Imperial College London

FRMRC flood risk management research consortium

IMPACTS OF LAND MANAGEMENT ON FLOOD RISK: A PLOT SCALE EXPERIMENTAL AND MODELLING INVESTIGATION IN AN UPLAND WELSH CATCHMENT

C. Ballard (1), Z. Frogbrook (2), B. Jackson (3), I. Solloway (1,2), M. Marshall (1,2), N. McIntyre (1), B. Reynolds (2), and H. S. Wheater (1)

(1) Department of Civil and Environmental Engineering, Imperial College London, United Kingdom (c.ballard@imperial.ac.uk),
(2) Centre for Ecology and Hydrology, Environment Centre Wales, Bangor, United Kingdom
(3) School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand

1. Introduction

Recent floods in the UK have focused attention on the effects of rural land use and land management change on flood risk. Attempts to quantify these effects from catchment scale responses have failed due to reasons such as climate variability, spatial distribution of land management types and poor historical records of land use and land management change (Beven, 2008). To improve our understanding, a multiscale experimental and modelling programme has been implemented in the Pontbren (18km^2) and Rhos Aflo (4km^2) catchments in mid-Wales (Marshall et al (2009)).

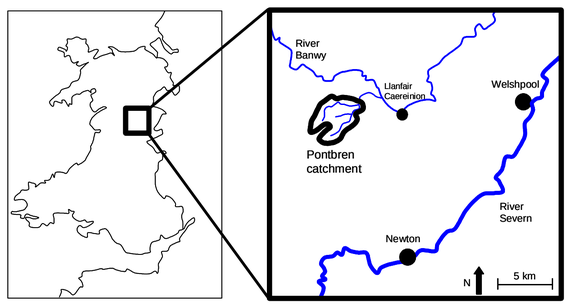

Figure 1 : Location of the Pontbren Catchment

2. Experimental Setup

As part of the experimental programme, four sets of three manipulation plots have been monitored both before and after land use changes. In each set of plots, the existing land use (grazed grassland) has been changed (in February 2007) to ungrazed grassland (by excluding sheep) and to young woodland (by excluding sheep and planting trees). Data collected include soil hydraulic properties, soil moisture and continuous overland flow, soil water pressure and rainfall.

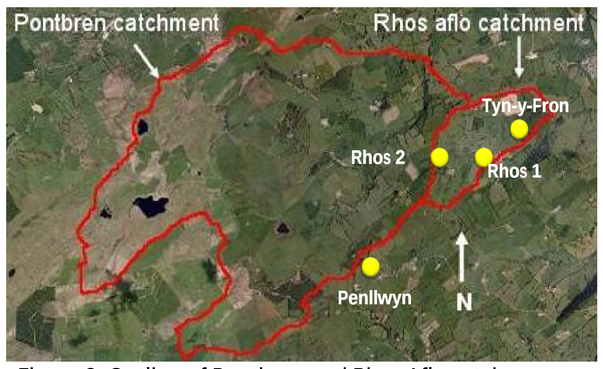

Figure 2. Outline of Pontbren and Rhos Aflo catchments with locations of the manipulation plots

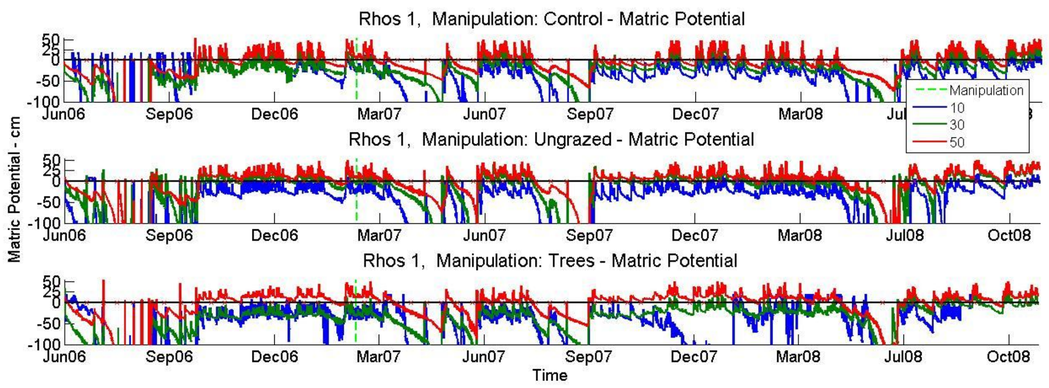

Figure 3: Matric Potential record at Rhos 1 (resolution - 10 minutes)

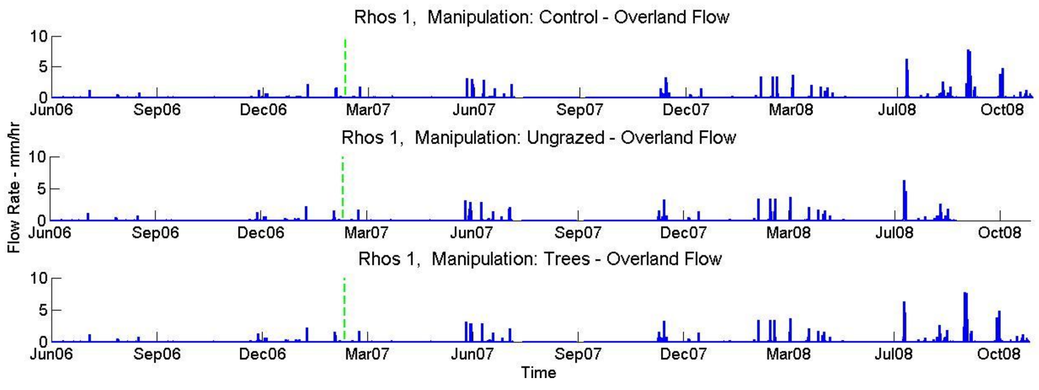

Figure 4: Overland Flow record at Rhos 1 (resolution - 10 minutes)

3. Observations

Soil moisture records (figure 5.) highlight heterogeneity between the sites and a relative drying of the A horizon at the trees site with time since planting. A drought in summer 2006 appears to have led to temporary macropores that were persistent for most of the time before manipulation, allowing faster drainage and therefore reduced overland flow (figure 4). Post-manipulation and relative to the control site, overland flow was reduced at both the ungrazed and tree planted sites, with the effects greatest in the tree plot.

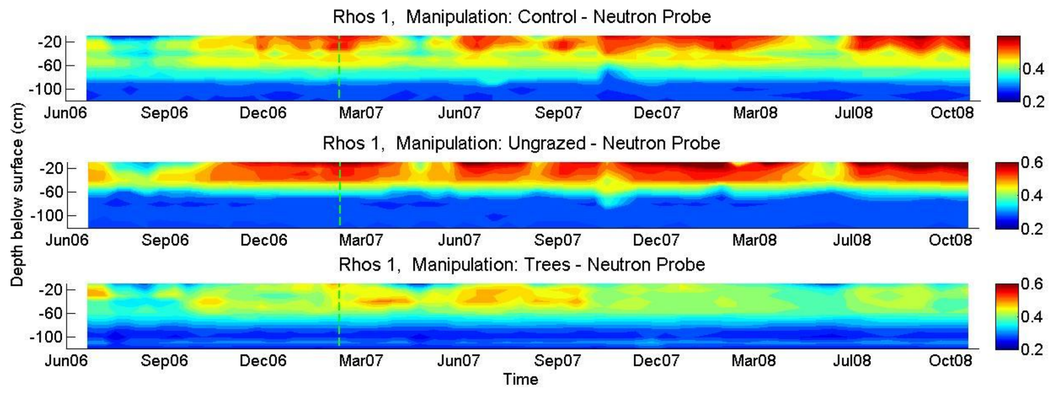

Figure 5: Soil Moisture record at Rhos 1 (resolution - 2 weeks)

4. Modelling

An inverse modelling programme is currently underway using a detailed physics based model, SPW, to simulate 1-dimensional saturated and unsaturated subsurface flow and overland flow. The aim is to quantify the changes in soil hydrological properties associated with the changes in land use. While some success has been obtained with the simulation of overland flow (figure 6), a number of challenges have been encountered in the modelling process.

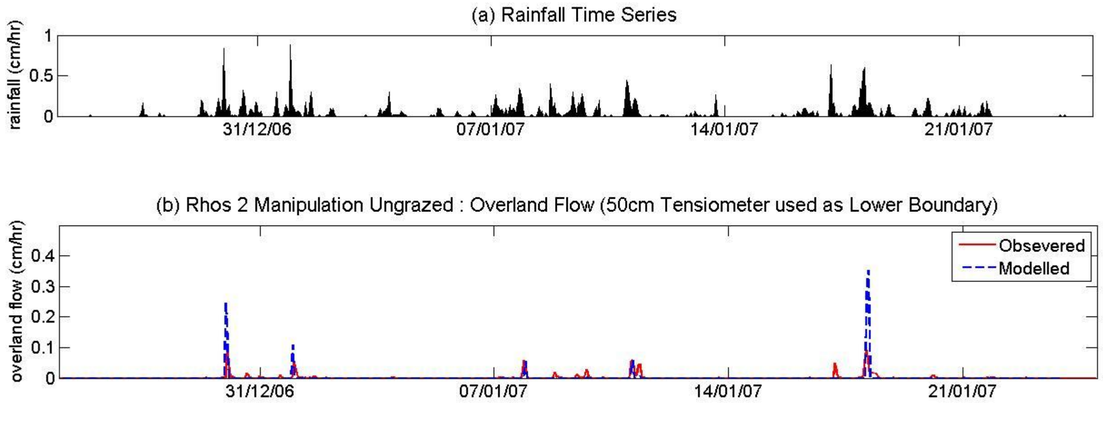

Figure 6: (a) Rainfall and (b) Simulated and Observed Overland flow for Rhos 2, Ungrazed

<u>1. Parameter Identifiability</u>

Initial best fits only appear to show a dependence on the lower hydraulic conductivity, and surprisingly, not to the parameters related to A horizon storage

<u>2. Boundary Conditions</u>

Although different boundary conditions can yield similar overland flow fits, the parameters determined through the inverse modelling are strongly influenced by the boundary condition assignment, as shown in figure 7.

<u>3. The Effects of Drought on the Site</u>

The effects of the drought make it difficult to distinguish between hydraulic property changes related to the drought and to the land use. Analysis of the raw data indicates that the drought has a larger effect than the land use change at this stage of the manipulation experiments.

<u>4. Conceptual Understanding of the System</u>

Best fit simulations tend to over predict larger overland flow events, suggesting that an important process, such as lateral flow or macropore flow, is missing from the model.

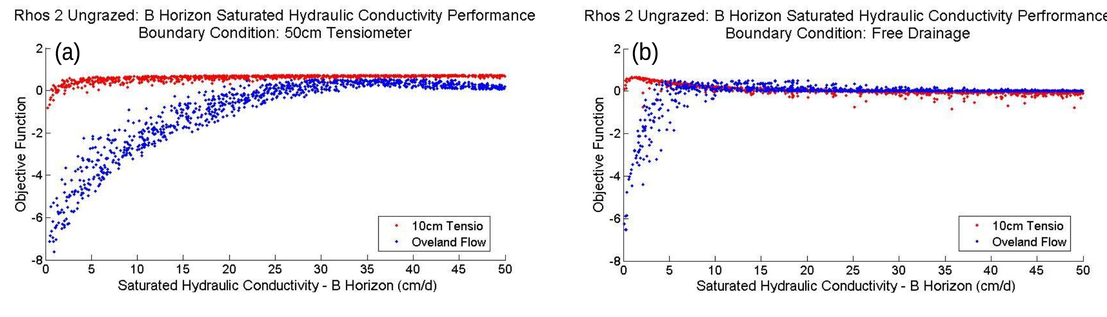

Figure 7: Monte Carlo simulation outputs. Scatter plots of saturated hydraulic conductivity versus modelling performance for both overland flow and the 10cm tensiometer. (a) shows results using the 50cm tensiometer as the boundary condition, and (b) shows the results of using a free drainage boundary condition

5. Future Work

Modelling work will continue, with the results ultimately used to inform conceptual models which in turn are used to upscale the observed field scale changes to examine catchment scale effects. The catchment scale models will be used to investigate the effects of land management changes, such as stocking changes and afforestation, on downstream flood risk.

References

Beven, K., Young, P., Romanowicz, R., O'Connell, E., Ewen, J., O'Donnell, G., Holman, I., Posthumus, H., Morris, J., Hollis, J., Rose, S., Lamb, R. and Archer, D. ,2008. Analysis of historical data sets to look for impacts of land use and management change on flood generation. Final Report for Defra project FD2120

Marshall, M.R., Francis, O.J., Frogbrook, Z.L., Jackson, B.J., McIntyre, N., Reynolds, B., Solloway, I., Wheater, H.S., and Chell, J., 2009. The impact of upland land management on flooding: results from an improved pasture hillslope, Hydrological Processes, 23(3): 464-475.

Acknowledgements

The research reported in this poster was conducted as part of the work of the Flood Risk Management Research Consortium (FRMRC). The FRMRC is supported by Grant EP/F020511/1 from the Engineering and Physical Sciences Research Council (EPSRC), in partnership with the Department of Environment, Food and Rural Affairs/Environment Agency (Defra/EA) Joint Research Programme on Flood and Coastal Defence, United Kingdom Water Industry Research (UKWIR), the Office of Public Works (OPW) Dublin and the Northern Ireland Rivers Agency (DARDNI). This financial support is gratefully acknowledged. The authors are also grateful to the EA for providing LiDAR data and to the Ordnance Survey for providing Mastermap® data.