IRSOIL: A National Series of Radon-in-Soil Intercomparison Exercises in Italy

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17th INTERNATIONAL WORKSHOP GARRM
September 16th – 18th, 2025, Prague, Czech Republic

Since 2021, every year an Inter-Laboratory Comparison (ILC) of radon in soil measurements has been carried out by the *Italian Radiation Protection Association* (AIRP) and the *Italian Association of Radon Professionals* (ASSORADON) in different places around Italy

Answer to practical needs of professionals:

- ***am I performing radon-in-soil measurements correctly?***
- ***what is the variability of radon-in-soil measurements when carried out by different laboratories and operators?***

The fields

ILC Code	Place	Region	Year	Number of spots	Number of participants	
IRSOIL 2021 – P1	Valle Cervo Campiglia Cervo (BI)	Piedmont	2021	6	11	
IRSOIL 2021 – P2	Riserva Naturale della Bessa Zubiena (BI)	Piedmont	2021	6	10	
IRSOIL 2022 – P3	Parco della Caffarella (Roma)	Lazio	2022	8	11	
IRSOIL 2022 – P4	Parco della Caffarella (Roma)	Lazio	2022	5	11	
IRSOIL 2023 – P5	Curinga (CZ)	Calabria	2023	4	9	
IRSOIL 2024 – P6	Ghedi (BS)	Lombardy	2024	10	11	
IRSOIL 2025 – P7	*Lecce (LE)*	*Apulia*	*2025*	*6*	*12*	*Ongoing*

Standard Timeline

Sites description

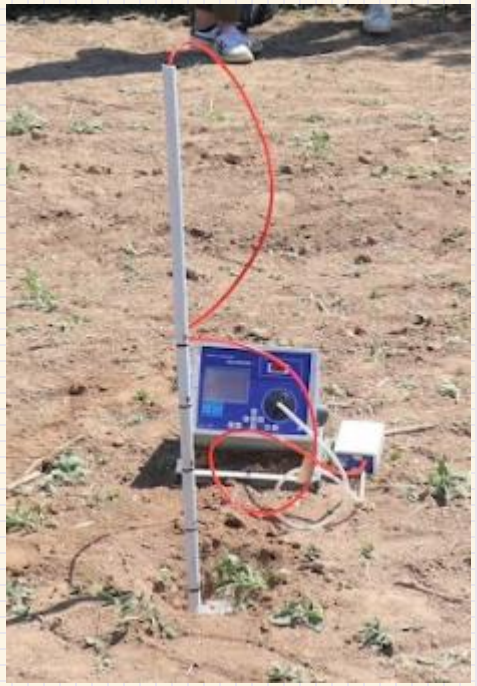
Each site has different geology and soil properties:

Oligocene pluton (P1), Pleistocene Ivrea morainic amphitheatre (P2), ignimbrites and alluvial deposits (P3,P4), coarse conglomerates resting on a complex of para-gneisses and schists (P5), fluvioglacial and fluvial deposits (P6), carsic region (P7)

The in-field situation

Participants	•9 – 12 groups
Detectors	•Lucas cells / Ionization chambers / Solid state
Sampling	•100% active with pump (2-25 min @ different flows)
Thoron	•Active or passive techniques to minimize the contribution of thoron

The in-field situation



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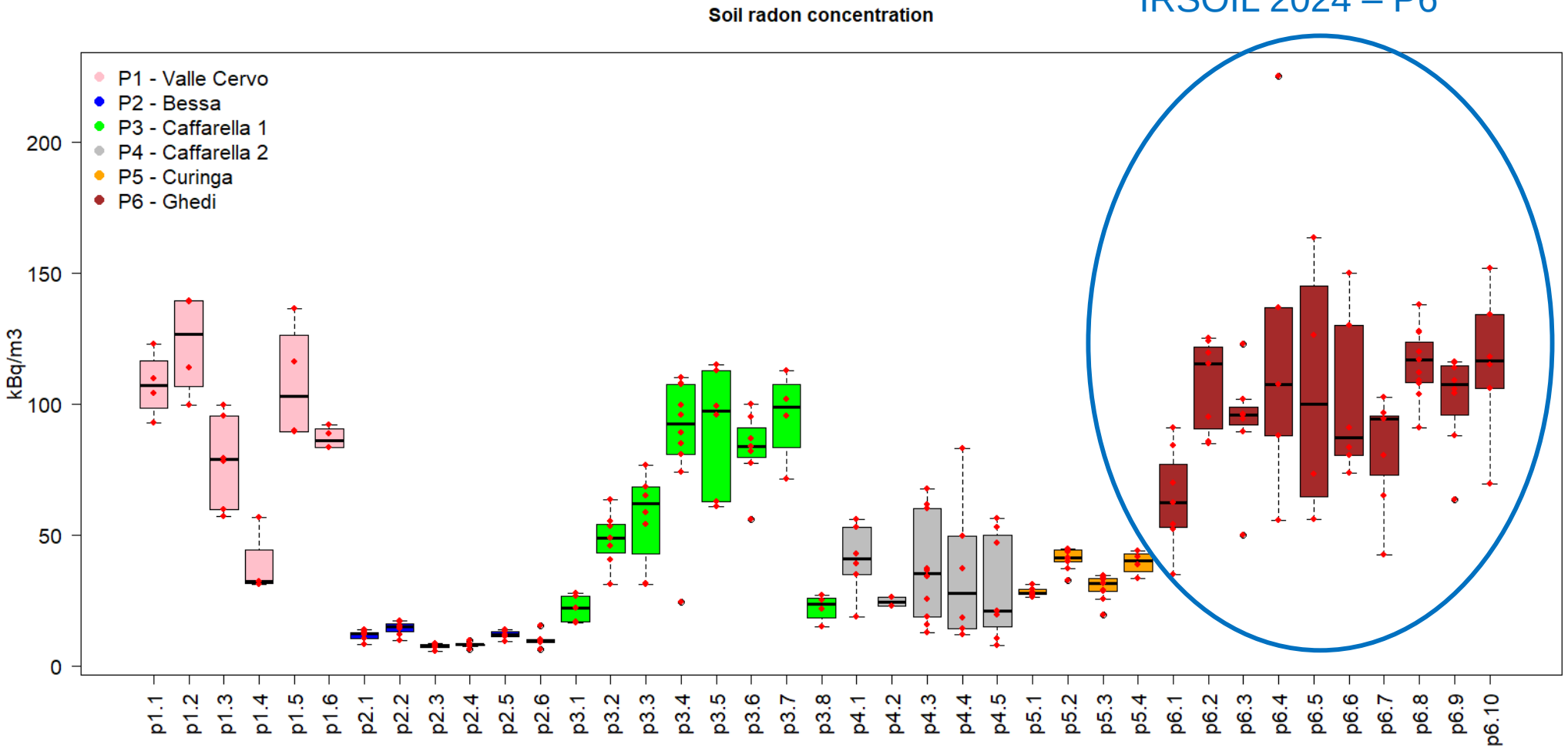
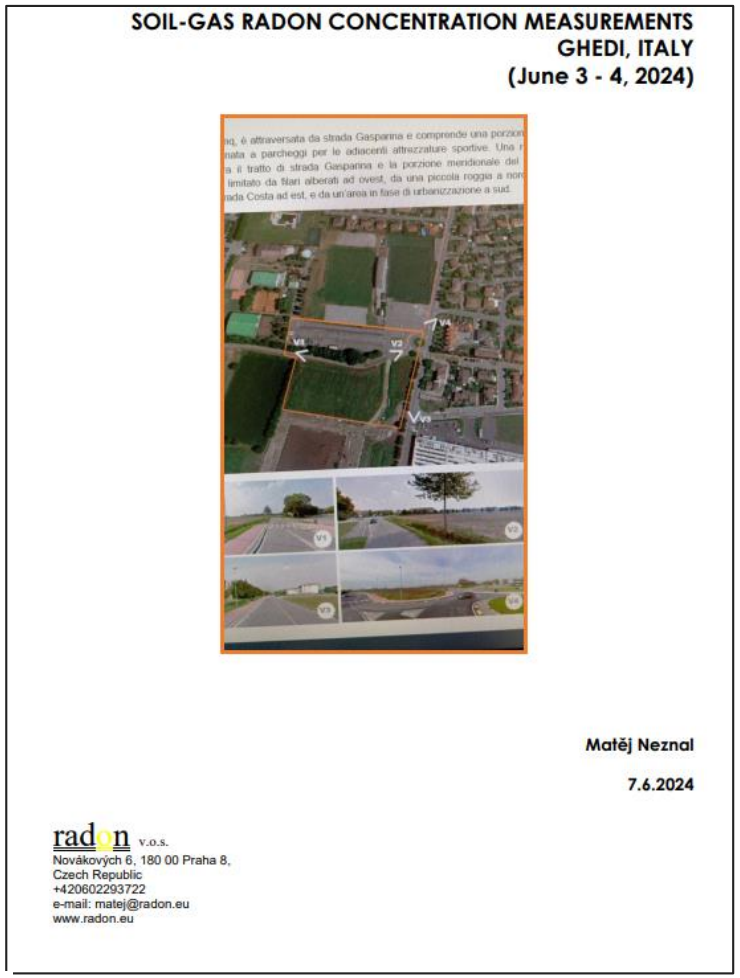
The ILC results

IRSOIL 2024 – P6



The IRSOIL 2024 (P6 – Ghedi – Lombardy)



SOIL-GAS RADON CONCENTRATION MEASUREMENTS
GHEDI, ITALY
(June 3 - 4, 2024)

Matěj Neznal

7.6.2024

radon v.o.s.
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Czech Republic
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e-mail: matej@radon.eu
www.radon.eu

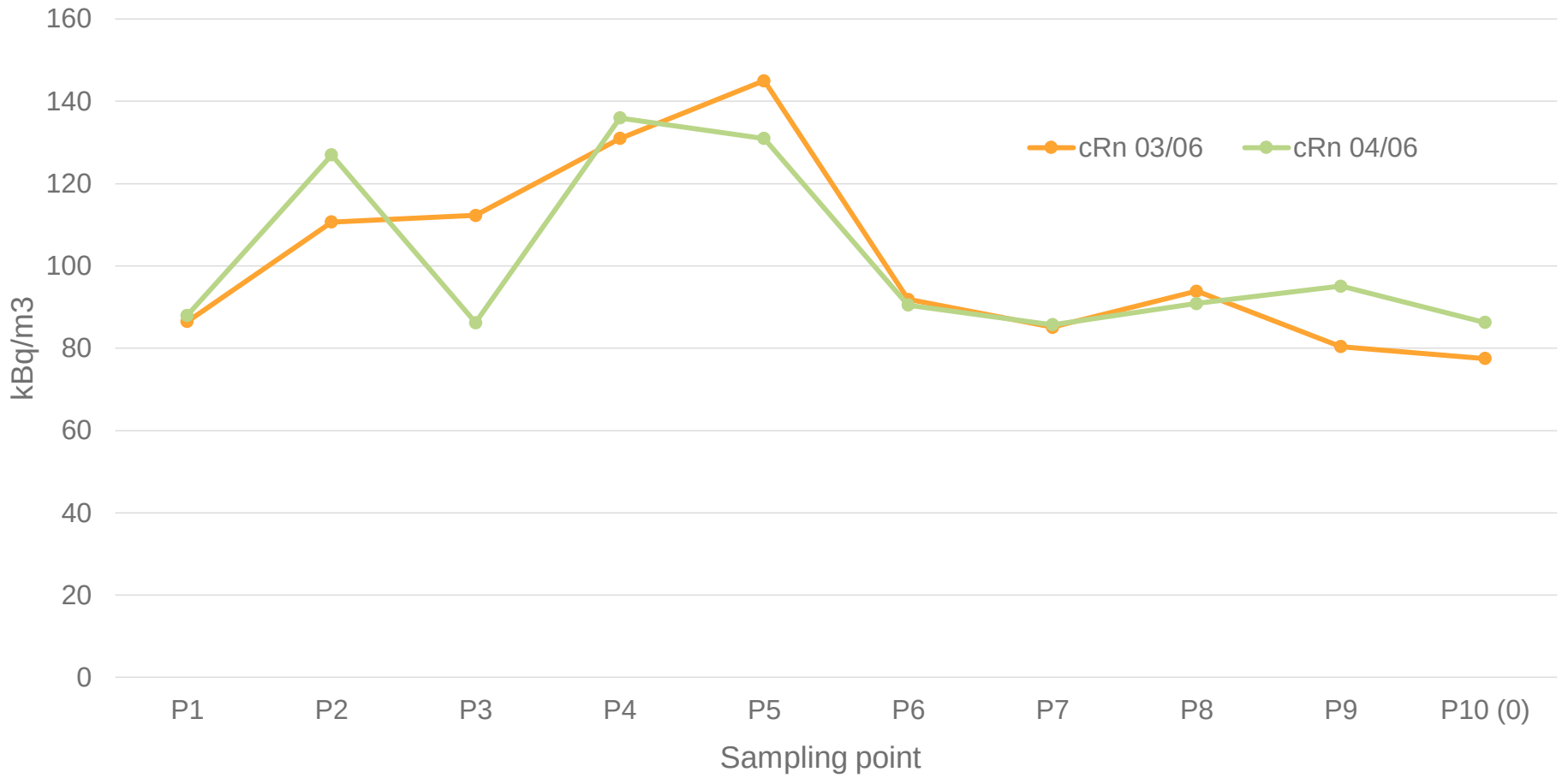
On June 3 and 4, 2024, preliminary radon gas concentration measurements were carried out by the company Radon v.o.s., Novákových 6, 180 00 Praha 8, Czech Republic, which has long been involved in the organization of international soil radon intercomparisons (REM).

The sampling spots

P6: Site characterization results (measurements on June 3rd)

Sampling point	Time of Sampling	Depth (cm)	cRn (kBq/m^3)	Inc ?	Permeability (m^2)
0	14:19	80	78.2		$k \geq 1.4\ 10^{-11}$ (high)
1	14:51	80	85.4		$k \geq 1.4\ 10^{-11}$ (high)
2	15:01	80	111		$k \geq 1.4\ 10^{-11}$ (high)
3	15:10	80	111		$k = 6.8\ 10^{-12}$ (high)
4	15:17	80	132		
5	15:23	80	143		
6	15:29	80	93.9		
7	15:32	80	84		
8	15:43	80	94.4		
9	15:50	80	81.5		

P6: Site characterization results

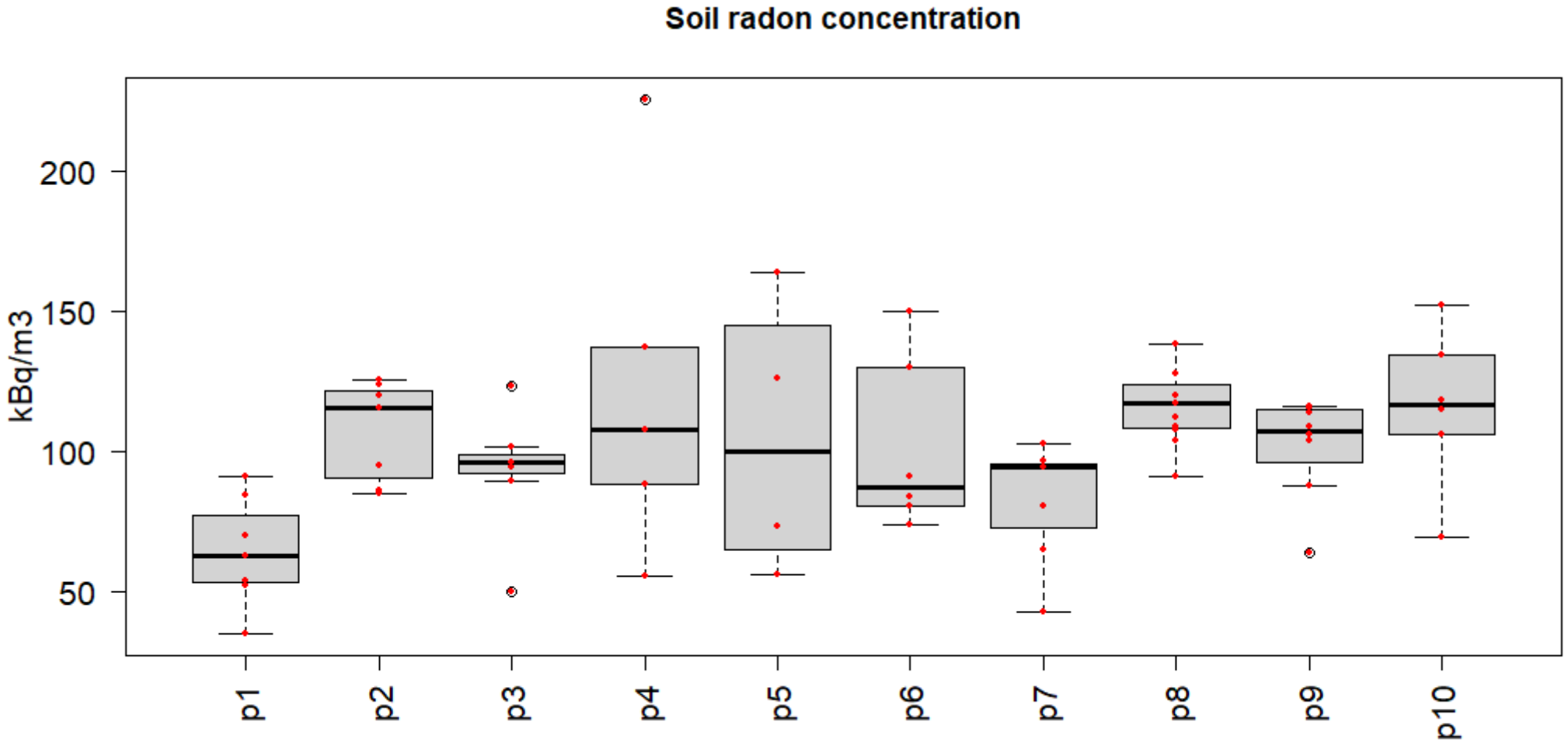


P6: Participants Results

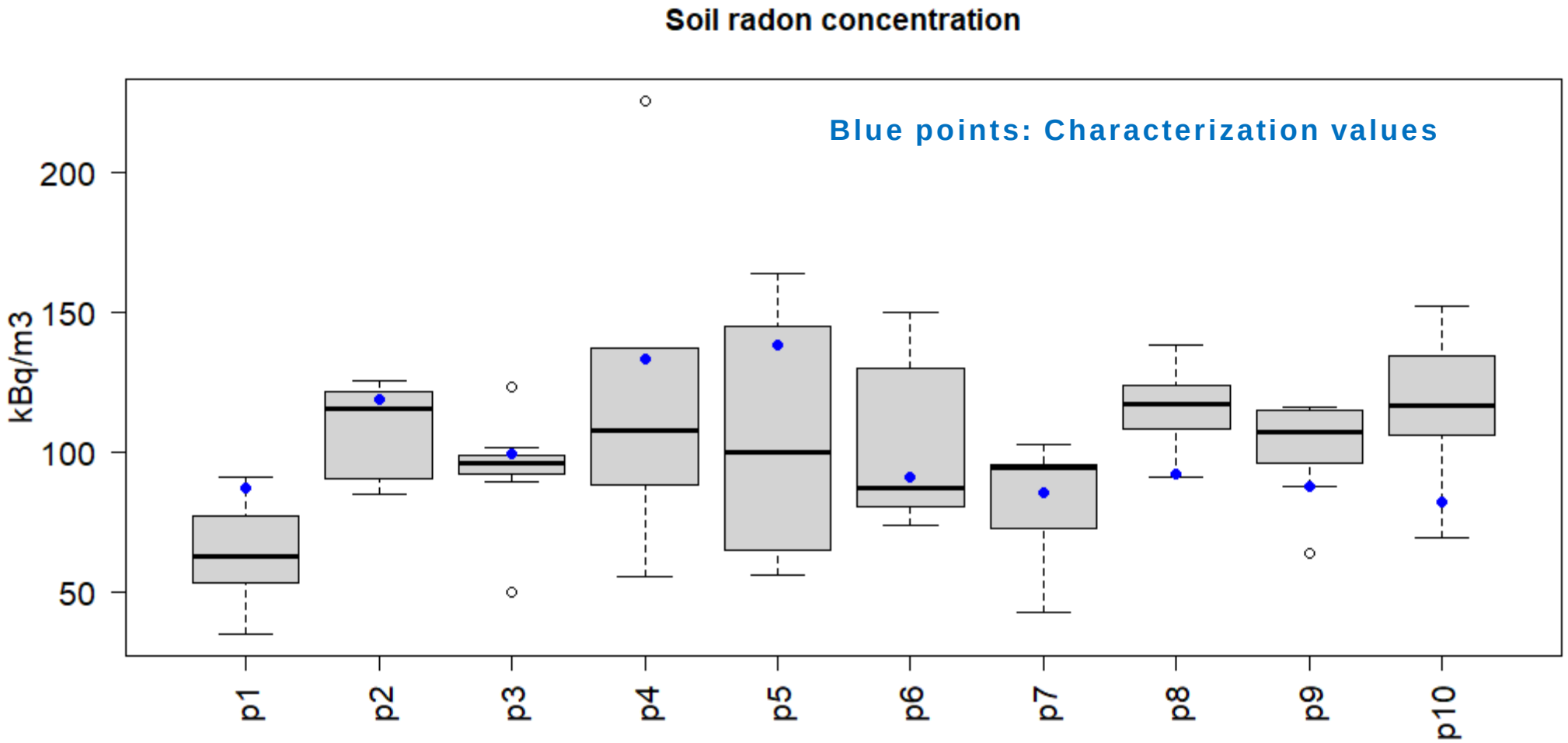
Concentrazione radon [kBq/m3] comunicata dai partecipanti, con incertezza (k=1)

Partecipante	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
1								127.7 ± 7.9	115.7 ± 6.8	134.3 ± 8.5
2								117.0 ± 12.0	109.0 ± 11.0	115.0 ± 12.0
2 bis								138.0 ± 5.0	104.0 ± 5.0	118.0 ± 5.0
3	35.0 ± 3.5		50.0 ± 5.0				65.0 ± 6.5	120.0 ± 12.0		152.0 ± 15.2
4	52.1	95.0	94.4	55.5		80.4	94.4	108.9	116.2	
6	69.9 ± 11.1	125.3 ± 19.8	96.3 ± 15.2	107.6 ± 17.0	56.1 ± 8.9	83.6 ± 13.2	96.6 ± 15.3	107.8 ± 17.0	63.7 ± 10.1	
7	54.0 ± 8.2	115.5 ± 17.4	89.6 ± 13.5	225.5 ± 34.1	73.4 ± 11.1	73.7 ± 11.0	102.8 ± 15.5	103.7 ± 15.6	105.8 ± 16.0	
8	84.2 ± 13.2	85.0 ± 13.8	123.0 ± 16.4	88.0 ± 14.4	126.3 ± 18.3	130.0 ± 19.9	80.5 ± 11.1	91.1 ± 12.2		
9		119.7 ± 25.0	101.8 ± 9.3	137.0 ± 14.7	163.8 ± 25.0	91.0 ± 17.4	94.4 ± 19.8	127.5 ± 11.7	87.9 ± 15.8	
10	62.5	85.9				150.0	42.5	120.1	114.0	69.4
13	91 ± 12	124 ± 11	96 ± 11					112 ± 11		106 ± 12

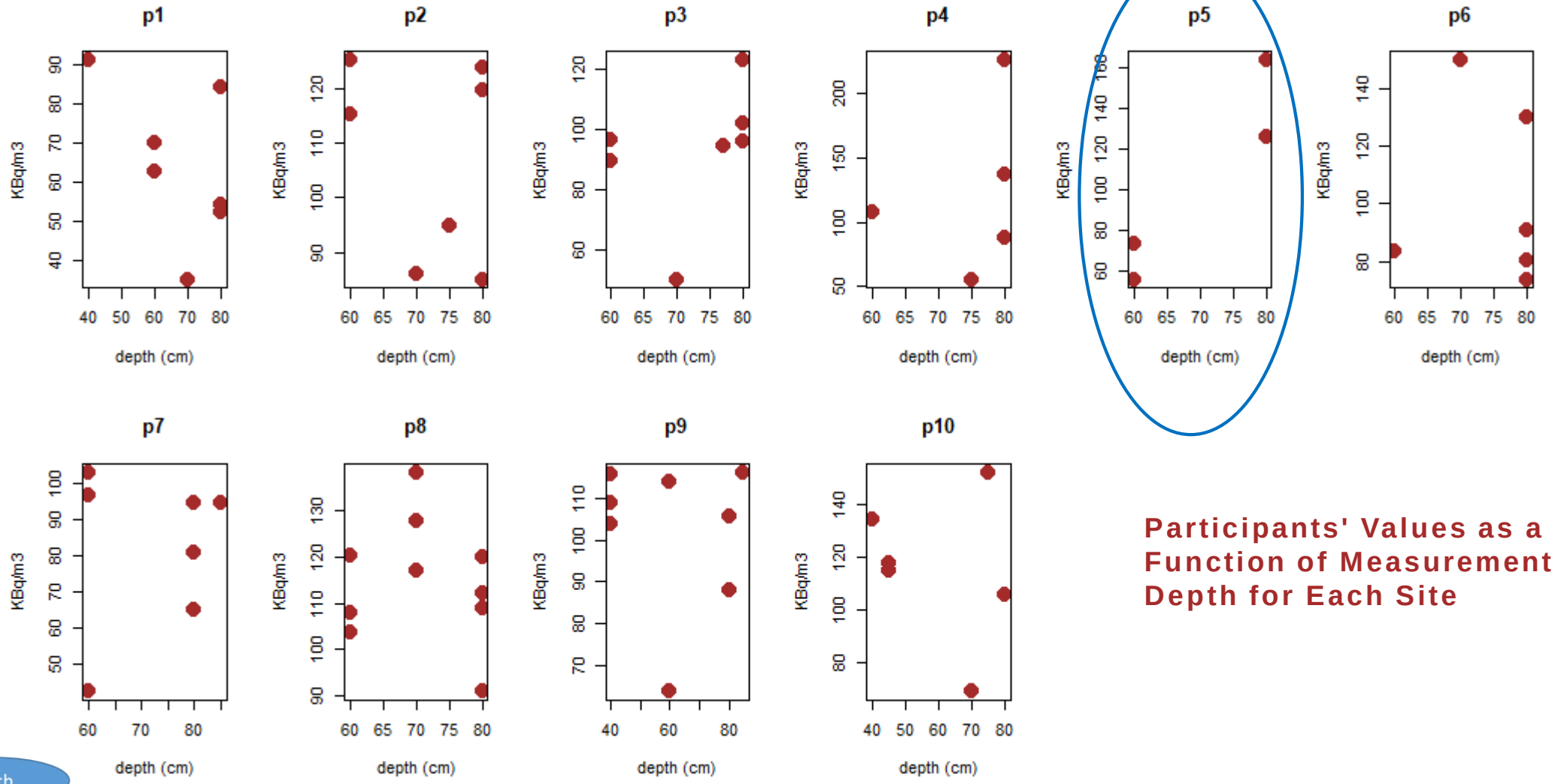
P6: Participants Results



Participants Results



P6: Participants Results



Participants' Values as a Function of Measurement Depth for Each Site

Statistics

Indicators

Ratio "R":

$$R = \frac{x}{X}$$

Difference "D":

$$D = (x - X)$$

Percentage difference "$D_{\%}$":

$$D_{\%} = \frac{(x - X)}{X} \cdot 100$$

z score:

$$z = \frac{x - X}{\hat{\sigma}}$$

ζ score:

$$\zeta = \frac{x - X}{\sqrt{u^2(x) + u^2(X)}}$$

x	Participant's results
X	Consensus value (**robust mean**)
$u(x)$	Participant's uncertainty (k=1)
$u(X) = 1{,}25 \cdot \frac{\sigma_{rob}}{\sqrt{p}}$	Consensus value uncertainty (k=1) σ_{rob}: robust standard deviation p : number of the partecipants
$\hat{\sigma} = 0{,}20 \cdot X$	Standard deviation for the calculation of the z-score chosen by the organizer, equal to **20%** of the reference value X

ISO/IEC 17043 – annex B
ISO 13528:2015

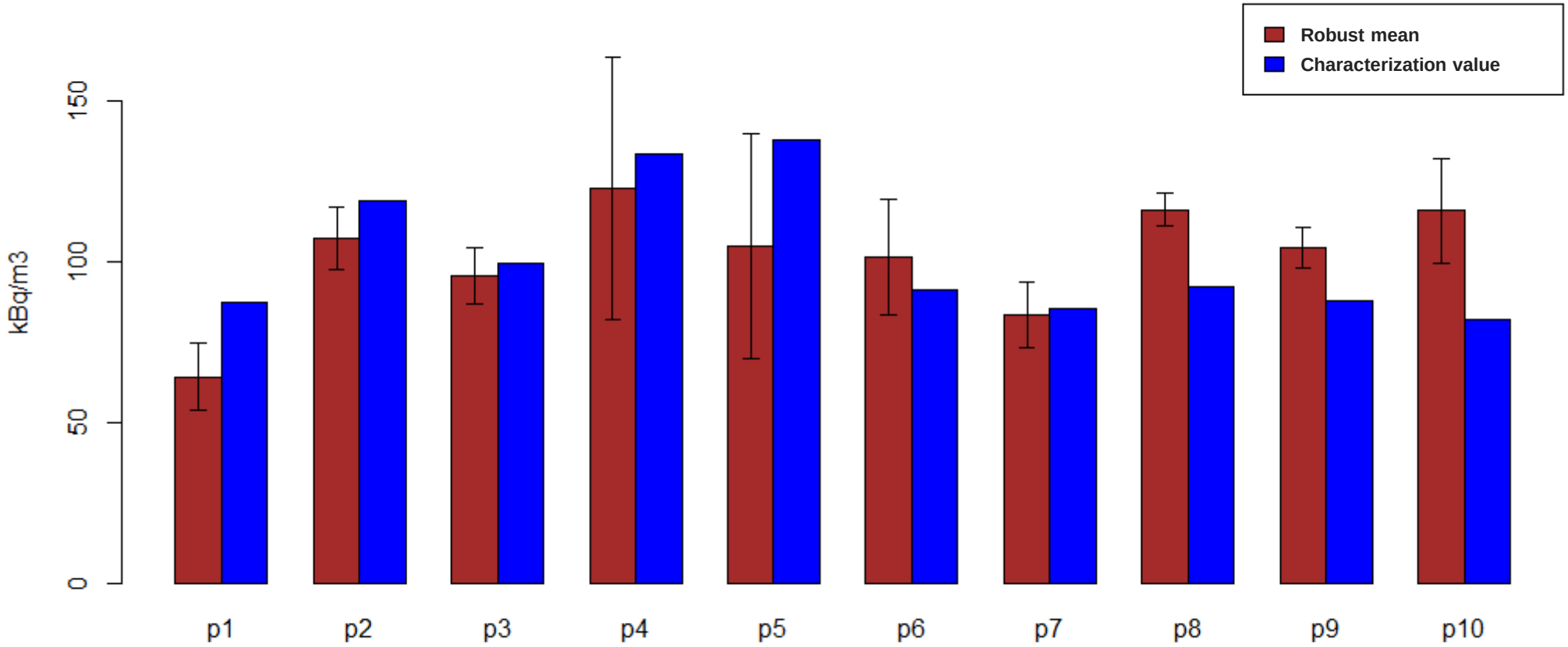
P6: Statistics for each sampling point

IRSOIL 2024

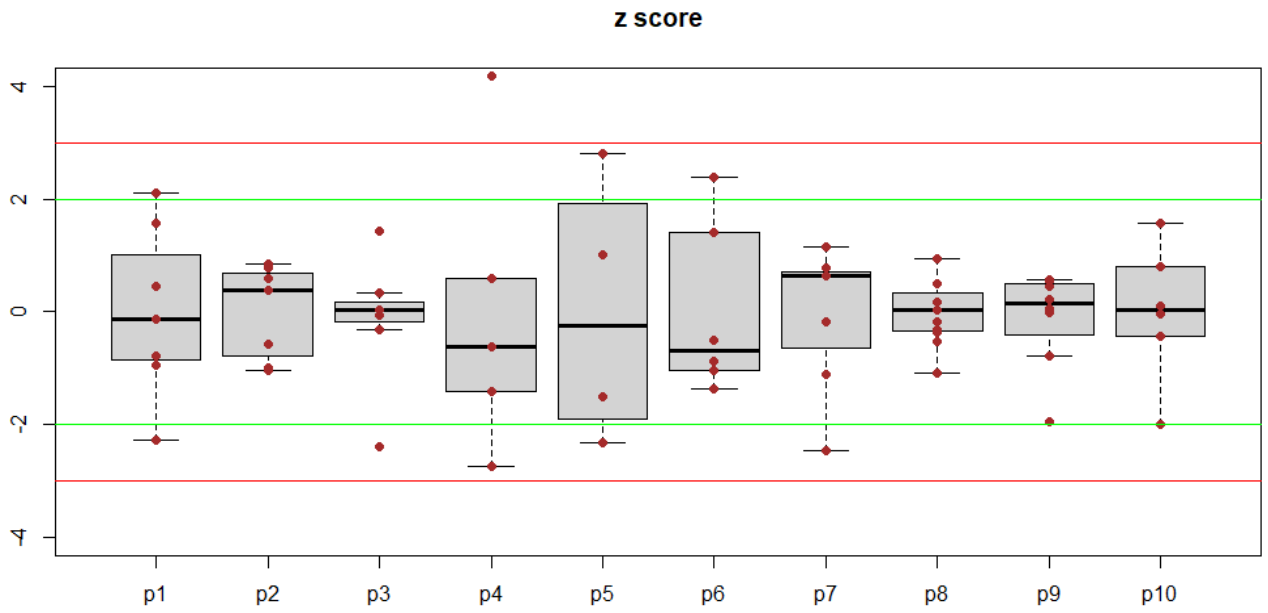
Indicatore	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
MAX	91.0	125.3	123.0	225.5	163.8	150.0	102.8	138.0	116.2	152.0
min	35.0	85.0	50.0	55.5	56.1	73.7	42.5	91.1	63.7	69.4
MA	64.1	107.2	93.0	122.7	104.9	101.4	82.3	115.8	102.0	115.8
σ	19.4	17.9	21.8	64.7	49.3	31.0	21.6	13.0	18.0	28.0
X	64.1	107.2	95.6	122.7	104.9	101.4	83.6	116.1	104.5	115.8
σrob	22.0	20.3	18.5	73.3	55.9	35.2	21.6	13.4	14.3	31.7
u(X)	10.4	9.6	8.7	41.0	34.9	17.9	10.2	5.0	6.3	16.2
$\hat{\sigma}$	12.8	21.4	19.1	24.5	21.0	20.3	16.7	23.2	20.9	23.2
Nmis	7	7	7	5	4	6	7	11	8	6

KBq/m^3

P6: Participants & characterization results



P6 Performance evaluation: z-score



z score

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Indicatore	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
1								0.50	0.54	0.80
2								0.04	0.22	-0.03
2 bis								0.94	-0.02	0.10
3	-2.27		-2.38				-1.11	0.17		1.56
4	-0.94	-0.57	-0.06	-2.74		-1.04	0.65	-0.31	0.56	
6	0.45	0.84	0.04	-0.62	-2.33	-0.88	0.78	-0.36	-1.95	
7	-0.79	0.39	-0.31	4.19	-1.50	-1.37	1.15	-0.53	0.06	
8	1.57	-1.04	1.44	-1.41	1.02	1.41	-0.18	-1.08		
9		0.58	0.33	0.58	2.81	-0.52	0.65	0.49	-0.79	
10	-0.12	-0.99				2.39	-2.46	0.17	0.46	-2.00
13	2.10	0.78	0.02					-0.18		-0.42

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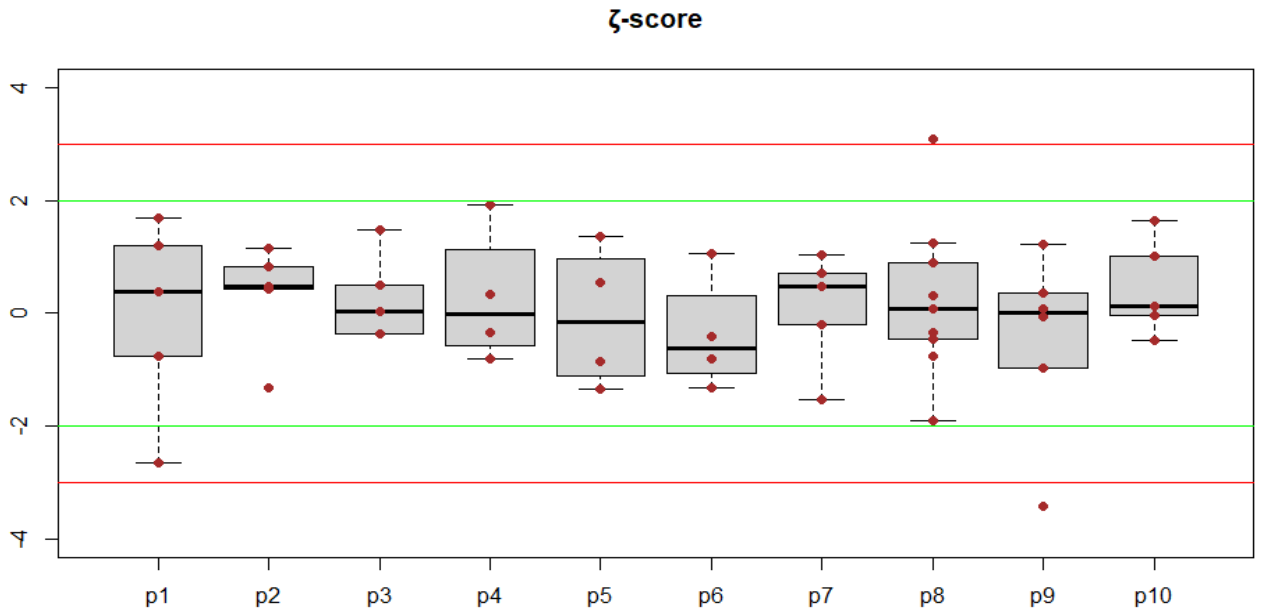
P6 Performance evaluation: ζ-score



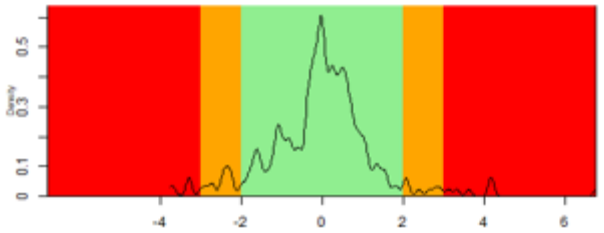
ζ-score

IRSOIL 2024

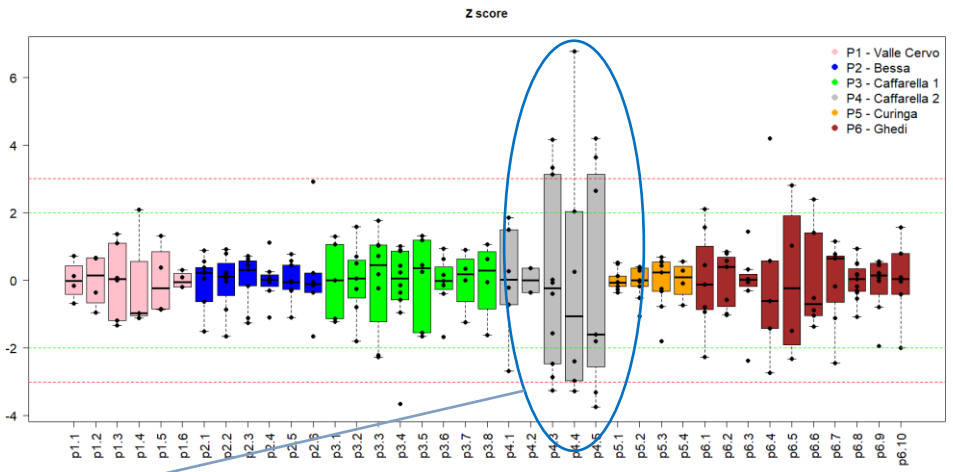
Indicatore	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
1								1.24	1.21	1.01
2								0.07	0.36	-0.04
2 bis								3.09	-0.06	0.13
3	-2.66		-4.52				-1.53	0.30		1.63
4	Uncertainty not provided									
6	0.38	0.82	0.04	-0.34	-1.35	-0.80	0.71	-0.47	-3.42	
7	-0.76	0.42	-0.37	1.93	-0.86	-1.32	1.04	-0.75	0.08	
8	1.20	-1.32	1.48	-0.80	0.54	1.07	-0.20	-1.89		
9		0.47	0.49	0.33	1.37	-0.42	0.49	0.90	-0.97	
10	Uncertainty not provided									
13	1.70	1.15	0.03					-0.34		-0.49

Performance evaluation for all the ILCs (P1-P6)

z-score	
|z| < 2	87 %
2 < |z| < 3	8 %
|z| > 3	5 %

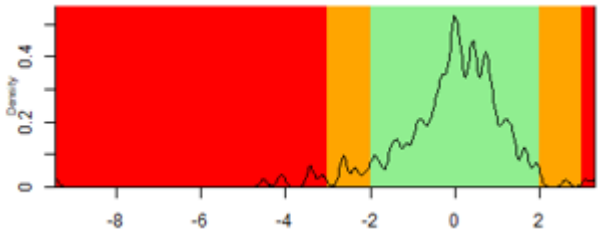


Density distribution of the z-scores

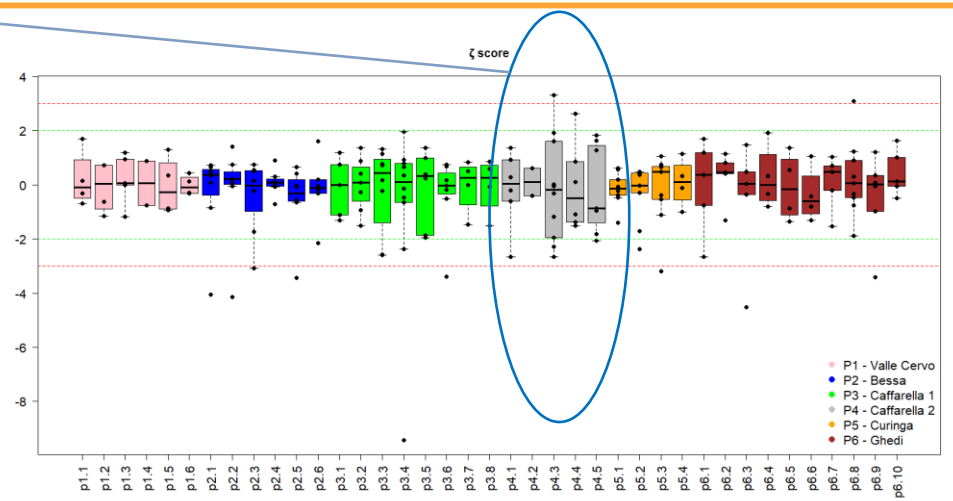


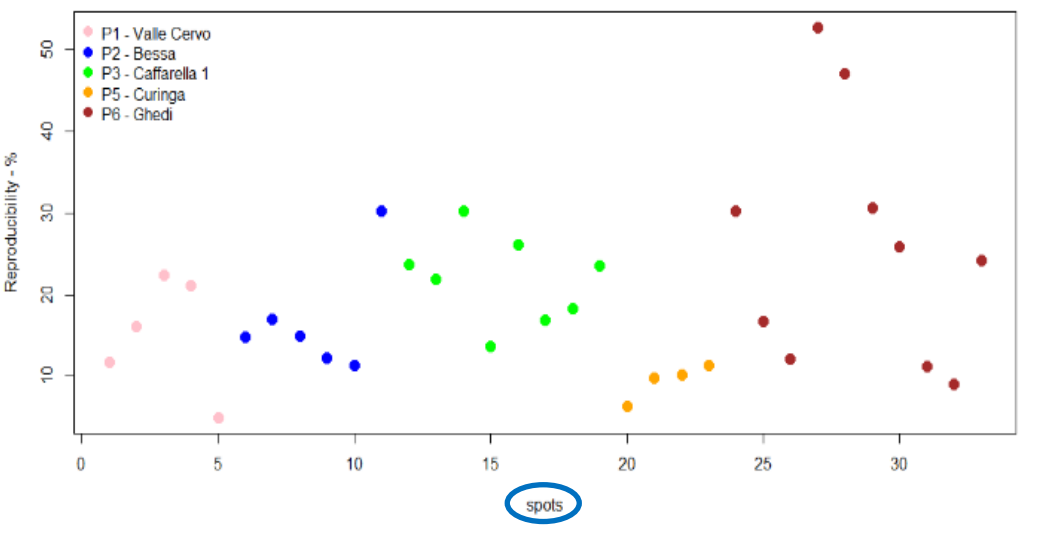
Moisture problems

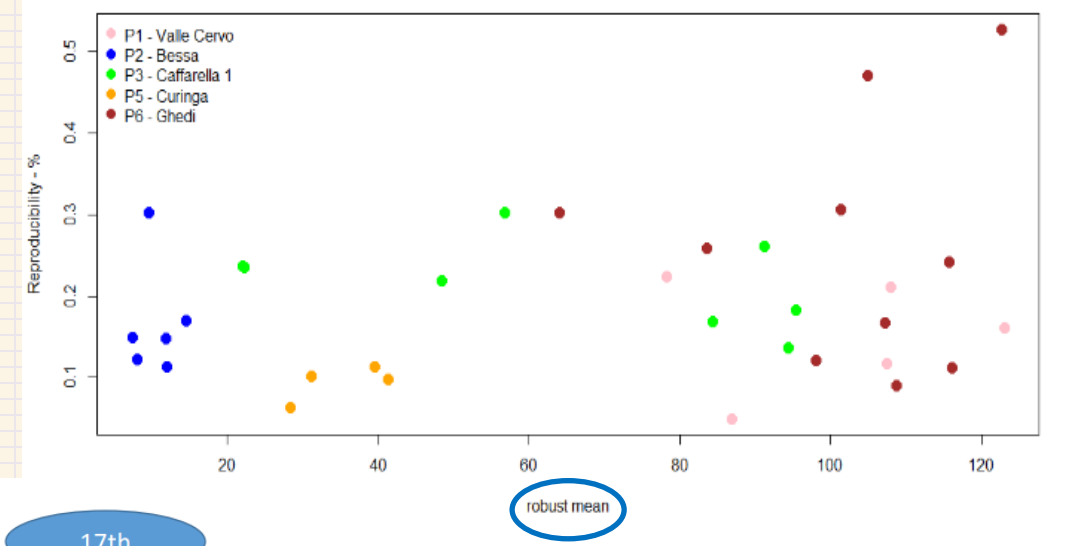
ζ-score	
|ζ| < 2	90 %
2 < |ζ| < 3	5 %
|ζ| > 3	5 %



Density distribution of the ζ-scores





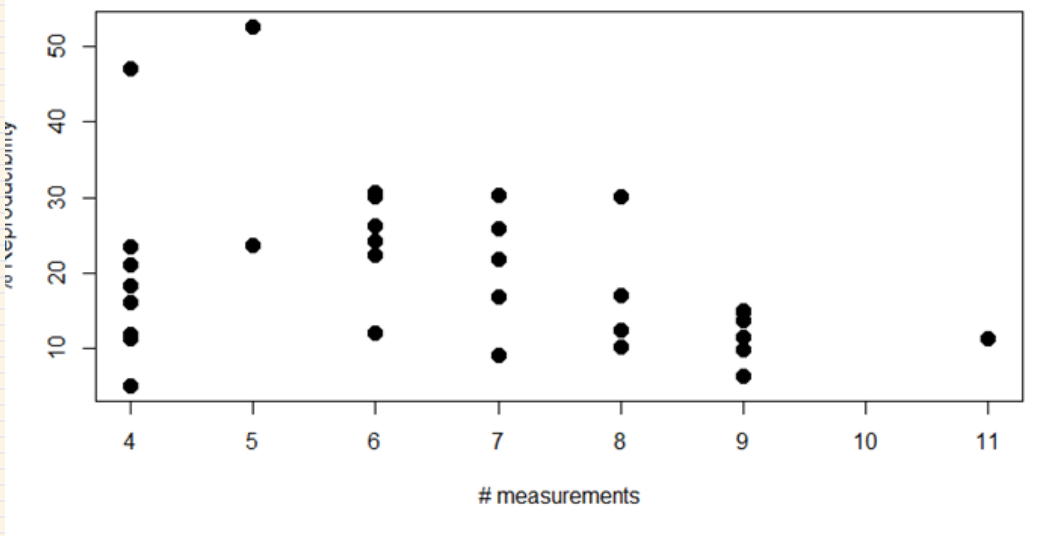


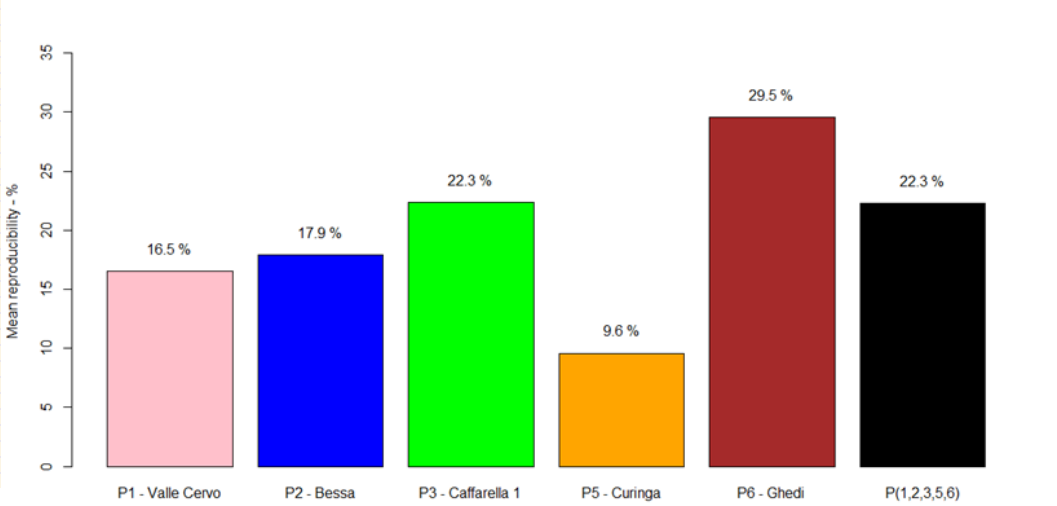
Reproducibility

These ILCs allow the evaluation of the performance characteristics of a method, in particular the evaluation of its *reproducibility standard deviation* (S_R)

Homogenous dataset:

- **outliers were removed**
- **results of the P4 field were discharged**





Reproducibility

- As the amount of data for each spot increases, the maximum value of the reproducibility becomes lower
- The overall reproducibility is around **22%**, a value that is consistent with the standard deviation for the comparison assessment ($\hat{\sigma}$) of **20%** chosen by the provider



Thank you for your attention

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