



Lithological controls on soil formation rates and the implications for soil sustainability

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Soils deliver multiple ecosystem services and their long-term sustainability is fundamentally determined by the rates at which they form and erode. Our knowledge and understanding of soil formation is not commensurate with that of soil erosion, but developments in cosmogenic radionuclide analysis have enabled soil scientists to more accurately constrain the rates at which soils form from bedrock. To date, all three major rock types – igneous, sedimentary and metamorphic lithologies – have been examined in such work. Soil formation rates have been measured and compared between these rock types but the impact of rock characteristics such as mineralogy or porosity on soil formation rates has seldom been explored. In this UK-based study, we addressed this knowledge gap by using cosmogenic radionuclide analysis to investigate whether the lithological variability of sandstone governs pedogenesis. Soil formation rates from two arable hillslopes underlain by different types of arenite sandstone were calculated. Rates ranged from 0.090 to 0.193 mm yr⁻¹ and although the sandstones differed in porosity, no significant differences in soil formation rates were found between them. On the contrary, these rates significantly differed from those measured at two other sandstone-based sites in the UK, and with the rates compiled in global inventory of cosmogenic studies on sandstone-based soils. We suggest that this is due to the absence of matrix and the greater porosities exhibited at our UK sites in comparison to the matrix-abundant, less porous wackes that have been studied previously. We then used soil formation rates to calculate first-order soil lifespans for both of our hillslopes. In a worst case scenario, the lifespan of the A horizon at one of our sites could be eroded in less than 40 years, with bedrock exposure occurring in less than 190 years. This underlines the urgency required in ameliorating rates of soil erosion. However, we also demonstrate the importance of measuring soil erosion and formation in parallel, at the site of interest, rather than calculating a mean rate from the literature, as we demonstrate soil formation rates can vary significantly among variants of the same rock type.