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Analyzing the temporal variability of the hydrological connectivity to assess the critical source areas for pesticides losses

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In order to propose relevant pesticide mitigation strategies within agro-systems, i.e. grass strips or storm basins, it is necessary to identify the areas that mostly contribute to pesticide losses in surface water. At the agricultural catchment scale, this identification requires assessing the hydrological connectivity between plots and the river network. When the infiltration-excess (IE) runoff mechanism dominates, a plot can be disconnected from the hydrological network if landscape components such as hedges block or limit the runoff generated. Conversely, some elements as ditches or road network can enhance the runoff from upstream to downstream areas and increase the pesticide losses. The degree of connectivity is closely linked both to the characteristics of the rainfall event considered and the initial moisture content of soil.

This study is aimed at analyzing the variability of connectivity degree according to the return period of rainfall event and the initial soil moisture content. This study was conducted on a vineyard catchment area located in the Alsatian piedmont (Rouffach, France). The transport of pesticides in surface water represents regionally a main threat because the runoff produced on the vineyard area rapidly flows towards downstream water bodies, which are closely linked to the large Rhenan aquifer. The Hohrain catchment, 40 ha, comprises more than 120 farming plots and a dense, mostly impervious road network. Hydrograms and pesticide chemograms are available for each storm event during the vine growing season since April 2003. The topographical information is provided by the digital elevation model obtained by the lidar technology. A field campaign allowed obtaining 1) the land use characteristics, including the identification of soil and water conservation methods, such as grass strips within or bordering the cropped area, and 2) the main soil hydrodynamic characteristics.

The physically-based model LISEM (Limburg Soil Erosion Model) was retained to perform this analysis. This fully distributed model allows taking into account the spatial and temporal variability of hydrological processes, i.e. rainfall, interception, surface storage in micro-depression, infiltration, vertical movement of water in the soil, overland flow, and channel flow within the catchment. To correctly take into account the landscape components, e.g. grass strips, hedges and ditch networks, a 2 m grid cell size was used. Preliminary studies have demonstrated the predictive ability of the LISEM model in the Hohrain catchment in terms of both discharge and runoff pathway within the catchment with a reduced calibration step.

To assess the impact of both the rainfall intensity and initial moisture conditions on the variability of the hydrological connectivity modeling with LISEM, six rainfall events were considered with associated return periods of 2, 5, 10, 20, 50 and 100 years respectively. Different initial moisture contents were considered based on the range of observed values at the field-scale. The hydrological connectivity is defined here as the upstream to downstream connectivity of active areas with respect to runoff process. The indicator of the connectivity variability used was the percentage of the catchment in which the active areas with respect to runoff are really connected to the outlet. The results showed that a risk of pesticide transfer can be associated for a combination of rainfall event intensity and initial moisture content. The results also underscored the limit of the Hydrological Response Unit (HRU) concept, especially for small catchment areas. Indeed, observed and simulated active areas (i.e., generating runoff) were smaller than the HRU obtained by crossing land use and soil type. This study showed that a detailed integration of the connectivity at the catchment scale is crucial to closely assess the dynamics of pesticides transfers.

Keywords: Hydrological connectivity, pesticide transfer, vineyard catchment, LISEM model