Hydrology in a Mediterranean mountain environment, the Vallcebre Research Basins (North Eastern Spain). IV. Testing hydrological and erosion models

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ABSTRACT

Three modelling exercises were carried out in the Vallcebre research basins in order to both improve the understanding of the hydrological processes and test the adequacy of some models in such Mediterranean mountain conditions. These exercises consisted of i) the analysis of the hydrological role of the agricultural terraces using the TOPMODEL topographic index, ii) the parameterisation of TOPMODEL using internal basin information, and iii) a test of the erosion model KINEROS2 for simulating badlands erosion.

Keywords: Mediterranean, modelling, hydrological processes, sediment yield, badlands

INTRODUCTION

The modelling of Mediterranean mountain areas is often seen as a complex challenge and an unresolved problem for which model improvements are required. In the Vallcebre small research basins, located in the Eastern Pyrenees (Latron et al., 2009), three main modelling exercises were conducted with hydrological and erosion models.

SATURATED AREAS VERSUS TOPOGRAPHIC INDEX

Gallart et al. (1994) analysed the hydrological role of the agricultural terraces at the Cal Parisa sub basin in Vallcebre. The spatial pattern of the patches covered with *Molinia coerulea*, a hydrophytic grass which grows in frequently water-logged soils, was compared with the TOPMODEL (Beven & Kirkby, 1979; Beven et al, 1995) topographic index map obtained with a 15m-mesh DEM that overrode the terraces. Furthermore, a tentative parameterisation of TOPMODEL using flow recession and soil moisture data was performed.

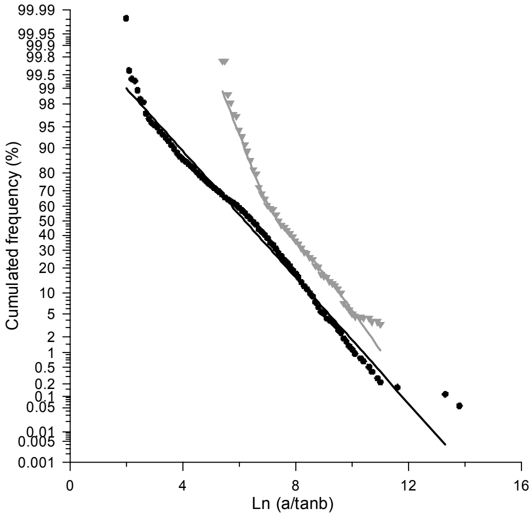

Figure 1. Cumulative distribution function of the topographic index for the Cal Parisa sub basin (black dots) and the frequently saturated areas (grey triangles) that covered 7.4% of the basin area. The bi-modal distribution of the topographic index of the saturated areas (grey line) was attributed to the differences between natural and terrace-induced saturated areas, with mean values of topographic index of 8.3 and 6.7 respectively.The average value of the topographic index for the whole sub basin was 6.2.

The results showed that the frequently saturated areas had a bi-modal distribution of topographic index values, one mode attributed to the general topography of the basin and the other (with lower values) to the role of terraces (Fig. 1).

The terraces promoted the formation of saturated areas in drier conditions than those expected by the main topography. These results were not validated nor refuted afterwards. However, this difference was also evident when the seasonal dynamics of the saturated areas was analysed (Latron and Gallart, 2007). Yet, the analysis of the response time of these basins demonstrated a delay of flows when compared with the response times expectable for saturated overland flow in basins of similar size (Gallart et al., 2005a).

TOPMODEL PARAMETERISATION WITH INTERNAL BASIN INFORMATION

When TOPMODEL was calibrated at the Can Vila sub basin using stream discharge observations (as usually done), the results were acceptable in terms of discharge simulation when compared with other models (Gallart et al. 2000). Nevertheless, the simulation of the partitioning between surface and subsurface flows and, consequently, the simulation of the saturated areas, was largely uncertain. The simulation of the saturated areas was one of the main requirements for the model, as the simulation of the internal processes in the basins is one of the main subjects of research at Vallcebre (Gallart et al. 2005a; Latron and Gallart, 2007).

For these reasons, an exercise consisting of the use of internal basin observations to gather information on TOPMODEL parameters using the GLUE approach was made (Gallart et al., 2007). The depth to the water table was used in two ways: First as an observed value for calibrating the model and second, coupled with discharge values, to obtain estimates for the main TOPMODEL parameters. Spare observations of the extent of saturated area were used, coupled with discharge measurements, for obtaining effective estimates of the transmissivity parameter. The two last approaches are adequate for use in poorly gauged basins as only scattered flow and internal data are required.

The use of the internal information meant a strong decrease of the uncertainty of the partitioning between surface and subsurface contributions and a more robust simulation of discharge. Nevertheless, an analysis of the limitations of this method (Gallart et al., 2008) showed that it was possible to simulate the extent of the saturated areas although their simulated patterns did not match well the observed ones, largely because the role of local controls beyond the topographic index (Fig. 2).

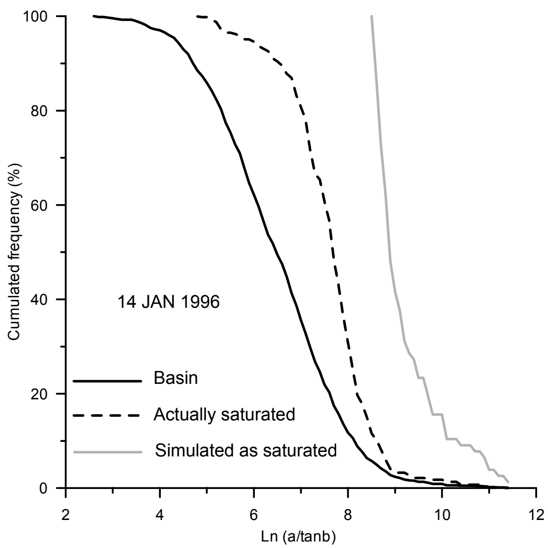

Figure 2 Cumulative distribution function of the topographic index for the Can Vila sub basin, the observed saturated areas on 14th January, 1996 (6.6% of the basin area), and the simulated saturated areas on that date. For a correct simulation of the pattern, all the areas with a topographic index higher than 8.5 should have been saturated, but the mean topographic index of the actually saturated areas was 7.6. This was however significantly higher than 6.5, the average value of the topographic index in the basin.

USING KINEROS2 FOR SIMULATING BADLANDS EROSION

The ability of the soil erosion model KINEROS2 (Smith et al., 1995) for simulating badlands erosion was tested at the Ca l'Isard sub basin (Martínez-Carreras et al. 2007). First, a calibration - validation test was made using event scale measurements of sediment yield obtained between 1991 and 1994 at the El Carot plot (1240 m^2) by Castelltort (1995). Sediment yield from this plot was successfully simulated, although with 90% confidence uncertainty bounds that represent ±30% of the mean value.

Subsequently, KINEROS2 was used to assess the catchment scale sediment yield from the major badlands areas in the Ca l'Isard sub basin, using the parameters obtained at the El Carot plot. The results (Fig. 3) showed a clear asynchrony between the erosion events in the badlands areas (as simulated by the model) and the sediment transport events measured at the basin scale, already evidenced in former studies (Gallart et al. 2005b). Nevertheless, the total sediment volumes were clearly underestimated by the model, a failure probably attributable to the lack of representativeness of the El Carot plot (because of its fair topography), and to the possible existence of other relevant sediment sources (stream banks and floors).

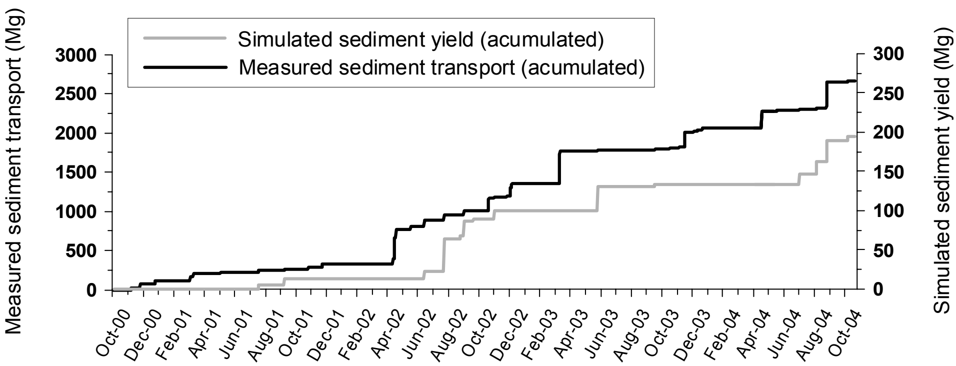

Figure 3. Comparison of the measured sediment transport at the Ca l'Isard sub basin and the simulated sediment yield from the badland areas in the basin using KINEROS2. Note the differences between the two scales.

CONCLUSIONS

The three modelling exercises carried out in the Vallcebre research basins, in Mediterranean mountain conditions, constituted a severe test for the applied models. These exercises allowed testing the adequacy of these models, but also helped to improve the understanding of the hydrological processes. Along with future modelling works, more process-orientated research is needed, to further update a perceptual model of the hydrological functioning of the Vallcebre basins. The objective should be to define more flexible process-based modelling structures that can capture the strong seasonality of these Mediterranean catchments' hydrology.

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