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Session 57

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Yearly monitoring of soil ingestion by dairy cows in a grassland system with feed supply

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Soil ingestion, a pathway of exposure

Anthropogenic activities result in the emission of pollutants:
industrial products (PCBs, pesticids, metals, …), by-products of **combustion** (PCDD/Fs, PAHs, …), …



Deposits in the environment …

… and **contamination of ecosystem** compartments

Contamination of animal …

- Dermal contact
- Inhalation
- **Ingestion of contaminated matrices (as soil)**

… and foodstuffs

⇒Issues : **food safety, resilience of farming systems, ecosystem services**

Why study soil ingestion in dairy cows?

Studies of soil ingestion in cattle:

- **Recent studies:**

beef cattle

tether-grazing

tropical conditions

(Jurjanz et al. 2017; Collas et al. 2019, 2020)

- **Dairy cows in temperate conditions:**

some **ancient** studies *(Healy 1968; Fries et al. 1982)*

particular method for soil ingestion estimation *(Mamontova et al. 2007)*

particular grazing conditions (strip-grazing) *(Jurjanz et al. 2012)*

⇒ **Few references in dairy cows**

⇒ **Mainly ancient data**

⇒ Few data from Europe

Experimental design & sampling

La Bouzule, experimental farm (ENSAIA, University of Lorraine, France)

70 dairy cow herd

July to Nov 19	Dec 19 to Feb 20	March to June 20
Pasture with access to barn	**Barn** (free-stall with cubicles)	**Pasture** with access to barn
Grass (+ mix ration)	Total mix ration	Grass (+ mix ration)

- **Estimation of soil ingestion** (in % of total DM intake):

  - analyse of an **internal soil marker** (TiO_2) in faeces, feed and soil
  - estimation of **digestibility**

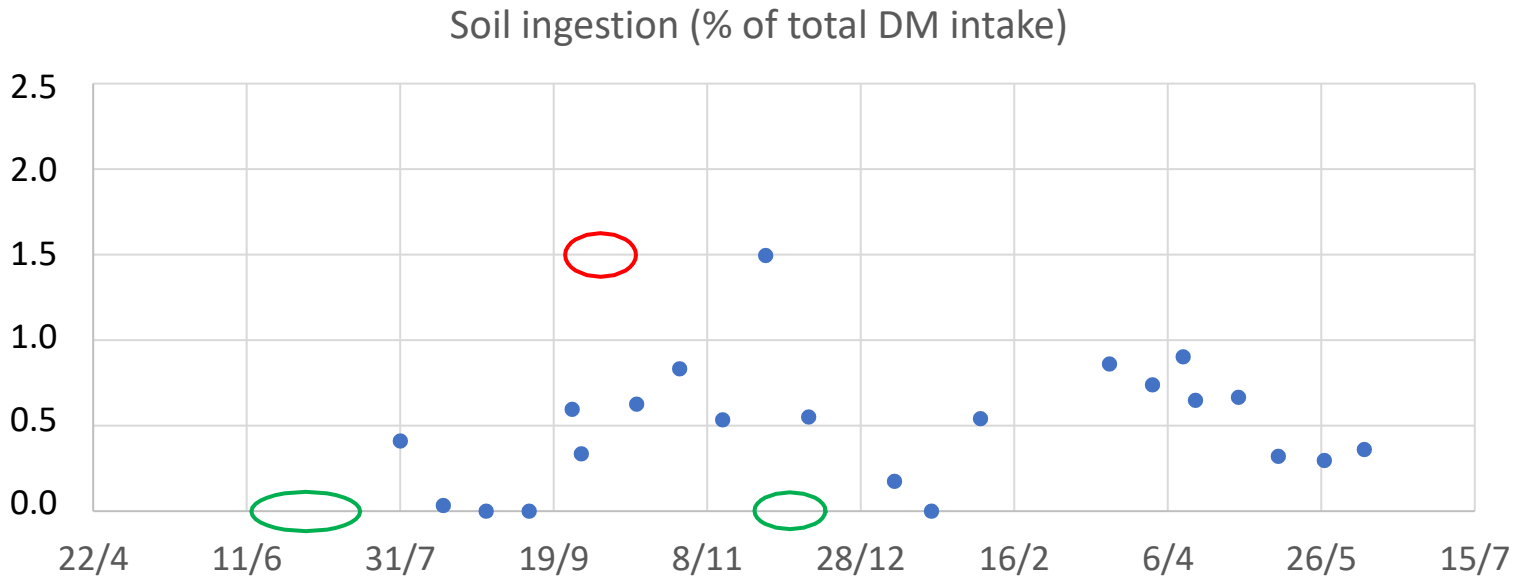
- **Herd-scale monitoring**:

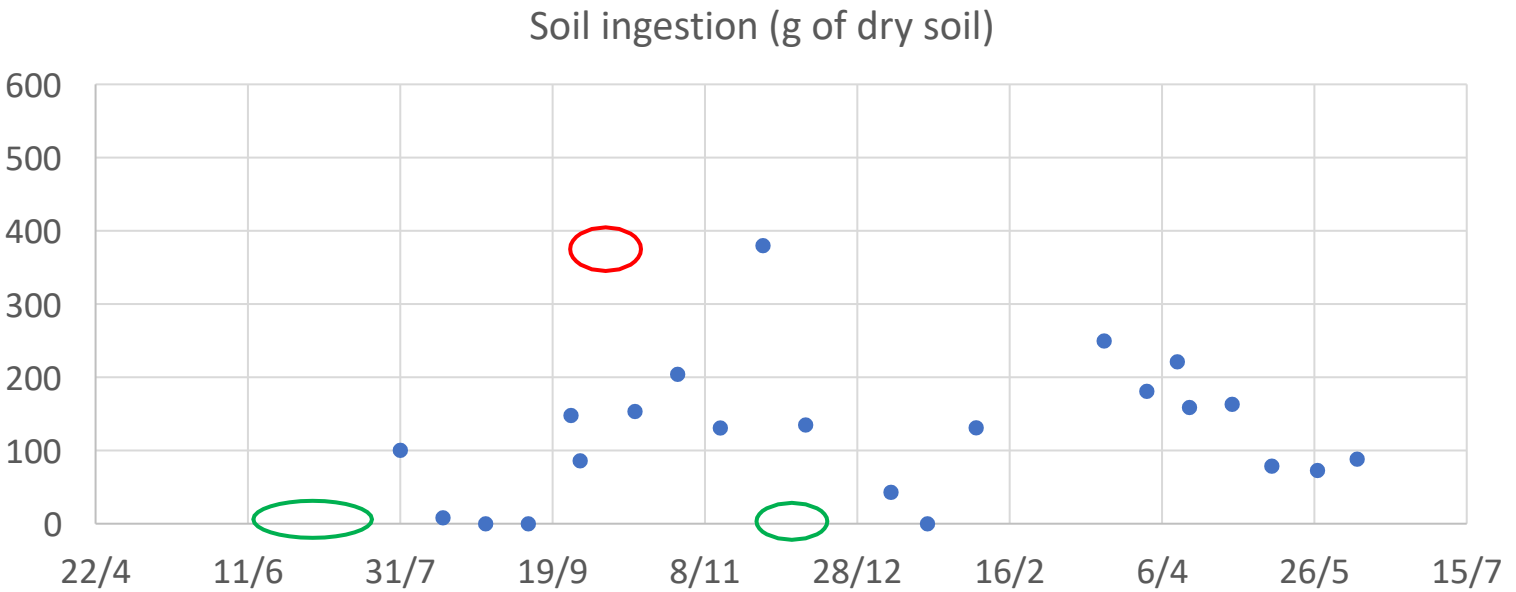
  - **a year** from **July 2019 to June 2020**
  - sampling **every 2 weeks (monthly in winter)**
  - composite faecal sample from **12 cows** (representative of the herd) for each date

- **Individual monitoring**:

  - **4 dates**: **July, Sept, Jan, April**
  - individual faecal samples from **30 cows** for each date (including the 12 cows for herd monitoring)

Results – Daily soil ingestions – Herd-scale monitoring over a year





in % of total dry matter intake:

Mean:	**0.5**	
Min:	**0**	(28/08, 11/09, 20/01)
Max:	**1.5**	(27/11)

⇒ **Highest value in late automn**
⇒ **very wet conditions, risk of soiled grass**

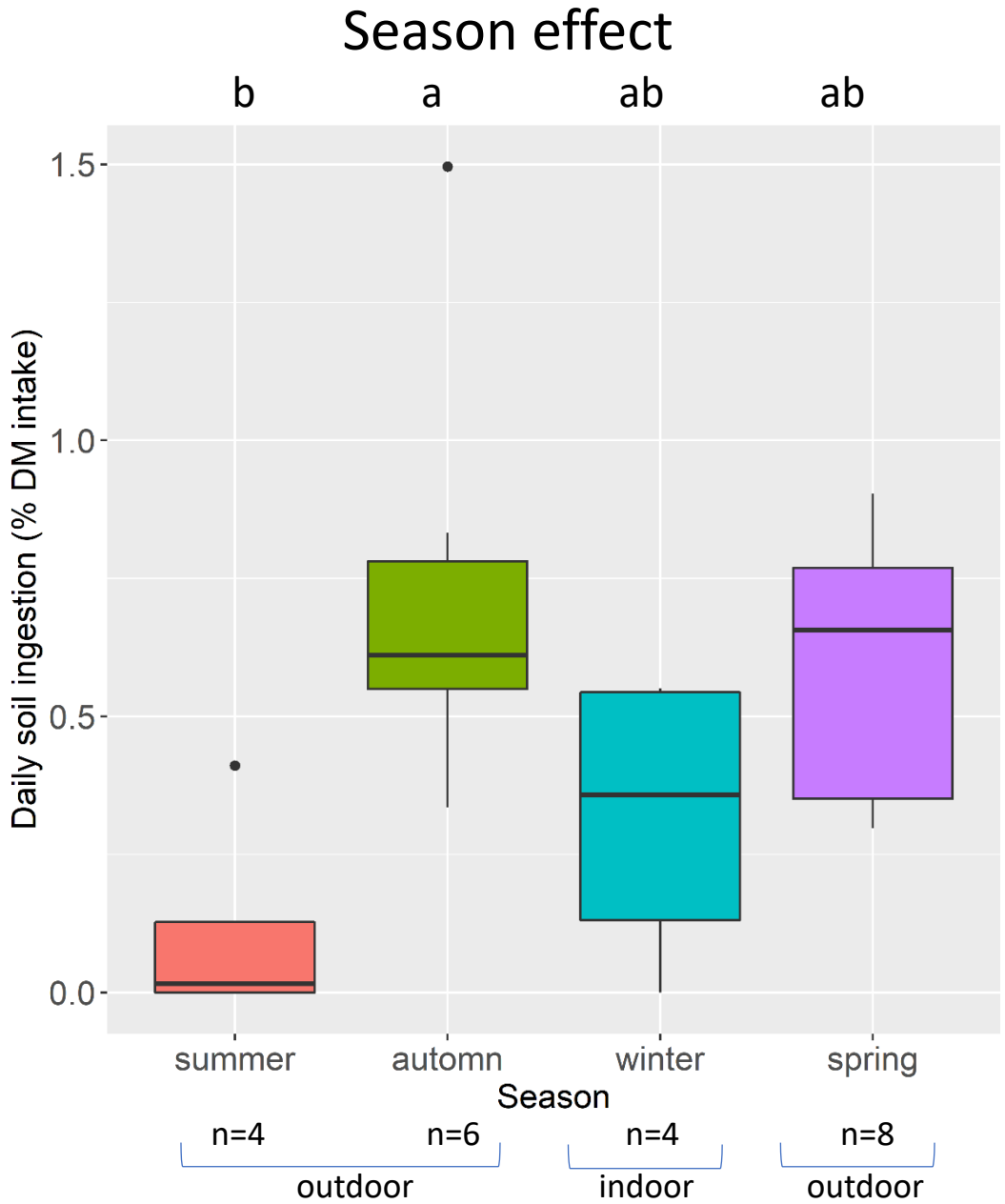
⇒ **Low or zero soil ingestion for some dates**
in summer (mix ration intake > grass intake, dry soil)
and winter (barn, no direct contact with soil)

⇒ **Variability even in barn**

in g of dry soil:

Mean:	**124**	
Min:	**0**	(28/08, 11/09, 20/01)
Max:	**380**	(27/11)

Results – Daily soil ingestions – Herd-scale monitoring over a year



Mixed models with date as a random effect

Housing conditions (outdoor vs indoor): $P>0.05$

Season: $P<0.05$

summer vs automn ($P<0.05$)

summer vs spring ($P=0.07$)

Winter is no significantly different from any of the 3 other seasons outdoor

Soil ingestion (% DM intake)	summer	automn	winter	spring
min	0	0.34	0	0.30
mean	**0.11**	**0.74**	**0.32**	**0.60**
max	0.41	1.5	0.55	0.90

⇒ **Soil ingestion highest in autumn and lowest in summer**

⇒ **Hyp => influence of weather and grass soiling**

⇒ No significant differences between outdoor and indoor

⇒ **Variability even in winter when cows are in barn**

Results – Daily soil ingestions – Individual monitoring (4 dates)

Soil ingestions
(in % of total DM intake)

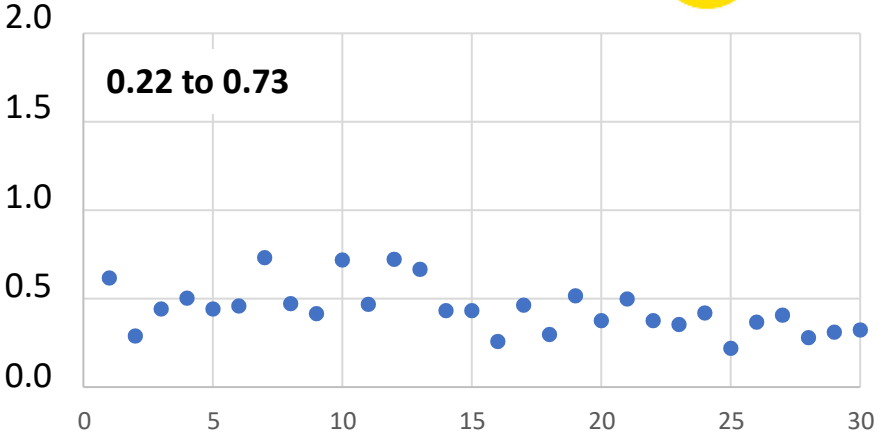
For each date, t test between

soil ingestions by the 12 cows used for herd-scale monitoring

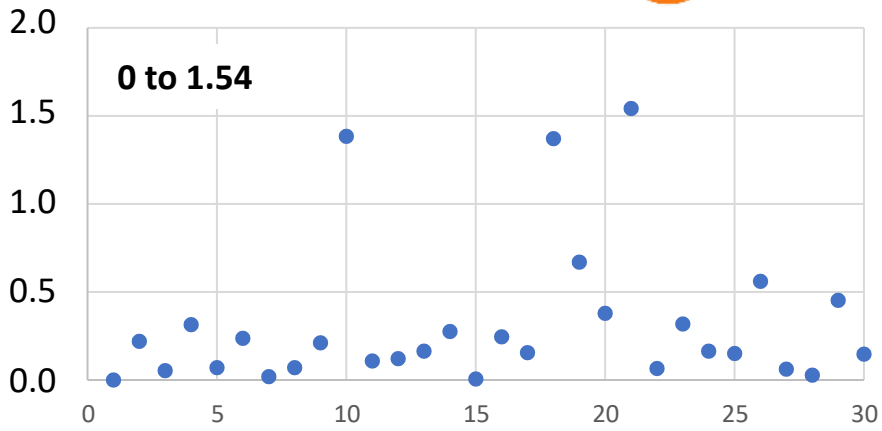
and soil ingestions by the 18 other cows

for all dates $P>0.05$

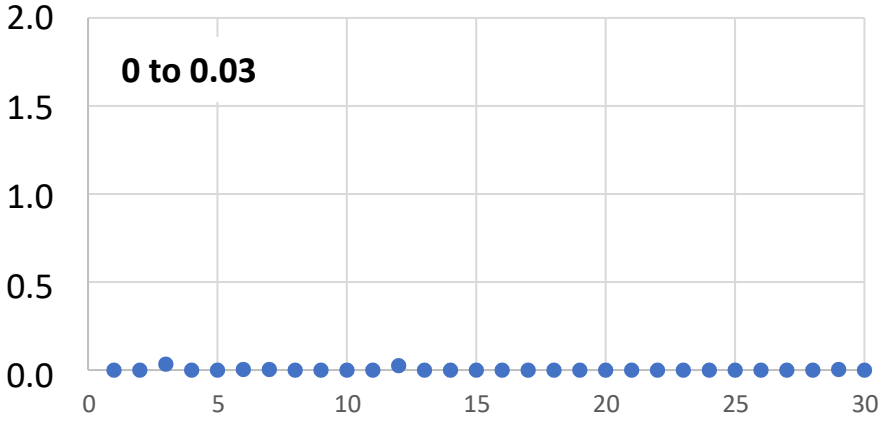
31/07



28/09



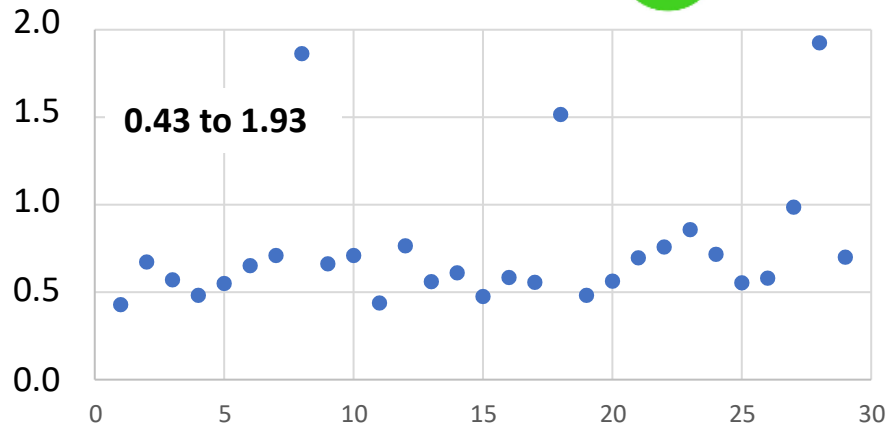
20/01



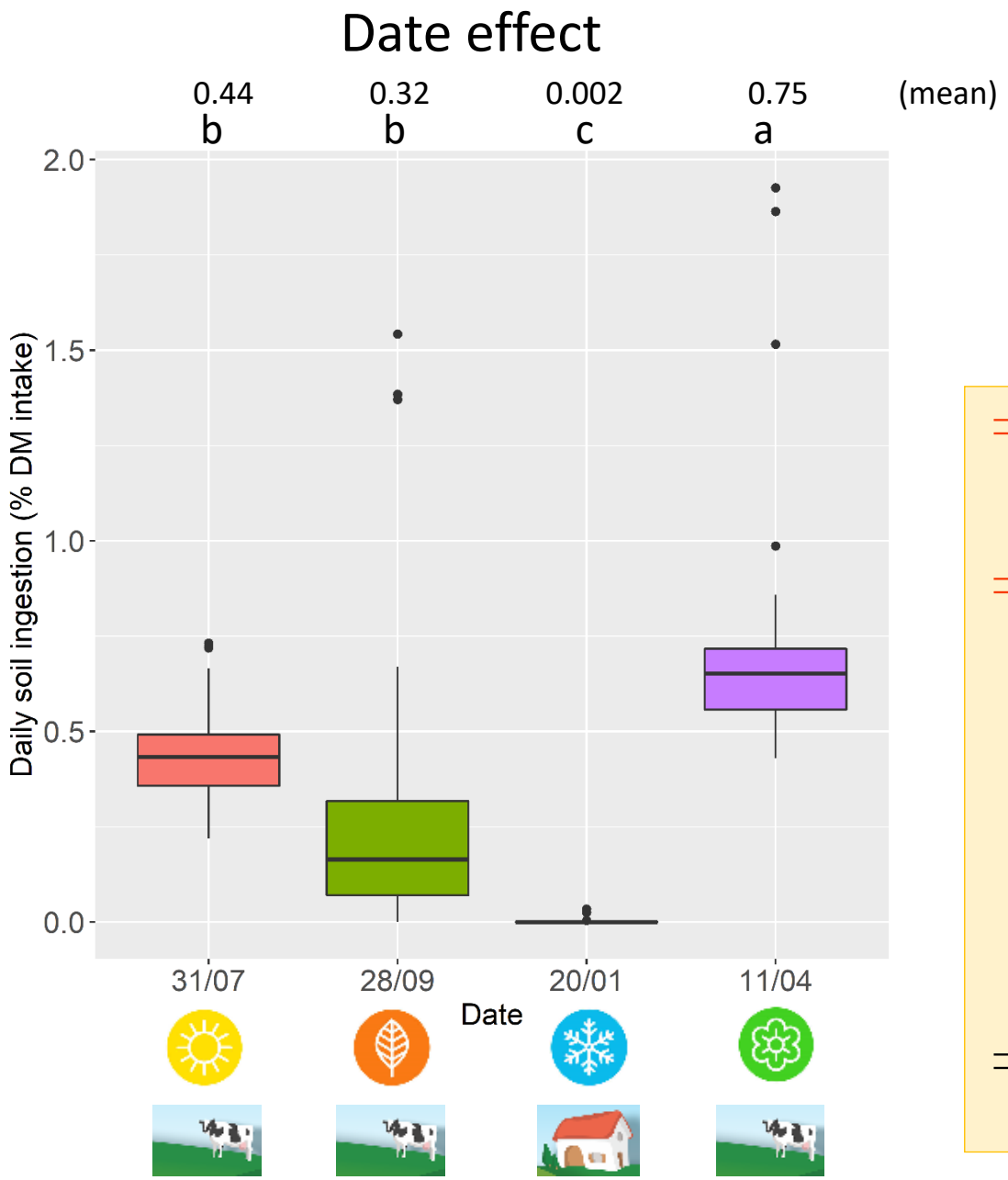
⇒ No significant difference between the 12 cows of the pool and the others

⇒ **The 12 cows of the pool were well representative of the herd**

11/04



Results – Daily soil ingestions – Individual monitoring (4 dates)



Mixed model with cow as a random effect

Date: $P<0.001$

for all 2-by-2 comparisons $P<0.01$

except 31/07 vs 28/09 ($P>0.05$)

⇒ **Significant differences between dates except for 31/07 and 28/09**
(whereas summer and automn were different with herd monitoring)

⇒ **20/01: soil ingestions near to 0 and very low inter-individual variability => no access to pasture**
(but indoor and outdoor conditions were not different with herd monitoring)

⇒ **Date effect does not give the same results as the season effect (with several dates grouped together)**

⇒ **Variations over time: influence of conditions at a given date**

⇒ 28/09 and 11/04: 3 highest values => **individual variability**

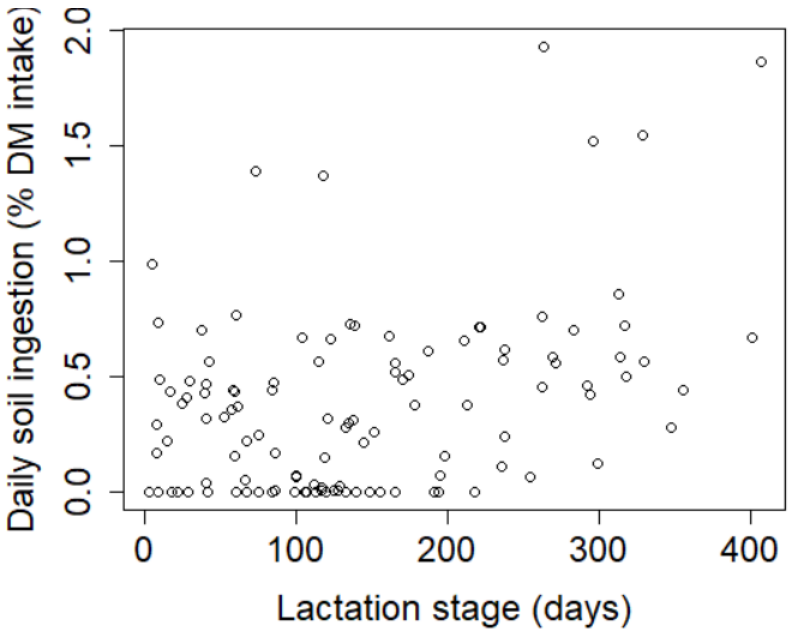
⇒ Can cow characteristics influence this?

Results – Animal characteristics

Mixed models with cow as a random effect

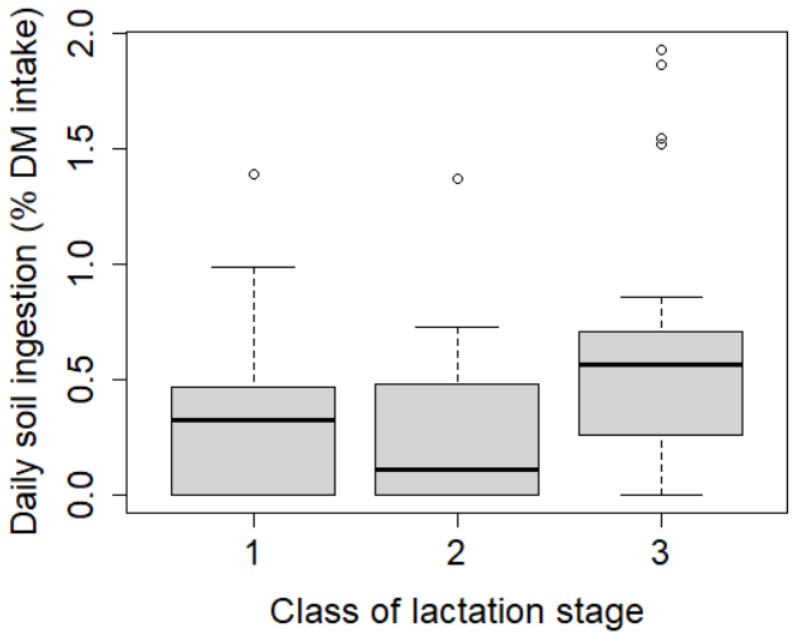
Lactation stage (*P*<0.001)

r = 0.4



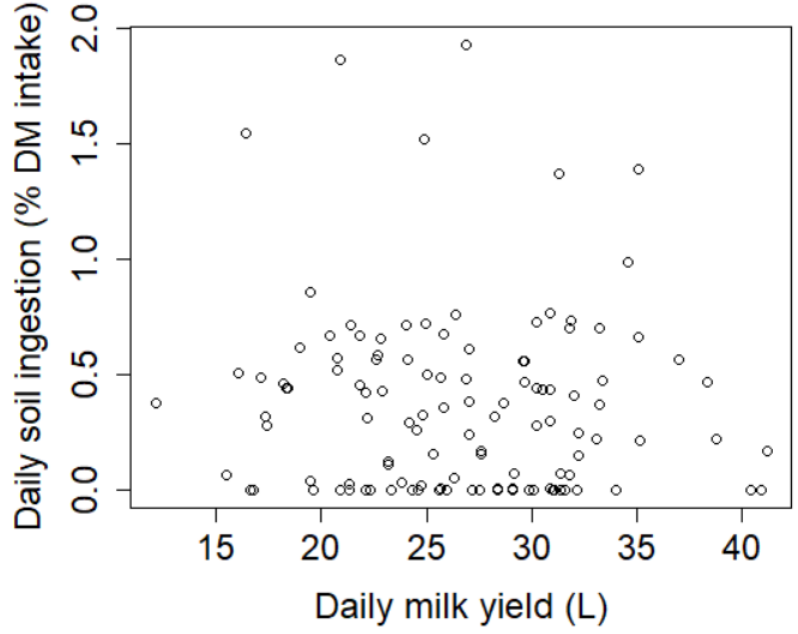
Class of lactation stage (*P*<0.001)

b b a



<80 80-180 >180 days

Milk yield (*P*>0.05)



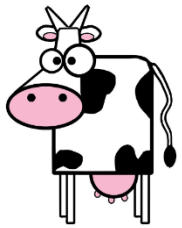
⇒ **No significant effect of age** (>2 to <10 years old)**, number of lactation, milk yield**

⇒ **Only lactation stage is significant, but low correlation (r=0.4)**

⇒ Soil ingestion lower for early lactation stage

⇒ **In this study, animal characteristics have little or no effect on soil ingestion**
(but relatively homogeneous dairy herd)

Comparisons with other studies in dairy cows



Housing conditions or grazing management	Season	Daily soil ingestions % of total DM intake	Daily soil ingestions kg of dry soil	Reference
Grazing (paddocks or platforms during winter)	April to March	-	0.46 – 1.7	Healy 1968
Barn Barn with soil bedding Unpaved lots with no vegetation	-	0.14 – 0.53 0.35 – 0.64 0.6 – 0.96	-	Fries et al. 1982
Grazing with supply	May to Sept	-	0.85 – 2.8	Mamontova et al. 2007
Strip-grazing	Spring & Automn	1.0 – 7.3	0.15 – 0.85	Jurjanz et al. 2012
Continuous grazing (with supply) Barn	Summer, Automn, Spring Winter	0 – 1.5 0 – 0.55	0 – 0.38 0 – 0.14	The present study

Soil ingestions of the present study:

- **At grazing => lower to those of previous studies**
  (but feed supply increased when pasture allowance decreased)
- **In barn => consistent with previous study**

⇒ Soil ingestion by dairy cows:

- **lower than 400 g per day in good grazing conditions (or with feed supply)**
- can be limited by adapting grazing practices

Conclusion & perspectives

- **Characterisation of daily soil ingestion by dairy cows**

- Dairy cow => not the most problematic animal for soil ingestion if grazing is not limiting
- But the high carry-over rate of persistent organic pollutants to milk can make even small soil ingestions far from harmless (several sanitary crisis in the past)

  ⇒**Reference data** for risk assessment

- **Temporal variations due to housing, weather and grazing conditions**

- **Feed supply during difficult pasture conditions** has shown to be an efficient practice to maintain **low levels of soil ingestion** and ensure **food safety**

  ⇒**Practical recommendations** for farmers

Acknowledgements:

- Technical staff of La Bouzule for dairy cow care and management
- Pamela Hartmeyer (URAFPA, University of Lorraine)

Additional slides if necessary for discussion/questions

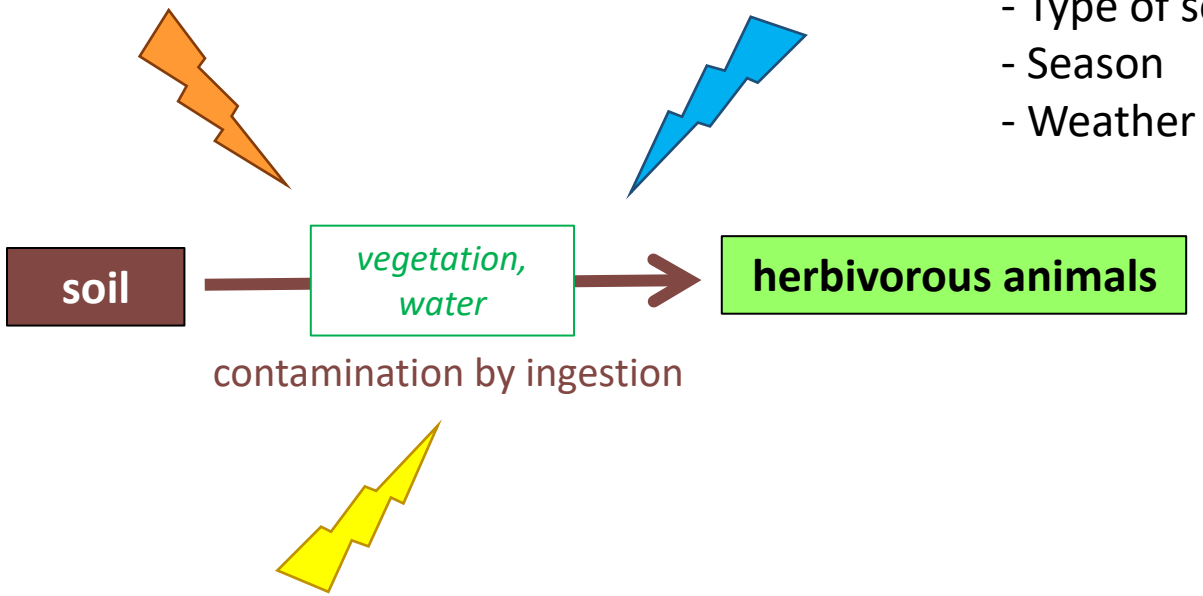
Variation factors of soil ingestion in herbivorous

Influence of factors linked to animal

- Species, breed
- Feeding behaviour
- Physiological stage

Influence of factors linked to environmental conditions

- Type of soil
- Season
- Weather conditions (rainfall)



Influence of factors linked to grazing management and feeding resources

- Resource abundance and diversity
- Resource accessibility (sward height)
- Surface area
- Supplementation

Methodology for daily soil ingestion estimation

- **Soil marker: titanium Ti**
- indigestible
- $[Ti]_{soil}$ ~ 8000 µg/g >>> $[Ti]_{feed}$ ~ 10-100 µg/g

Samples for analysis

FAECES

FEED (including grass)

SOIL

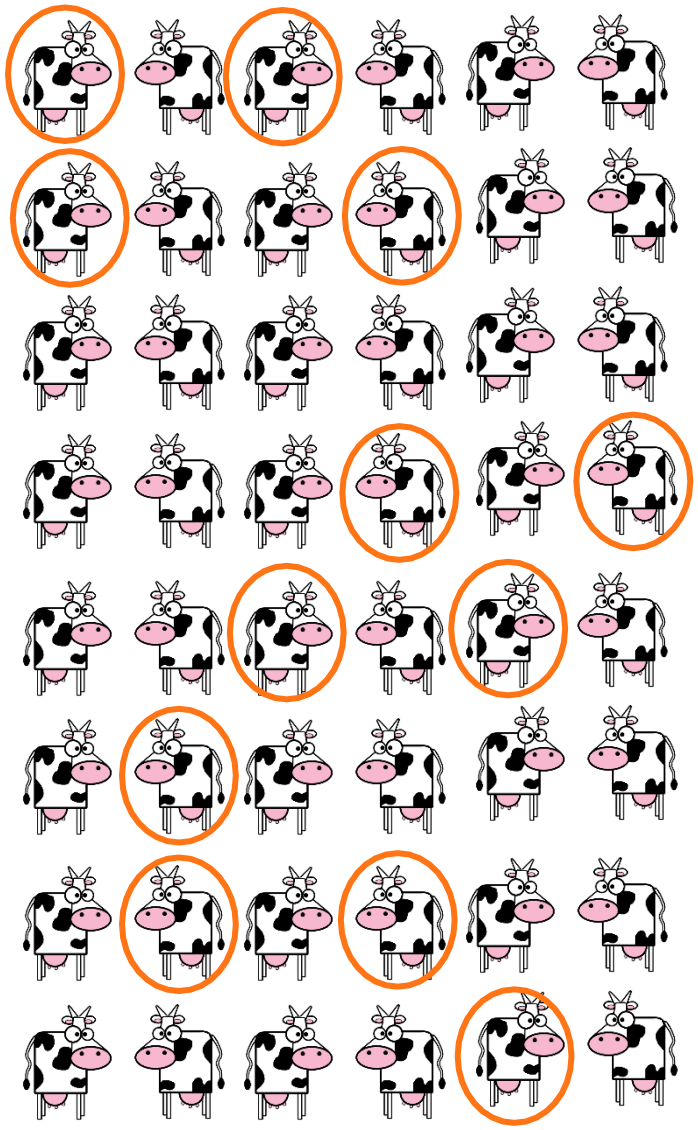
- Adapted from *Beyer et al. (1994)*:

$$\textbf{soil ingestion}\ (\%\ of\ total\ DM\ intake) = \frac{[Ti]_{feed} - [Ti]_{faeces} + DMdig \times [Ti]_{faeces}}{DMdig \times [Ti]_{faeces} - [Ti]_{soil} + [Ti]_{feed}}$$

$DMdig$ = dry matter digestibility

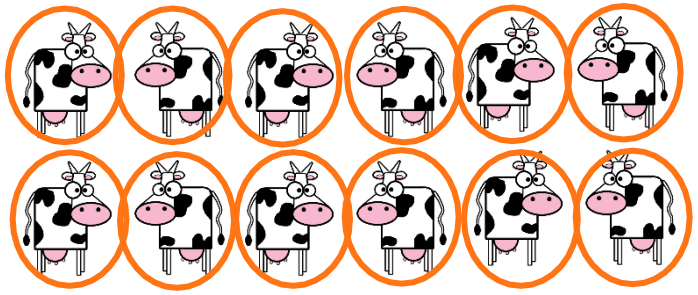
Herd-scale monitoring over a year

Dairy cow herd of La Bouzule farm (n=75)



identification of 12 cows representative of the herd

(and among those that will remain the longest in lactation)



individual faeces sampling every 2 weeks (monthly in winter)

creation of a composite faecal sample from 12 individual samples for each date

⇒To analyse **temporal variability** according to different factors:

- **Outdoor vs indoor**
- Outdoor in different conditions (grass availability, soil moisture, …) => **weather/season effect**
- **Different diets**

Individual monitoring on 4 dates

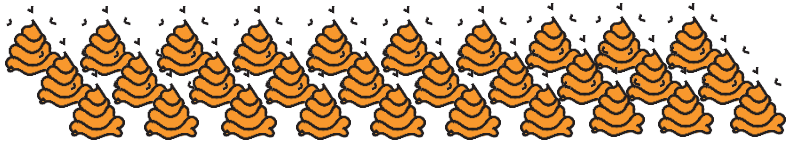
Dairy cow herd of La Bouzule farm (n=75)

selection of 30 cows within the herd

(including the 12 cows monitored over the year)

⇒To analyse **interindividual variability** in **4 contrasted situations** (different seasons):

- July: few grass, dry soil
- Sept: few grass, wet soil
- Jan: barn without outside access
- April: abundant grass, dry soil



individual faeces sampling on 4 dates (monthly in winter)

Comparisons between species

	Animal model	Daily soil ingestions			References
		g DM	g DM / 100 kg BW	g DM / kg MW	
herbivorous	Sport horses (strip grazing) 	543 - 648	89 - 107	4.4 - 5.3	Jurjanz et al. 2021
herbivorous	Dairy cows	0 - 380	0 - 58	0 - 3.0	The present study
herbivorous	Dairy cows (strip grazing) 	170 - 830	28 - 145	1.4 - 7.1	Jurjanz et al. 2012
herbivorous	Growing bulls (tether grazing)	73 - 159	27 - 98	1.1 - 3.5	Jurjanz et al. 2017 Collas et al. 2019, 2020
herbivorous	Rabbits (mobile cages) 	4	72	1.1	Jurjanz et al. 2019
omnivorous	Chicken 	0.1 - 4.7	8.7 - 236	0.09 - 2.8	Jurjanz et al. 2014, 2015
omnivorous	Lactating sows	300	131	5.1	Jurjanz & Roinsard 2014
omnivorous	Growing pigs 	116 - 171	368 - 548	8.7 - 12.9	Collas et al. 2023

⇒ A minimum ingestion of soil has to be integrated in risk assessments

Variation factors:

- herbage offer & supplement,
- season & soil surface moisture,
- foraging behaviour,
- etc.