year 2014) to 297 (year 2011) farms
- ✓ Details on length of grazing events and stocking density
- ✓ Approx. 24’450 grazing events
- ✓ Total number of grazing days (all years, all farms, all pastures): 690'000 days (approx.1900 years)



Distribution of farms

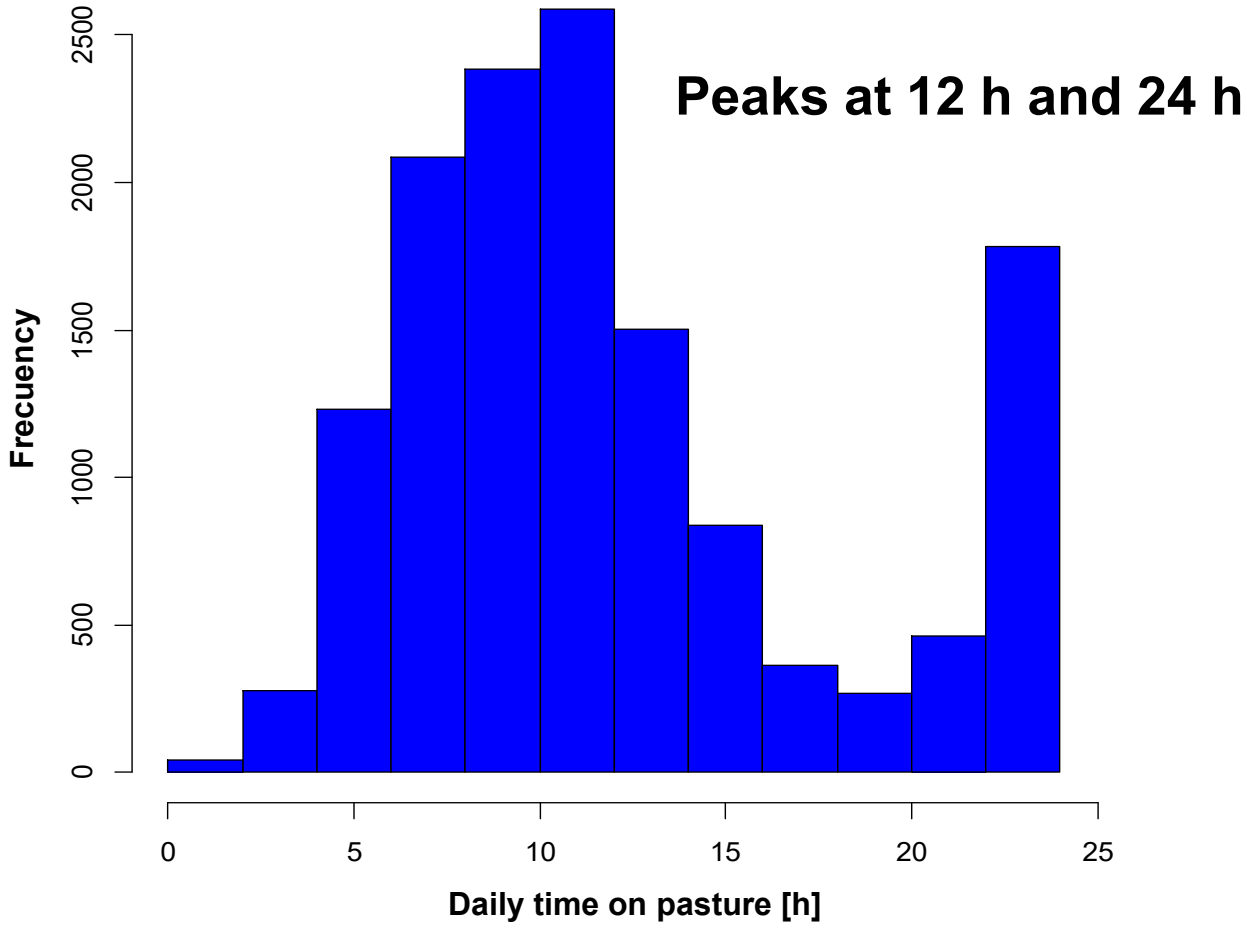


Distribution of grazing periods

Data kindly provided by Alain Valsangiacomo (Agroscope)

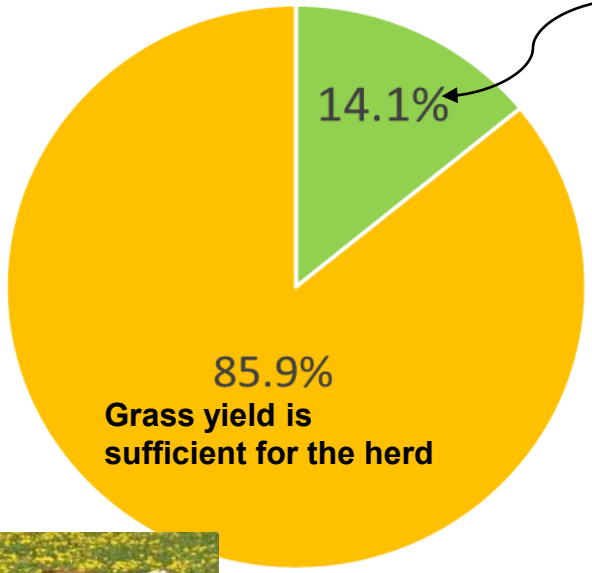
Daily grazing time

SAEDN-farms, 2011-2014



Result: Correction factor c_2

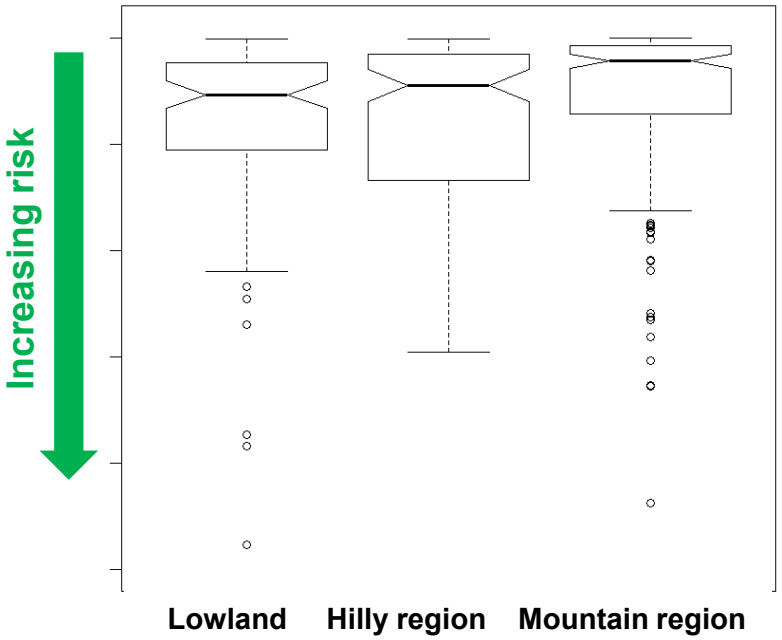
Is the grass yield sufficient for the herd?



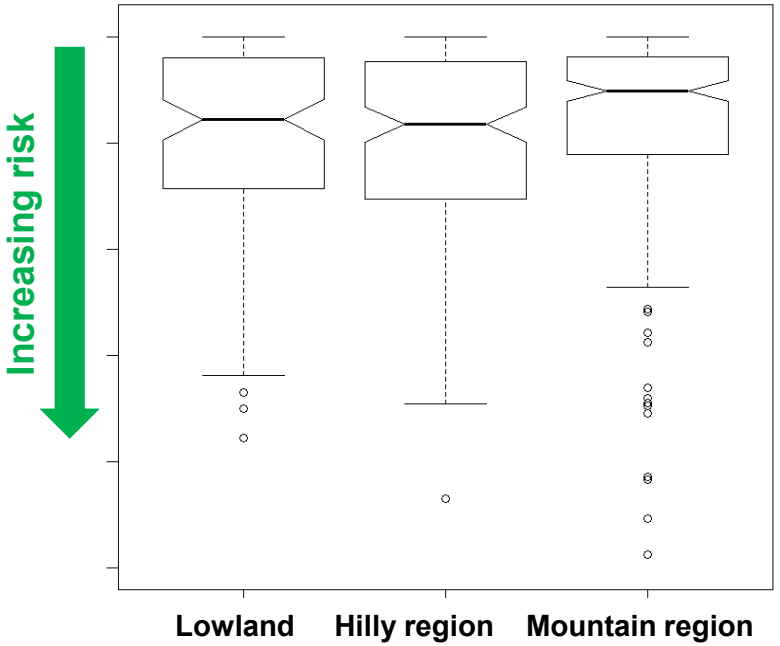
Potential risk that cows suffer from a lack of feed.

No risk ☺

Method comparison: risk of compaction through grazing



Approach «Overuse»

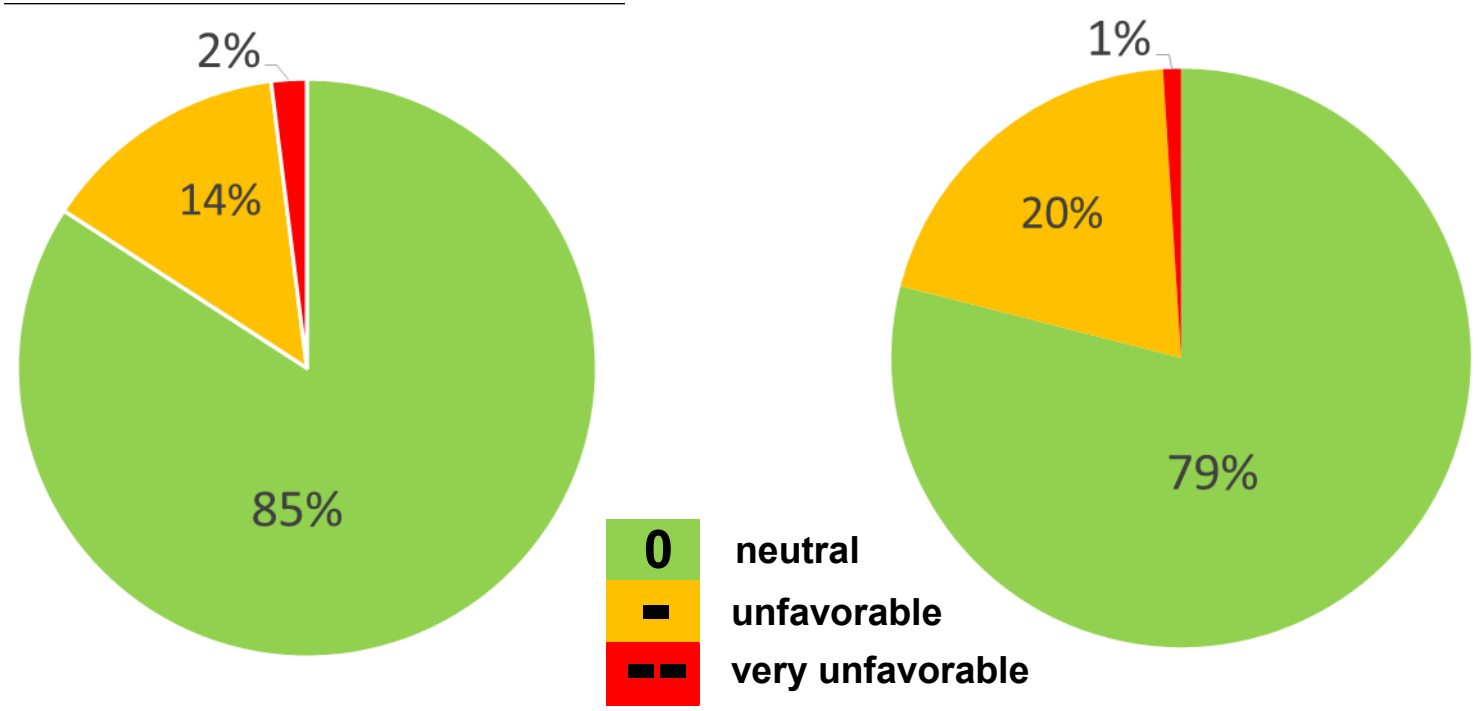


Approach «Wheeling»

Difference between the two approaches is not significant.

Evaluation of indicator Aggregate stability

(Negative) impact of animal treading on soil structure

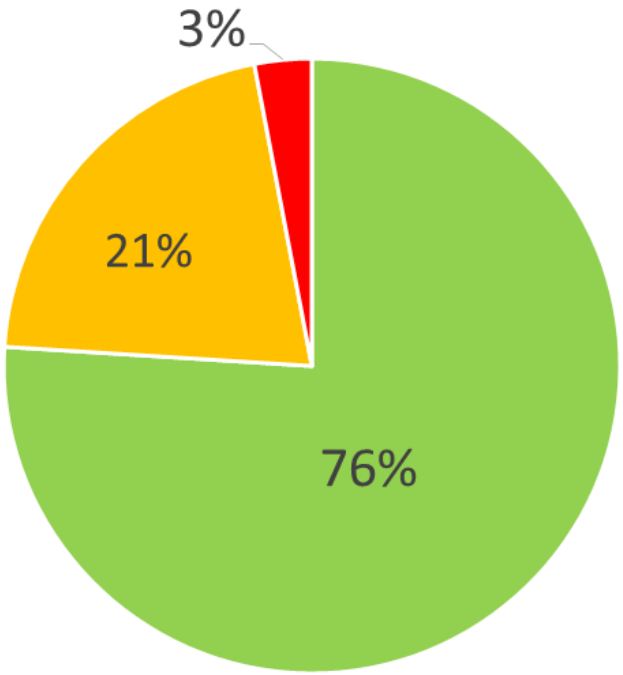


Method «Overuse»

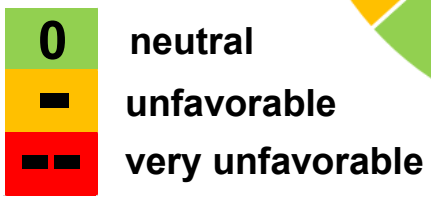
Method «Wheeling»

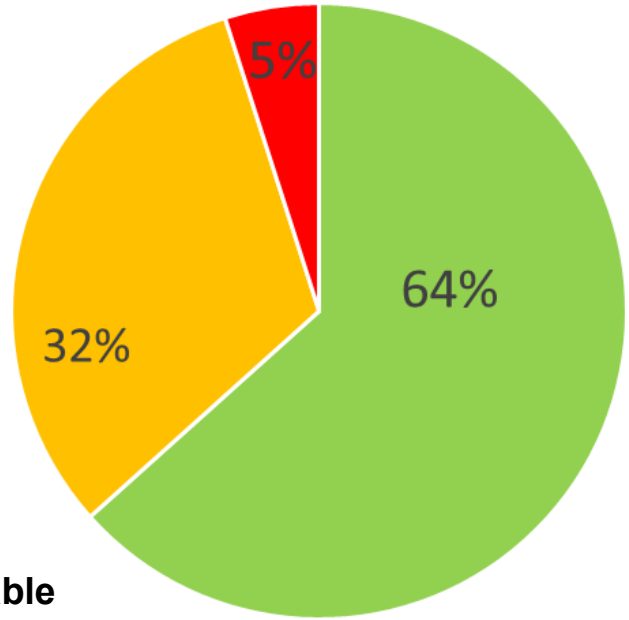
Evaluation of indicator Macropore volume

(Negative) impact of animal treading on soil structure



Approach «Overuse»





Approach «Wheeling»

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Discussion

- **New approach** «Wheeling» is a promising method for modelling soil compaction of treading animals similar to wheeling
- The new approach «Wheeling» is based on **measurable** (verifiable) soil mechanics properties: only quantifiable are included in the calculations
- **SAEDN-Data** are ideal for validating the plausibility of the two approaches
- Both approaches «Overuse» und «Wheeling» do provide (at least) **plausible** results
- **Large variability** among the farms

Outlook

- Future research is needed (both field trials and methodological developments)
- Validation of new approach "Wheeling" with field trials
- Estimation of relative importance of soil structure damage induced by grazing animals and agricultural machinery












Thank you very much for your attention

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