Postprint of a Study on Soil Electrical Conductivity Estimation Based on Simulated Different Satellite Spectra

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Abstract

Soil electrical conductivity (EC) is an important indicator for evaluating soil salinization. By measuring soil EC and visible-near infrared spectral data in the Xinjiang Ebinur Lake Wetland Nature Reserve, broad-band data from Landsat 8 OLI, Sentinel 2, and Sentinel 3 satellites were simulated using spectral response techniques. Three-dimensional spectral indices (TDSI) were constructed from the simulated broad-band data and five pre-processed versions, and gradient boosting regression tree (GBRT) algorithms were employed to establish soil EC estimation models for the three satellites, with comparisons of model accuracy changes after incorporating TDSI. The results showed that under different soil EC conditions, the three satellites exhibited similar spectral trends, with higher reflectance in the red and near-infrared bands. The correlation between TDSI and soil EC was basically above 0.4, maximally retaining information from bands highly sensitive to soil EC, including red, green, blue, near-infrared, and shortwave infrared. GBRT demonstrated outstanding capability for soil EC estimation, with the best prediction accuracies (R^2) of the three satellites being 0.831, 0.847, and 0.903, respectively. After incorporating TDSI, R^2 improved to 0.835, 0.857, and 0.935, respectively. Comprehensive analysis revealed that Sentinel 3 achieved the best soil EC estimation performance (R^2 = 0.935, Root Mean Square Error RMSE = 2.986 mS·cm ¹, Akaike Information Criterion AIC = 57.500). By combining spectral response techniques with TDSI to deeply exploit synergistic information among bands and employing GBRT to validate the estimation effectiveness of different satellites for soil EC, this combination can effectively improve model prediction accuracy and provide valuable guidance for quantitative monitoring and prevention of soil salinization in arid regions.

Full Text

Estimation of Soil Conductivity Based on Spectral Simulation of Different Satellites

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Abstract

Soil salinization, as one of the major environmental issues in global arid regions, not only constrains agricultural production but also causes severe land degradation. This issue has attracted widespread attention from scholars both domestically and internationally. Current monitoring and assessment of soil salinization primarily rely on integrating various remote sensing data with different model inversion methods; however, few studies have combined ground-measured spectra with satellite remote sensing data to obtain soil salinization information. Therefore, this study explores the effects of different satellite broadband simulations on soil electrical conductivity (EC) to characterize soil salinization.

Taking the Ebinur Lake Wetland National Nature Reserve in Xinjiang Uyghur Autonomous Region, China as an example, 40 soil samples were collected in the field, and soil electrical conductivity (EC) and visible-near-infrared (VIS-NIR) spectral data were measured. The broadband data of Landsat 8 OLI, Sentinel-2, and Sentinel-3 satellites were simulated using spectral response techniques. A three-dimensional spectral index was constructed by simulating broadband data and its six spectral forms after five preprocessing treatments: first-order differential (FD), second-order differential (SD), continuum removal (CR), absorbance conversion (ABS), and multivariate scattering correction (MSC). Three satellite soil EC estimation models were established by combining the gradient boosting regression tree (GBRT) algorithm, and the accuracy of model estimation was compared after adding the three-dimensional spectral index. The soil estimation potential of the three satellites was then analyzed.

The results show that Landsat 8 OLI, Sentinel-2, and Sentinel-3 have similar spectral trends under different soil EC conditions. With increasing soil EC, the reflectance of each band for the three satellites correspondingly increases, and all show high reflectance in the red and near-infrared regions. The correlation between TDSI and soil EC was basically above 0.4, with Sentinel-3 based on SD pretreatment showing the highest correlation at -0.720. TDSI retains information from red, green, blue, near-infrared, and short-wave infrared bands that are sensitive to soil EC, indicating that TDSI increases the effective information of soil EC while taking into account the remote sensing mechanism, which has certain scientific significance.

The GBRT algorithm demonstrates outstanding performance for soil EC estimation. The soil EC estimation models for the three satellites based on broadband simulation data produced the best prediction accuracy with R^2 values of 0.831, 0.847, and 0.903, respectively. After adding TDSI, the estimation accuracy of different spectral forms for the three satellites was significantly improved, with the corresponding prediction accuracy R^2 increasing to 0.835, 0.857, and 0.935, respectively. Comprehensive analysis found that Sentinel-3 had the best estimation effect for soil EC ($R^2 = 0.935$, RMSE = 2.986 $mS \cdot cm^{-1}$, AIC = 57.500), followed by Sentinel-2 ($R^2 = 0.857$, RMSE = 4.596 $mS \cdot cm^{-1}$, AIC = 45.247), and finally Landsat 8 OLI ($R^2 = 0.835$, RMSE = 4.348 $mS \cdot cm^{-1}$, AIC = 32.765).

This study verifies that the spectral response technique combined with the GBRT algorithm has good effect on soil EC estimation in arid areas. TDSI can deeply mine the synergistic information between bands and improve the prediction accuracy of the model. The combination of the two methods could provide favorable guidance for quantitative monitoring and prevention of soil salinization in arid areas.

Keywords: spectral response; soil conductivity; spectral pretreatment; three-dimensional spectral index; gradient boosting regression tree

Note: Figure translations are in progress. See original paper for figures.