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Spatially distributed modelling of extreme flood events with overbank flow on farmed catchments

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Extreme flood events which occur in southern France are a major threat to human life and infrastructures. These are generally due to intense rainfall intensities, and are poorly understood due to the lack of experimental sites and accurate and long-term hydro-meteorological data. The lack of understanding hydrological processes, sometimes compounds problems of flooding, with settlements, roads and other structures in agricultural zone such as ditches, pipes and tillage practices inappropriately located and designed relative to the flood risk. In agricultural zone, the drainage network is generally formed by man-made ditches which generally follows agricultural field limits, and consequently, water flow doesn't necessarily follow the steepest slope of the catchment surface topography. Thus when overbank flow occurs, we can expect that the ditch networks modify the average distance and slope between the fields and the catchment outlet; major changes are also observed on the pathways followed by the flow, because depending on the position of the ditch on the hillslope, overbank flow is either routed on hillslope and then deviated towards another subcatchment, either routed back to the ditch. Another limitation is the way pipes function in the system. Pipes are generally located on the ditch network under roads. During intense flood events, the flow regime can vary, and pipes can block the flow of water because of their limited dimensions and consequently reduce the flow of water downstream of the pipe. Water can be stored upstream the pipe and/or re-routed through the hillslope to another ditch. In addition to limiting the understanding of hydrological processes in ditches and pipes, this situation handicaps human use and development in agricultural regions, necessitating the use of spatially distributed modelling approaches for prediction of sites prone to flooding, planning of damage minimisation activities, and for environmental prediction of the impact of land use changes. The focus of this paper is on spatially distributed modelling of intense floods with overbank flow on an elementary farmed basin with a dense network of ditches and pipes, and the fundamental problems associated with their estimation, illustrating these through the particular example of an application in the Roujan experimental basin (0.91 km^2) located Southern France. The distributed hydrological model of flood events MHYDAS (Distributed Hydrological Modelling of AgroSystems) was extended in order to simulate overbank flows, and is designed to operate with high-resolution Digital Elevation Models, which are becoming increasingly available. The transfer function consists of a one-dimensional diffusive wave approximation for channel flow and a quasi-two-dimensional diffusion wave representation of floodplain flow. The model was applied to simulate flood events between 1992-2006 on the Roujan basin. First the model parameters were calibrated on flood events without overbank flows, and then the parameters of the modules related to the overbank flow were calibrated on events where overbank flow occurs. The model was validated on a set of flood events, and the model was applied to simulated the impact on hydrographs of land use change such as a modification of the geometric properties of the ditch network such as width, height, slope and topology. Results show the importance of the role of the ditch network and the pipes on the form of the hydrograph, the lag time, the runoff volume and the peak discharge. The model enables to quantify the overbank hydrograph flow on each ditch and pipes. These simulations enable the decision-maker to compare different land use configurations and to propose country-planning schemes. The methodology proposed herein is useful for simulating both sensitivity analysis of distributed hydrological models on farmed catchments, and the long-term geomorphologic evolution of the ditch network especially after land use changes.