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What to do where? Demonstration of synergistic interactions between diffuse landscape scale measures to reduce flood risk.

Nicholas Odoni and Stuart Lane

Durham University, Institute of Hazard, Risk and Resilience and Department of Geography, DURHAM, United Kingdom (Nick.Odoni@durham.ac.uk)

There is considerable interest in the possibility that diffuse interventions in river catchments can provide an alternative method for reducing downstream flood risk. Field measurements at quite small scales (between 1 m2 and 1 km2) have confirmed that land management may affect locally the amount of runoff generation and its speed of transfer over the land surface. Small scale interventions have been shown to have considerable local benefits in reducing peak river flows during extreme events. Such interventions have included: (1) small ponds; (2) localised tree planting and restrictions on livestock grazing; and (3) field-scale land use change such as replacing arable cover with grassland. However, there remains great uncertainty over whether and to what extent such small scale benefits can scale up to have larger scale effects. Further, if many interventions are introduced, each having beneficial local effects upon the reduction of peak river flows, the interventions change the relative timings of sub-catchment responses and, possibly, increase peak river flows downstream. Indeed, statistical analysis has shown that in larger river basins (> 10 km2), the relative timing of tributary peaks with respect to the main channel may explain between 10 and 20% of the variance in downstream peak river flow magnitudes. Even measures that are locally beneficial may therefore be problematic at larger scales and need to be analysed in a catchment-scale evaluation. This paper presents the results of applying a new model ('OVERFLOW'), based upon the spatially distributed unit hydrograph, to apply such a catchment scale evaluation to three medium-sized (c. 65 to 120 km2) rural catchments in the U.K. The model focuses upon the effects of in-stream debris dams and floodplain wet woodland, both as individual site interventions and as combinations across multiple sites in the catchment. The model allows for many 100s of thousands of model simulations, in which either: (a) an intervention is dropped into a reach of a stream and its effects are assessed in isolation; or (b) multiple interventions are added in different sets of randomly generated or specifically design-stratified locations. A number of crucial findings result. First, individual interventions which may reduce flood risk locally may also, over larger scales of analysis, exacerbate flood risk farther downstream because of changes to the relative timing of tributary peaks. Second, when used in combination with a number of interventions distributed across the landscape, interventions that are beneficial on their own may be found to have a much reduced effect or even a negative impact on the flood peak owing to the interaction effects with the other interventions. Third, statistical analysis suggests that because of these interactions, local characteristics of the landscape (e.g. floodplain width, channel slope) only control 20 to 30% of the variability of intervention effectiveness. Interactions between interventions are therefore dominant over the impacts of interventions in isolation. Thus, the work shows that whilst small interventions distributed across the landscape have the potential to reduce downstream flood risk, this potential can only be achieved with an holistic analysis of the entire river catchment. Piecemeal interventions, introduced independently at specific or preferred sites, and without strategic planning, may therefore still be able to reduce flood risk locally but actually increase it at the catchment-scale.