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Which soil carbon characteristic is the best for assessing management differences? View from statistical power perspective

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Conservational agricultural managements have a potential to increase soil organic carbon sequestration. However, due to typically slow response of soil organic C to management and due to its large spatial variability many researchers find themselves failing to detect statistically significant management effects on soil organic carbon in their studies. One solution that has been commonly applied is to use active fractions of soil organic C for treatment comparisons. Active pools of soil organic C have been shown to respond to management changes faster than total C; however, it is possible that larger variability associated with these pools can make their use for treatment comparisons more difficult. The objectives of this study are to assess the variability of total C and C active pools and then to use power analysis to investigate the probability of detecting significant differences among the treatments for total C and for different active pools of C. We also explored the benefit of applying additional soil and landscape data as covariates to explain some of the variability and to enhance the statistical power for different pools of C. We collected 66 soil from 10 agricultural fields under three different management treatments, namely corn-soybean-wheat rotation systems with 1) conventional chemical inputs, 2) low chemical inputs with cover crops and 3) organic management with cover crops. The cores were analyzed for total organic carbon (TOC) and for two active C pool characteristics, such as particulate organic carbon (POC) and short-term mineralizable carbon (SMC). In addition, for each core we determined the values of potential covariates including soil particle size distribution, bulk density and topographical terrain attributes. Power analysis was conducted using the estimates of variances from the obtained data and a series of hypothesized management effects. The range of considered hypothesized effects consisted of 10-100% increases under low-input, 10-50% decreases in conventional and 10-50% increases in organic management treatments. The results showed that variability in C characteristics was generally large and when expressed in a unitless form as a coefficient of variation (CV) was the lowest for SMC (CV of 30%), followed by TOC (CV of 50%), while being substantially larger for POC (CV > 100%) Applying additional soil and topographical data as covariates in the data analysis decreased the variances for TOC by 60% and for POC by 14%, however, none of the covariates could help to decrease the variances for SMC. Differences in variability were reflected in the power analysis results. For example, in a hypothetic scenario of a 50% increase in the studied C characteristics under low-input and a 25% decrease under conventional treatment the statistical power was equal to 60% for TOC while it was >90% for SMC, and only <10% for POC. Given the faster reaction to management of SMC as compared to TOC and its lower variability as compared to POC, we recommend SMC measurements as the preferred C characteristic for detecting differences between treatments in agricultural field experiments.