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Mapping cation exchange capacity using a quasi-3d joint-inversion of EM38 and EM31 data

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The cation exchange capacity (CEC, cmol(+)/kg) is a measure of soil's capacity to retain exchangeable cations. However, it is expensive to collect CEC across a heterogenous field and at different depths. To value-add to limited data, proximal sensed electromagnetic (EM) data has been coupled to CEC through linear regression (LR) models, because they measure apparent soil electrical conductivity (EC_a, mS/m). However, these LRs have been depth-specific. This approach was compared with one universal LR between estimates of true electrical conductivity (s, mS/m) and CEC from various depths, including topsoil (0-0.3 m), subsurface (0.3-0.6 m), shallow subsoil (0.6-0.9 m) and deeper subsoil (0.9-2.1 m). We estimated s from inversion of EM38 and EM31 EC_a either alone or in combination (joint-inversion), in horizontal (EC_{ah}) and vertical (EC_{av}) modes, using a quasi-3d (q3-d) inversion software (EM4Soil) and various parameters, including EM38 at two different heights (i.e. 0.2 or 0.4 m). In terms of performance, the LR correlation (R^2 > 0.60) was largest between deeper subsoil CEC and EM38 EC_{ah} at 0.2 m. However, the LR was unsatisfactory for CEC calibration in the topsoil (0.31), subsurface (0.37) and shallow subsoil (0.52). In comparison, a universal LR between CEC and σ was well correlated (0.72), when both EM38 (0.2 m) and EM31 EC_a in both modes, were inverted using a forward model (CF), inversion algorithm (S2) and small damping factor (λ = 0.03). The calibrations tested using a leave-one-out cross validation, showed CEC prediction was precise (RMSE, 2.35 cmol(+)/kg), unbiased (ME, -0.002 cmol(+)/kg) with good concordance (Lin's, 0.83). To improve areal prediction, closer spaced transects need to be collected, while improved vertical resolution of CEC prediction we recommend DUALEM-421 EC_a data be acquired.