Miniaturised visible and near-infrared spectrometers for assessing soil health indicators in mine site rehabilitation

soil & landscape science lab

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Post-mining rehabilitation requires the monitoring of a wide range of soil health indicators. Miniaturized spectroscopy may enable a portable, accurate and cost-efficient soil diagnostic solution. However, miniaturized spectrometers' performance in modelling mine site soil health indicators remains unknown.

Aims

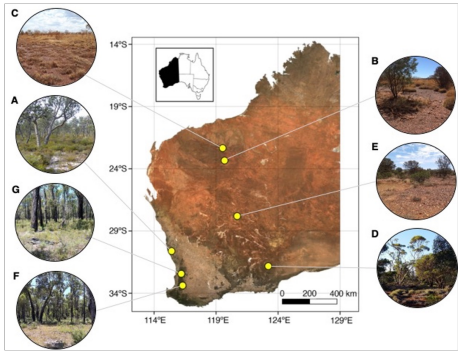
Compare four miniaturised visible (vis) and near-infrared (NIR) spectrometers and a portable research-grade vis–NIR spectrometer for estimating a wide range of soil chemical, physical, and biological properties, which are indicators of soil health in post-mining soil rehabilitation. We compared the:

- Accuracy of the spectroscopic modelling with spectra from different spectrometers
- Repeatability of the spectra and modelling
- Overall performance

Data

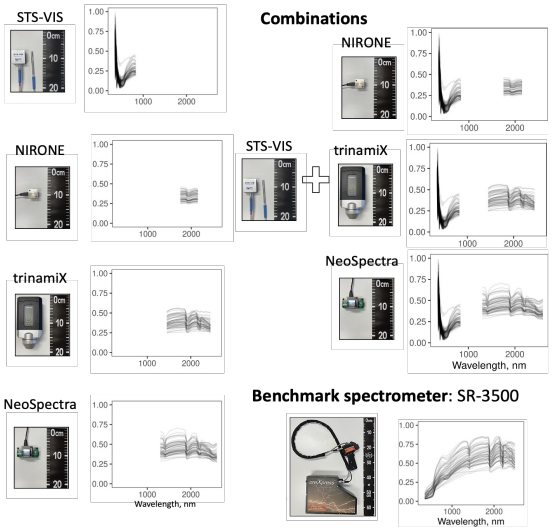
We collected topsoil samples from 7 mine sites with a total number of 56 sampling plots (280 subplots) and measured 29 soil physical, chemical, and biological soil properties [1].

Two spectral replicates were collected using each spectrometer for the subplot samples. We also combined spectra from a miniaturised visible range spectrometer and NIR spectrometers.

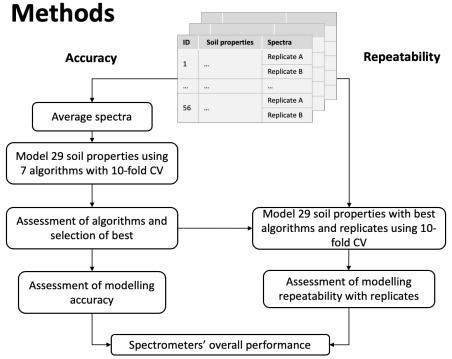


Miniaturised spectrometers:

- Visible: STS-VIS
- Near-infrared: NIRONE, trinamiX, and NeoSpectra

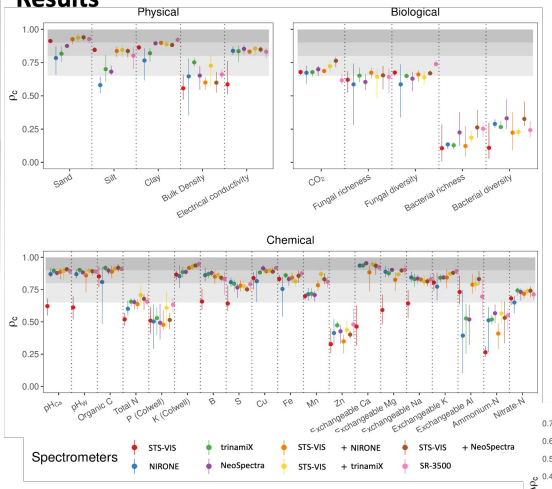


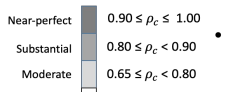
Methods



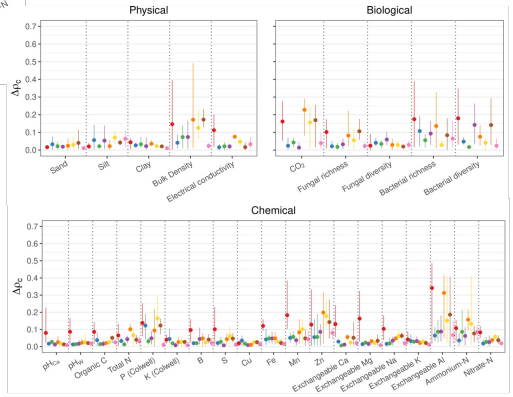
We assessed the Accuracy and Repeatability of the spectroscopic models built with the spectra collected using the spectrometers. We used concordance correlation coefficient (ρ_c) to assess the models' inaccuracy [2].

Results





- The visible range spectrometer accurately estimated soil texture (sand, silt, clay)
- The NIR spectrometers estimated most soil properties with moderate or greater accuracy.
- Combining the miniaturized visible and NIR spectrometers produced more accurate estimates.
- Miniaturised spectrometers and combinations estimated 24 out of 29 properties with moderate or greater accuracy.



- The miniaturized NIR spectrometers and the vis–NIR combinations showed similar repeatability to the benchmark spectrometer.
- The small visible spectrometer was least repeatable for most biological and chemical properties.

Overall performance

$$e = \frac{\sum_{i=1}^{N} \overline{\rho_c^i}}{N} + \frac{\sum_{i=1}^{N} (1 - (^{max}\rho_c^i - ^{min}\rho_c^i))}{N} + \frac{\sum_{i=1}^{N} \overline{\Delta\rho_c^i}}{N} + \frac{\sum_{i=1}^{N} (1 - (^{max}\Delta\rho_c^i - ^{min}\Delta\rho_c^i))}{N}$$

Spectrometer	e
STS-VIS	3.18
NIRONE	3.17
trinamiX	3.55
NeoSpectra	3.51
STS-VIS + NIRONE	3.42
STS-VIS + trinamiX	3.50
STS-VIS + NeoSpectra	3.51
Benchmark: SR-3500	3.58

Conclusions

- Developing efficient, reliable, and cost-effective methods for measuring and monitoring soil properties that can indicate soil health is essential.
- The miniaturised visible and NIR spectrometers performed similarly to the benchmark spectrometer which is an order of magnitude more expensive.
- Miniaturised soil spectroscopy enables the collection soil data at finer spatial and temporal resolutions, improving soil health diagnosis and ecologic rehabilitation and restoration.

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