Monitoring Soil Organic Carbon Across Multiple Satellites Driven by Machine Learning in Israel and the UAE

[1]Or Amir, Sharad Gupte, Sweta Singh, [2]Marcelo Sternberg, [1]Ori Kanner, [3]Maryam Alshehhli, [3]Abdel Rahman Hussein Alsaleh, [3]Mariam Ashraf Alcibahy, [1]Jonti Shepherd, [1]Eyal Ben Dor
1 Porter School of Environment and Earth Science, Faculty of Exact Sciences, Tel Aviv University; 2 School of Plant Sciences and Food Security, Faculty of Life Sciences, Tel Aviv University; 3 Khalifa University Abu Dhabi, UAE

Introduction

A joint project between the Israel Space Agency and the UAE Space Agency, in collaboration with Tel Aviv University (Israel) and Khalifa University (Abu Dhabi, UAE), was conducted from 2023 to 2025 to utilize VENμS satellite data among other spaceborne platforms for monitoring soil organic carbon (SOC) in both countries. SOC is a key component of soil health and plays a critical role in soil functionality. It significantly influences the global carbon cycle by sequestering carbon and climate change mitigation. The dynamics of SOC are governed by the balance between organic inputs (crop residues) and outputs (microbial respiration and decomposition). To further enhance monitoring capabilities, the project also aimed to compare various orbital sensors to assess their consistency and added value in tracking SOC, an important task for advancing soil research and management.

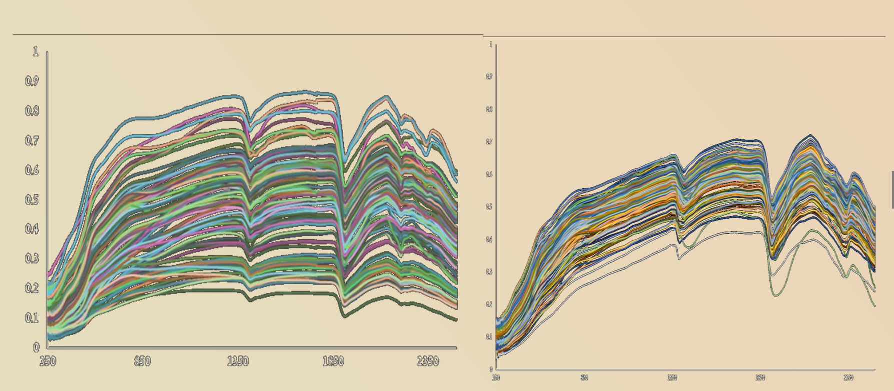
Methodology

To predict soil properties, machine learning models were trained on a ground truth Soil Spectral Library from the UAE and Israel, matched by resampling to the central wavelength of each satellite band. The models were applied to satellite data from multispectral sources VENμS, Sentinel-2, and Landsat 9, along with hyperspectral data from EMIT and EnMAP imageries. Regularization techniques were employed to address challenges posed by the high dimensionality of the data, ensuring robust performance across all datasets.

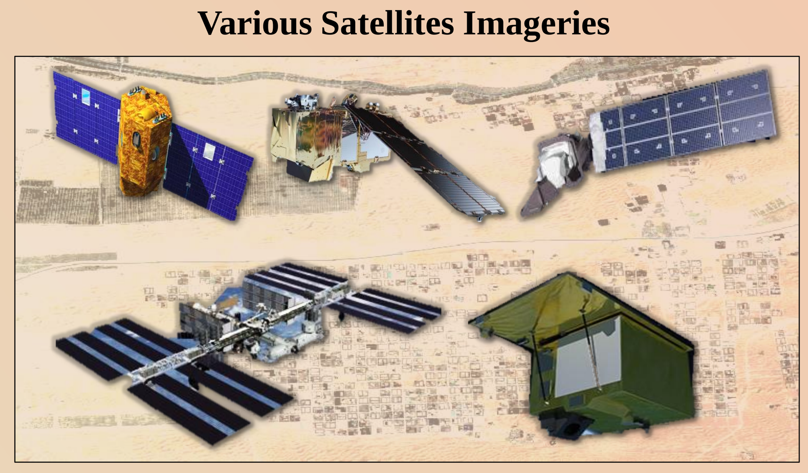
Results:

The results showed a clear trend in the predicted Total Organic Carbon (TOC) and soil texture across different land types: Agriculture, Shrubby Dune, and Dune. As hypothesized, the predicted TOC was highest in agricultural land, likely due to the greater presence of crops, decreased in shrubby dunes, and was lowest in dunes. Similarly, the predicted soil texture exhibited a clear pattern: the sand percentage was highest in dunes, lower in shrubby dunes, and lowest in agricultural land. Conversely, clay content followed the opposite trend, being highest in agricultural land and lowest in dunes. The most effective algorithms Ridge Regression, Elastic Net, and Partial Least Squares Regression (PLSR) delivered accurate and reliable predictions. Furthermore, these results were consistent across all tested sensors, confirming that the observed patterns have a natural physical basis.

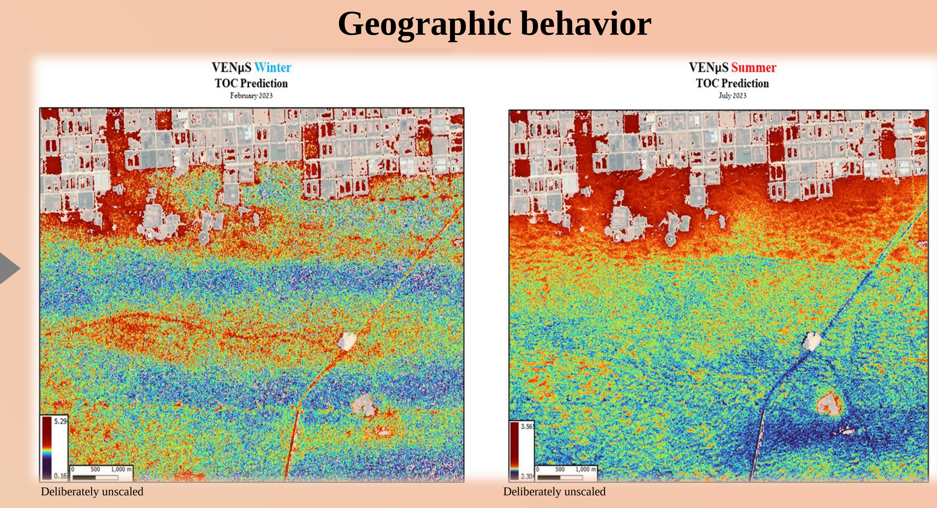
Training:
Ground Truth Spectral & Chemical Library



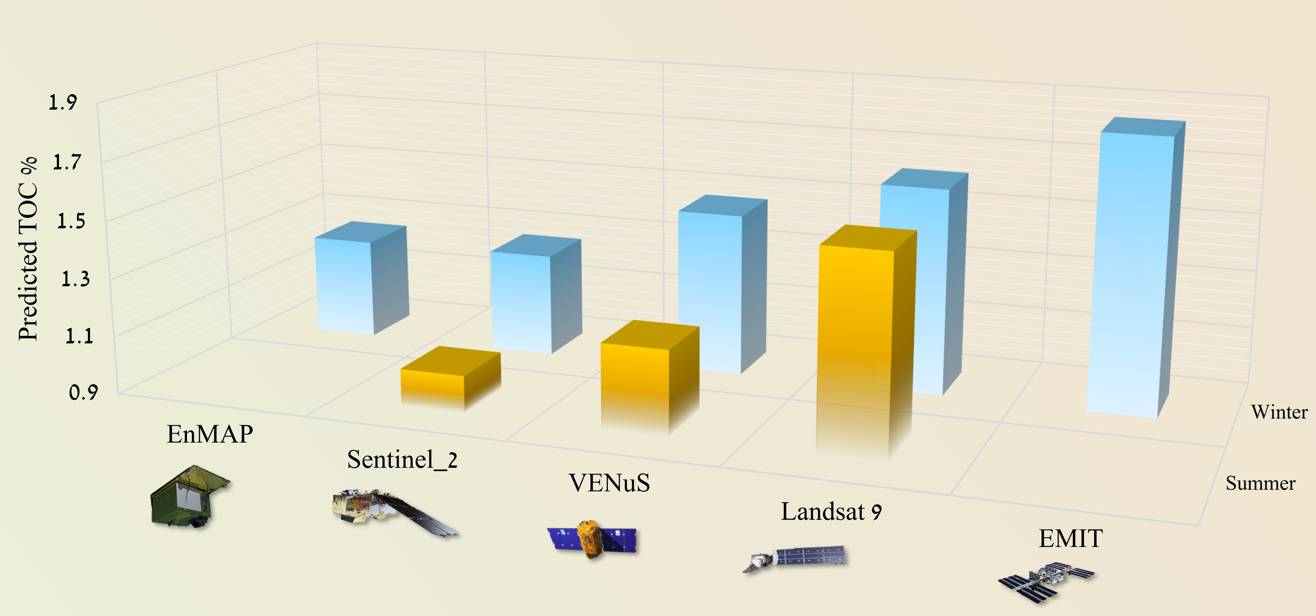
Prediction:
Various Satellites Imageries



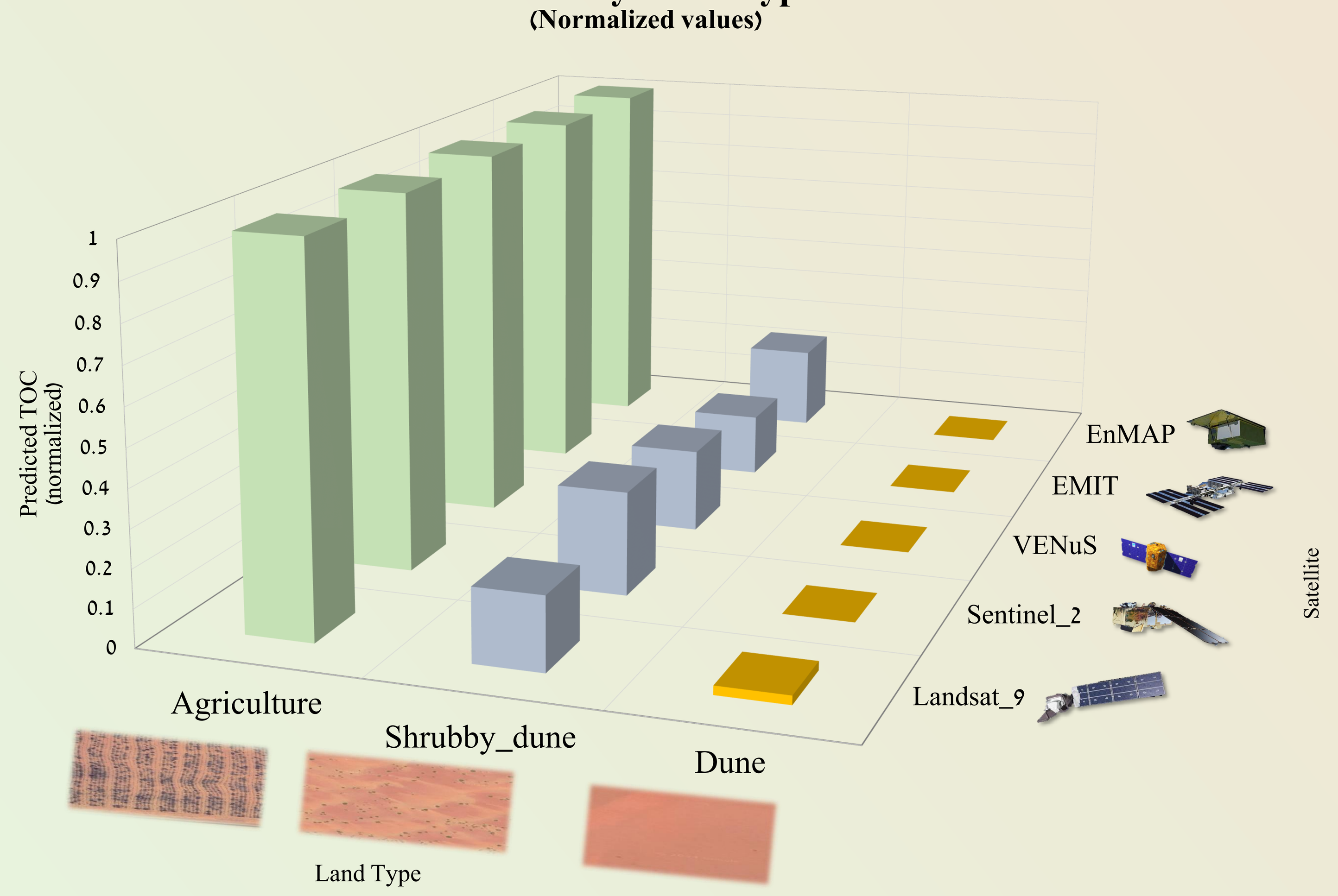
Geographic behavior



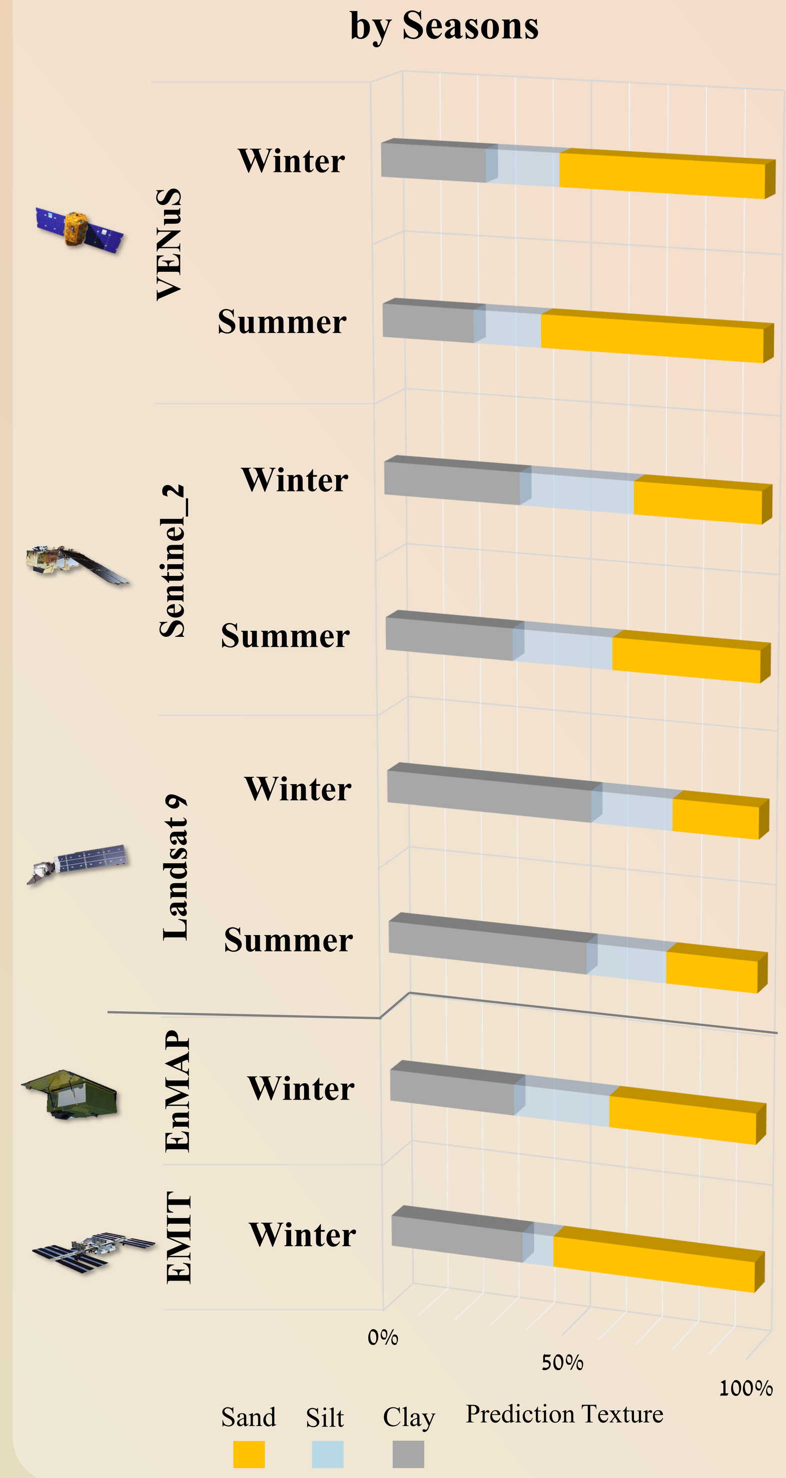
IL - Predicted TOC
Seasonal Trend



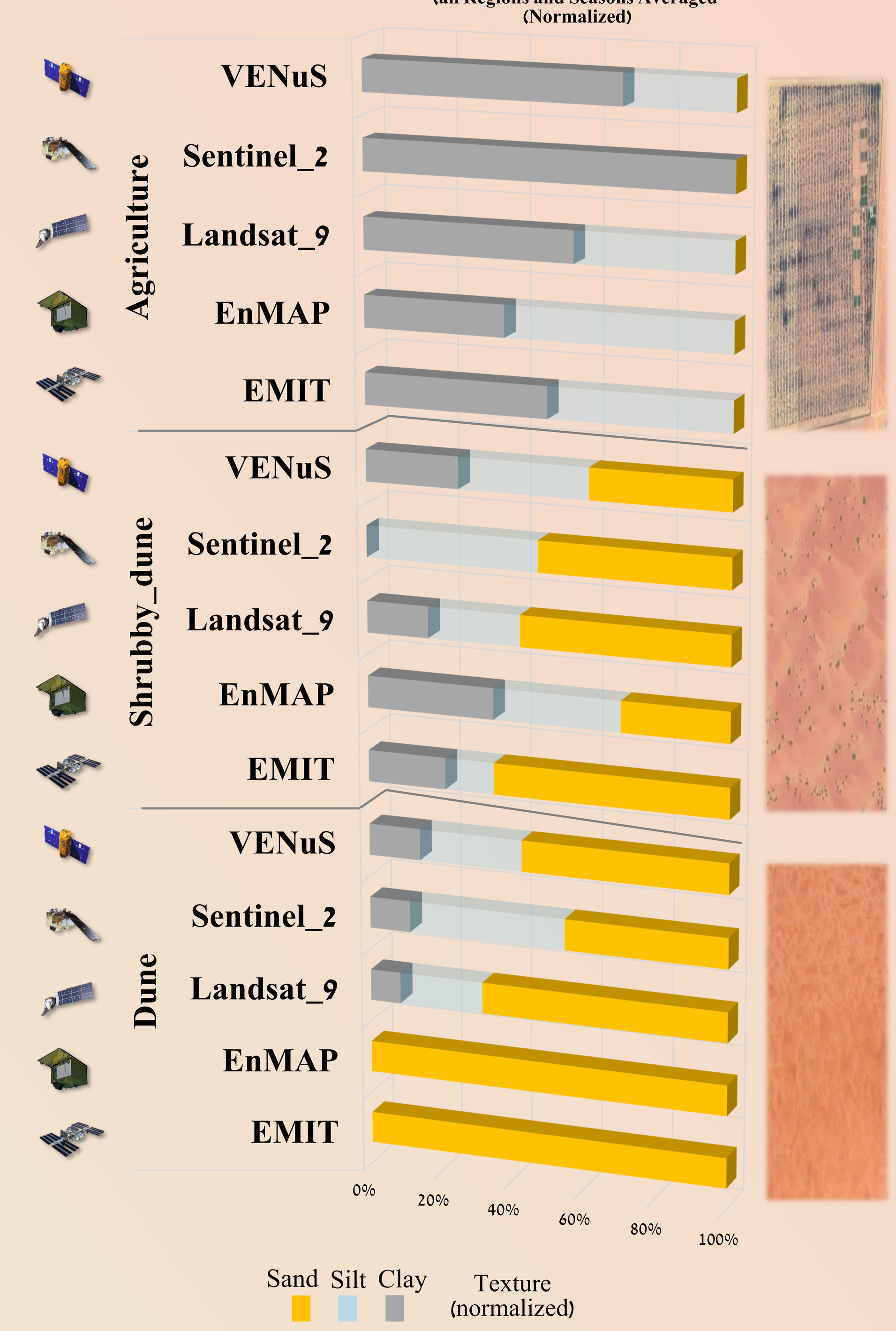
UAE - Predicted TOC %
Trend By Land Type
(Normalized values)



IL - Texture Prediction
by Seasons



UAE - Texture Prediction Trend
by Land Types
(all Regions and Seasons Averaged (Normalized)



Conclusion

The agreement among all the tested sensors confirmed that the extraction of Total Organic Carbon (TOC) and texture via spaceborne platforms has a physical basis, both sensor-wise and soil-wise.