Explaining the spatially variable impacts of flood-generating mechanisms is a longstanding challenge in hydrology, with increasing and decreasing temporal flood trends often found in close regional proximity. Here, we develop a machine learning-informed approach to unravel the drivers of seasonal flood magnitude and explain the spatial variability of their effects in a temperate climate. We employ 11 observed meteorological and land cover time series variables alongside 8 static catchment attributes to model flood magnitude in 1268 catchments across Great Britain over four decades. We then perform a sensitivity analysis to understand how +10% precipitation, +1°C air temperature, or +10 percentage points of urbanisation or afforestation affect flood magnitude in catchments with varying characteristics. Our simulations show that increasing precipitation and urbanisation both tend to amplify flood magnitude significantly more in catchments with high baseflow contribution and low runoff ratio, which tend to have lower values of specific discharge on average. In contrast, rising air temperature (in the absence of changing precipitation) decreases flood magnitudes, with the largest effects in dry catchments with low baseflow index. Afforestation also tends to decrease floods more in catchments with low groundwater contribution, and in dry catchments in the summer. These reported associations are significant at p<0.001. Our approach may be used to further disentangle the joint effects of multiple flood drivers in individual catchments.