Minimizing the effect of soil salinity on prediction accuracy of soil organic carbon

Saham Mirzaei

Introduction

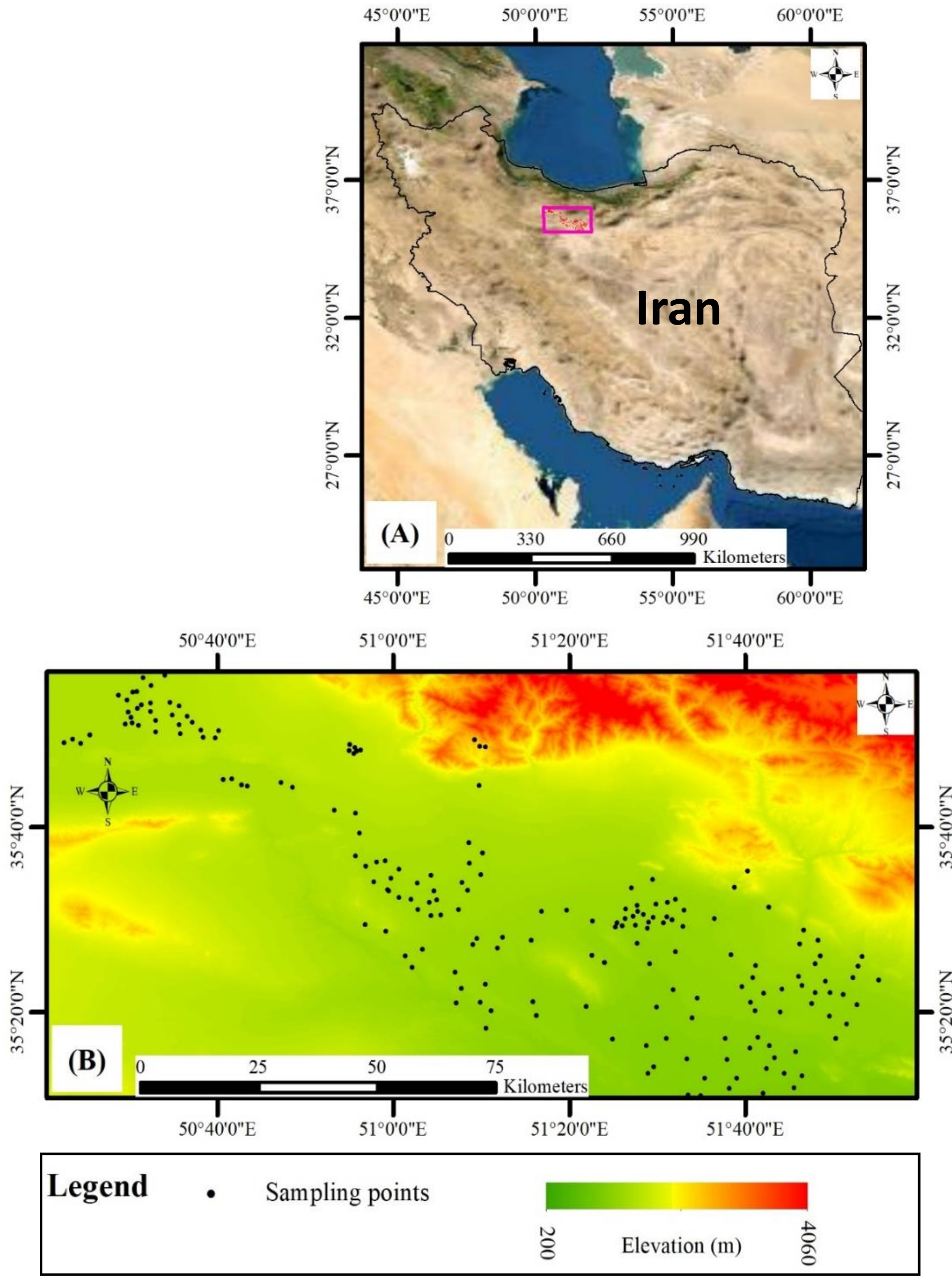
- In the past decades, numerous visible and near-infrared (VNIR) spectrometry techniques and technologies were developed to quantitatively measure soil characteristics.
- The development of visible and near infrared (VNIR) spectrometry is related to a variety of experiments and efforts, including efforts to develop portable spectrometer equipment for in-situ field soil spectrometry (Mouazen et al., 2005, 2007).
- Moreover, the differences in ecological-climate and environmental circumstances of soils and unwanted properties of soil, called external parameters, are also limiting soil property estimations via spectrometry.
- It is not possible to easily use soil spectra for measuring selected soil properties by considering the variations in the spatial-temporal behavior of external parameters (e.g. moisture) in the field.

Problem statment

- About 34 million ha (20%) of Iran's total land area is affected by salinity (Qadir et al., 2008).
- Farifteh (2011) argues that salt causes anomalies in soil spectra and can disturb the soil moisture prediction using VNIR. The external parameter orthogonalization (EPO) method has been recognized as the most effective method to minimize external effects to date (Nawar et al., 2020).
- Mirzaei et al (2022) argues that the performances of the EPO algorithm for clay and soil organic carbon (SOC) modeling dropped by increasing EC. This suggests that further studies are required to develop a method for eliminating the effects of the external parameters caused by increased salt levels in the soil.

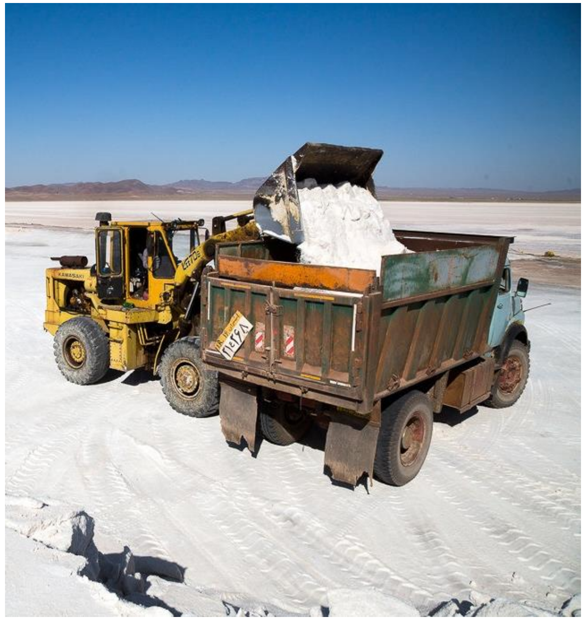
Soil sampling

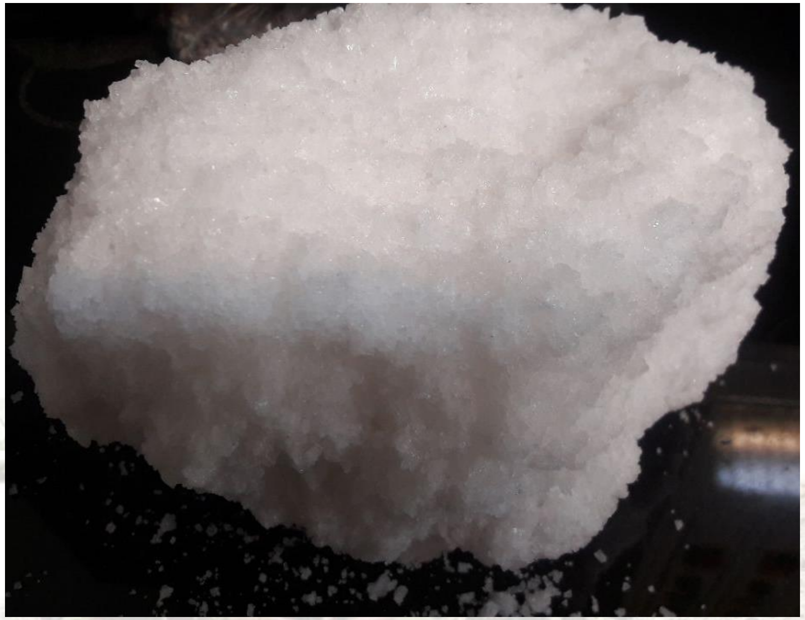
- 230 soil samples were taken at 0-30 cm depths.
- Tehran and Alborz provinces are located in northern Iran with a semiarid, steppe climate.
- Soil samples were dried, ground, and, sieved.
- SOC was measured using the Walki Black method



Natural salt sampling

- Natural salt collected from Hoze Soltan Salt Lake (35º00′00′′ N, 50º56′25′′ E), was used for comprising the salinity treatment





Ions concentration

The concentrations of B, K^{2+} and Na^{+} were measured using flame photometry method; $Ca^{2+}$and Mg^{2+}were measured using EDTA complexometric titration method; Cl^{-} was determined using the silver nitrate (AgNO3) titration method; SO_4^{2-} was determined by the EDTA indirect titration method; and HCO_3^{-} and CO_3^{2-}were determined using the double indicator neutralization method.

Results showed that the dominant salt type is sodic.

Main chemical attributes of salt sample used in this study (mg l^{-1}).

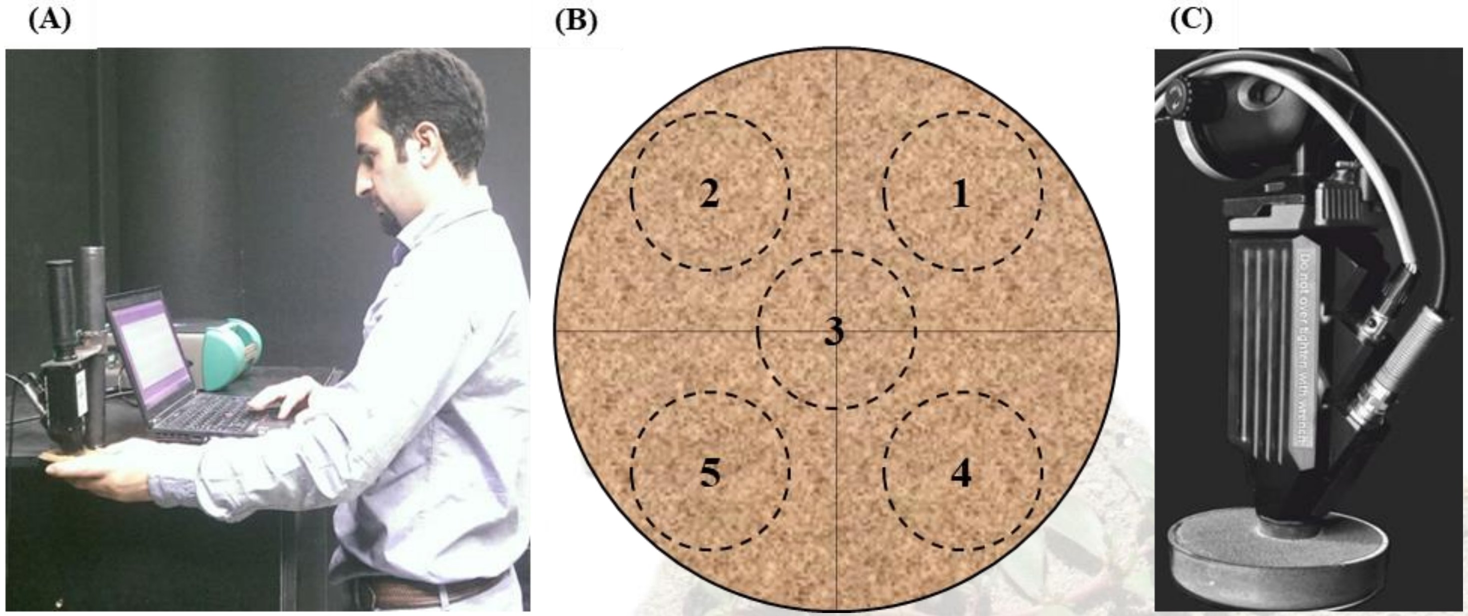
Soluble boron (B)	Potassium (K^{2+})	Sodium (Na^{+})	Calcium (Ca^{2+})	Magnesium (Mg^{2+})	Bicarbonate (HCO_3^{-})	Chloride (Cl^{-})	Sulphate (SO_4^{2-})	Carbonate (CO_3^{2-})
0.002	0.014	80.5	0.93	0.29	0.13	127.7	0.00	0.00

Salinity treatment

- Salinity treatment into five classes of salinity based on Richards (1954): < 2 dS/m (non-saline soil), 4 dS/m (slightly saline), 8 dS/m (moderately saline), 12 dS/m (very saline), and 16 dS/m (extremely saline).
- The soil samples with initial salinity (electrical conductivity (EC) < 1), and classified as non-saline soil, were saturated with double distillate water.

Spectral measurment

- The samples’ spectra were measured by the FieldSpec-3 spectrometer using a contact probe and an internal light source. For each soil sample, five spectra were collected from different parts of the petri dish.

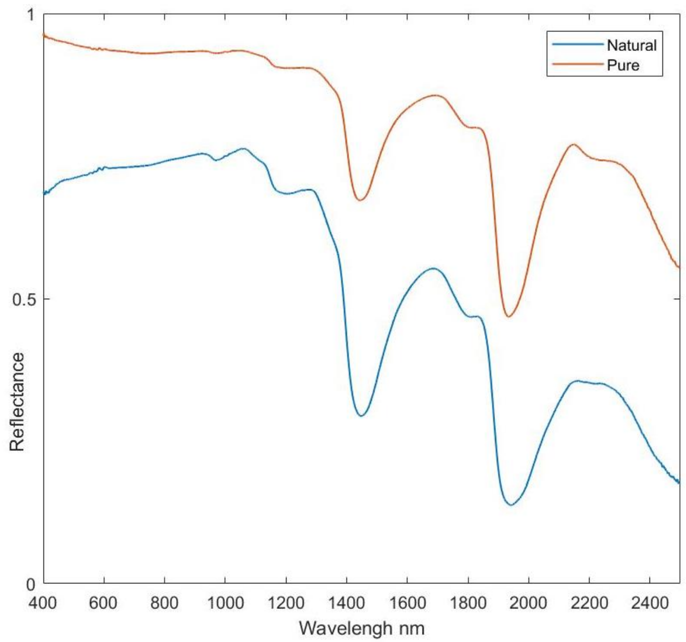


Spectral preprocessing

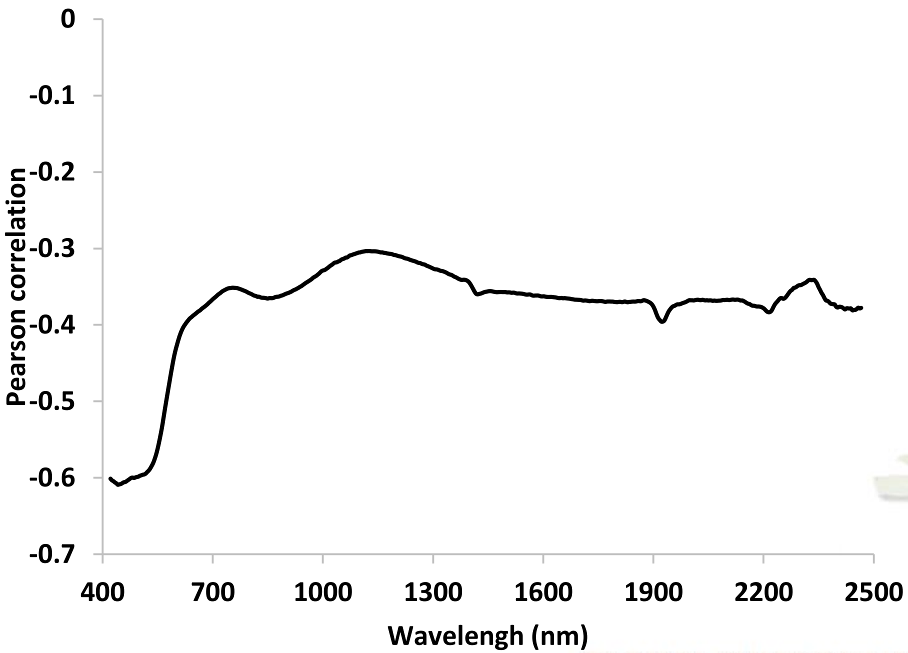
- (i) Splice correction for matching the splice point in 1000 and 1830 nm;
- (ii) A Savitzky-Golay smoothing filter with a frame size of 11 data points (second-degree polynomial) was adapted to smooth spectra
- (iii) 350-420 and 2470-2500 nm were identified as the noisy portions of spectrum and were eliminated, because of high std;
- (iv) the five-preprocessed spectra in 420 to 2470 nm range were averaged (arithmetic mean);
- (v) 3000 spectra with 2050 bands were used for EPO projection and soil property prediction using PLS–BPNN.

Soil organic carbon effect on spectra

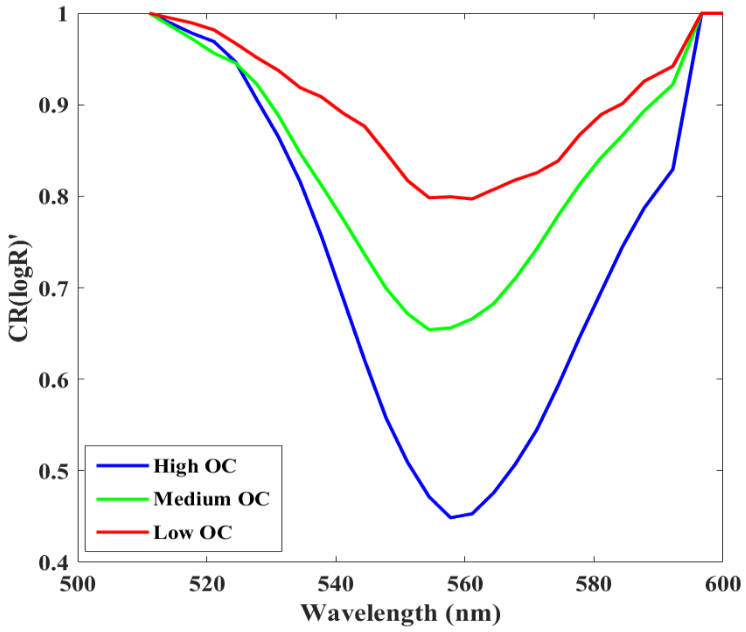
Natural and pure NaCl salt spectra



Correlation between SOC and soil reflectance



CR reflectance of absorption features located in ~574 for different SOC levels



EPO developlent

External parameter orthogonalization (EPO) algorithm assumes that the spectra can be decomposed into three components: (i) useful component attributable to selected parameter(s) (XP), (ii) a parasitic component attributable to non-selected parameter(s) (XQ), and (iii) independent residual (R) as illustrated in Equation 1:

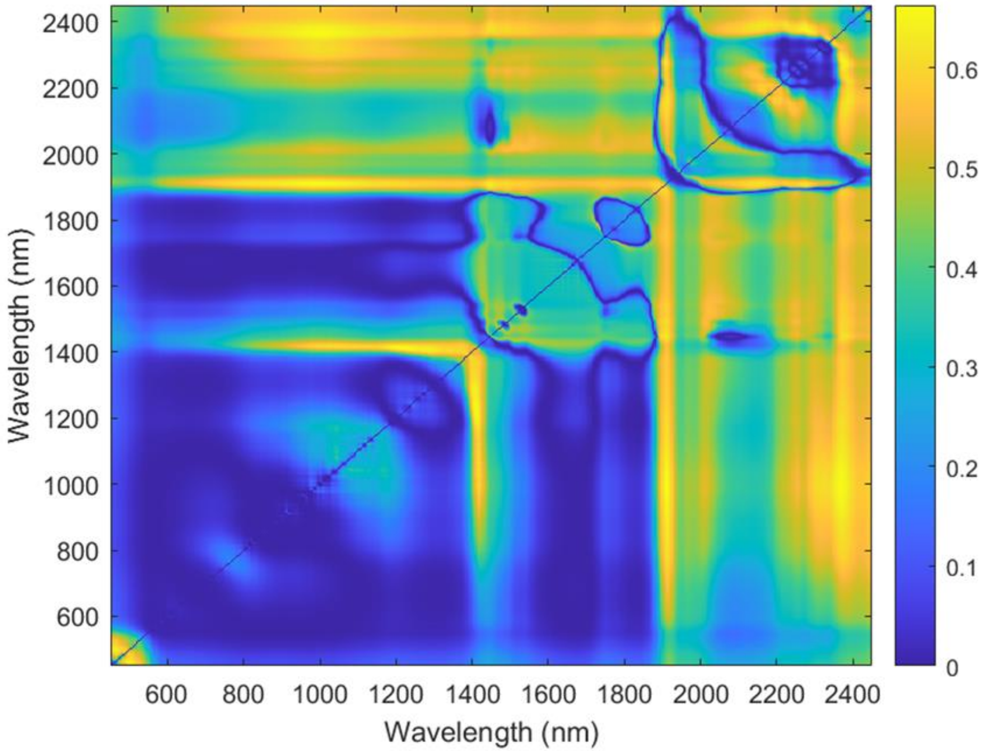
$$\boldsymbol{X} = \boldsymbol{XP} + \boldsymbol{XQ} + \boldsymbol{R} \quad \text{Eq. (1)}$$

- An EPO algorithm was developed for soil salinity.
- The EPO projected spectra were used for predict SOC through partial least squares (PLSR).
- Overall, 95, 45, and 90 samples were used for SOC model calibration, EPO development, and evaluation, respectively.

Result

- Results show that the overall reflectance was changed proportionally as salt concentrations were increased in soil.

Ration Soil Index for soil salinity

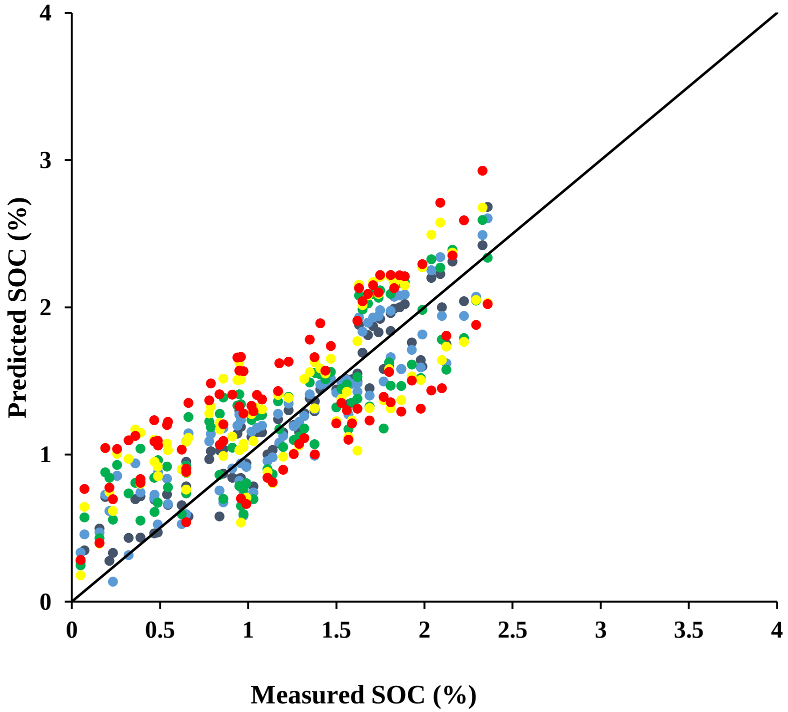


Result

- The width and depth of the absorption features (AFs) around ~1400 and 1900 nm were increase while the depth of AF around ~2200 nm decrease as samples became more saline.
- Change of the soil reflectance caused by the presence of salinity was seen in all spectra, whereas, it was more obvious in AFs located around ~1400, 1900, and 2200 nm.
- These results are in agreement with Wang et al. (2018). Farifteh et al. (2008) argued that the degradation of the absorption band ~2200 nm due to the presence of salt, is related to loss of crystallinity in the clay minerals.

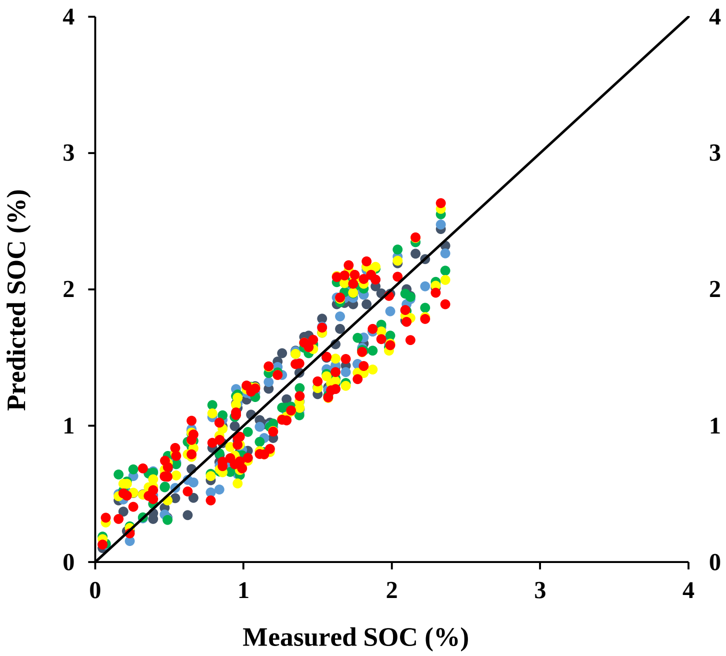
Result

- The similarity between EPO transformed spectra was 98%.
- SOC prediction through salt-affected spectra showed moderate accuracy (RPD = 1.81).



Result

- After EPO implementation, the accuracy of SOC prediction experienced an improvement (RPD from 1.81 to 2.34).
- EPO was able to successfully remove the effect of salinity in soil spectra and improve the SOC prediction accuracy as well.



Conclusions

- The presence of sodic salt up to 16 dS/m in soil can disturb the soil reflectance and reduce the accuracy of OC prediction by VNIR spectrometry.
- EPO implementation leads to moderate improvement in the accuracy of SOC prediction.

References

a. Farifteh, J. 2011. Interference of salt and moisture on soil reflectance spectra. International Journal of Remote Sensing, 32(23): 8711-8724.

b. Farifteh, J., Van Der Meer, F., Van Der Meijde, M. & Atzberger, C. 2008. Spectral characteristics of salt-affected soils: a laboratory experiment. Geoderma, 145, 196–206.

c. Mirzaei,S., Darvishi Boloorani, A., Bahrami, H.A., Alavipanah, S.K., Mousivand, A., & Mouazen, A.M. 2022. Minimising the effect of moisture on soil property prediction accuracy using external parameter orthogonalization. Soil and Tillage Research, 215l 105225. https://doi.org/10.1016/j.still.2021.105225.

d. Mouazen, A.M., De Baerdemaeker, J. & Ramon, H., 2005. Towards development of on-line soil moisture content sensor using a fibre-type NIR spectrophotometer. Soil Tillage Res, 80: 171–183.

e. Mouazen, A.M., Karoui, R., Deckers, S., De Baerdemaeker, J. & Ramon, H. 2007. Potential of visible and near infrared spectroscopy to derive colour groups utilising the Munsell soil colour charts. Biosystems Engineering, 97(2): 131-143.

f. Nawar, S., Abdul Munnaf, M. & Mouazen, A.M. 2020. Machine learning based on-line prediction of soil organic carbon after removal of soil moisture effect. Remote Sens, 12(8): 1308.

g. Richards, L.A. 1954. Diagnosis and improvement of saline alkali soils, agriculture, 160: Handbook 60. US Department of Agriculture, Washington DC.

h. Qadir, M., Qureshi, A.S. & Cheraghi, S.A.M. 2008. Extent and characterization of salt-affected soils in Iran and strategies for their amelioration and management. Land Degradation and Development, 19: 214–227.

i. Wang, J., Ding, J., Abulimiti, A. & Cai, L. 2018. Quantitative estimation of soil salinity by means of different modeling methods and visible-near infrared (VIS-NIR) spectroscopy, Ebinur Lake Wetland, Northwest China. PeerJ, 6: 1-24. https://doi.org/10.7717/peerj.4703.

GLOBAL SYMPOSIUM ON SALT-AFFECTED SOILS

20 - 22
October, 2021
Virtual meeting