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Could climate change drive alterations in soil structure and hydraulic properties within anthropogenically-relevant timescales?

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Soil structure has a disproportionate effect on vadose zone water flux through the development of macropore networks that form as a result of structural pedogenesis. Even small changes to the internal arrangement of the soil constituents can have large effects on soil hydraulic properties. Although it is reasonable to speculate that climate influences the development of macropores through soil-forming processes, soils and their corresponding hydraulic properties are often treated as static in both climate and hydrological models. Here we answer the question, “Could the climate drive changes in soil structure and, therefore, soil hydraulic properties within timescales relevant to end-of-century climate simulations?” in the affirmative. Specifically, we use effective porosity - defined as total porosity minus field-capacity water content - as a proxy for soil structure/macroporosity, and investigate continental-scale effects of climate on A and B horizons using openly available soil and climate data from across the USA. We highlight recent work that shows that drier climates induce the formation of greater effective porosity compared to more humid climates. In addition, we show that these changes occur over shorter timescales than are generally appreciated as indicated by the alterations of effective porosity observed in horizons modified by tillage. Using the relationships established between climate and soil structure in this work, we calculate changes in saturated hydraulic conductivity (Ksat) from current and predicted effective porosity using a generalized Kozeny-Carman equation and end-of-century predictions of mean annual precipitation within the CMIP5 RCP6 scenario for five physiographic regions in the USA. Our results indicate that these regions could experience changes in Ksat ranging from -55 to +34%, which are likely to alter the balance between infiltration and surface runoff in these regions. The mechanisms underlying the response of soil structure to climate at a continental scale is unknown. The rate at which these effects occur suggests biotic processes such as increased microbial turnover of soil organic carbon and concomitant effects on aggregate stability and aggregate turnover rate although abiotic processes cannot be ruled out either. Nonetheless, our work indicates that the coupling of climate and soil structure may be important for understanding continental-scale water cycling by the end-of-the century and should be incorporated into parameterizations of hydrological and climate models. The development of climate-dependent pedotransfer functions that utilize climate variability to update hydraulic properties during simulations could provide a way of incorporating this climate-structure relationship into these models.