Case study 16

Pontbren catchment land use change study - North Powys

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1. Catchment summary

Study location

Pontbren is located in the headwaters of the Upper Severn, Powys, in mid-Wales.

Catchment summary

The Pontbren Project takes its name from the stream which drains this small headwater catchment of the River Severn. It is set in a rolling upland landscape of predominantly grassland farms about 10 miles to the west of Welshpool, in one of the wettest areas of the UK. Like most of upland Wales, the structure of farming changed during the 19th and 20th centuries. There was a shift from small scale mixed farming to predominantly sheep farming on grassland, with suckler beef and a few small dairy enterprises. The farms became fewer and larger, and the workforce shrunk. This had the effect of simplifying the landscape and providing fewer habitats for wildlife, as field structures were rationalised and farm woodland lay unused.

Study summary

This case study describes the modelling work performed by the Flood Risk Management Research Consortium (FRMRC) between 2004 and 2011 (Imperial College, undated). This work built on the longer term Pontbren project, a ‘grass roots’ farmer led initiative involving 10 hill farms and over 1,000ha of agriculturally improved pasture and woodland (Keeleyside 2013).

When the tree planting began, only 1.5% of the Pontbren land was woodland, mostly neglected riparian woodland and small areas of larch, but 10 years later 120,000 new trees and shrubs had been planted, 16.5 km of hedges had been created or restored, and nearly 5% of the Pontbren land is now woodland. This is a major achievement in just 10 years, with no loss of agricultural productivity. Pontbren is also a focus of Welsh Assembly research on sustainable agriculture and forms part of the Upper Severn, which is a Catchment Hydrology and Sustainable Management (CHASM) element of the UK National Infrastructure for Catchment Hydrology Experiments.

Community involvement

The Pontbren project was initiated by farmers in the early 1990s and, as such, engagement with stakeholders has been implicit in all aspects of the work.

2. Data summary

Datasets and analysis techniques used

The components measured were:

- precipitation
- potential evapotranspiration
- interception
- through-fall
- stem flow
- infiltration
- soil water state (moisture content and pressure potential)
- groundwater elevation
- drain flow
- overland flow
- drainage ditch flow
- stream flow

Data restrictions

This was a large consortium-led investigation with an ethos of data-sharing and which produced 7 years of catchment data (Imperial College, undated).

3. Model summary

Catchment processes investigated

The focus was on the processes and model representation of those processes that lead to run-off generation and peak flows, together with land use modification of those flows. The study was not concerned with the receptor. The aim of the FRMRC work in Pontbren was to collect data to help develop both understanding and models of how water moves through the catchment and how trees and hedgerow impact on this movement. Ultimately the aim was to upscale from the multiscale experiments to develop physically based models to predict catchment scale effects of land use change. The primary concern was run-off, with a separate work package for sediment, but the modelling work also considered effects on other diffuse pollutants and wider ecosystem services as detailed below.

The study showed that strategic tree and hedgerow planting has the potential to reduce peak flows in upper catchments and subsequently reduce the need for downstream flood defences. At both field and small catchment scale, flow peak reduction of around 40% is possible given optimal placement of trees and hedgerows.

The study investigated:

- run-off generation mechanisms and patterns
- sediment sources, pathways and receptors
- mobilisation and inputs of diffuse pollutants from the land

The main concern of the FRMRC project was the detailed processes that lead to run-off generation in these catchments. However, it did consider the wider benefits of modifying land use on sediment and other diffuse pollutants. The broader Pontbren project which covers a much longer period than the FRMRC project also considered ecosystem services (see Polyscape mapping tool in Jackson et al. 2013) and specifically aquatic biodiversity.

Model assumptions

The primary hydrological models were developed specifically from the observations at the Pontbren catchments. There are many assumptions in the modelling process including the upscaling steps taken to produce the catchment scale model as reported by Wheater et al. (2008). In particular, the meta-model approach which saw the Pontbren model expanded to simulate the Hodder and Eden is of interest.

Data and model outputs

Multiscale datasets were collected from plot, field and catchment scale to understand processes which were subsequently built into the modelling approaches. These data also spanned a variety of land uses.

Much of the project data are available under specific licence restrictions (CEH 2012) and as reported in the Pontbren hydrological database report (Reynolds et al. 2012). These data include:

- automatic weather station dataset
- bowl study site run-off and soil water tension data
- groundwater data
- hillslope study site run-off and soil water tension data
- Llyn Hir study site soil water tension data
- land use manipulation plot data

- neutron probe soil moisture data
- rain gauge data
- streamflow data

Models were developed on the Pontbren catchments, but have been extended to the larger Hodder and Eden catchments. Pontbren model developments included:

- detailed hillslope model
- semi-distributed catchment scale hydrological model
- Polyscape mapping tool looking at multiple ecosystem services and trade-off maps

Extended modelling involved the following:

- Physically based models were developed to represent upland peat management associated with grips and grip-blocking and models of afforestation processes. These were used to develop meta-models for application to the Hodder and linked to grip blocking practices.
- New Bayesian methods of regionalisation were developed for prediction of land management impacts for ungauged catchments and tested on the Pontbren catchment, the Plynlimon paired catchments in Wales, and the Hodder.
- A source–pathway–receptor modelling framework was developed by a team Newcastle University which identifies, using information tracking, those areas in a catchment that make a major contribution to the downstream flood hydrograph and hence for which land management interventions would be most effective.
- The research is also linked to the Sediment Toolbox (Wallerstein 2006). The Cellular Automaton Evolutionary Slope and River (CAESAR) model has been used to investigate long-term changes to sediment yields.

Model performance

Failure of the WwNP tree planting measures was not explicitly modelled in this project. McIntyre and Thorne (2013) provide a summary of the use of CAESAR in the Pontbren case study (for the smaller 3.2km2 catchment) to predict how sediment yields change under a variety of future land use and climate change scenarios. The modelling process highlighted the unpredictability of geomorphologically effective events and hence the associated sediment yield. One finding suggested that strategic land use changes, such as woodland planting, can reduce the sensitivity to climate change of small catchments in upland transfer zones.

4. Lesson learnt

Choice of tools

This study is important as it specifically includes some of the processes that may be modified by land use. It used a catchment with very good quality and amounts of data/information which may be an issue when moving to other catchments in terms of consistency of process representation/model evaluation. The meta-model approach is therefore crucial in how the model is applied to other catchments. There may be significant uncertainties where the models are used on a different catchment where the required data are not available and/or where the process representation is inappropriate.

Catchment scale and typology

The observations made for this project were taken at a range of scales to enable upscaling to the catchment scale modelling approach. This took the form of monitoring and experiments from 1.2m × 1.2m plots looking at soil water movement, 12m × 12m plots for replicate land use manipulation experiments and hill slope scale (~0.1km2) up to catchment scale (1–10 km2).

At Pontbren, tree planting resulted in significant flood attenuation at the small scale (area 6km2). However, this has not been matched in terms of performance in the larger scale (261km2) Hodder catchment.

Wider benefits

The study found that tree and hedgerow planting to reduce run-off can also help to mitigate diffuse pollutants such as sediment, phosphorus and pesticides, and can help to change sediment yields. Riparian planting was also shown to stabilise riverbanks and to offer refuge for wildlife. Additional benefits were considered in the ecosystems mapping exercise (using Polyscape – see above) and the Pontbren project itself sits within broader scope of agricultural and woodland management strategies as well as contributions to greenhouse gas strategies, in terms of increasing farmland carbon storage.

Multiple benefits were considered as part of the sediment study and in the development of the Polyscape tool.

Future research needs

The study showed that strategic tree and hedgerow planting has the potential to reduce peak flows in small scale upper catchments and to potentially reduce the need for downstream flood defences. However, attempts to scale these risk management benefits to the larger scale have not yielded similar levels of attenuation. Long-term sediment transport modelling suggested that strategic land use changes, such as woodland planting, can also reduce the sensitivity to climate change of small catchments in upland transfer zones.

The research at Pontbren confirms other investigations showing that, at the small scale, the placement of individual trees and shelter belts will generally have a positive effect on flooding by increasing interception losses, increasing water storage within the soil and increasing the rate of water movement to the subsurface. More work is needed on how flow peaks from upland catchments combine as they move down river.

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Project background

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