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Effects of fire-related eco-hydro-geomorphic feedbacks in the development of asymmetry in soil depth and hillslope gradient in south eastern Australia

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Asymmetry in soil depth and hillslope gradient are often attributed to differential coevolution processes resulting from aspect-related differences in insolation. Across the steep uplands of the south-eastern Australia, forest cover decreases, and fire frequency and post-fire erosion rates increases systematically with aridity. Here we hypothesise that these conditions result in asymmetry in soil depth and hillslope gradient between the drier-north (equatorial) and wetter-south (polar) facing hillslopes; and that the magnitude of difference between the opposing hillslopes depend on fire-related eco-hydro-geomorphic feedbacks that operate at different rates across an aridity gradient. Patterns of asymmetry in soil depth and landform were quantified using soil depth measurements and topographic analysis across a contemporary rainfall gradient. Then, mechanisms which affect the development of asymmetry were identified by using a newly developed 1D numerical model, and by analysing data from a set of microclimate sites.

Landscape analysis and analysis of soil depth measurements showed that polar-facing hillslopes are consistently steeper and have greater soil depth than equatorial facing ones, and that both soil depth and hillslope asymmetry trend non-linearly with aridity, with the greatest difference near the water-limitation boundary. Model simulations with stochastic fire, which depend on soil moisture deficit, replicated the observed trend in soil depth asymmetry between polar and equatorial facing hillslopes across an aridity gradient, highlighting the importance of fire in diving differences in soil depth between the aspects. Analysis of model simulations highlighted specific mechanisms in which fire affect coevolution trajectories, and the data from the field sites provided evidence on how these mechanisms are regulated by contemporary system states across an aridity gradient. Factors affecting soil moisture at a point were found to be important in driving processes and feedbacks both by controlling fire frequency, productivity and soil development. Furthermore, the effect of individual fires on infiltration capacity was found to drive changes in systems states, especially on drier climates, highlighting soil development as an important process in coevolution. This study contributes to the increasing body of knowledge regarding the geomorphic implication of fire to soilscape and landscape evolution in some fire-prone forested landscapes.