

Case study 27. Investigating the Impacts of Upland Land Use Management on Flood Risk at Pontbren, Wales

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Main driver: Flood risk management

Project stage: Multi-scale experimental and modelling project



Photo 1: A farm in the Pontbren catchment (**source:** Forest Research)

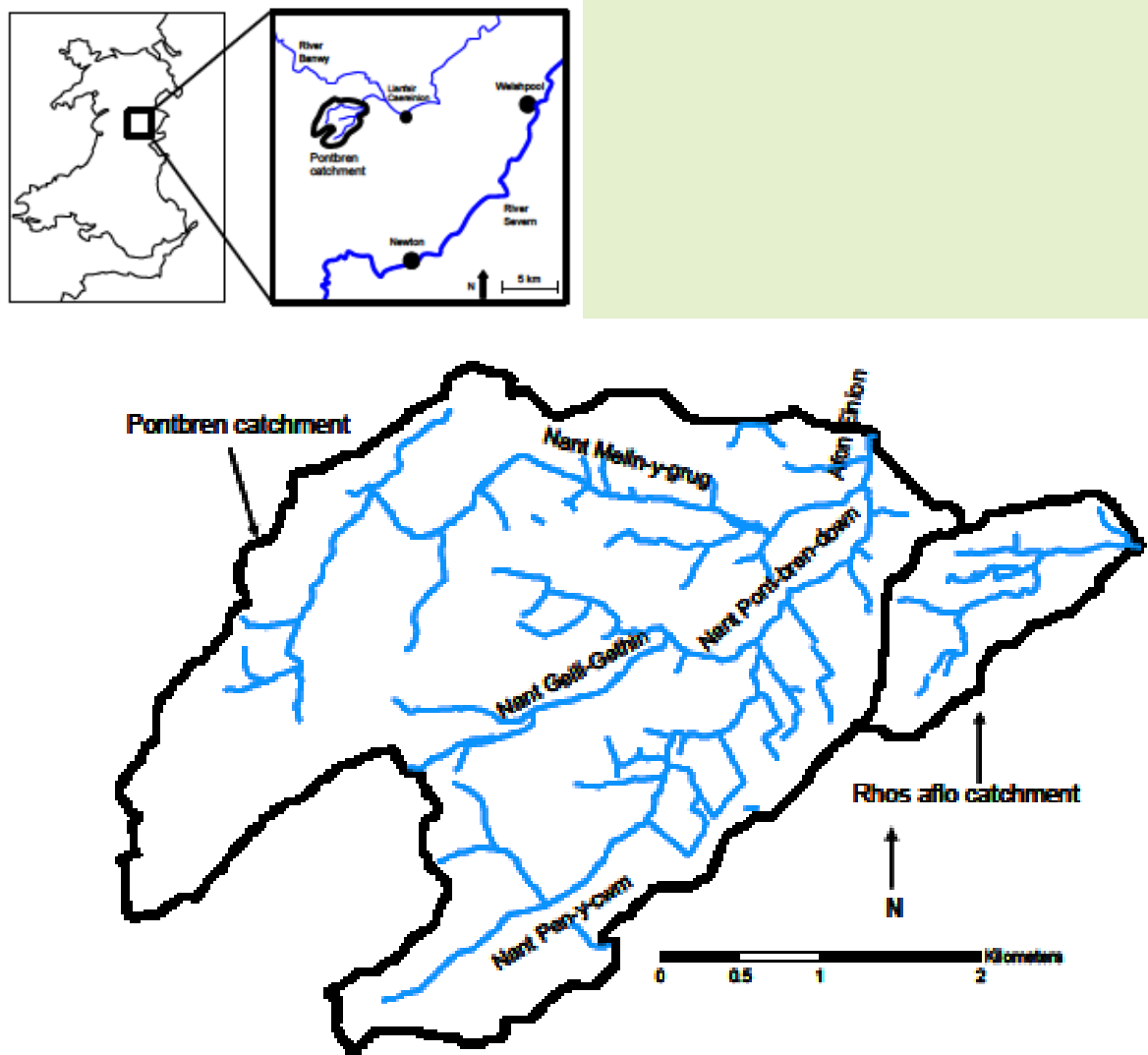
Project summary:

The aim of this research project on the Pontbren catchment in north Wales (Photo 1 and Map 1) was to improve understanding of how changes in upland land management impact on flood risk at the catchment scale. Experimental plots were established to measure the effects of sheep grazing and tree planting on soil structure and the generation of flood run-off. The data from these plots were used to derive parameter values and uncertainty bounds for a multi-scale modelling methodology. The model was applied to the headwater catchment to predict the impact of alternative land use practices on flood flows. Results showed that land management can have a major effect on run-off processes, providing scope for targeted interventions to significantly reduce flood risk in low permeability, upland landscapes at local scales.

Key facts:

Soil infiltration rates were found to be 67 times higher within woodland plots and shelterbelts planted on improved grassland compared with grazed pasture; this reduced measured surface run-off volumes by an average of 78% compared with the control. These differences were quick to develop, becoming apparent within one year of sheep exclusion and tree planting. This was partly explained by the removal of the grazing pressure on the soil, which reduced run-off volumes by 48%, and partly by the action of tree rooting and growth, which was responsible for the remaining 30% decrease.

Modelling predicted that planting tree strips across 7% of the 12km² headwater catchment could reduce a severe flood (return period of 180 years) by an average of 5%. The effect of complete afforestation was much greater, reducing the same flood peak by an average of 36%.



Map 1: Location of Pontbren catchment in north Wales

1. Contact details

Contact details	
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2. Location and catchment description

Catchment summary	
National Grid Reference:	SJ 061075
Town, County, Country:	Llanfair Caereinion, Powys, Wales
Regional Flood and Coastal Committee (RFCC) region:	Wales
Catchment name(s) and size (km²):	Pontbren, 12km ²
River name(s) and typology:	Afon Einion Mid, small and siliceous
Water Framework Directive water body reference:	GB109054049840
Land use, soil type, geology, mean annual rainfall:	Predominantly improved grassland on clay rich, cambic stagnogley and cambic stagnohumic gley soils overlying glacial drift derived from Ordovician and Silurian greywackes Mean annual rainfall: 1,670 mm (2005 to 2008)

3. Background summary of the catchment

Socioeconomic/historic context

The study was established as part of the Flood Risk Management Research Consortium set up by the Engineering and Physical Sciences Research Council (EPSRC). It was set up to address uncertainty about the degree to which land use management could reduce flood risk at the catchment scale. An earlier review had found good evidence of land management influencing run-off generation at the hillslope scale but data were lacking on how these effects propagate downstream within river catchments.

Quantifying the effects of rural land use on flood flows was one of 5 main topics of research undertaken during the 8-year research programme that ran from 2004 to 2012. This led to the multi-scale experimental and modelling programme of work at Pontbren. The research study was part of a wider Pontbren project, which was centred on the efforts of the local farmers' co-operative to improve the sustainability of their farm management, including for run-off and sediment control.

Flood risk problem(s)

The project is a research study and was not designed to address a local flood problem. Flooding is a major issue in the wider River Severn catchment to which Pontbren drains, but the vast majority of the 29,000 properties at risk from a 1% annual exceedance probability event are located lower down the catchment or along other major tributaries. The preferred policy for the upstream area is to work with landowners and local interest groups to reverse trends in land use and management that are thought to have increased flood risk over time. The vision is to deliver a more sustainable approach to flood risk management that better utilises opportunities to attenuate rainwater and to store more flood water within the landscape.

Other environmental problems

The water body is at good ecological status, but headwaters are known to be subject to soil erosion and sediment issues.

4. Defining the problem(s) and developing the solution

What evidence is there to define the flood risk problem(s) and solution(s)

Agricultural intensification is thought to have contributed to increased generation of run-off by reducing soil infiltration and soil water storage. Sheep grazing is a particular issue due to the pressure exerted by sheep's hooves compacting surface soil layers, especially where stocking rates are high. This acts to enhance overland flow and rapid run-off. The experimental work at Pontbren therefore focused on establishing field plots to quantify the effects of sheep grazing on run-off processes and the potential for alternative land management treatments such as tree planting to mitigate the problem.

What was the design rationale?

The project included monitoring at the plot (~100m²), field (10,000m²) and catchment (up to 12km²) scale. After a baseline period of soil hydrology and run-off measurements in 4 sets of grassland plots, 2 manipulation treatments were studied: sheep removal and sheep removal plus tree planting.

One plot in each set was left as a control subject to continued sheep grazing. The field scale experiments involved measurements of canopy interception, soil infiltration and soil drainage across a 10m × 100m tree shelter belt located within a 12% sloping, grazed field. At the catchment scale, flow gauges were installed at different locations to try and characterise the flow response to the different land management regimes. The plot and field measurements were then used to build and test physics-based and conceptual models. These models were subsequently applied to the catchment scale to simulate the effects of the different land management interventions.

Measurements were also made of suspended and coarse sediment losses within the catchment and their interactions with land use and stream flows. These data were used to test a sediment yield model and to predict the impact of climate and land management scenarios. A GIS tool, Polyscape, was developed and groundtruthed to assist local farmers and other stakeholders in exploring opportunities for enhancing the provision of ecosystem services through land use management.

Project summary

Area of catchment (km²) or length of river benefitting from the project:	The research catchment covers an area of 12km ² .
Types of measures/interventions used (Working with Natural Processes and traditional):	Sheep removal and sheep removal plus tree planting Beyond the experimental study, measures extended to the wider catchment to include stock de-intensification, targeted tree planting, hedgerow planting and wetland

	restoration.
Numbers of measures/interventions used (Working with Natural Processes and traditional):	This was an experimental study that measured the effect of sheep removal and tree planting on soil run-off at the plot and field scale. There were 4 sets of manipulation plots and one main tree shelterbelt.
Standard of protection for project as a whole:	Not applicable
Estimated number of properties protected:	Not determined – no local properties at risk

How effective has the project been?

The project has been very effective in quantifying the effects of sheep grazing and tree planting on soil hydrology and run-off at the plot, field and small catchment scale. Soil infiltration rates were found to be 67 times higher within woodland plots and shelterbelts planted on improved grassland compared with grazed pasture; this reduced measured surface run-off volumes by an average of 78% compared with the control. These differences were quick to develop becoming apparent within one year of sheep exclusion and tree planting. Removal of grazing pressure reduced run-off volumes by 48%, while the action of initial tree rooting and growth produced the remaining 30% decrease.

Modelling predicted that planting tree strips across 7% of the 12km² headwater catchment could reduce a severe flood (return period of 180 years) by an average of 5% (95% confidence interval of 2–11%). The effect of complete afforestation was much greater, reducing the same flood peak by an average of 36% (95% confidence interval of 13–48%).

Suspended sediment yields during flood events were 5 times higher from areas of heavily grazed, improved pasture compared to more traditional (pre Second World War) grassland management. The difference in bedload yields was even larger, amounting to a 12-fold increase.

Modelling of different land management scenarios under a future climate found sediment yields to be highly variable, depending on the timing and magnitude of individual sediment transport events. Despite the large uncertainty in the predictions, overall, the results suggested that strategic low-footprint woodland planting could be used to desensitise the sediment transfer systems from anticipated changes in climate – though the level of uncertainty made it difficult to justify such planting on the basis of sediment control alone.

5. Project construction

How were individual measures constructed?

The measures tested were relatively simple, involving sheep exclusion from previously grazed plots and sheep exclusion plus broadleaved woodland planting. There were 4 sets of plots sited across a range of representative slopes and aspects. Each set comprised three 12m × 12m plots across a hill slope separated by 10m wide buffers. The 3 treatments of sheep exclusion, sheep exclusion plus tree planting and continued sheep grazing (control) were randomly assigned between the plots.

Hillslope measurements targeted existing areas of grazed pasture and a mixed (native broadleaved and conifer) woodland shelterbelt.

How long were measures designed to last?

The plot-based measures were established for the purpose of the 4-year study, while the existing woodland shelterbelts formed semi-permanent features.

Were there any landowner or legal requirements which needed consideration?

The close involvement and support of the local farmers' co-operative was crucial to the success of the

project. A large proportion of the catchment was farmed by a group of 10 farmers, who were at the forefront of developing a more sustainable approach to upland farming, including by diversifying farming practices as a way of increasing economic returns. This included fencing off small areas of land for tree planting to provide shelter for livestock and woodchips for animal bedding.

Members of the co-operative were keen to host the experimental studies on their land and facilitated regular access for measurements and sampling. They also played an important role in sharing local knowledge to assist with the siting and design of the experimental work, as well as the development of the hydrological modelling and geographical information system (GIS) tools.

6. Funding

Funding summary for Working with Natural Processes (WWNP)/Natural Flood Measures (NFM) measures	
Year project was undertaken/completed:	The project was established in 2005 and completed in 2008.
How was the project funded:	The research project was primarily funded by the EPSRC, but the wider work has received funding from a range of sources including the Pontbren farmers' co-operative, the Lottery Fund and the Welsh Government.
Total cash cost of project (£):	Not available
Overall cost and cost breakdown for WWNP/NFM measures (£):	Not available in terms of establishing experimental plots Costs of planting woodland shelterbelts depend on width, structure and density of trees. The cost for planting a 100m long and 10m wide shelterbelt occupying 0.1ha was estimated at £1,900. Funding support for destocking and tree planting was provided by the Welsh Government through destocking payments, 'top up' payments to the Farm Woodland Premium Scheme and via Woodland Grant Schemes.
WWNP/NFM costs as a % of overall project costs:	Not available
Unit breakdown of costs for WWNP/NFM measures:	Not available – see above for estimated cost of a woodland shelterbelt and country Rural Development Programmes for the level of grant support for woodland creation.
Cost–benefit ratio (and timescale in years over which it has been estimated):	Not available

7. Wider benefits

What wider benefits has the project achieved?

Wider benefits included:

- more sustainable farm management
- farm business diversification
- improved livestock shelter

- more effective integration of agriculture and woodland management
- improved water quality
- creation of wildlife habitats
- future production of timber for on-farm use and added value processing
- enhancement of the landscape

Some of these benefits were captured by the Polyscape GIS tool, which created maps to explore trade-offs and synergies among the ecosystem services associated with the different land management interventions. These maps assisted the farmers' co-operative with identifying which parts of the catchment had the potential to provide most benefits for flood mitigation together with sediment and carbon management, while having the least adverse effects on farm productivity.

How much habitat has been created, improved or restored?

The wider project has led to the creation of nearly 20ha of native woodland and the restoration of a further 10ha, resulting in more than 120,000 trees being planted in the catchment. In addition, nearly 5km of hedgerow have been planted and 12 ponds established covering a total area of 2.3ha.

8. Maintenance, monitoring and adaptive management

Are maintenance activities planned?

The shelterbelts and other areas of woodland planting will require occasional intervention to maintain stockproof fencing and to replace any dead or damaged trees.

Is the project being monitored?

Detailed monitoring was conducted during the 4-year period of the research study but this has now stopped.

Has adaptive management been needed?

The wider project has continued to evolve as the farmers' co-operative seek to improve the sustainability of their farm management. The tree planting measure has been extended to increase its footprint, with benefits for run-off and sediment management at the local scale (see above for area of woodland created).

9. Lessons learnt

What was learnt and how could it be applied elsewhere?

When evaluating the impacts of land use management on flood risk, it is important to consider both site hydrology and sediment interactions. Monitoring at Pontbren revealed that agricultural intensification can lead to large increases in suspended sediment and load that can impact on downstream channel conveyance and flood risk. There remains a need to better integrate models to assess the interactions between land use, flood flows, sediment and channel morphology, which should be a focus for future research.

The Polyscape tool proved to be a very effective way of communicating and engaging with local stakeholders. It greatly facilitated the exchange of ideas about land management options and objectives, as well as helped to visualise different scenarios in a landscape setting.

The project highlighted the value of multi-scale experiments and the collection of field data to quantify hydrological processes and help with the development and testing of hydrological models. An important lesson was that 5 years is not long enough to properly assess the impacts of measures against a

backdrop of climate variability. Longer term catchment studies are necessary to isolate land management effects on higher peak flows, as well as to determine how effects change over time as the measures bed in and develop.

Lastly, woodland grant support needs to be better tailored to farmer needs. Current grant schemes are focused on larger scale woodland creation and thus often unattractive to farmers who seek smaller scale, targeted planting that better integrates with their farming business. In particular, minimum area and size thresholds need to be reduced to permit the planting of shelterbelts and other smaller scale features, such as planting on swales and within riparian buffer areas.

10. Bibliography

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Project background

This case study relates to project SC150005 'Working with Natural Flood Management: Evidence Directory'. It was commissioned by Defra and the Environment Agency's [Joint Flood and Coastal Erosion Risk Management Research and Development Programme](#).