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Digital pedogenon mapping as basis for assessing changes in soil condition

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The response of soils to different human forcings may vary among soil classes (in magnitude and direction of change) depending on their resistance and resilience. We propose a modelling framework for mapping soil-class specific references (i.e., genosoils) and their variants (i.e., phenosoils) that can be used for assessing changes in soil condition due to land use change and management practices. The methodology consists of a first step that creates groups characterized by homogeneous soil-forming factors for a given reference time, under the hypothesis that these groups represent soil classes resulting from multimillennial natural pedogenesis and historic anthropedogenesis (i.e., soil formation processes modified by human activities) (i.e., pedogenons). In this study we applied the methodology to New South Wales (Australia) at the time of the European settlement, because from 1788 onwards the intensification of land use may have accelerated the rate of change of soil properties. A thousand pedogenon classes were generated applying k-means clustering to a set of quantitative state variables that represent the soil-forming factors at the time of the European settlement. Hierarchical clustering was applied to the centroids of the pedogenon classes for assessing their similarities and organization. In a second step, information on native vegetation extent, status (cleared or intact), and current land use was combined for creating a categorical map distinguishing areas with different expected degree of human-induced soil change. The combination of both maps resulted in 5448 subclasses, ranging from remnant genosoils (located in protected areas of intact native vegetation), genosoils II, cleared, grazing and cropping phenosoils. For each pedogenon there was at least a 90-m grid cell classified as a remnant genosoil. The median of the proportion of the pedogenon of origin preserved as a remnant genosoil was 5.3%. Phenosoils grazing and cropping occupied larger areas, with mean values of 73 km^2 and 153 km^2 respectively. Finally, we tested differences in topsoil pH, as proxy for soil condition, by genosoil and phenosoil classes using legacy soil data accessed with the Soil Data Federator from the Terrestrial Ecosystem Research Network. A gls model indicated that the effects of pedogenon, genosoil/phenosoil and their interaction were statistically significant ($p < 0.001$). Paired mean comparisons suggested that mean pH did not differ between remnant genosoils and genosoil II, but the mean pH of both genosoil classes differed from phenosoils. Estimated pH means did not differ between phenosoil classes, although it followed the trend remnant genosoil < genosoil II < phenosoil cleared < phenosoil grazing < phenosoil cropping. The proposed methodology has several potential applications, including soil security and soil change assessment, and designing soil monitoring surveys.