Modelling tools for catchment hydrological connectivity: Terrain analysis, dynamic simulation and software agents

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Terrain Analysis: Network Index

The Network Index is a flow path tracing algorithm that works with detailed DEM data. The aim of the index is to determine the catchment wetness conditions required for each point in the landscape to generate runoff and for there to be a connected pathway to the river, an example is shown in figure 1.

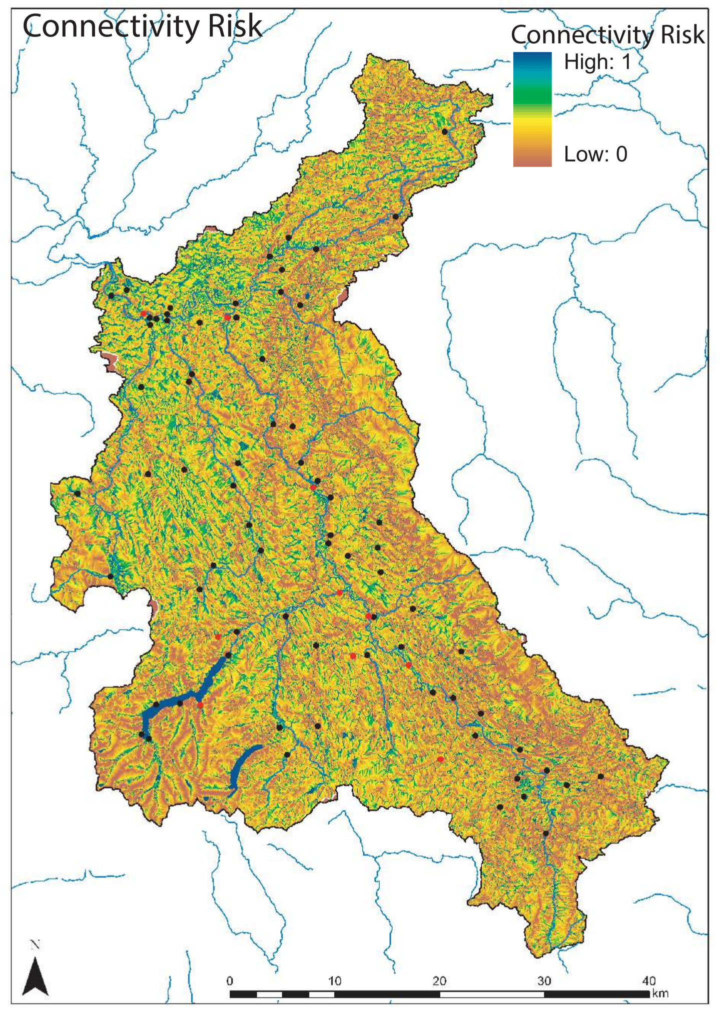

Figure 1: the Network Index of hydrological connectivity applied to the River Eden catchment

Figure 2 illustrates the Network index: Boxes A-C (below) illustrate an example of cells on a hill slope generating runoff during a rain storm. Early in the storm, cells near the channel with a high propensity for saturation begin to generate runoff, these are connected to the river (green); later as more rain falls and the catchment becomes wetter a patch with a slightly lower propensity to saturation begins to generate runoff but these cells are not connected to the channel (red) because there is no continuous flow path of runoff generating cells connecting them with the channel. Finally the (white ringed) cell with a still lower propensity to saturation begins to generate runoff and at this point all the cells upslope of it that are generating runoff become connected to the channel (green). Boxes E and F show the differences between propensity to saturation as defined by the topographic index (E) and propensity to connection as defined by the network index (F). Note, the red values in F highlight cells where these two values differ, and the white ring highlights the cell controlling connectivity, in this case.

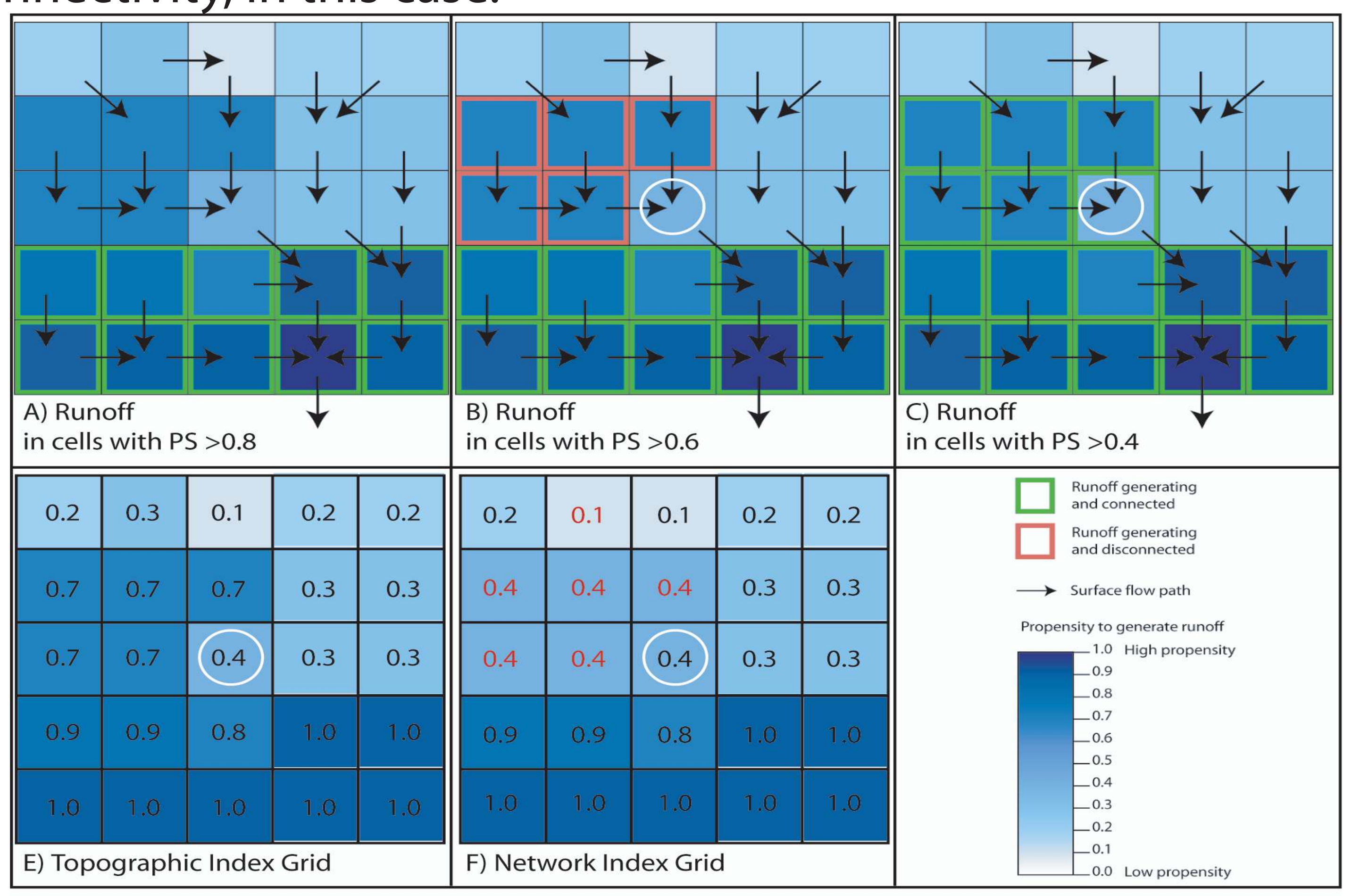

Figure 2: Calculation of the Network Index

Dynamic Simulation: CRUM3

The Connectivity of Runoff Model version 3 (CRUM3) is a distributed, physically based, catchment hydrological model designed to balance the conflicting demands of computational costs, data needs, predictive uncertainty and detailed output. The model contains four major sections: 1, weather generation; 2, terrestrial hydrological processes; 3, two dimensional lateral routing across the landscape and 4, in-channel flow. These process representations are combined in a grid spatial structure and a network based channel system to represent the catchment system.

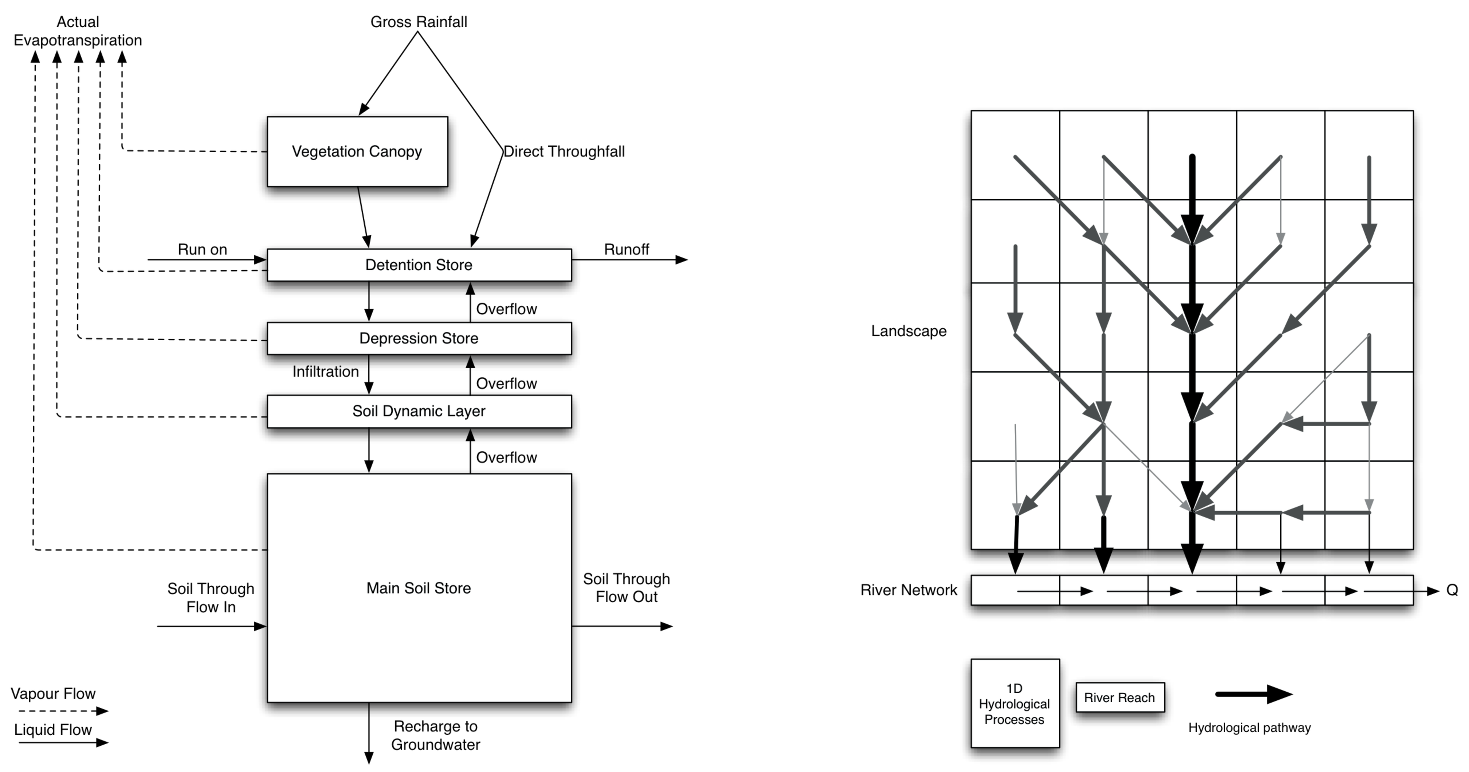

Figure 3: Vertical hydrological process representation and spatial routing of water within the CRUM3 model.

Embedded within the CRUM3 model is the Network Index, hence it is possible to calculate the potential hydrological connectivity based on the simulated soil moisture patterns on a daily basis, Figure 4. Therefore, it is possible to see how the predicted relationship between the simulated discharge and connectivity changes over time.

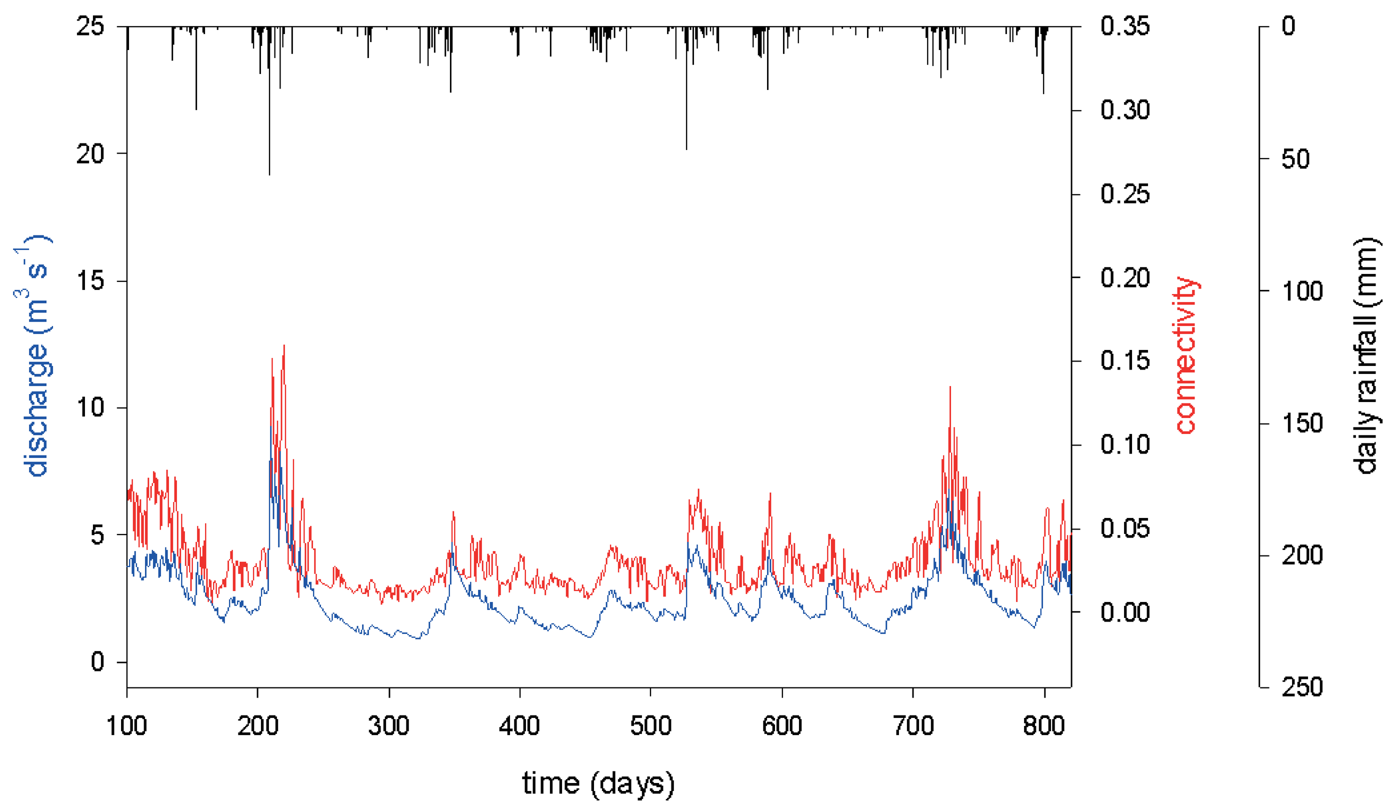

Figure 4: Predicted discharge and catchment hydrological connectivity from the CRUM3 model

Software Agents: hydroAgents

Agents are software components that are capable of moving through and responding to their local environment. In this application, the agents mimic the path taken by water. The agents have information on their local environment and make decisions to stay in the current cell, infiltrate into soil or flow into a neighbouring cell. A physically based, distributed, dynamic hydrological model (CRUM) has been used to generate the hydrological environment. During the storm event, agents are introduced into the model across the catchment and they trace the flow paths of water. This modelling approach is capable of giving a novel picture of the temporal and spatial dynamics of flow generation and transmission during a storm event.

The agent based modelling approach has been applied to a catchment in South-East Spain. The modelling approach was able to show the build up and retreat of the connected areas within the catchment and highlighted the key source areas for overland flow. The model showed that the time of travel to the nearest flow concentration is important for determining the connectivity of a point in the landscape with the catchment outflow.

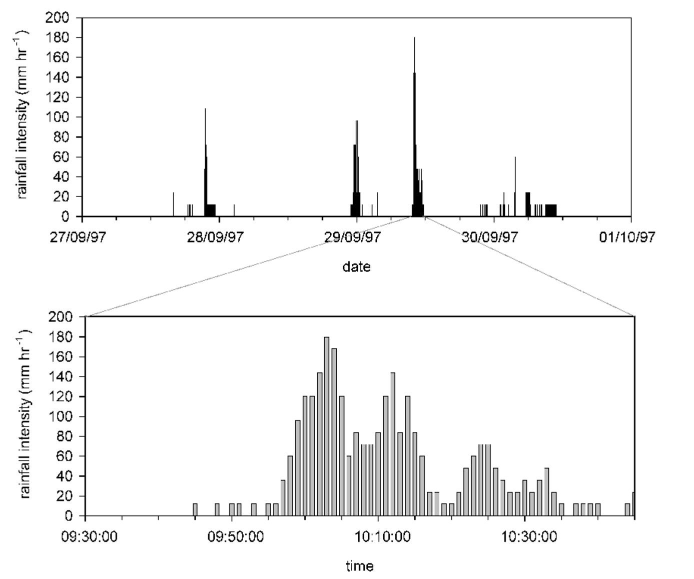

Figure 5: The September 1997 storm event as recorded at the rain gauge with detail of the main rainfall pulse.

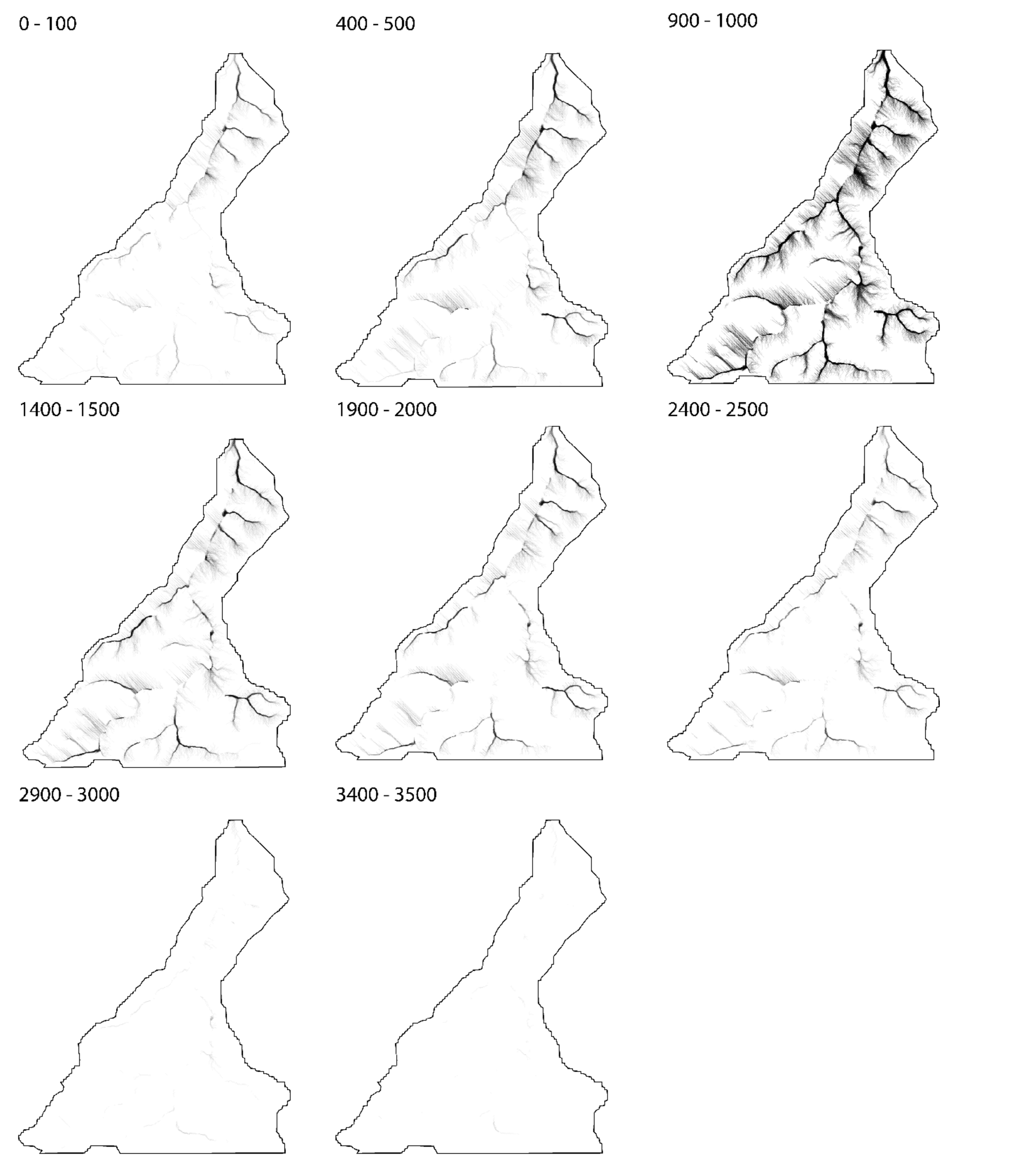

Figure 6: Predicted active contributing areas for the lower Cardena for the 29 September 1997 storm event. The numbers refer to the time slice in seconds during the storm event.