Tel-Aviv University.
The Department of Geography.
The School of Geophysics
The Faculty of Exact Sciences

MASTER THESIS

"Estimation and Detection Limit of Organic Matter with Different Composition in Sand Dunes Using Hyperspectral Remote Sensing and Point Spectroscopy"

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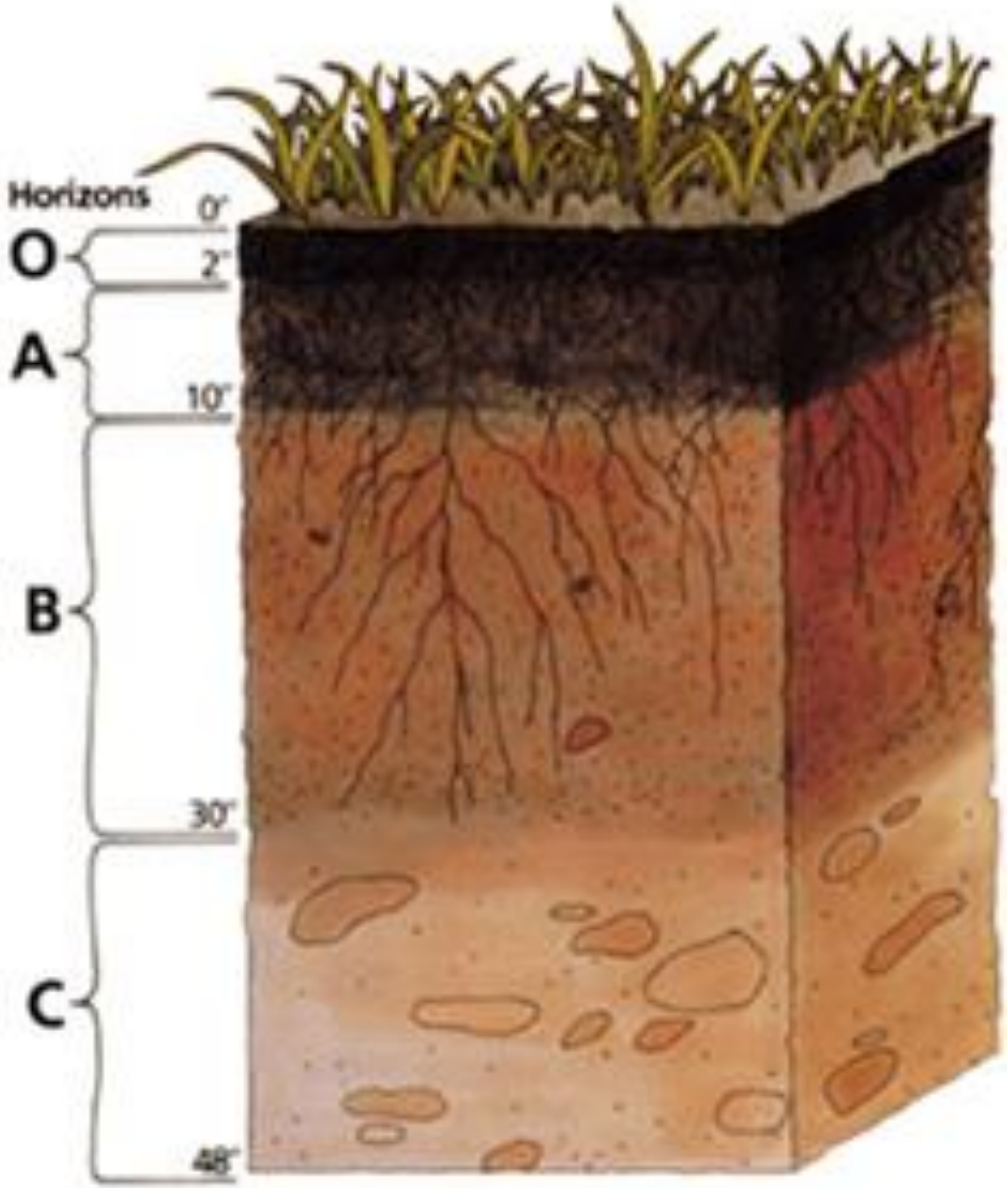
Literature Review:

Organic Matter (OM)

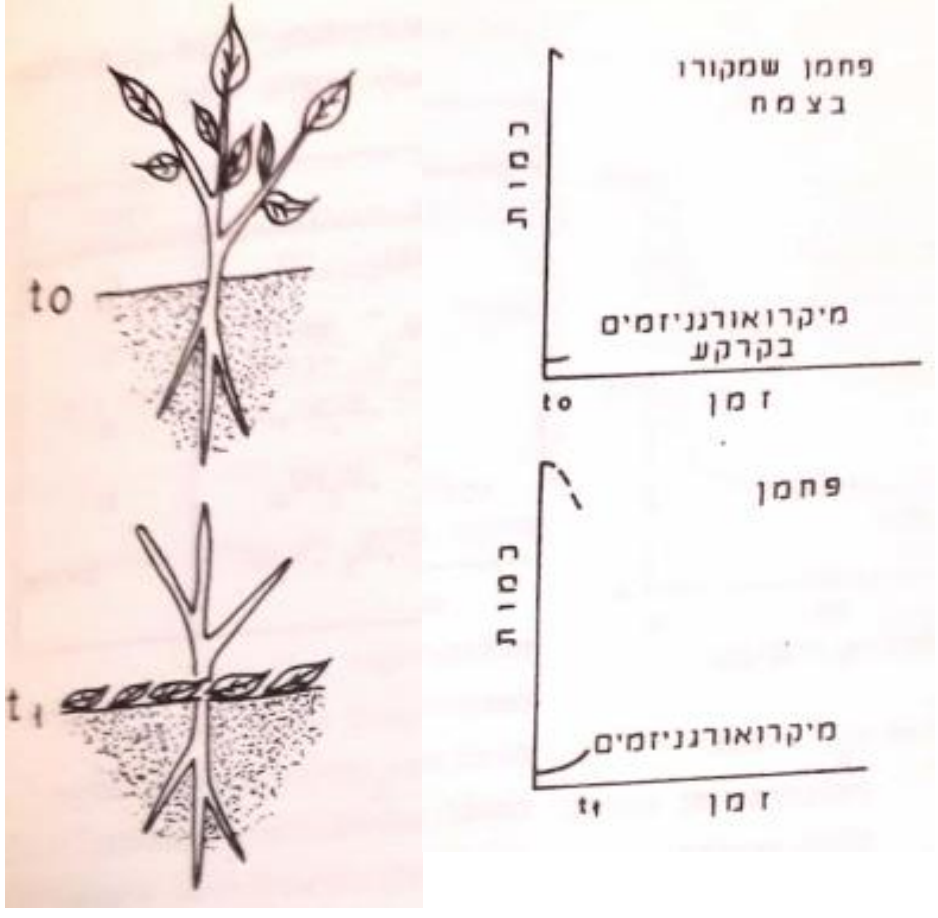
Hummus

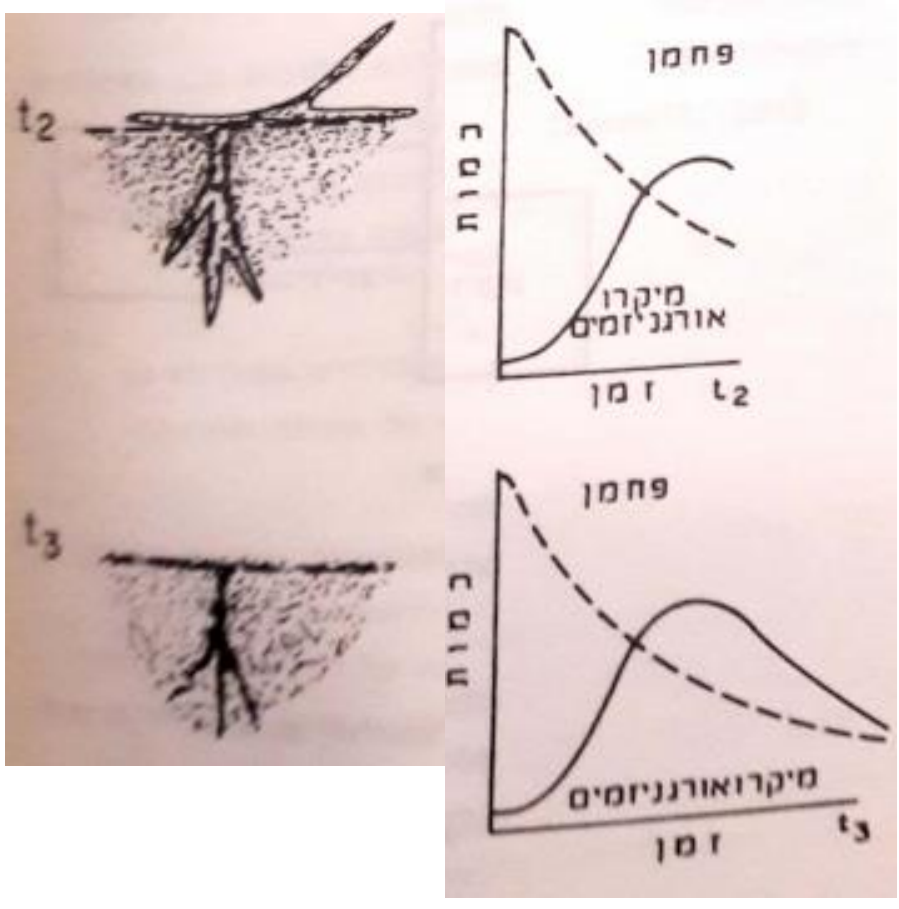
Limit of Detection (LOD) (Shrivastava and Gupta, 2011).

C:N ratio



- C:N ratio of the initial material should be 26-35 (Mote and Griffis, 1980).
- C:N ratio below 20 is indicative of an acceptable maturity (Inbar et al., 1990).
- C:N ratio of 15 or even less it is much better (Inbar et al., 1990).





Several works by Inbar published between 1987-1990, showed that OM is diverse in its spectroscopy and its chemistry (Chen et al., 1989; Inbar et al., 1989).

Author and Year	Indicative Wavelengths (nm)	Spectral Range
(Viscarra Rossel et al., 2006)	410, 570, 660	VIS
(Nocita et al., 2014)	600	VIS
(Brown et al., 2006)	520, 540, 550	VIS
(Xie et al., 2011)	570 to 630	VIS
(Wang et al., 2010)	623	VIS
(Daniel et al., 2004)	960, 1100	NIR-SWIR
(Palacios-Orueta and Ustin, 1998)	1400, 1900	SWIR
(Jin et al., 2016)	1720, 2180, 2309	SWIR
(Dalal and Henry, 1986)	1744, 1870, 2052	SWIR
(Rossel and Behrens, 2010)	1100, 1600, 1700, 1800-2000, 2000-2400	SWIR

The creation of statistical models consists in two stages:

1. **Calibration stage:** a prediction equation for a given property is developed.

2. **Validation stage:** the calibration stage is validated.

Hypothesis

This research aimed to address the following hypotheses:

- It is incorrect to estimate the SOM through statistical models based on spectral data, given the diverse chemical composition of OM, and its various stages of decomposition.

- The misprediction of SOM through spectral data, is affected by the decomposition stage of the OM in question.

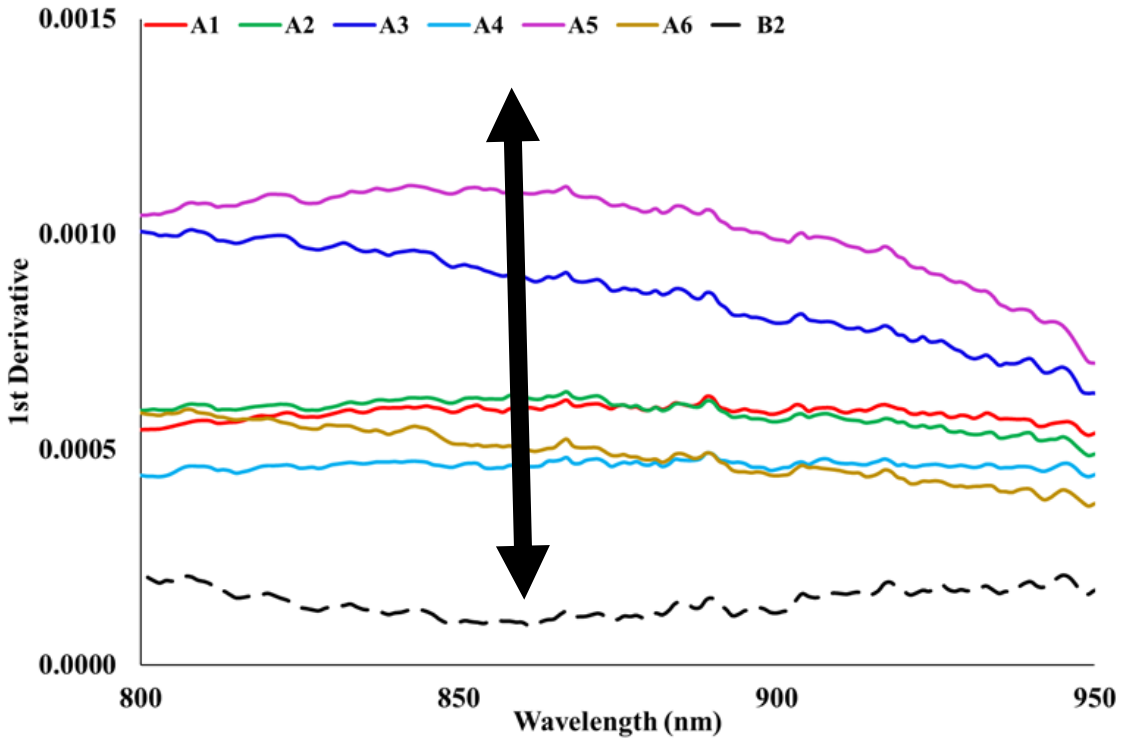
The OM content of every sample was calculated though the LOI (Loss of Ignition) method (Schulte and Hopkins, 1996).

For this, the different species of OM, were air dried and sieved through a 2-mm sieve.

Thus, the OM percentage was calculated by the following equation:

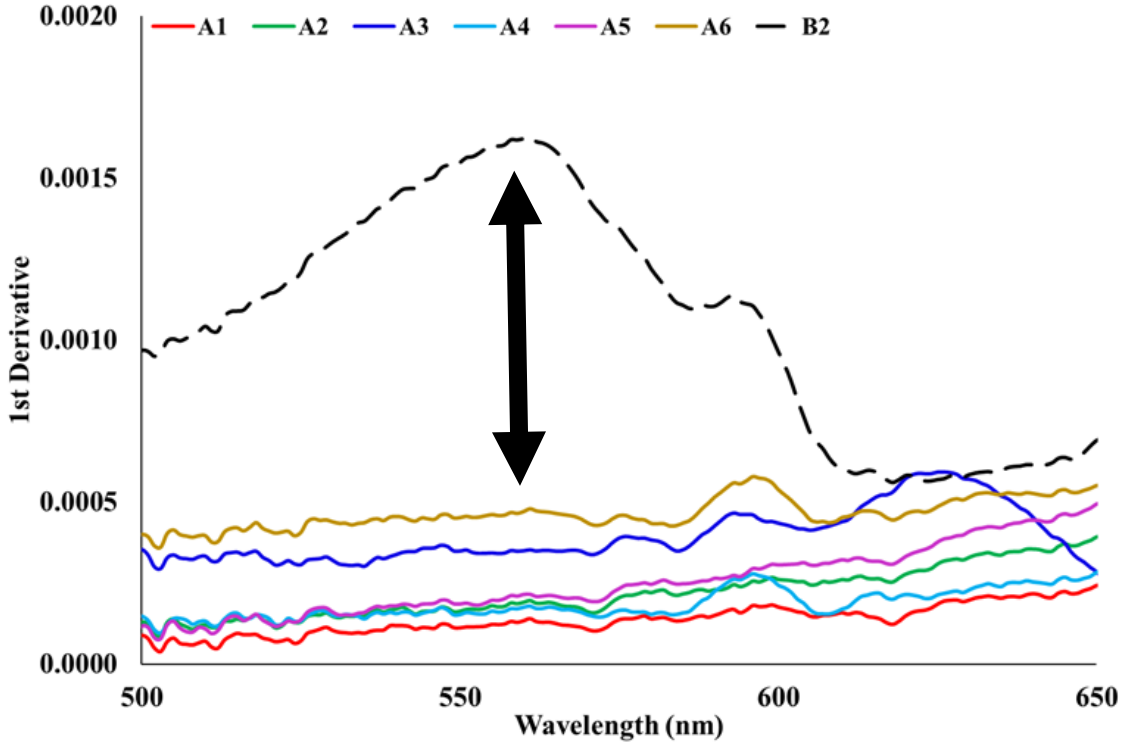
$$\mathbf{OM\%} = \frac{(\mathbf{Sample\ After\ Combustion(Wt.)} - \mathbf{Oven\ Dry\ Sample\ (Wt.)})}{\mathbf{Oven\ Dry\ Sample\ (Wt.)}}\ \mathbf{X\ 100}$$

COMPOST INDICATIVE WAVELENGTH



1st derivative pre-processing spectra of the different sources of organic matter (A1, A2, A3, A4, A5, A6) and sand dune (B2) in the range 800-950 nm.

SOIL INDICATIVE WAVELENGTH

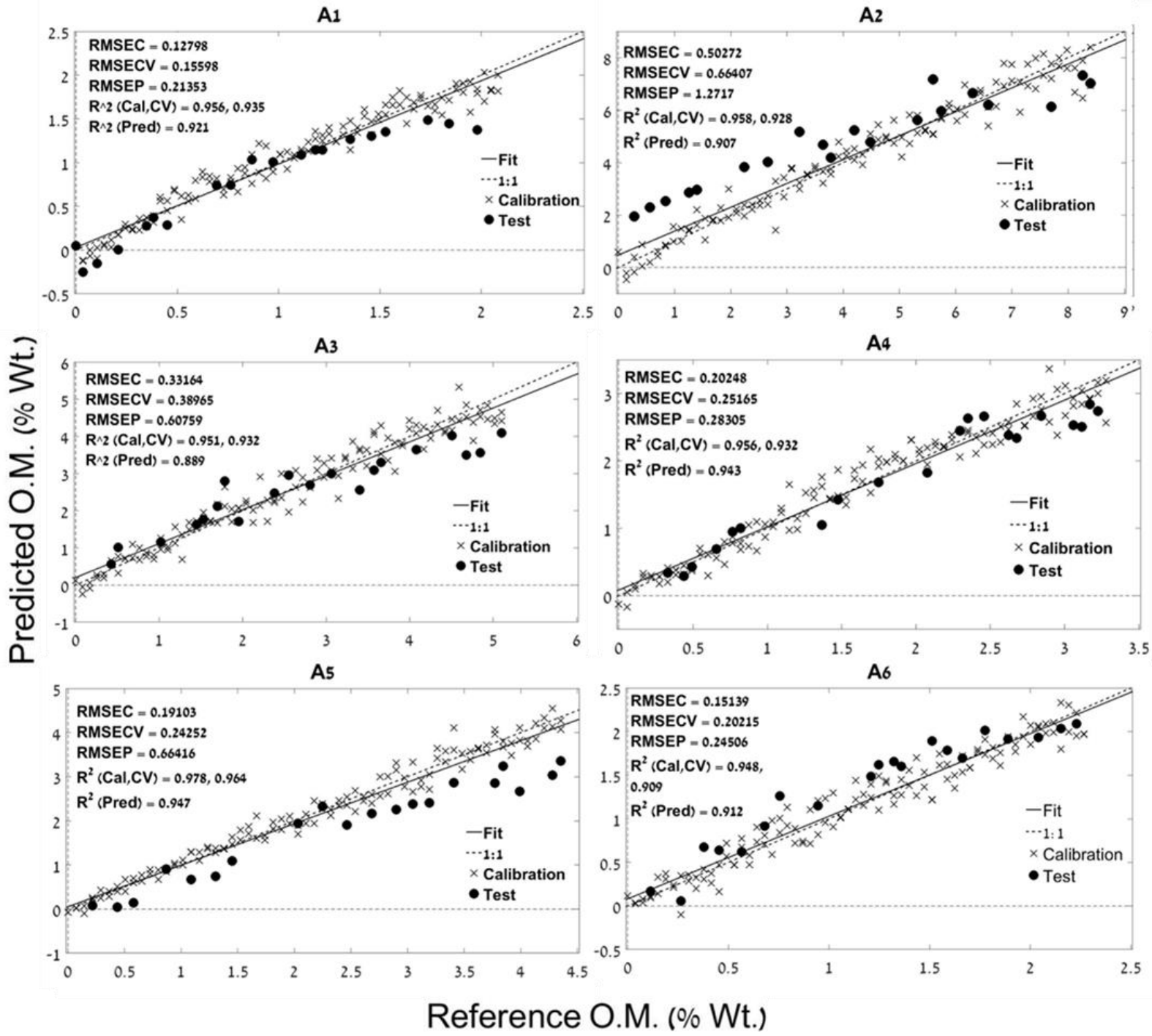


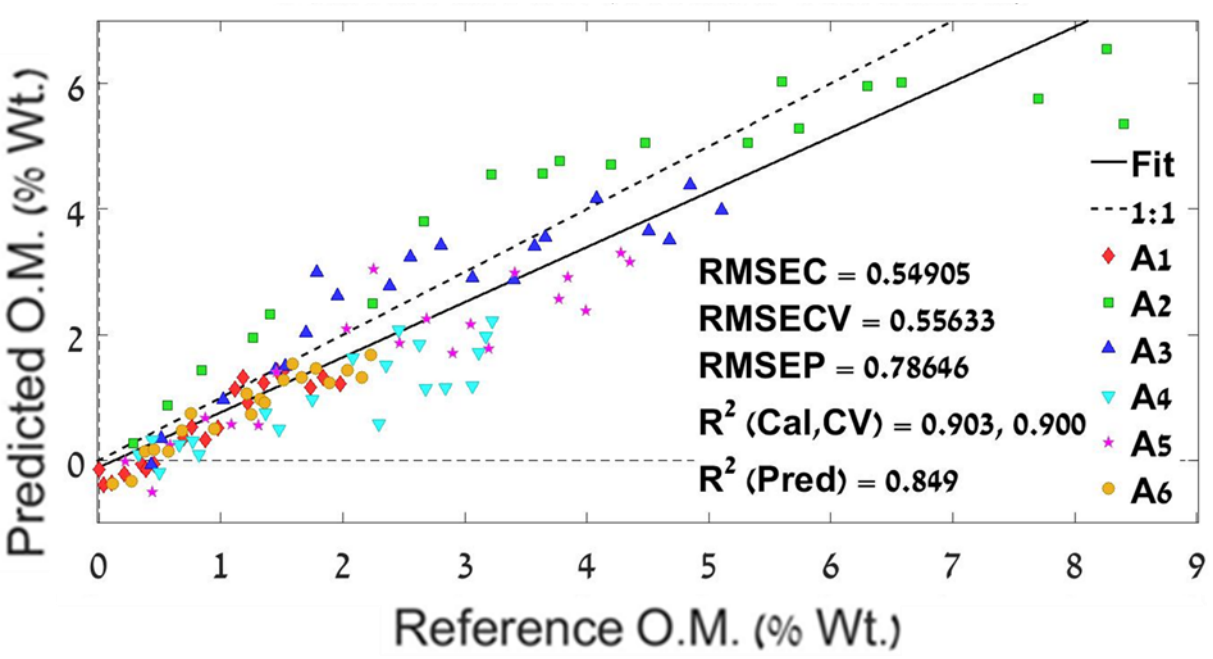
1st derivative pre-processing spectra of the different sources of organic matter (A1, A2, A3, A4, A5, A6) and sand dune (B2) in the range 500-650 nm.

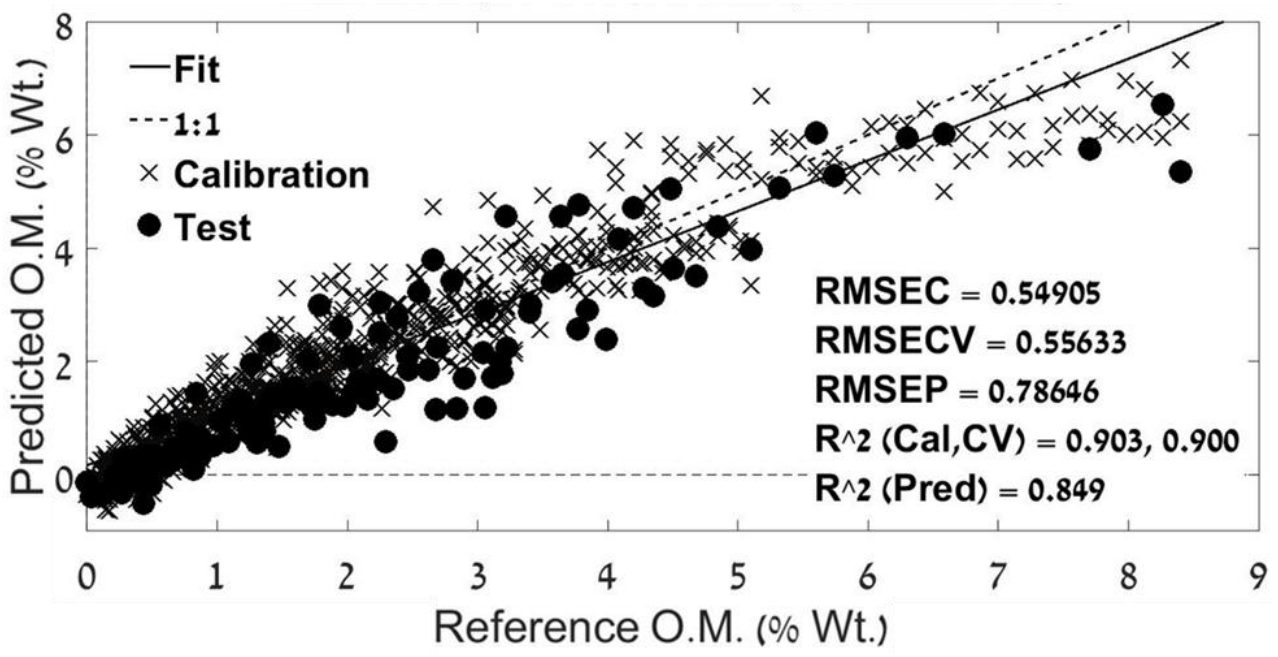
Sample	SIW/CIW (λ_{nm})	C/N	SSDL
A1	560/889	11.4	0.13
A2	560/870	**41.9**	0.37
A3	560/800	12.9	0.16
A4	560/890	9.4	0.24
A5	560/843	**54.3**	0.12
A6	560/808	9.7	0.59

Ogen Y., Goldshleger N., and Ben-Dor E., 2017. Detection limit assessment of soil organic matter using imaging spectroscopy – **Submitted**

PLS Regression models that were developed for every compost. The X axis represents the referenced OM. (% Wt.) content, and Y axis represents the predicted OM (% Wt.) content.







Chemical Property	A1	A2	A3	A4	A5	A6	Generic Model
OM	2.86	1.91	2.45	3.36	1.89	2.71	2.24

The RPD values of all the PLSR models that were created.

1) excellent models, with RPD >2;

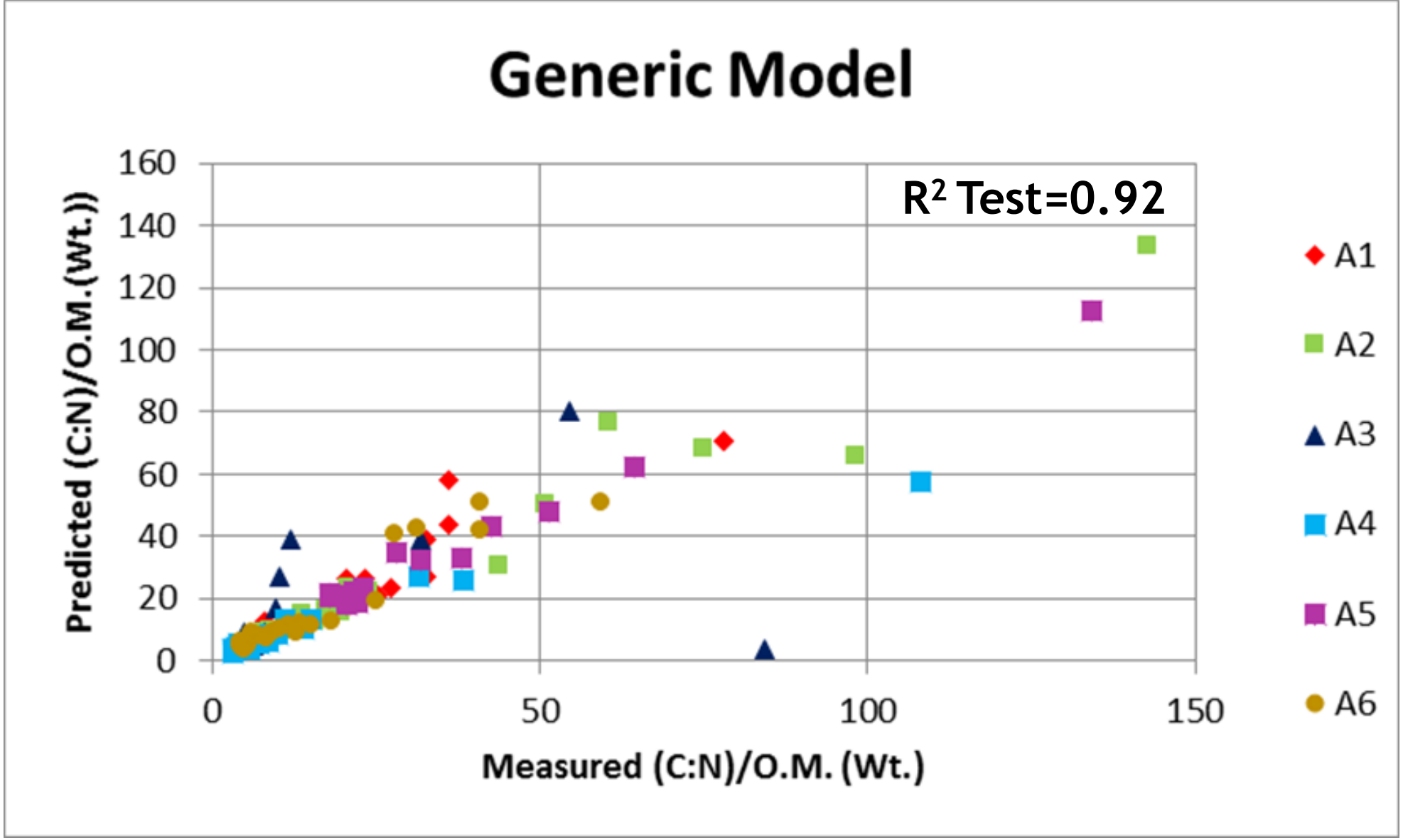
2) fair models, with 1.4 < RPD < 2;

3) non-reliable models, with RPD <1.4

(Chang et al., 2001).

Chemical Property	A1	A2	A3	A4	A5	A6	Generic Model
OM	2.86	1.91	2.45	3.36	1.89	2.71	2.24
C:N	1.26	4.57	1.67	1.11	9.00	1.30	2.31
O. Carbon	2.38	1.40	1.89	1.76	1.81	1.92	1.91
Nitrogen	2.00	1.50	2.25	2.30	1.00	2.00	2.33
(C:N) / OM	3.10	4.60	3.19	4.91	8.83	10.88	3.48

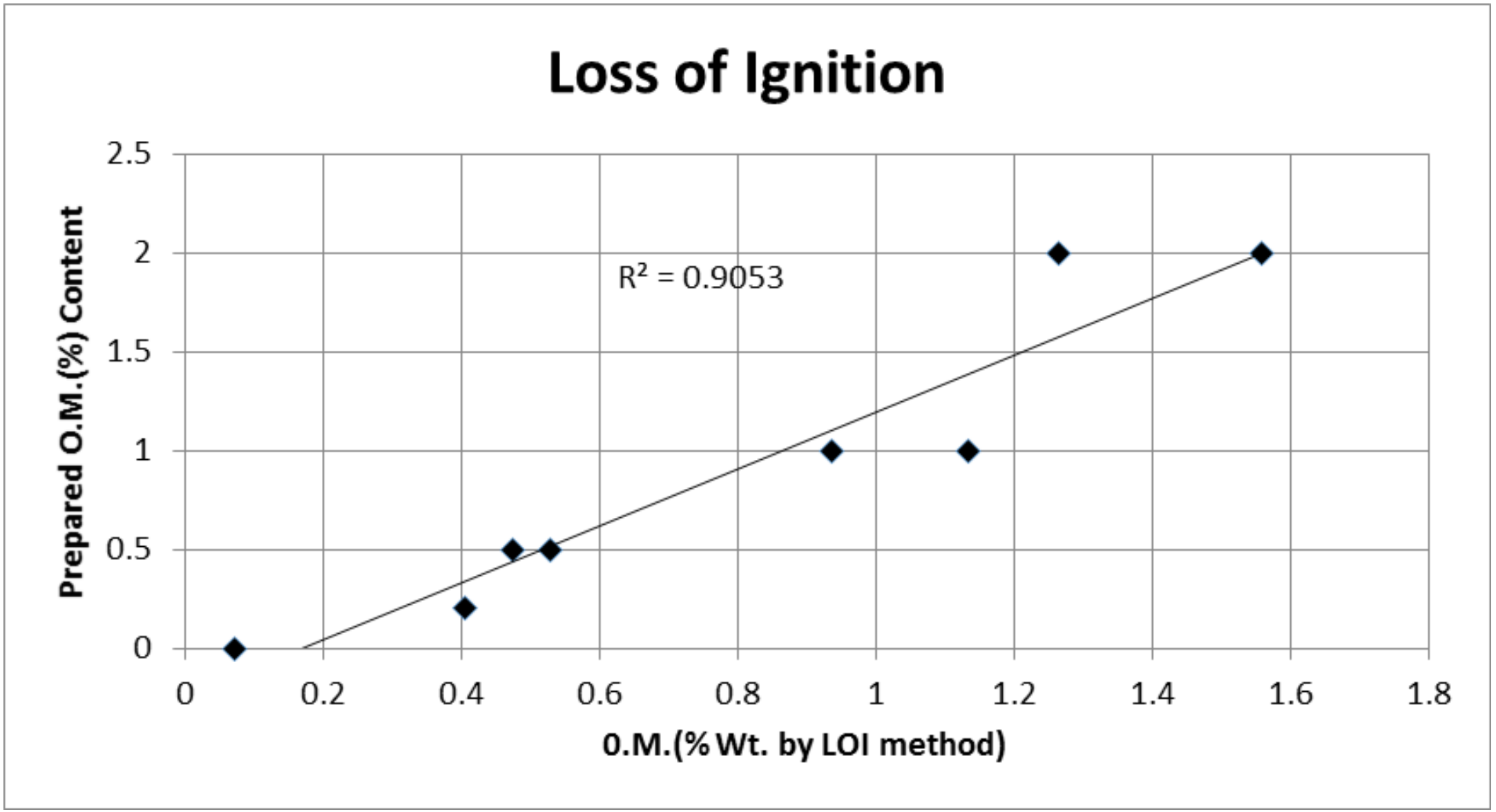
The **RPD** values of all the PLSR models that were created. The RPD values colored green qualified as excellent models, yellow as fair models, and red as non-reliable models (Chang et al., 2001).



The Generic PLS Regression model applied to the validation samples, classified by their source of organic matter. The X axis represents the measured (C:N)/(O.M(%Wt.)), and the Y axis represents the predicted (C:N)/(O.M(%Wt.)).

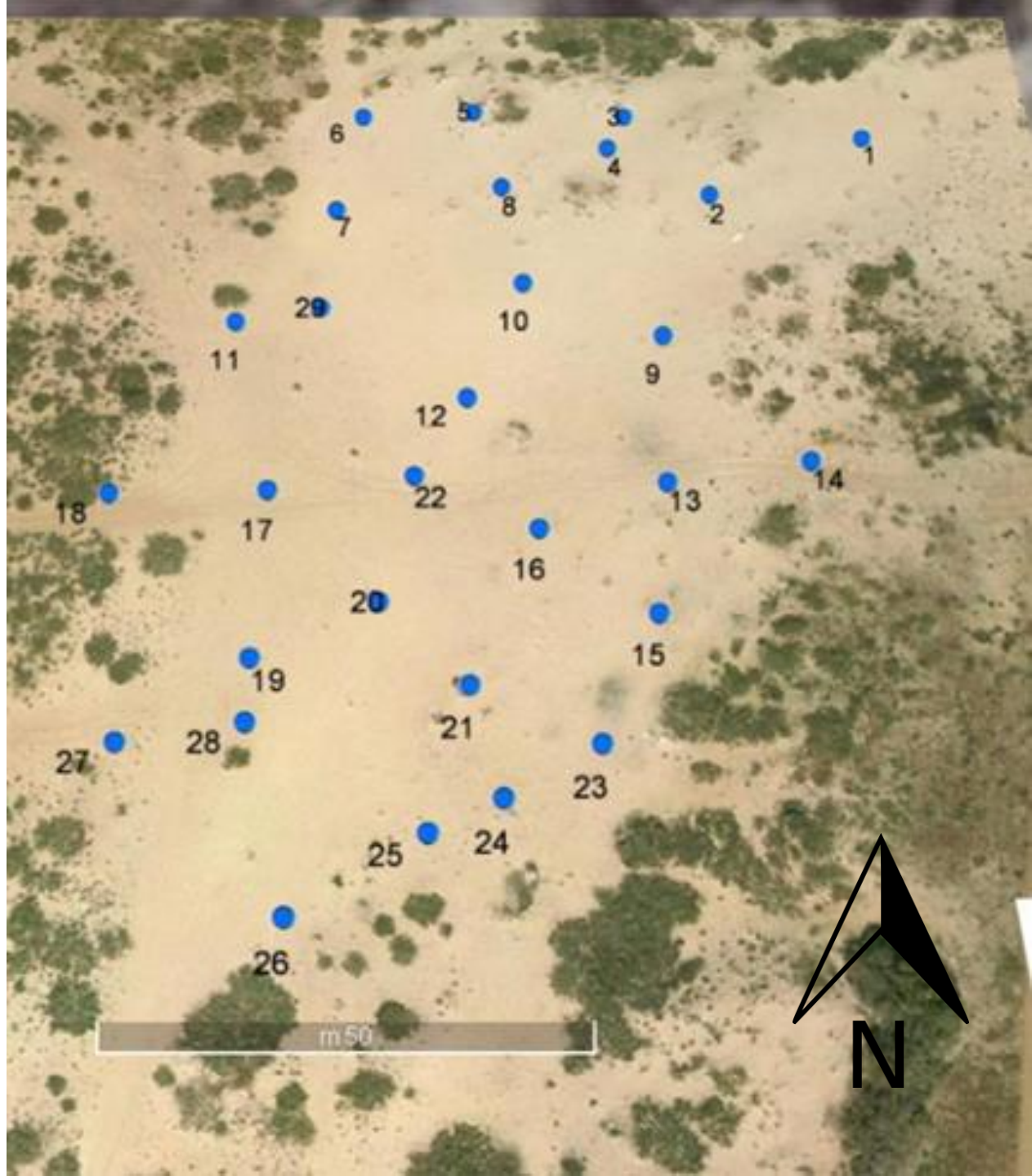
Samples Preparation Protocol for the Hyperspectral Scanning:

1. Estimation of OM content
2. Wetting, Mixing and Drying
3. Samples Spreading
4. Nylon Covering
5. Hyperspectral Scanning



LOI validation for the samples that were prepared for the hyperspectral scanning.

	Detected (V/X)
0.2A5	X
0.5A5	X
1A5	X
2A5	V
0.5A2	V
1A2	V
2A2	V


6
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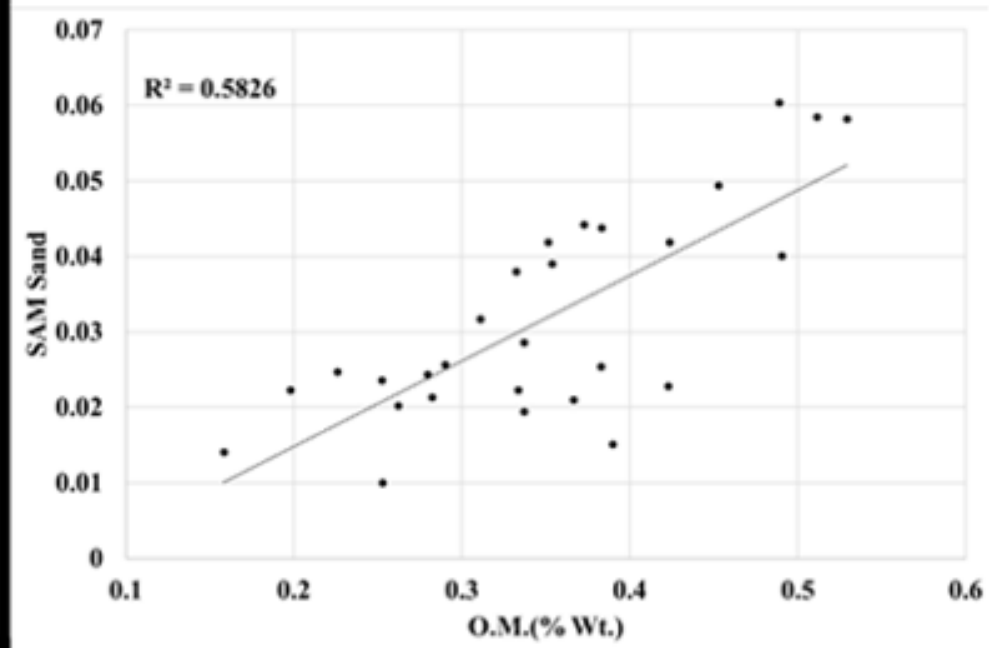
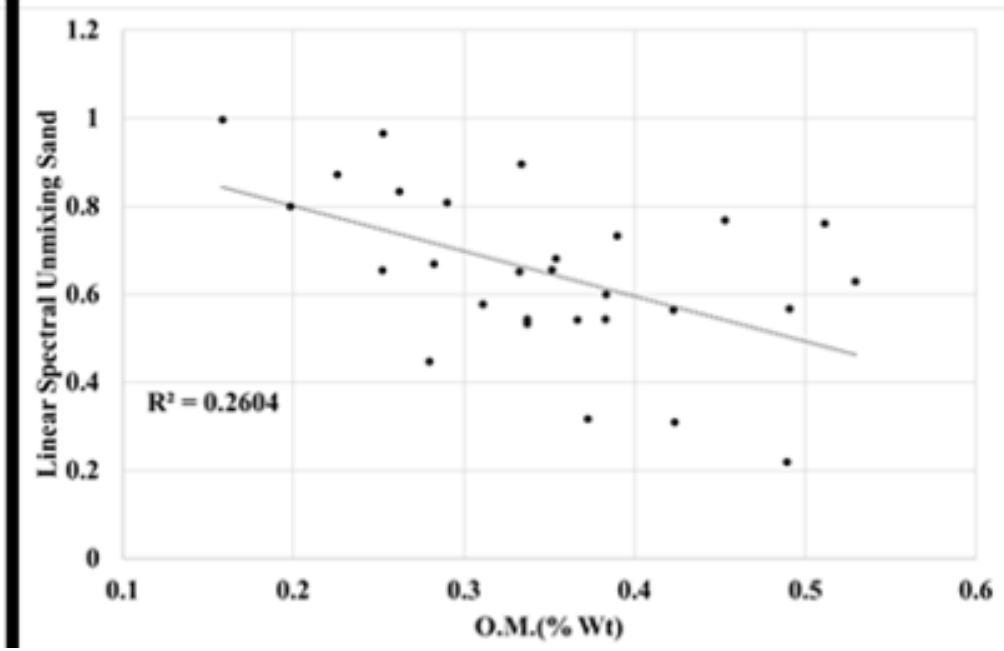
	SAM	Linear Spectral Unmixing
Sand		

Conclusions

- Almost all the PLS regression models created for the estimation for different sources of OM presented superior results in comparison to the generic model.

- The misprediction of OM through statistical methods is affected by the degree of decomposition of the source of OM in question.

- When the C:N ratio is high, it is easier to predict using PLSR models. However, this method was not effective in samples in advanced stages of decomposition.

- Some sources of OM are easier to detect than others using spectroscopy and/or HRS.

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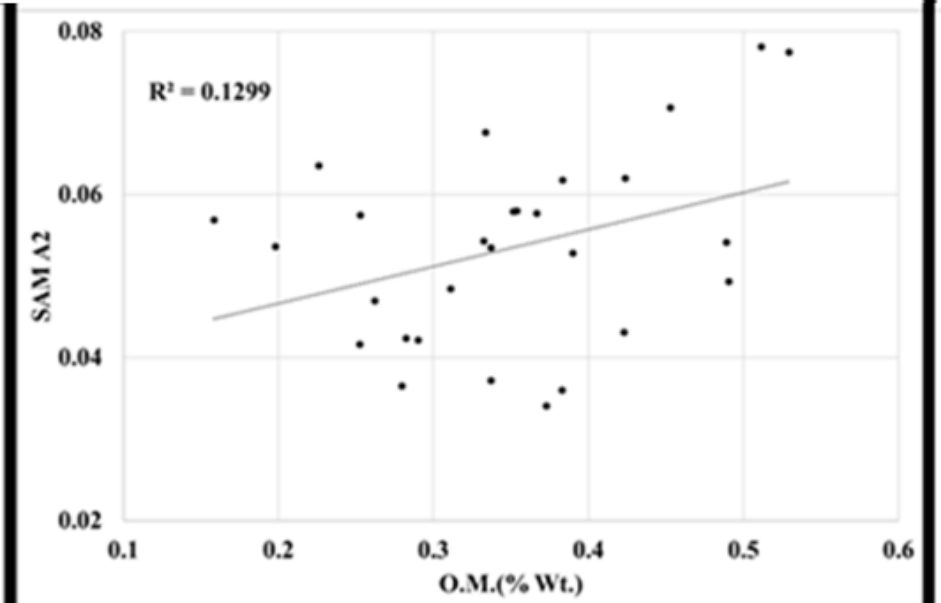
Table 1: The following table introduces the codes and the contents of the composts and soils that were examined in this research.

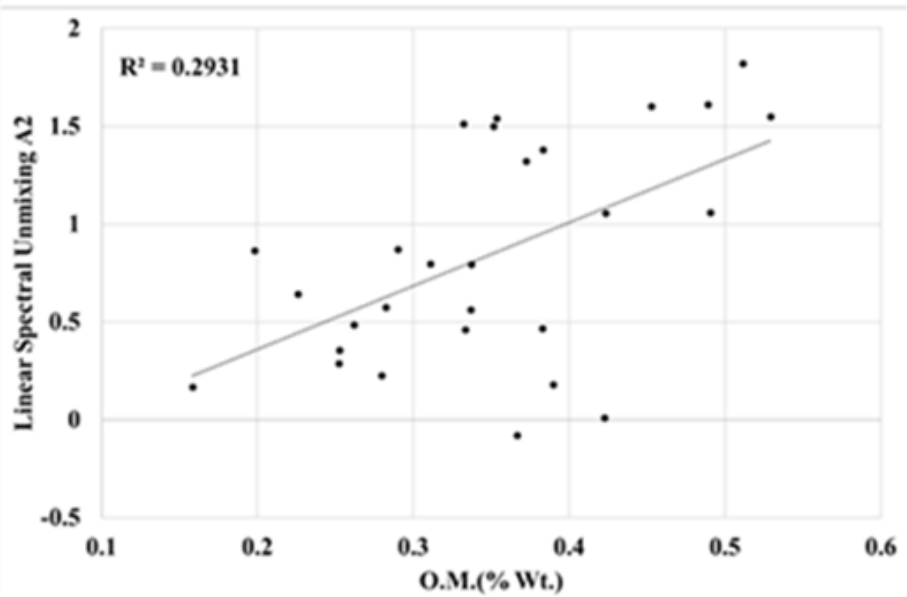
Code	**Content**
A1	Compost "biocompost": cow dung compost
A2	Planting mix titanium: soil with peat
A3	No composted cow dung
A4	Compost "Garin": 85% cow dung, 15% leaves
A5	Compost "Aben Ari": Baltic peat, coconut fibers, ventilation materials
A6	Worm humus "Green 4 Ever"
B2	Sand dune

SAM

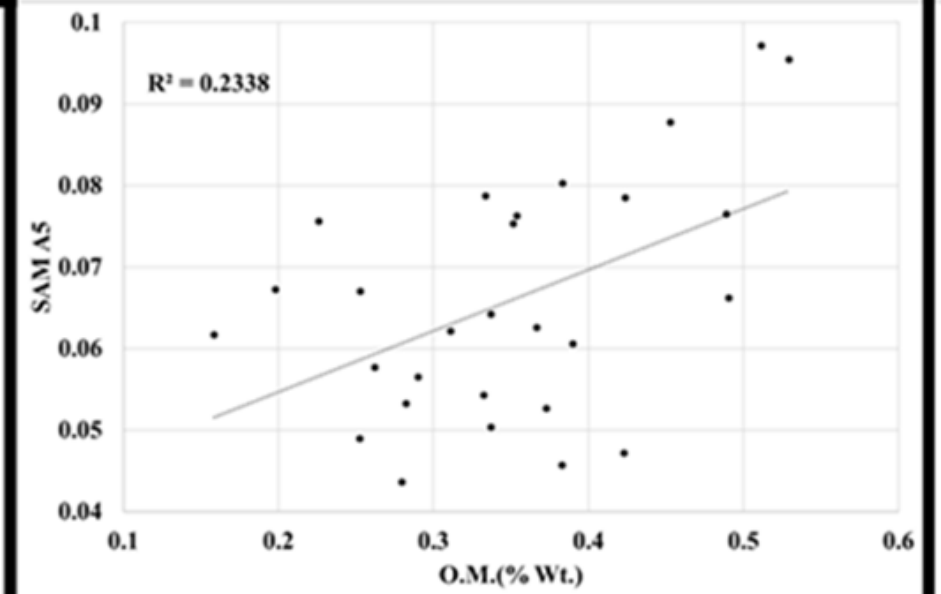
Linear Spectral Unmixing

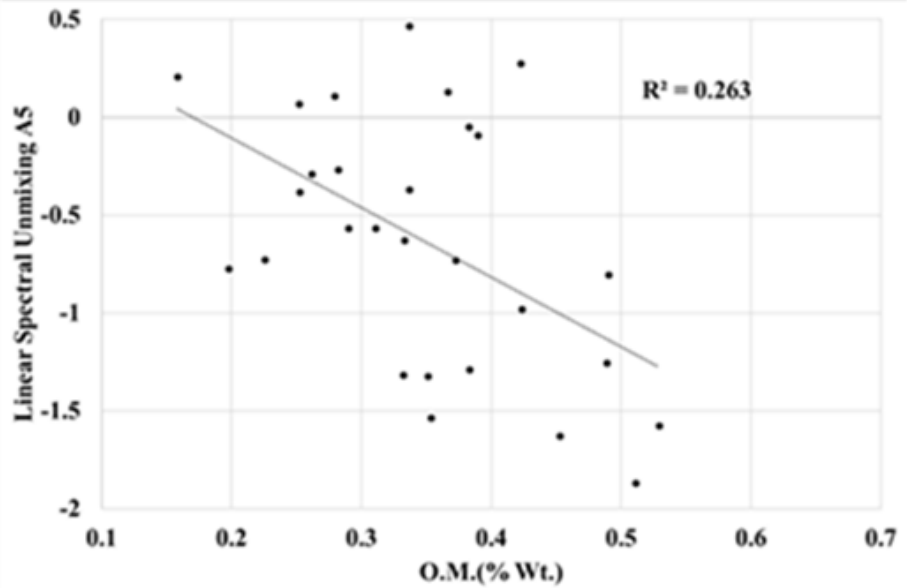
2% A2



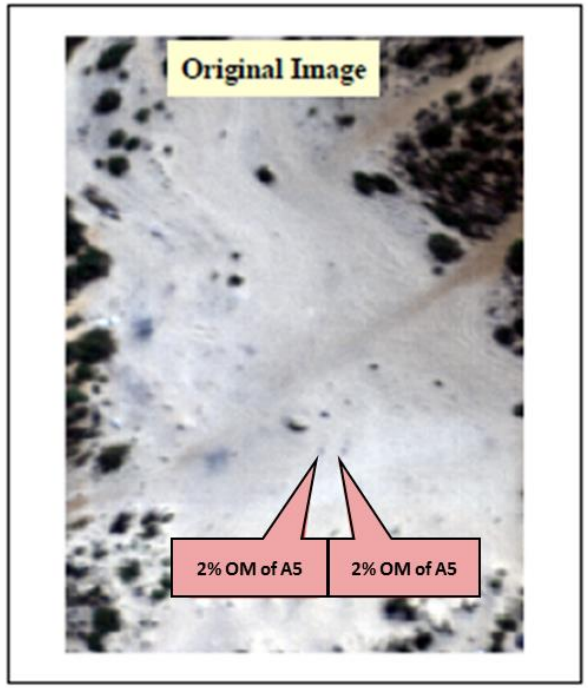


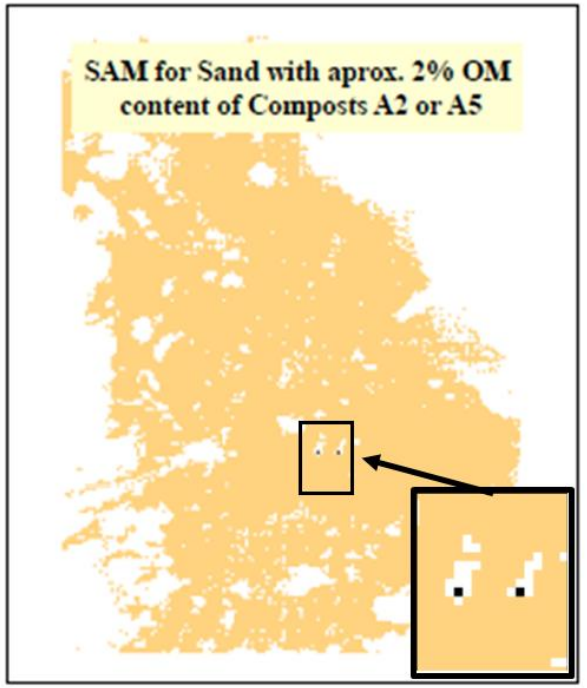
2% A5

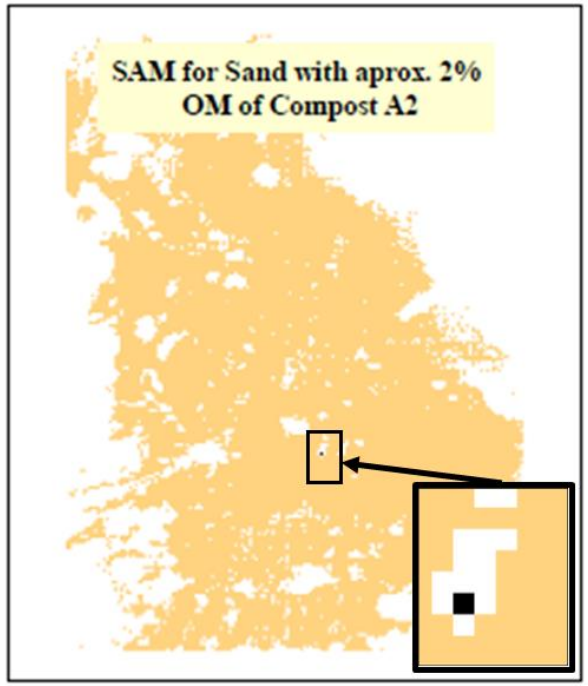


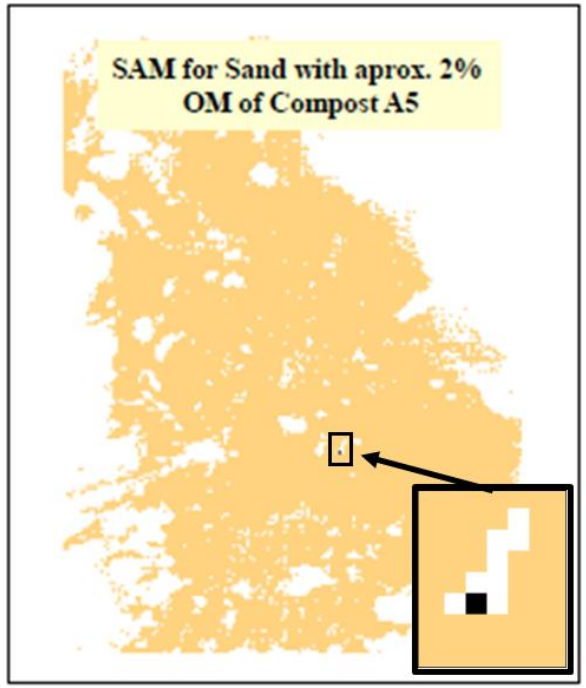


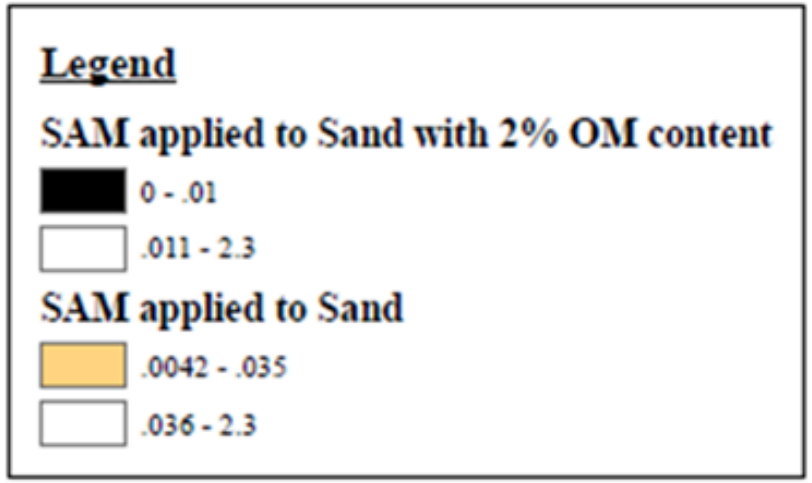
SAM applied to sand with 2% OM Content. The classification considered those pixels that showed SAM values under 0.01.

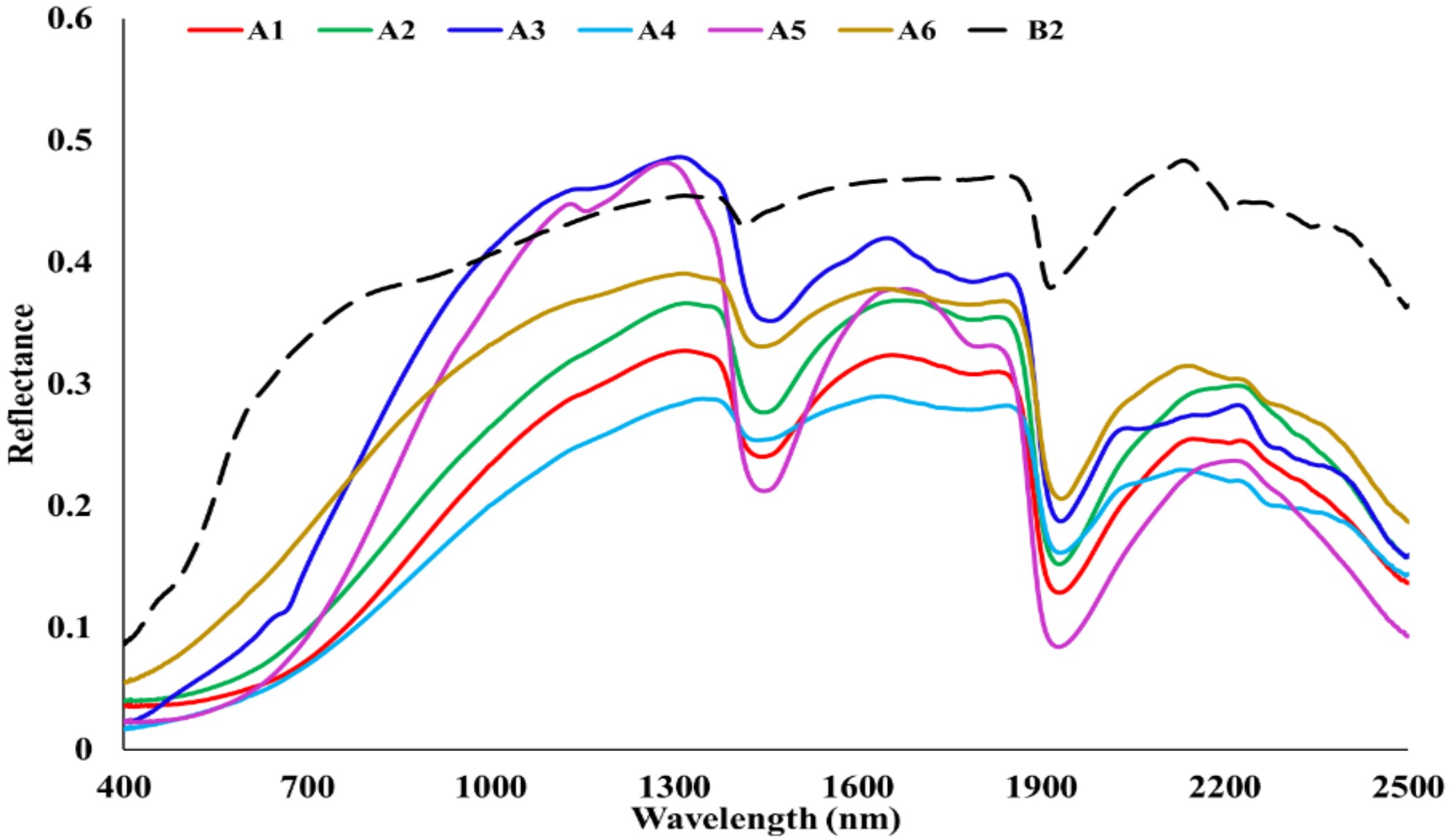












The spectra of 6 sources of OM (A1, A2, A3, A4, A5, A6) and sand dune (B2).

i. The SG (Savitsky Golay) smoothing (Savitzky and Golay, 1964), the first derivative and a secondary SG smoothing were applied.

ii. The SIW for each soil type was identified.

iii. The CIW was identified.

iv. The CIW/SIW ratio for each sample was calculated.

v. The mean ($\bar{x}$) and standard deviation (σ) of CIW/SIW ratio for the <blank> measurements of each soil type were calculated.

vi. The first 10 samples of each soil series were chosen and the linear correlation curve was created between the CIW/SIW ratio and the added compost amounts.

vii. The coefficient of determination (R^2) was calculated.

viii. Additional samples were added while the R^2 was measured continuously.

ix. The linear equation was selected where the highest correlation was obtained.

x. The SSDL was calculated using the following equation:

$$\mathbf{SSDL_{compost}}\ (\%\ \mathbf{Wt.}) = \mathbf{a}(\bar{\mathbf{x}} - \mathbf{3}\boldsymbol{\sigma})_{\mathbf{<blank>}} + \mathbf{b}$$