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Hydrophobicity, overland flow and erosion: influences of local spatial variability, vertical routeways and switching dynamics

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This paper argues that the influence which hydrophobicity may have on overland flow and erosion in areas where it occurs will vary with its three-dimensional character (notably its vertical extent and position and local spatial variability), the frequency and vertical connectivity of any routeways through the hydrophobic layer and the spatiotemporal dynamics of hydrophobicity at the location. Although much is known about soil hydrophobicity, assessments of its significance for hillslope runoff generation and erosion are limited by a lack of knowledge and understanding of the three-dimensional dynamics and controls of switching of soils between hydrophobic and hydrophilic states. In general, soils that are susceptible to hydrophobicity tend to be water-repellent when dry but hydrophilic in prolonged periods of wet weather, although correlations of hydrophobicity with changes in soil moisture are very imperfect. Progress in understanding change is severely limited by the destructive nature of methods of determining hydrophobicity and the ambiguity of data deriving from continuous or repeat methods of recording soil moisture change. Thus one cannot monitor change in hydrophobicity at individual points and soil moisture measurements (using time domain reflectrometry or tensiometers) give only hints rather than definitive information as to whether changes in readings indicate changes in matrix or macropore soil moisture.

This paper uses a mixture of field and laboratory data to test a spectrum of alternative models of how (and how quickly) change in soil hydrophobicity may occur. The two end members of the spectrum are the 'progressive' and '3D-simultaneous' models. In the progressive model, then hydrophobicity change occurs first close to vertical preferential flow routeways (such as vertical cracks or vertically contiguous stone clasts). Matrix soil volumes remain hydrophobic at first , but contract progressively in size as wetter conditions spread. In the second model, change is sudden rather than progressive, occurring throughout the soil volume over a short time period. The models are tested in two ways. The first approach is statistical using field data derived from grids of monitoring points, where the differences in frequency distribution of hydrophobicity classes between monitoring occasions can be inferred to indicate whether change is sudden or progressive. The field datasets used are (1) seasonal datasets derived from four 60-point grids (2 metres spacing) in burnt and different-aged Eucalyptus globulus terrain in northern Portugal and (2) daily datasets during drying phases following rainstorms from two 50-point grids (1 metre spacing) on unburned and newly burned heather moorland in central Portugal. Initial results are also presented and used from a laboratory-based programme assessing three-dimensional change in initially hydrophobic soil with and without different types of vertical routways (including those provided by contiguous stone clasts and vertical holes or cracks). Implications of the results for overland flow and erosion in different types of hydrophobicity-affected environments are considered.