Impacts of Cover crops on soil hydraulic properties: A global meta-analysis

Abstract:

Cover crops (CCs) are widely known for their potential to enhance soil hydraulic properties. However, their effectiveness varies depending on factors like soil, climate and crop management, which differ by location and year. Here, we applied meta-analysis approach to (a) determine the overall effect of CCs on six key soil hydraulic properties, namely total porosity, infiltration rate, saturated hydraulic conductivity (Ksat), field capacity, permanent wilting point, and available water holding capacity and, (b) explore how environment, and management factors moderate the overall CC response. Data were extracted from the peer-reviewed research articles available in Thomson Reuters ISI Web of Science database along with relevant literature references adhering to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The dataset comprised 146 publications with 494 observations across 34 countries and 6 continents. Effect sizes were calculated using the log response ratio, which compares the impacts of CCs to no cover crop (no-CC) treatment on soil hydraulic properties. The meta-analysis revealed that CCs significantly improved total porosity by 7.59% ($P < 0.0001$), infiltration rate by 44.54% ($P < 0.0001$), Ksat by 66.53% ($P < 0.0001$), field capacity by 6.33% ($P < 0.0001$), and permanent wilting point by 7.71% ($P < 0.0044$) compared to no-CC. Although CCs did not significantly increase the overall available water holding capacity, 65.5% of the dataset showed positive effect size, indicating potential benefits in certain conditions. Among the moderators analyzed, CC biomass at termination and CC functional group emerged as key factors influencing soil hydraulic responses. Higher biomass improved total porosity, infiltration, field capacity, and water holding capacity. Legume CCs showed superior performance in enhancing infiltration and retention. These findings support wide-spread adoption and improved management of CCs as a viable strategy for climate-smart, sustainable agriculture.

Keywords: Cover crops, soil hydraulic properties, field capacity, permanent wilting point, available water holding capacity, total porosity, infiltration rate, saturated hydraulic conductivity, soil moisture, moisture retention, climate-smart agriculture.