Laboratory VIS-NIR-SWIR setups with different spectroscopy accessories for characterization of soils from wildfire burns

Olga Rosero Vlasova

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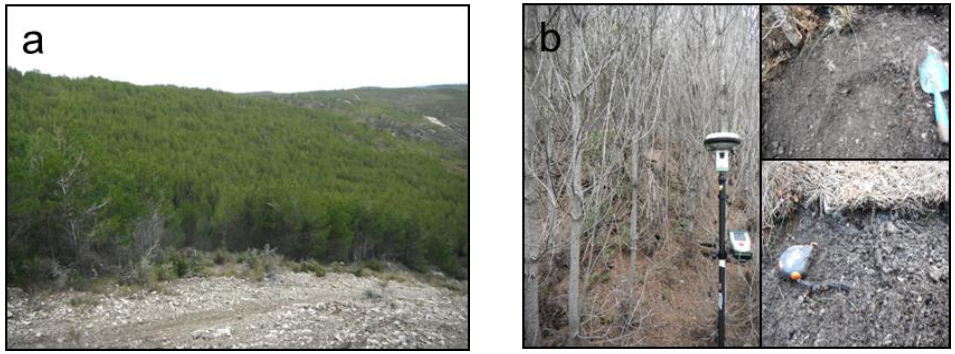
Fernando Pérez-Cabello, Raquel Montorio Llovería
Department of Geography and Land Management,
GEOFOREST Group – IUCA
ERTAlab
University of Zaragoza, Spain

Research background

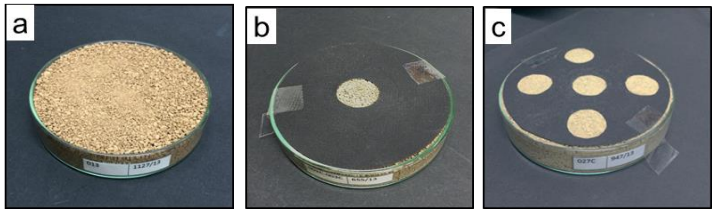
- Forest fires affect landscape components.
- They cause changes in soil organic constituents and modify soil physical properties.
- Changes in soil are related to changes in soil spectral properties and can be detected by proximal soil sensing techniques.
- Soil reflectance is composed of regular (specular) and diffuse (non-directional) reflectance
- **Study area:** Samples collected in the region of Aragón (Northern Spain).



A typical view of the study area and one of the sampling points.

Materials and methods

- **Samples** obtained from upper soil layer (0-10 cm).
  - Sieved (< 2mm)
  - Spread (Petri dish)
  - Dried



- **Laboratory spectral measurements:** Done under controlled conditions
  - Spectroradiometer ASD FieldSpec4
  - Spectroscopy accessories
    - ASD External Integrating Sphere RTS-3ZC
    - ASD Contact Probe
    - ASD Illuminator Lamp + Pistol Grip

Shortcomings

- Even slight variations in sample preparation, instrument configuration and measurement protocols can affect the quality of models relating spectral and edaphic properties.

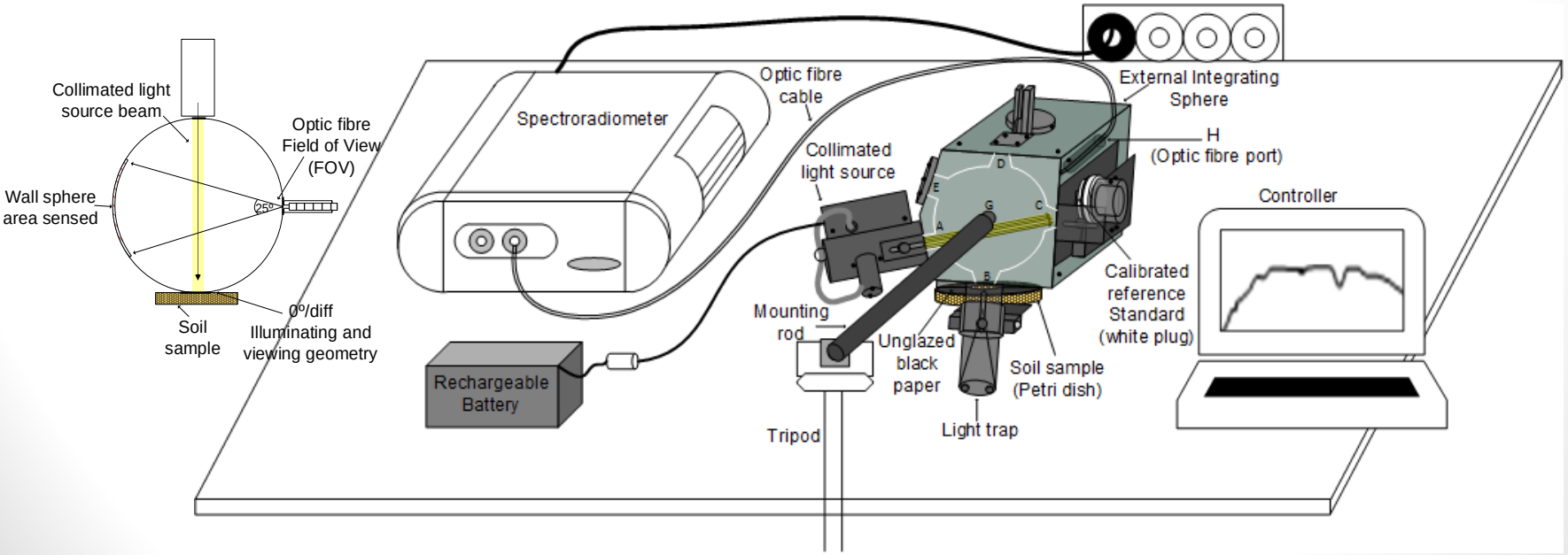
- Performance of used accessory can be more critical for stability of reflectance measurements than that of the spectroradiometer (Knadel et al., 2013 and Ben-Dor et al., 2015).

Research objective

- Evaluate the impact of between-setups differences in reflectances on predictive ability of statistical models, for example, for soil organic matter (SOM).

Integrating Sphere setup

- Accessory is a spherical cavity 7.62cm in diameter coated with a white diffuse polymer.
- Allows spatial integration of radiation reflected over the wavelengths in the 350-2500nm.
- Sensor registers the light reflected by the wall and makes an estimate of the sample reflectance.

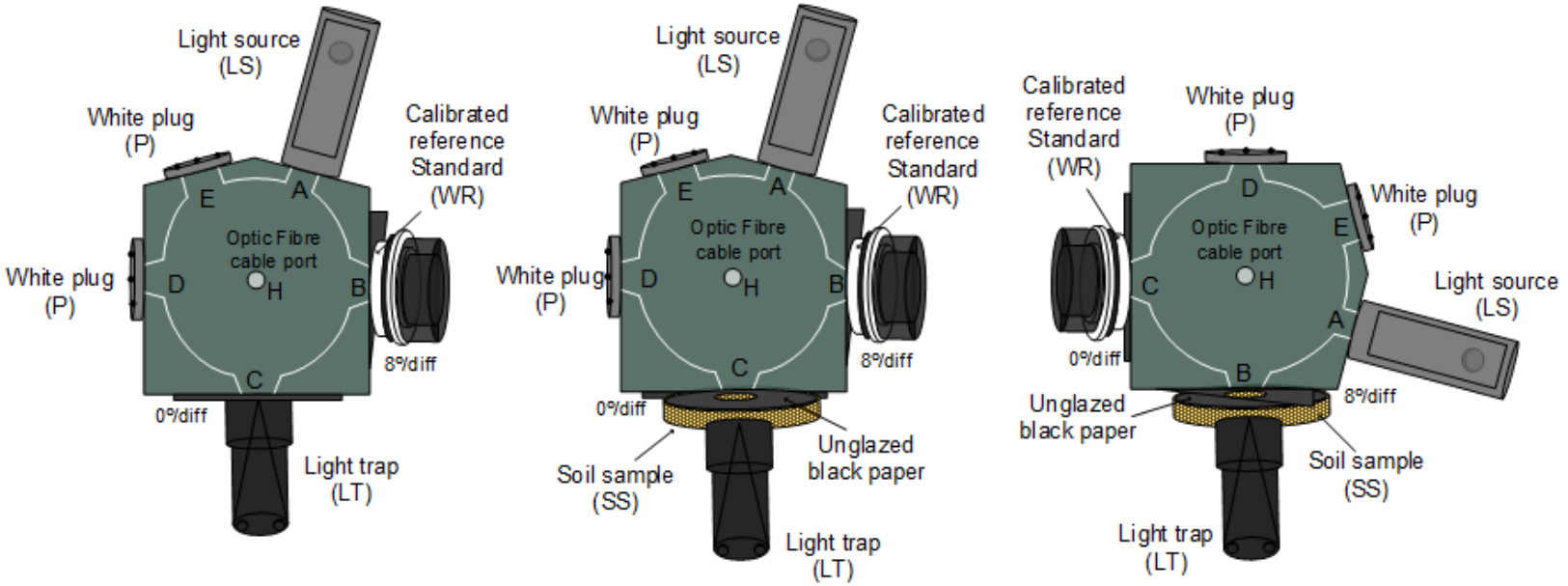


Integrating Sphere ports

- Sphere provides six ports 13mm (ports A, D and H), 15mm (ports C and B) and 19mm (port E) in diameter.

Quantity	Reflectance Measurement Port Configuration				
	Port A	Port B	Port C	Port D	Port E
DR	LS	WR	LT	P	P
R_{sample}	LS	WR	SS+LT	P	P
$R_{reference}$	LS	SS+LT	WR	P	P

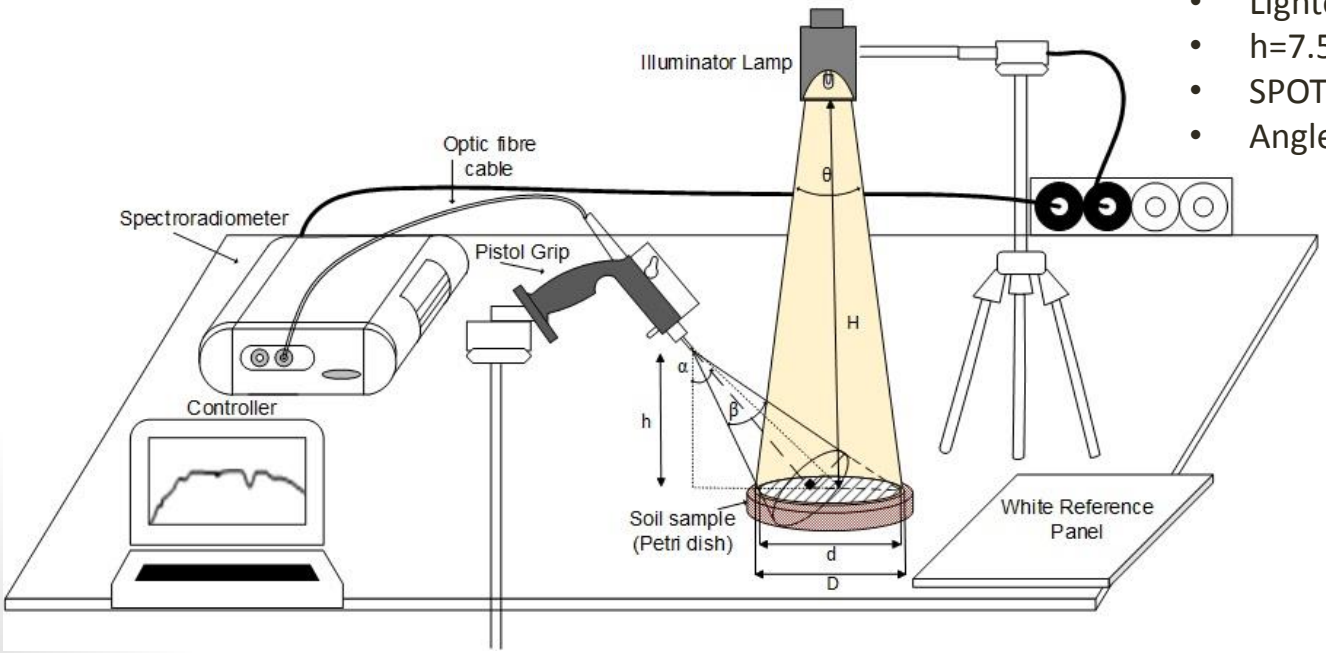
$$R_T(\lambda) = \frac{(R_{sample}(\lambda) - DR(\lambda))}{(R_{reference}(\lambda) - DR(\lambda))} R_{ref\_cal}(\lambda)$$



Illuminator Lamp setup

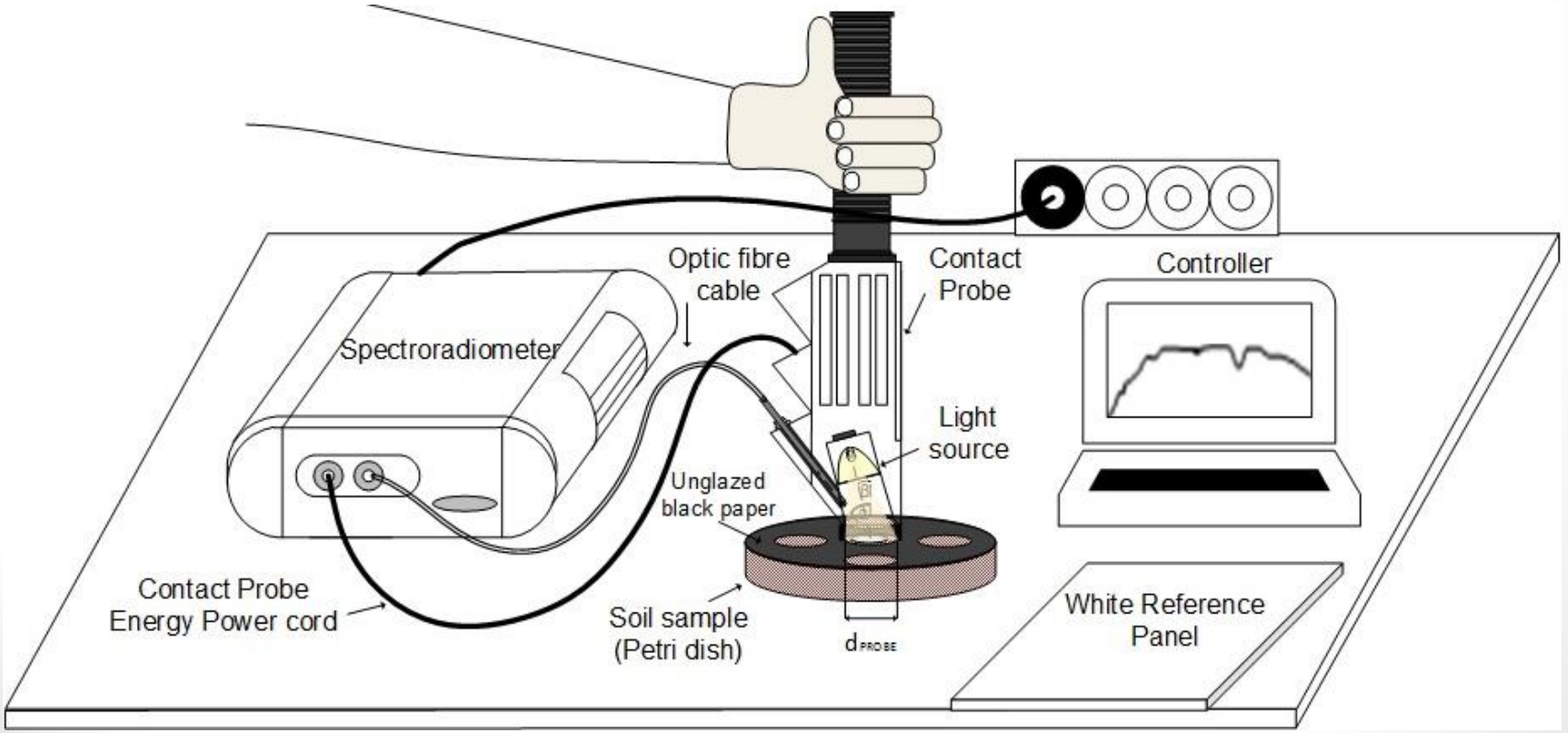
- ASD Illuminator halogen lamp
- Observation geometry previously calculated
  - (i) distance between the target and the sensor
  - (ii) distance between the target and the source of illumination
  - (iii) the angle between the two.

- Lamp beam angle θ=12°
- H=42cm (lamp)
- Lighted spot D = 8.82cm
- h=7.5cm (pistol grip)
- SPOT d=6,99cm (sensed area)
- Angle α=45° to vertical axis



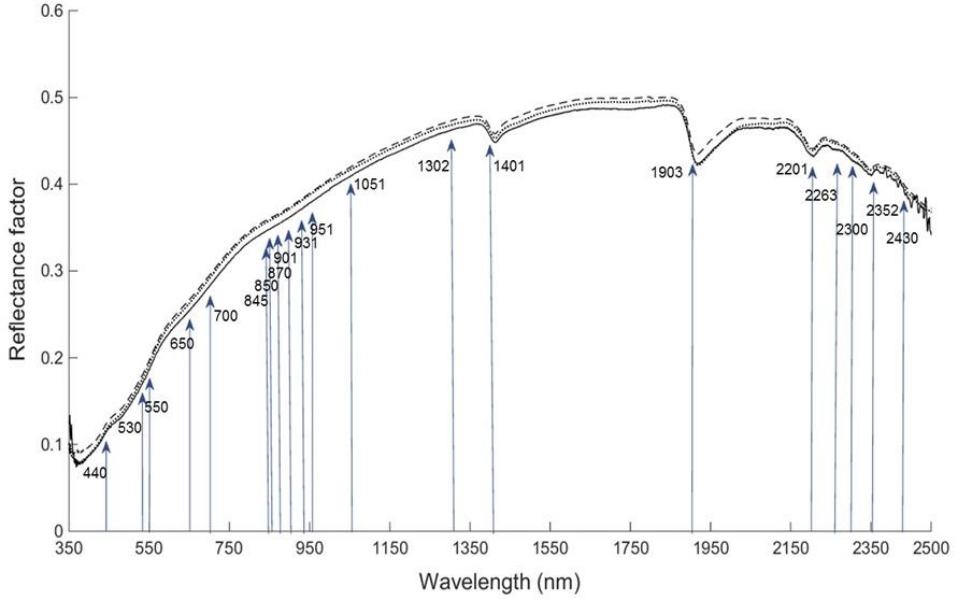
Contact Probe setup

- Reflectorized halogen lamp aligned at 12° to the probe body.
- Sensed spot has a diameter d_{probe} = 1,1cm with a FOV of 1.33 cm^2



Results:
Comparison of soil reflectance spectra

- Quite similar.
- Variations in instrumentation, protocols, environmental conditions and personnel may have negative consequences and affect comparability of the results (Ben-Dor et al., 2015; Brown, 2007; Ge et al., 2011).
- Performance of the used accessory (contact probe) was more critical for stability of reflectance measurements than that of the spectroradiometer.



Predictive modeling

- Partial-Least-Square Regression (PLSR) approach was applied.
- PLSR has capacity to deal with a great number of predictors solving the problem of multicollinearity.
- The method combines the characteristics of principal component analysis and multiple linear regression.
- The number of latent variables (components) and the final model are defined by cross-validation (leave-one-out approach).
- The resulting model was validated on a set of 20 samples left out for this purpose.

SOM prediction model (1)

Calibration results

- Setup IS presents the lowest R^2_{CV} (0.66) and highest level of uncertainty (RMSECV=1.91 g 100 g^{-1}).
- Compared to L, CP models showed comparable predictive capacity (R^2_{CV} =0.74), but higher RMSECV (1.69 g 100 g^{-1}).
- Better results were obtained with setup featuring Illuminator Lamp.

Statistic	Setup IS		Setup L		Setup CP	
R^2_{CV}	0,66	(0,62 - 0,70)	**0,77**	(**0,74 - 0,78**)	0,74	(0,68 - 0,77)
RMSECV (g 100 g^{-1})	1,91	(1,75 - 2,08)	**1,56**	(**1,47 - 1,65**)	1,69	(1,46 - 1,81)

SOM prediction model (2)

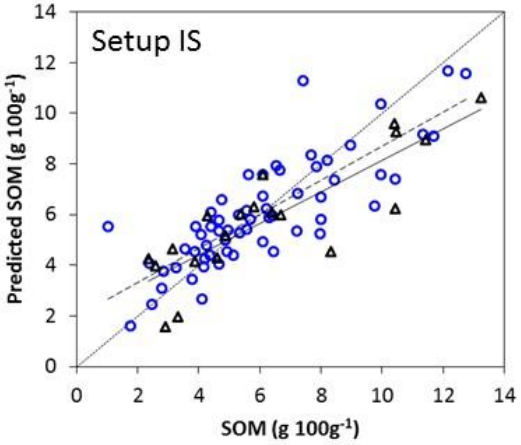
Validation results

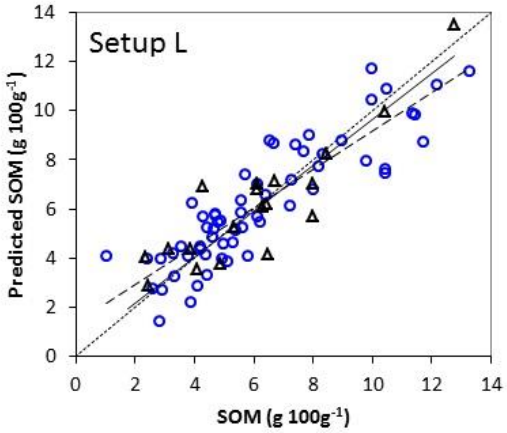
- R^2_V are slightly above those achieved by the corresponding calibrations; closeness of calibration and validation estimates evidences good quality of models and leads to the conclusion that there is no overfitting.
- Setup L demonstrates the best predictive capacity explaining around 80% of the variance (average R^2_V = 0.81; 0,78 R^2_V 0,86; 2,13 RPD 2,55).

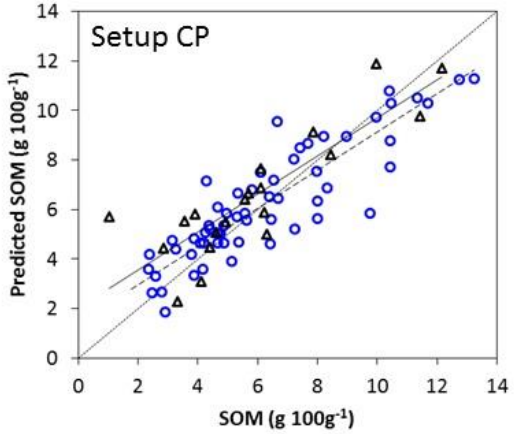
Statistic	Setup IS		Setup L		Setup CP	
R^2_V	0,73	(0,64 - 0,83)	**0,81**	**(0,78 - 0,86)**	0,75	(0,69 - 0,81)
RMSEP (g 100 g^{-1})	1,48	(1,13 - 1,80)	**1,28**	**(1,10 -1,43)**	1,41	(1,23 - 1,57)
RPD	1,88	(1,60 - 2,21)	**2,25**	**(2,13 -2,55)**	2,00	(1,81 - 2,25)

Scatter plots

- Predicted versus observed SOM values.







Conclusions (1)

- Although comparison of soil reflectances obtained with the three laboratory setups detected no statistically significant differences – between-setups differences in average R^2 of spectroscopic models were up to 11% for calibrations and 8% for validations.

- Most stable measurements of fire-affected soils were obtained with the setup using Illuminator lamp.

Conclusions (2)

- Model based on data of the Integrating Sphere presents lower R^2_{CV} (0.66) and highest level of uncertainty (RMSECV=1.91 g 100 g^{-1}).

- Illuminator Lamp and Contact Probe – SOM models capable of accurate prediction($0.75 \leq R^2_V \leq 0.81$; $2{,}00 \leq RPD \leq 2.55$).

- High predictive capacity of models based on the setup with Illuminator Lamp (Setup L) leads to a conclusion that VIS-NIR-SWIR spectroscopic configurations integrating this accessory can be used for monitoring post-fire evolution of soils.

Thank you all!!