Quantifying the hydrological effect of woodland creation in the Camowen and Drumragh catchments, Omagh, Northern Ireland

Flooding in Omagh, Northern Ireland, October 2011 (Michael Cooper, DfI Rivers)

Report prepared for the Forest Service, Department of Agriculture, Environment and Rural Affairs by Forest Research

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The Research Agency of the Forestry Commission

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Executive Summary

A rainfall-runoff model based on the Soil Conservation Service (SCS) Runoff Curve Number method has been applied to the catchments draining to Omagh, Northern Ireland, to assess the potential effect of woodland creation on flood flows. Realistic woodland creation targets that would extend woodland cover to 13.8% of the catchment was predicted to reduce more frequent flood events (1 in 5 year) at Omagh by 13%, reducing to 8% for more extreme storms (1 in 100 year). The existing 6% woodland cover was predicted to be making a relatively small contribution to flood alleviation, decreasing peak flows by between 1% and 3% (for the 100 year and 5 year flood, respectively).

Modelled runoff maps were created for the different land use scenarios to allow identification of areas which generate largest amounts of runoff. Unfortunately, the scope for woodland planting in these target areas was often constrained, requiring investigation of opportunities for improved management or suitability for other natural flood management measures. Where woodland creation is not possible, management of the existing land cover should be considered in order to help reduce runoff. This is particularly relevant on upland heather and heather-grassland for example, since woodland creation opportunities are very small on both land areas. Heather cover itself is effective at reducing runoff, having a high surface area, thus increasing evapotranspiration rates, and its root systems allows increased infiltration, compared to other landuses.

As with all modelling, the results need to be treated with caution since the SCS method remains to be validated for UK conditions. However the potential reductions in flood peak predicted lie within the range of values generated by other modelling studies and therefore add to the growing body of evidence that woodland creation and management may have a significant role to play in flood risk management. The SCS method provides a potentially powerful tool for evaluating the impact of land use change and management on runoff, as well as for identifying areas where such measures could be most effective.

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1. Objective

To model and quantify the hydrological effect of woodland planting opportunities identified in the Camowen and Drumragh catchments in Omagh, Northern Ireland using rainfall-runoff modelling techniques.

2. Background

Land use in Northern Ireland is continuing to change; following a period of land reform at the beginning of the 20th Century tree cover has increased from about 1.5% of land area in 1908 (Kilpatrick, 1987) to 4% in 1981 and 8% by 2016 (Forestry Commission, 2016). Between the end of the Second World War and 1981 the major expansion was in the state sector, when the Forest Service acquired numerous farms in areas of severe agricultural limitation because of water-logging, low soil fertility and high exposure, which were mostly planted with conifers. Government policy towards forestry changed after 1987, when land purchase for state planting reduced and fiscal advantages for private forestry were removed in favour of direct grant. Since then non-state forest has increased by about one thousand hectares each year, part of which was grant aided and part natural, probably as a result of land abandonment.

Today there are 122,000 hectares of woodland in Northern Ireland and Government policy continues to support woodland creation to deliver multiple benefits for society, including for carbon sequestration, biodiversity and landscape improvement. The importance of woodland water services is increasingly being recognised by regulators, including the positive role that forestry can play in managing flood risk and meeting the objectives of the Water Framework Directive (WFD).

Woodland has the ability to 'slow the flow' and thereby reduce downstream flood risk (EA, 2017). Other water benefits include protecting water quality by removing or reducing diffuse pollutant inputs associated with more intensive land uses, and alleviating thermal stress to fish through shade provision (Nisbet et al, 2011). Managing the risk of flooding to householders and businesses is a major challenge facing the UK and one that is expected to increase in the future with climate change. Government policy recognises the importance of working with natural processes and Catchment Flood Management Plans identify broad areas where beneficial changes to land-use and/or land-management (including woodland creation) is recommended to alleviate flood risk over the next 100 years.

In order to realise woodland benefits for water there is a need to engage in landscape scale planning to identify, map and target areas where woodland creation would be most effective. Opportunity mapping was developed to facilitate this task and has been applied to Northern Ireland (Forest Research, 2017).

The Opportunity Mapping project provided GIS spatial datasets and maps displaying opportunities and priorities for woodland creation to help reduce flood risk. Further discussions led to a request to develop a case study to model the hydrological effect of woodland planting opportunities in the Camowen and Drumragh catchments, which drain into and through Omagh in County Tyrone, Northern Ireland.

3. Project Description

The Camowen and Drumragh river catchments are part of the larger Foyle catchment which drains a significant area of Northern Ireland west of Lough Neagh. At the upstream limits of the Foyle, the main channel is known as the Quiggery River, which originates in Fintona where it flows for some 9 km until it reaches the confluence with the Ballynahatty Water. At this point the river becomes known as the Drumragh and flows for a further 7 km to its confluence with the Camowen River in the centre of Omagh, draining some 316 km^2 at this point. The Camowen originates near Six Mile Cross and has a catchment area of 275 km^2 at Omagh.

Omagh has a history of significant flooding with 11 notable events recorded within the last 60 years, causing widespread flooding of the upstream and downstream floodplains, and on some occasions Omagh town centre. The flood of November 2015 was particularly significant, resulting in bridge closures, and much flood damage and disruption for the residents of Omagh.

Omagh benefits from existing defences estimated to provide protection to the 1 in 75 year flood, but falling to 1 in 50 years in some places. Estimated financial damages due to a 1 in 100 year flood are £21.7 million arising from 543 properties flooded (JBA, 2016).

A detailed hydraulic modelling and flood alleviation feasibility study was carried out for Omagh in 2016 by JBA Consulting. This looked at several options, primarily focussing on engineering solutions. The study also considered upstream Natural Flood Management, including woodland creation and management, as potential options to improve flood storage capacity and attenuate flows.

This study builds on the previous work by helping to quantify the potential hydrological effect of woodland creation in the Camowen and Drumragh catchments, based on the opportunities identified in the Opportunity Mapping project carried out by Forest Research for the Northern Ireland Forest Service in 2017. Figure 1 shows the project location, boundaries and topographical features.

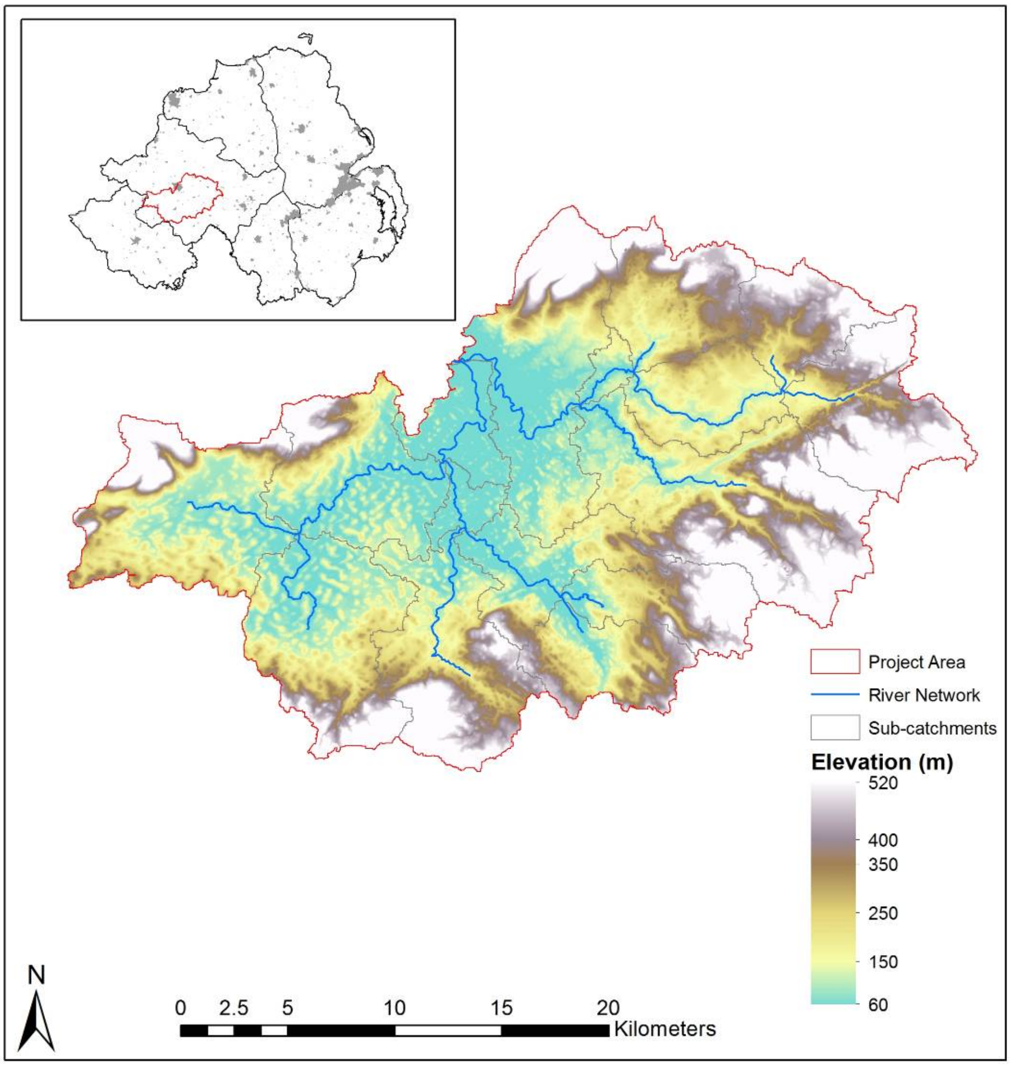


Figure 1 Project location in Northern Ireland, catchment boundaries and main topographical features.

4. Data Sources

Land use/cover data were extracted from the Land Cover Map 2015 (CEH, 2017). This was then merged with soil hydrology data and used to assign appropriate runoff curve numbers based on the Soil Conservation Service Curve Number (SCS CN) method (detailed in Section 5.1 below).

A composite 2 m Digital Elevation Model (DEM) was used to delineate the catchment boundaries and modelling domain, as well as to develop the physical properties of the rainfall-runoff model. Channel cross sections of the Camowen and Drumragh rivers were obtained from the Department for Infrastructure Rivers, Northern Ireland.

Design rainfall events were generated using the Revitalised Flood Estimation Handbook (ReFH2) method using appropriate catchment parameters extracted from the latest Centre for Ecology and Hydrology Flood Estimation Handbook Web Service (https://fehweb.ceh.ac.uk/). Datasets extracted from the Opportunity Mapping for Woodland Creation to Reduce Flood Risk in Northern Ireland project (Forest Research, 2017) were used to create and model different woodland planting scenarios.

5. Modelling Approach

To develop a better understanding of how flood flows are generated across catchments and where natural flood management measures, in particular woodland creation, would be most effective, a hydrological modelling assessment was undertaken using the Soil Conservation Service Runoff Curve Number methodology reported in Urban Hydrology for Small Watersheds TR-55 (USDA, 1986). This method was originally developed to facilitate the hydrological assessment of catchments in North America that had been subject to land use change.

The principles of the approach were adapted in Thomas and Nisbet (2016) to quantify the effects of woodland planting measures in the Pickering Beck catchment in North Yorkshire, UK, as part of the "Slowing the Flow at Pickering" project (Nisbet et al, 2015). The same method has since been applied to the Duchray Water catchment in Scotland as part of the Strathard Ecosystems Services Project.

5.1 SCS Curve Number Method

The SCS Curve Number method (US Soil Conservation Service, 1972) has been widely used internationally for water resources management and planning (Hawkins, 1978; Ragan and Jackson, 1980; Slack and Welch, 1980; Hawkins, 1993; Lewis et al., 2000). Halcrow (2011) applied the SCS CN method within a UK context in order to establish baseline hydrological conditions in the Allan Water catchment in Scotland.

The model estimates runoff as a function of cumulative precipitation, soil cover, land use, and potential maximum retention, using the following equation:

Equation 1

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

Where
Q = runoff
P = rainfall
Ia = the initial abstraction (initial loss)
S = potential maximum retention, a measure of the ability of a catchment to abstract and retain storm precipitation.

Initial abstraction (Ia) comprises all water losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and soil infiltration. Ia is highly variable but generally well correlated with soil and land cover parameters. Through studies of many small agricultural watersheds in North America, Ia was found to be approximated by the following empirical equation:

Equation 2

$$Ia = 0.2S$$

S is related to the soil and land cover conditions of the catchment through the CN. CN has a range of 0 to 100, and S is related to CN by:

Equation 3

$$S = \left(\frac{25400 - 254CN}{CN} \right)$$ (SI units)

CN values range from 100 (open water) to approximately 30 for permeable soils with high infiltration rates.

The CN for a catchment can be estimated as a function of soil type and land cover using tables published by the Soil Conservation Service in the United States Department of Agriculture, Urban Hydrology for Small Watersheds TR 55 (1986) report.

For a catchment that consists of several soil types and land uses, a composite CN is calculated as:

Equation 4

$$CN_{composite} = \frac{\sum AiCNi}{\sum Ai}$$

In which CN composite = the composite CN used for runoff volume computations; i = an index of catchment subdivisions of uniform land use and soil type; CNi = the CN for subdivision i; and Ai = the drainage area of subdivision i.

The method classifies soils into one of four hydrologic soil groups (HSGs; A (lowest runoff potential), B, C and D (highest runoff potential)) based on their hydrological characteristics. This includes the infiltration rate (the rate at which water enters the soil at the surface) and the transmission rate (the rate at which water moves within/through the soil). Approximate numerical ranges for both rates were first published by Musgrave (1955). The standard percentage runoff (SPR) figures from soil hydrology data for Northern Ireland were used to assign the HSG for the soil types in the Camowen and Drumragh catchments (Table 1).

Standard Percentage Runoff	HSG
<10%	A
10-20%	B
20-40%	C
>40%	D

Table 1 Hydrologic Soil Group and associated soil Standard Percentage Runoff (SPR)

Curve numbers were assigned to different combinations of land use and soil classes using the SCS land use descriptions and cross referencing these to UK land cover types (Land Cover Map 2015) present in the catchment. Different values are available for each land cover type depending on general condition, ranging from poor, fair to good. Numbers were selected based on expert judgement informed by local knowledge. This allowed a SCS Curve Number grid to be generated for the catchment and for weighted average curve numbers to be determined for each sub-catchment represented in the model.

LCM2015 Description	SCS Land Use Description	HSG A	HSG B	HSG C	HSG D
Woodland	Fair, woods	36	60	73	79
Arable & Horticulture	Good, fallow ground	74	83	88	90
Improved grassland	Poor, Pasture	68	79	86	89
Neutral grassland	Poor, Pasture	68	79	86	89
Acid grassland	Poor, Pasture	68	79	86	89
Heather	Fair, Brush	35	56	70	77
Heather Grassland	Good, Brush	48	67	77	83
Bog		85	85	85	85
Inland water	Open Water	100	100	100	100
Exposed rock	Fallow, bare soil	89	92	92	95
Suburban	Residential	61	75	83	87
Urban	Urban	89	92	94	95

Table 2 Curve numbers assigned to land use and Hydrologic Soil Groups using the SCS land use descriptions and cross referencing these to UK land cover types present in the catchment. The CN values given for floodplain storage areas are also shown.

5.1.1 Worked example

A worked example is described below to demonstrate the application of the SCS CN method, which estimates the runoff (Q) generated from an area of woodland on soil with a 40% Standard Percentage Runoff (SPR) in response to a rainfall event (P) of 40 mm.

First, a Curve Number (CN) is assigned to the area of woodland. Soils with a SPR of 40% or more fall within Hydrologic Soil Group (HSG) D and based on Table 2, a CN of 79 can be applied.

Next, the term S is calculated to estimate the potential maximum retention of that area of land. Using equation 3, S = 67.5 mm. The term Ia is then derived to estimate the amount of water that will be retained in the area of woodland following rainfall due to processes such as interception loss, evaporation, soil infiltration and water stored in surface depressions. Based on equation 2, Ia = 13.5 mm.

Using these figures and equation 1, the resulting runoff from the area of woodland following the 40 mm rainfall event or Q = 7.5 mm.

For comparison, if the same area of woodland was replaced with improved grassland (CN = 89), the resultant Q for the same rainfall depth (40 mm) would be 17.5 mm. Similarly, if an area of woodland occurred over a soil with a SPR of 15% (i.e. HSG B), the CN would be 60 and the resultant Q from the same rainfall would be 0.2 mm. This demonstrates how runoff is thought to vary with changing land use and soil type.

5.2 Hydrologic Engineering Centre – Hydrologic Modelling System (HEC-HMS) Rainfall-Runoff Model

The next step was to develop a rainfall–runoff model for the catchment using the Hydrologic Modelling System (HEC-HMS) programme (USACE, 2000), a numerical model that can simulate catchment and channel behaviour and thereby predict river flows and response times. It was applied in this study to run the SCS CN method to predict the potential impact of land use change on the hydrology of the catchment.

Key catchment characteristics were obtained from a digital elevation model, including slope, river channel network and catchment boundaries. The catchment was sub-divided into 17 sub-catchments and model outflow defined for a short distance below the confluence of the Camowen and Drumragh catchments in Omagh. Figure 2 shows a diagram of the basic structure of the model, including sub-catchment boundaries, main river network, inflows from each sub-catchment and river junctions. Cross section data and roughness values were obtained from the existing hydraulic model for Omagh to define the Drumragh and Camowen channel for rainfall-runoff routing purposes.

The SCS Curve Number method (explained in 5.1) was applied to define catchment losses based on the composite Curve Number values for each sub-catchment generated from the soil and land use data for each modelled scenario. Appropriate SCS unit hydrographs for each sub-catchment defined how they responded to rainfall, including the general shape of the hydrograph and response time (lag) from rainfall to runoff. The Muskingum-Cunge method (USACE, 2000) allowed the runoff generated from each sub-catchment to be routed through the river network to the model outflow. This takes into account the channel shape, gradient, length, and roughness values (Manning's n values for channels) for each river segment defined in the model.

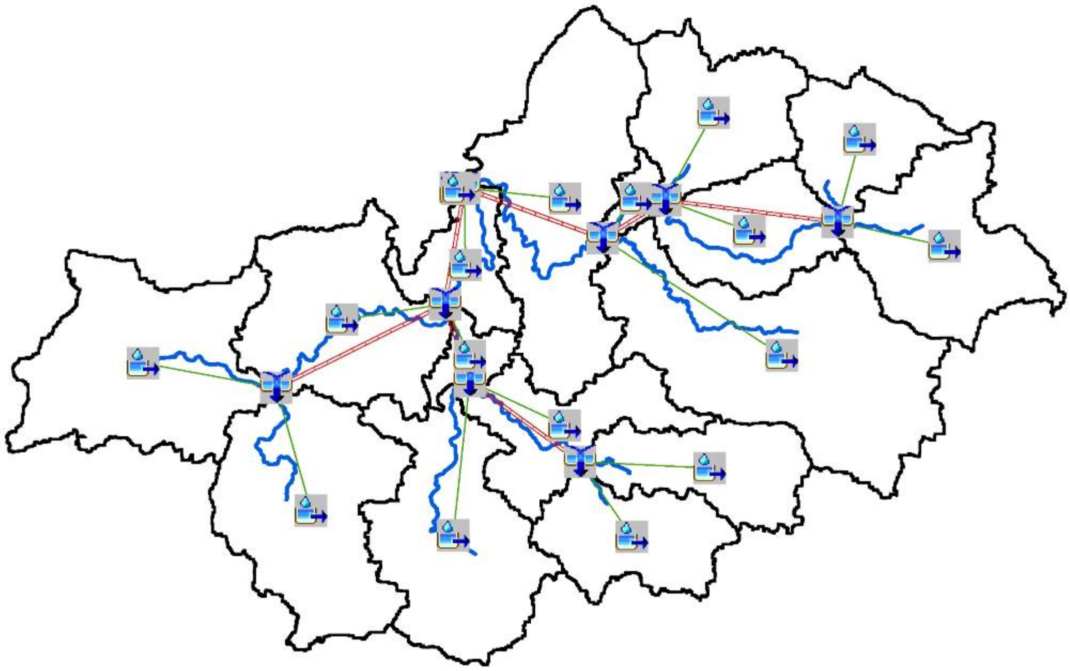
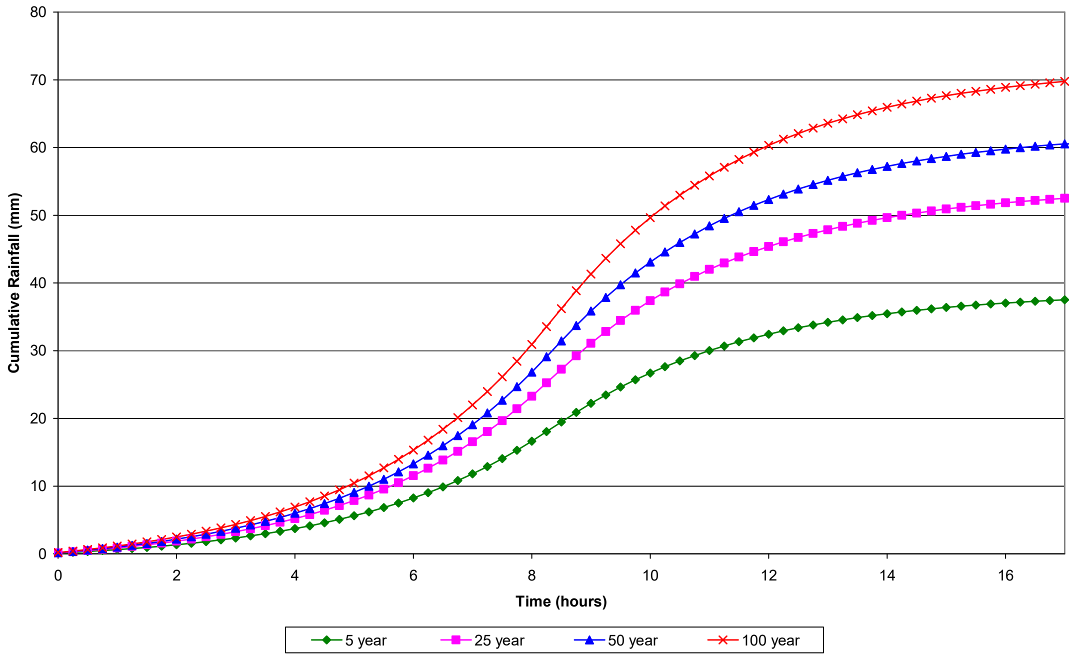


Figure 2 Diagrammatic representation of the rainfall-runoff model for the Camowen and Drumragh catchments draining to Omagh

6. Rainfall Modelling

Rainfall-runoff modelling requires rainfall as the main input in order to generate runoff and resultant flow. Real gauged rainfall events can be used as well as modelled design events. Design rainfall events were generated using the Flood Estimation Handbook (FEH) 2013 rainfall model in the Revitalised Flood Hydrograph 2 modelling software. This allows a rainfall event of a particular duration corresponding to a given return period to be generated. It was deemed appropriate to use a relatively long storm duration of 17 hours to represent the typical prolonged periods of rainfall that generate floods in the region, rather than use a shorter, more intense storm. Figure 3 shows the rainfall depths and distribution for each return period applied in the model.



Return Period	Rainfall (mm)
5	37.1
25	52.5
50	60.5
100	69.8

Figure 3 Revitalised Flood Hydrograph 2 (ReFH2) modelled "design" rainfall events for the Omagh rainfall-runoff model

7. Model Calibration

Application of the SCS Runoff Curve Number method and HEC-HMS model allowed a set of predicted flood growth curves to be generated based on the existing mix of soil types and land cover in the catchment. The results are compared with the growth curves from a previous detailed hydrology study of the Foyle rivers system from 2013, which includes the Camowen and Drumragh catchments, as well as hydrology data from a more recent flood alleviation feasibility study for Omagh (JBA Consulting, 2016).

The Foyle study considered the FEH statistical method to be the most appropriate for deriving peak flow estimates. This generates unique catchment descriptors for the study area and pools together data from a group of hydrologically similar gauged catchments to produce flood growth curves for the Camowen and Drumragh catchments. A "dummy" gauge was created to represent the combined peak flow estimate for both catchments immediately downstream of their confluence at Omagh. It was assumed that all water flowing past the two gauging stations upstream of the confluence reaches the downstream channel at the "dummy" gauge. Consequently, this point was used as the model outflow for the study.

In order for the peak flow estimates from the FEH statistical method to be applied to the rainfall-runoff model for use as calibration events, a full hydrograph was required. Hydrographs were generated for each peak flow using the ReFH2 method and appropriate catchment descriptors to generate the hydrograph shape. The hydrographs were then scaled to each peak flow.

The peak flow estimates and hydrographs obtained from the Foyle study and the peak flow values from the JBA Consulting (2016) report were used to assess the performance of this study's rainfall-runoff model. Model calibration usually relies on using a single known or observed hydrograph. In this case the 1 in 25 year peak flow and hydrograph from the Foyle study were selected as the "calibration" event, although checks were also made to assess how the model performed across a range of rainfall return periods.

The HEC-HMS model allows a number of parameters to be adjusted for the model calibration. In this case the general shape of the hydrograph from each sub-catchment, as well as the lag time parameter (i.e. how quickly the modelled sub-catchment responds to rainfall and for the resulting runoff to reach the sub-catchment outflow) were adjusted so that the time to peak of the hydrograph at the model outflow matched that of the calibration hydrograph.

The results of the calibration exercise can be seen in Figure 4, which shows the model to be performing well, with the peak flow within 0.6% of the calibration event and an identical Time to Peak (Tp) of 7 hours. However, the model significantly under-predicts the response of the rising and falling limbs, which will result in differences in hydrograph volume. This is probably due to the limitations of the modelling method, which only considers surface runoff with minimal attention given to groundwater contributions, other than initial baseflow estimates at the onset of the modelled rainfall-runoff event.

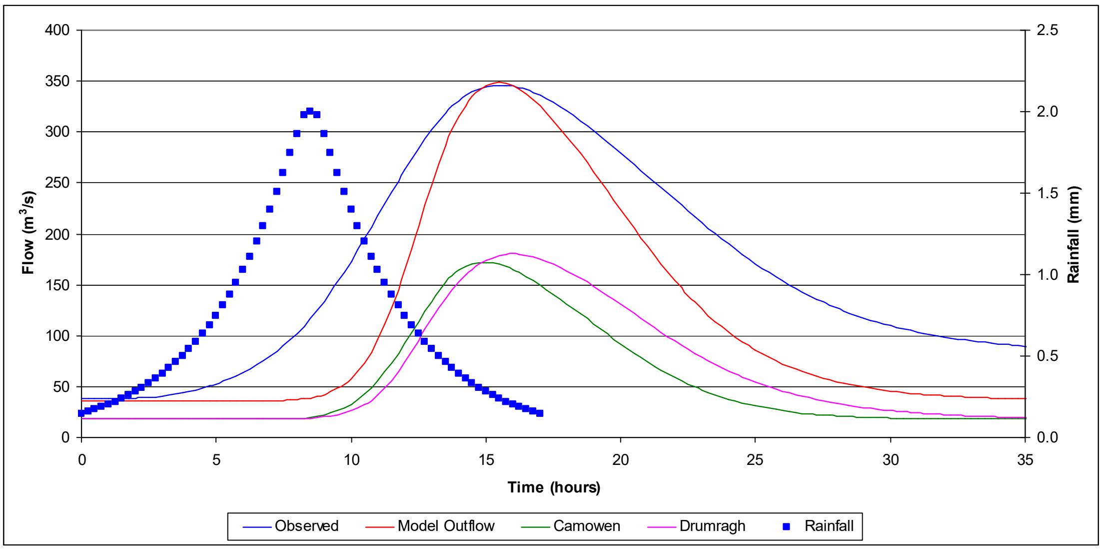


Figure 4 Calibrated hydrographs for the 1 in 25 year rainfall event

Figure 5 shows how the model performs across a range of return periods compared to the peak flows generated using the FEH Statistical method in the Foyle andJBA Consulting studies. This shows

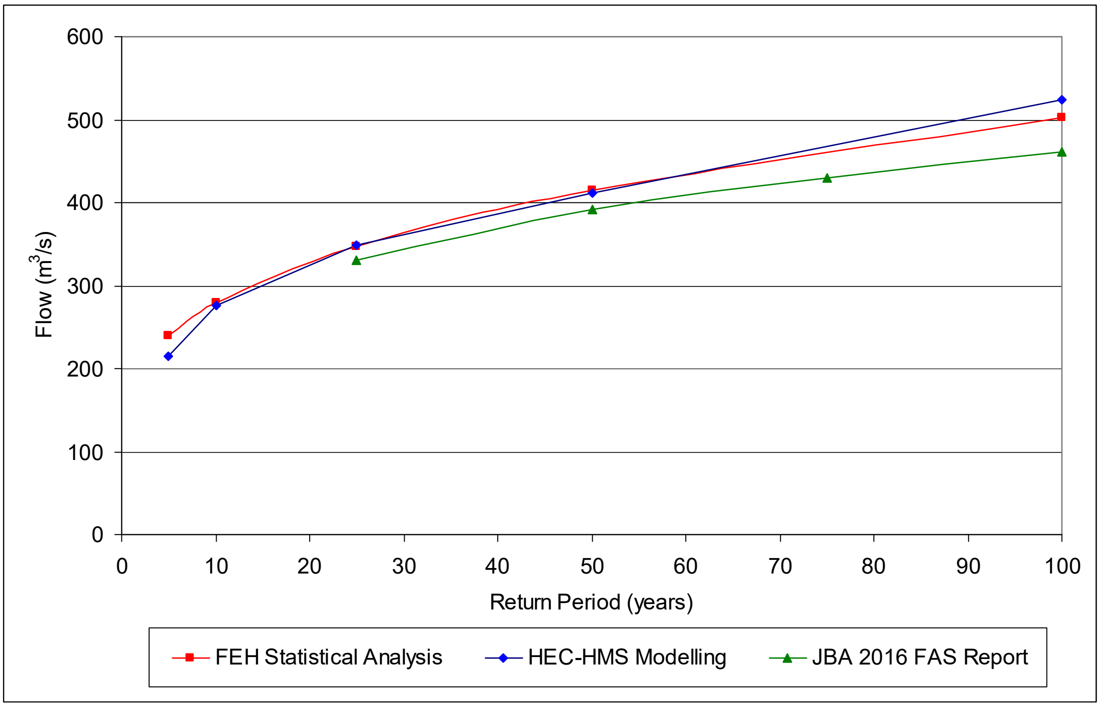


Figure 5 Comparison of the HEC-HMS modelled peak flows for the baseline scenario versus other modelling methods

a reasonable fit in the middle of the flow range, within 1.2, 0.4 and 0.5% of the 1 in 10, 25 and 50 year return periods respectively, but under-predicts more frequent flood events by 11% for the 1 in 5 year and over-predicts by 3.8% for the 1 in 100 year flood peak.

These discrepancies could be due to the following factors:

- The CN values are derived from US studies and catchment conditions. While an attempt was made to translate values to UK soil and land cover types, as well as general management condition, this is based on expert judgement rather than calibrated values.
- The use of the soil hydrology data set and mapped Soil Associations to assign catchment soils to HSGs within the SCS model introduces significant uncertainties linked to the scale of mapping and soil variability. This could result in marked local discontinuities in runoff conditions that are not reflected by the model.

8. Modelling Scenarios

The calibrated model was run with a range of rainfall events of increasing return periods to first establish baseline conditions for the existing land use and then to simulate the potential effect of woodland creation, based on the areas identified by the opportunity maps.

Baseline Land Cover Scenario

This scenario represents existing land use using the 2015 Land Cover Map. Improved grassland is the dominant land use type, covering almost 71% of the catchment, followed by bog at just under 13% of the catchment. Existing woodland cover is relatively small (6%) and scattered across the catchment, with few large blocks of woodland. Figure 6 provides a breakdown of the land cover types by area.

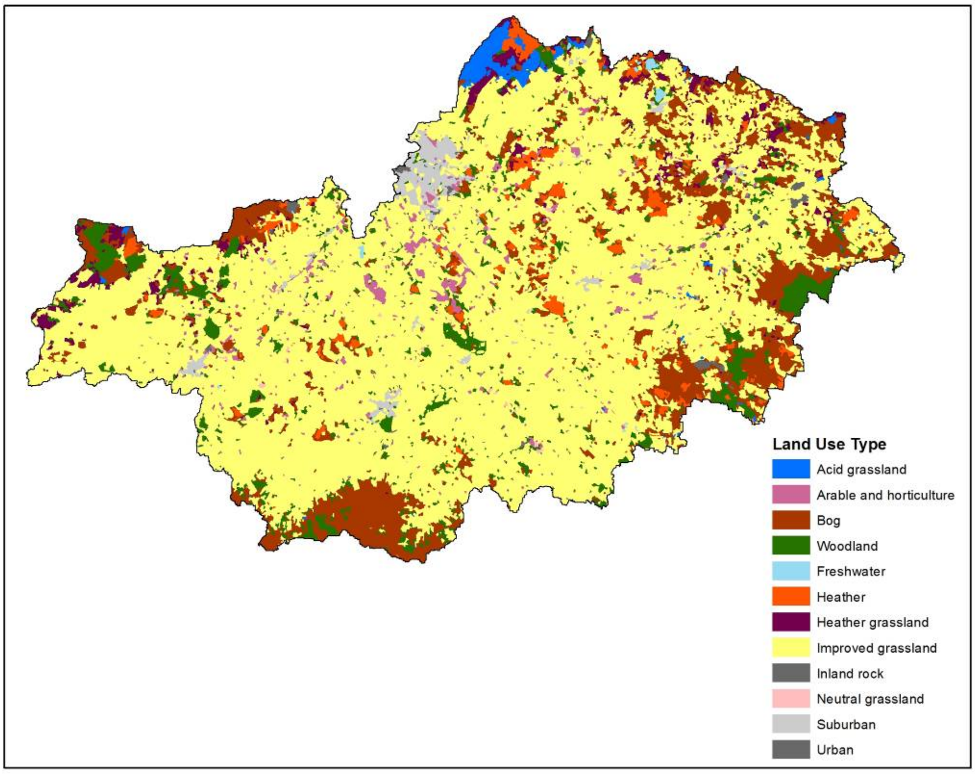


Figure 6 Existing land use in the catchment (LCM 2015 data)

Scenario 1

Scenario 1 assumes that all of the area identified by the opportunity mapping study (Forest Research, 2017) as a priority for woodland creation to reduce flood risk is actually planted. This would amount to an additional 9,000 ha of woodland and increase the proportion of woodland cover to just under 21% of the catchment. Figure 7 shows the distribution of this potential woodland creation in the catchment.

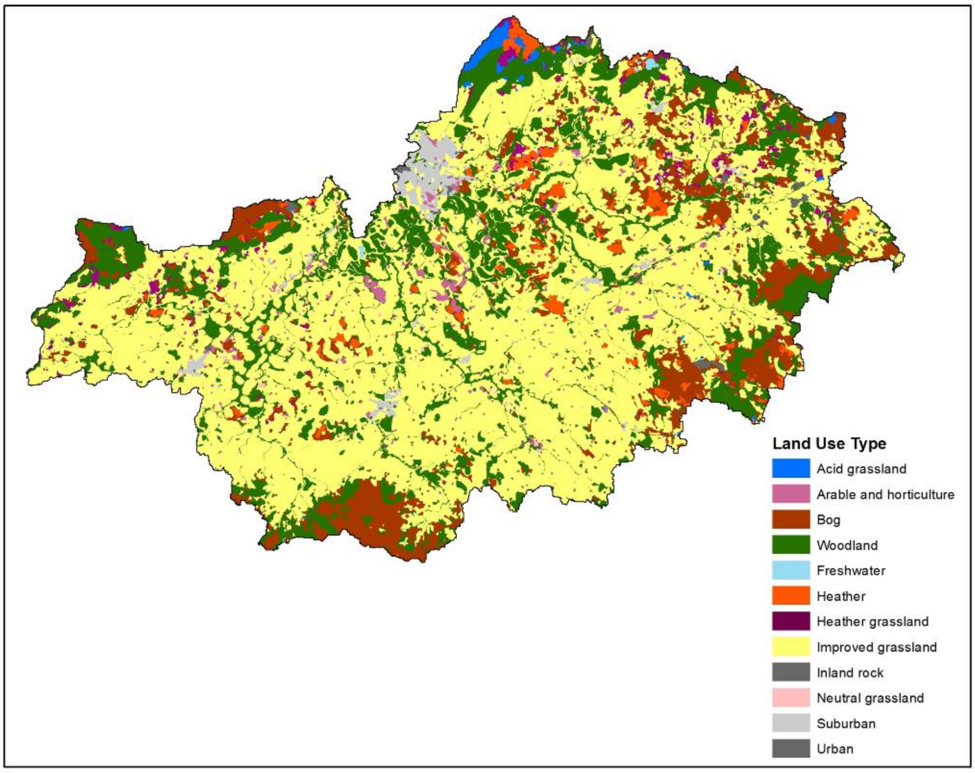


Figure 7 Landuse cover under Scenario 1

Scenario 2

The 2nd scenario (Figure 8) builds on Scenario 1 by extending woodland creation to include all potential areas for planting to reduce flood risk that were identified by the opportunity mapping study (Forest Research, 2017). This included soils with standard percentage runoff (SPR) values of <40%, the upper threshold selected for classifying the priority area. The result would be a massive expansion in woodland cover to almost 62% of the catchment (36,818 ha). This degree of land use change is highly unlikely in reality but has been included as a theoretical scenario for modelling purposes.

Scenario 3

A third scenario (Figure 9) was generated to create a more realistic woodland planting scenario in line with the Northern Ireland Government Forestry Strategy's long term aim of achieving 12% woodland cover by the middle of the 21st Century.

The revised potential planting area was achieved by restricting the priority area identified in the first scenario to Agricultural Land Classes (ALC) 4 and 5 (Cruickshank, 1997). ALC 4 is defined as poor quality agricultural land with very severe limitations, which restrict the range of crops and/or level of yield. These areas are mainly suited to grass with occasional arable crops, e.g. cereals and forage crops, with variable yields. Grade 5 land has severe limitations that restrict use to permanent pasture or rough grazing.

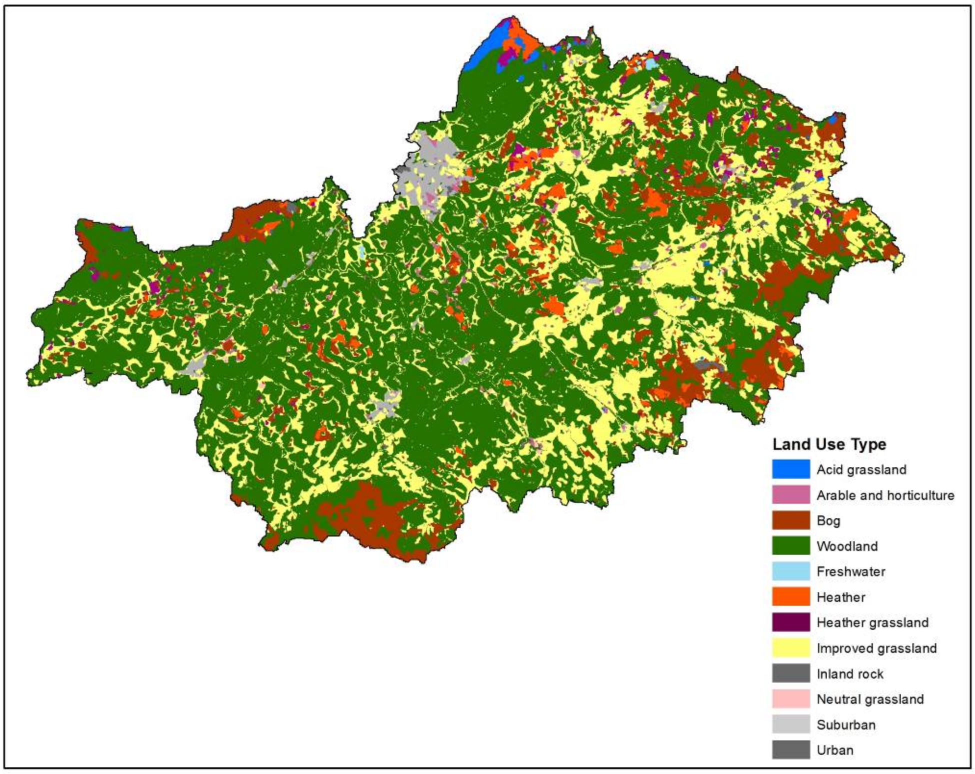


Figure 8 Landuse cover under Scenario 2

This process created a potential woodland planting area of 13.8%, just over the 12% target of the NI Government Forestry Strategy.

Scenario 4

The final scenario was created to explore the impact of removing all of the existing woodland and replacing this with improved grassland. This allows an estimate to be made of the existing contribution of woodland to flood alleviation.

Figure 10 shows the proportion of the individual land use types for each of the modelled scenarios.

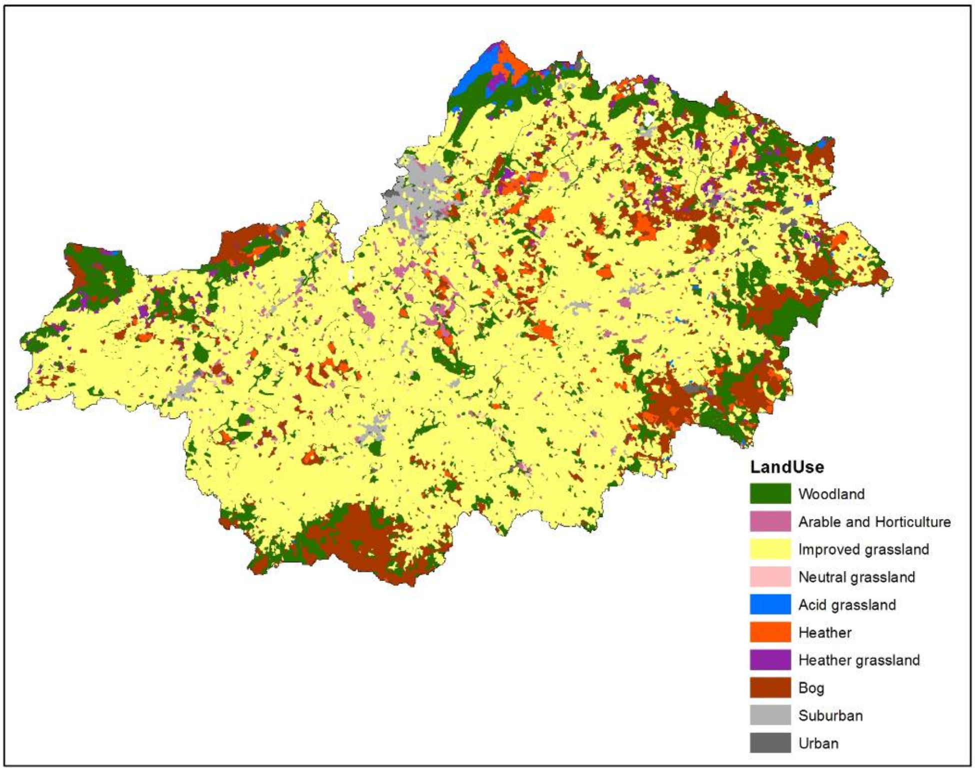


Figure 9 Land use cover under Scenario 3

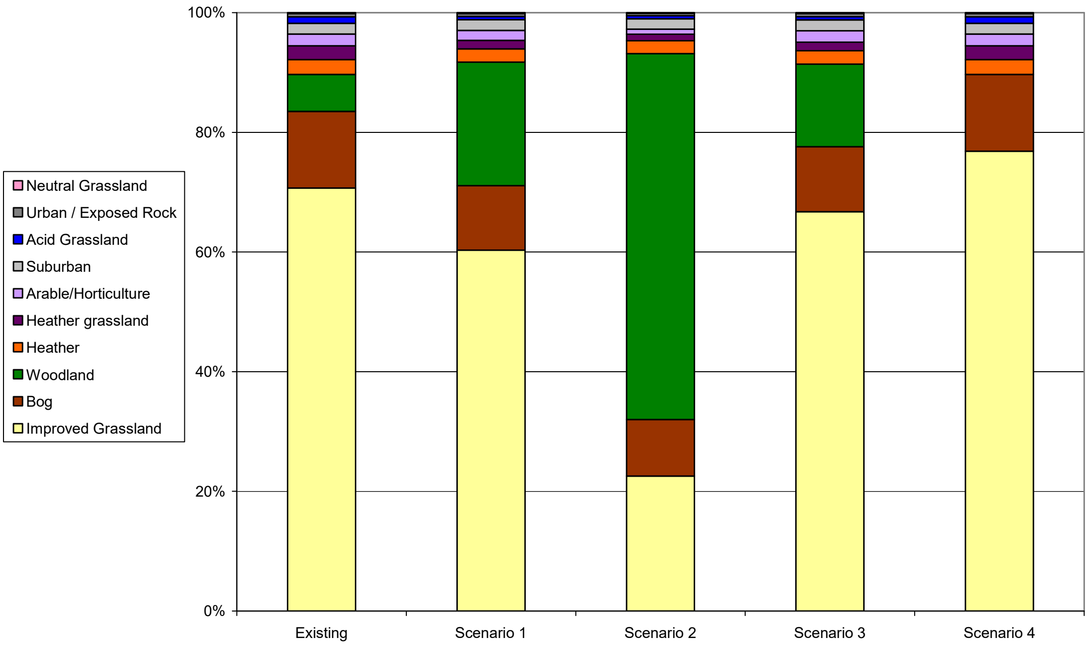


Figure 10 Comparison of land use proportions for each modelling scenario

9. Rainfall-runoff Modelling Results

Figure 11 shows the flood peak growth curve for the modelled baseline conditions of the catchment versus the effect of the woodland planting or removal in each of the four modelling scenarios.

Some 53% of the total flow at Omagh is generated from the Drumragh catchment, and 47% from the Camowen. This proportion is fairly consistent across all the modelled return periods. The model suggests that the Drumragh catchment peaks about 1.25 hours after the Camowen during more frequent events, with the delay narrowing to just 0.5 hours for the 100 year flood.

An increase of woodland cover to 21% of the catchment in Scenario 1 could reduce flows by as much as 18% at Omagh for more frequent floods (5 yr return period), declining to 11% for more extreme events (100 year return period). The greatest reduction is predicted for the Camowen catchment, amounting to a 20% decrease for the 5 year flood. Almost 57% of the woodland planting opportunities identified in Scenario 1 lie within the Camowen catchment, which would account for the higher contribution to flood peak reduction at Omagh.

The flood peak at Omagh is delayed by as much as 1.5 hours by the woodland creation, with further de-synchronisation of peaks occurring between the two catchments, the greatest effect being in the Drumragh catchment (despite there being less woodland expansion), with as much as a 1.75 hour delay.

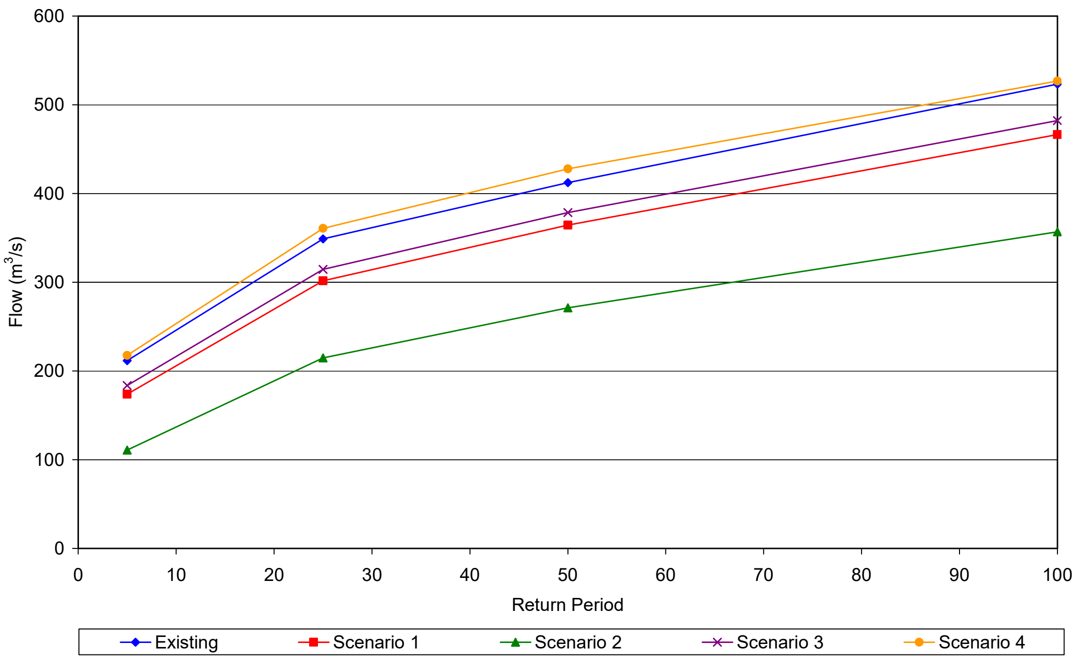


Figure 11 Peak flows for the modelled baseline versus woodland planting scenarios

	Peak flow change			
Return Period	5	25	50	100
Camowen	-20%	-15%	-15%	-11%
Drumragh	-15%	-11%	-10%	-10%
Outlet	-18%	-14%	-12%	-11%

Table 3 Percentage change in peak flow for Scenario 1 woodland planting

Table 3 summarises the effects of woodland planting by flood return period for Scenario 1. As expected, the much larger increase in woodland cover to 62% of the catchment in Scenario 2 generated the largest decrease in flood peaks, with as much as a 48% reduction at Omagh for the 1 in 5 year flood, decreasing to a 32% reduction for the 1 in 100 year flood. The delay in the flood peak was also marked and ranged between 1.75 and 2.75 hours for the 1 in 100 and 1 in 5 year flood, respectively. However, this level of land use change is unrealistic in terms of land use balance and therefore unlikely to be achievable in practice.

The more realistic woodland expansion to 13.8% total cover in Scenario 3 could potentially reduce peak flows by as much as 13% for the 1 in 5 year flood, decreasing to an 8% reduction for the 1 in 100 year flood. This equates to an average reduction in peak flow across the catchment of between 5.9 and 8.6 l/s/ha of woodland planted.

The greatest reduction is seen in the Camowen with as much as a 15% decrease for more frequent flood events. An additional de-synchronisation of the peaks is also apparent, with an overall delay of up to 1.25 hours at Omagh.

	Peak flow change			
Return Period	5	25	50	100
Camowen	-15%	-11%	-11%	-8%
Drumragh	-11%	-8%	-7%	-7%
Outlet	-13%	-10%	-8%	-8%

Table 4 Percentage change in peak flow for Scenario 3 woodland planting

Figure 12 compares the effects of the three woodland creation scenarios versus the existing baseline condition on the 1 in 100 year modelled hydrograph at Omagh. This demonstrates both the greater reduction and delay in the flood peak resulting from expanding woodland cover in the catchment.

Further analysis was carried out to assess the relative contribution of woodland creation within the individual sub-catchments. Table 5 summarises the effects of woodland planting under Scenario 3 on the 1 in

50 year flood, as well expressed on a per hectare basis for each sub-catchment.

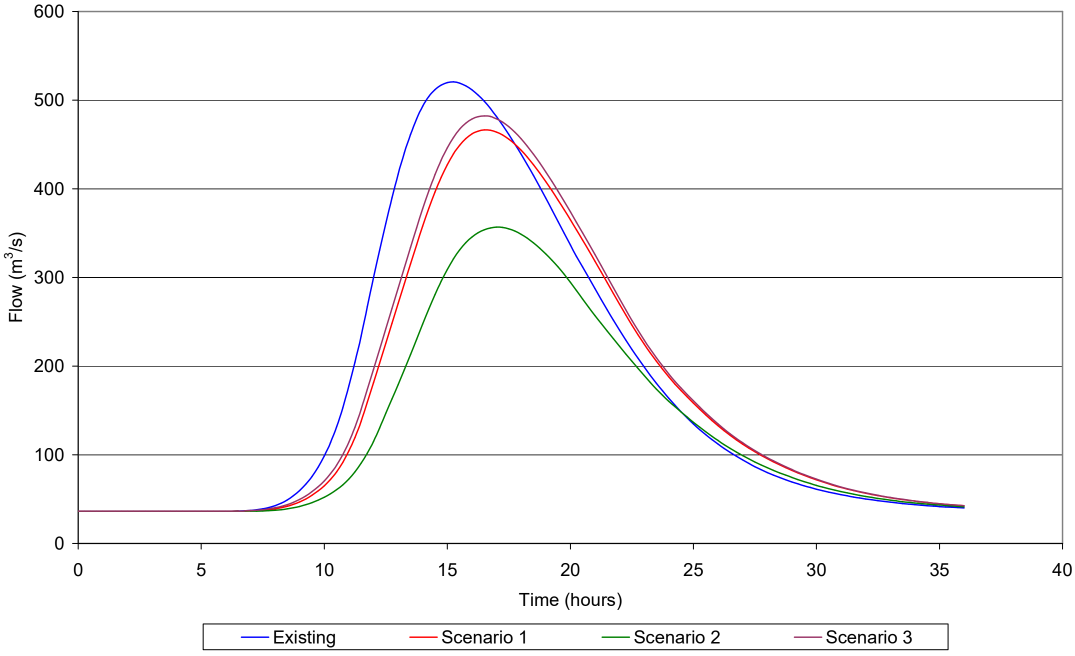


Figure 12 Modelled 1 in 100 year hydrograph at Omagh for the existing land cover and three woodland planting scenarios.

As expected there is a strong relationship between peak flow reduction and increasing woodland cover across all return periods, although the relationship weakens as the magnitude of flow increases (Figure 13). This implies that the effectiveness of woodland in reducing runoff weakens with increasing storm rarity.

Catchment	Sub-catchment ID	Total area km^2	Additional woodland planting ha	% new woodland cover	Peak flow Existing m^3/s	Peak flow Scenario 3 m^3/s	% change	Reduction l/s/ha
Drumragh	W340	27.6	69.0	2.5	26.1	25.6	-2%	7.2
	W300	51.9	216.1	4.2	30.4	29.9	-2%	2.3
	W330	27.3	107.7	4.0	19.2	18.8	-2%	3.7
	W320	28.7	42.6	1.5	23.4	23.0	-2%	9.4
	W290	59.1	630.2	10.7	39.7	38.3	-4%	2.2
	W310	55.9	362.4	6.5	42.0	40.3	-4%	4.7
	W280	46.7	275.9	5.9	30.8	29.8	-3%	3.6
	W270	7.3	11.4	1.6	7.5	7.3	-3%	17.5
	W260	16.7	8.8	0.5	11.9	11.8	-1%	11.3
Camowen	W190	23.4	555.0	23.7	22.8	20.4	-11%	4.3
	W180	33.1	453.4	13.7	23.5	21.8	-7%	3.7
	W230	27.5	95.2	3.5	22.8	22.5	-1%	3.2
	W250	81.7	634.7	7.8	60.5	58.4	-3%	3.3
	W240	41.8	503.2	12.0	29.0	27.3	-6%	3.4
	W220	4.9	36.4	7.5	6.1	5.9	-3%	5.5
	W200	64.0	764.6	11.9	42.3	39.9	-6%	12.9

Table 5 Summary of the effect of woodland planting (Scenario 3) on sub-catchment peak flows for the 1 in 50 year flood.

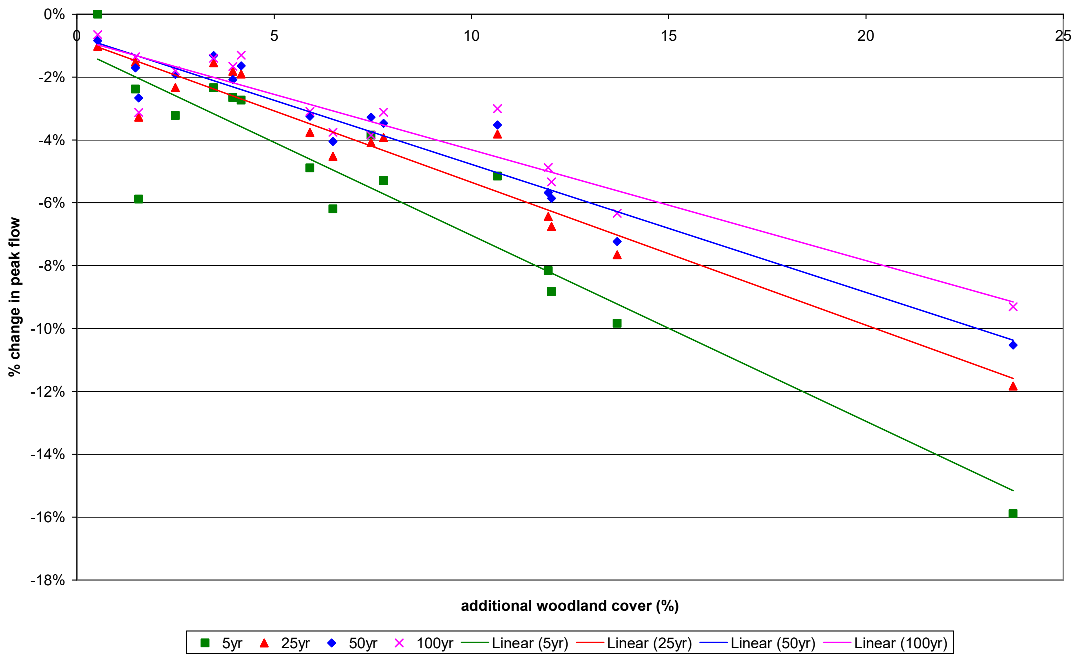


Figure 13 Relationship between flood peak reduction and increasing woodland cover

Complete removal of the existing woodland in Scenario 4 is predicted to have a relatively small impact on flood peaks, with an increase of 3% for more frequent 5 year floods decreasing to a 1% increase in the 1 in 100 year flood. This reflects the relatively small proportion of woodland present in the catchment.

The SCS CN method can also be used to identify areas within catchments that generate the greatest amounts of runoff. This could provide a very useful tool for targeting natural flood management measures, such as woodland planting, to where they would be most effective, as well as allow different options to be quantified and compared.

For example, Figure 14 shows the spatial distribution of runoff within the catchment for the 1 in 100 year rainfall event, based on the modelled runoff from each grid cell. The greatest runoff (>40 mm) for this 69.8 mm storm event was generated from areas of wet soils covered by acid grassland and heather in the north of the catchment, as well as from pockets of improved grassland at the lower end of the catchment upstream of Omagh.

Figure 15 demonstrates the effect of woodland creation in Scenario 3 on catchment runoff, resulting in up to a 20 mm reduction in some areas. Of interest is the fact that environmental constraints often limit the scope for planting woodland in such locations, as in the lower portion of the catchment, upstream of Omagh. This highlights the need to investigate alternative natural flood management measures for reducing runoff where woodland creation is not suitable.

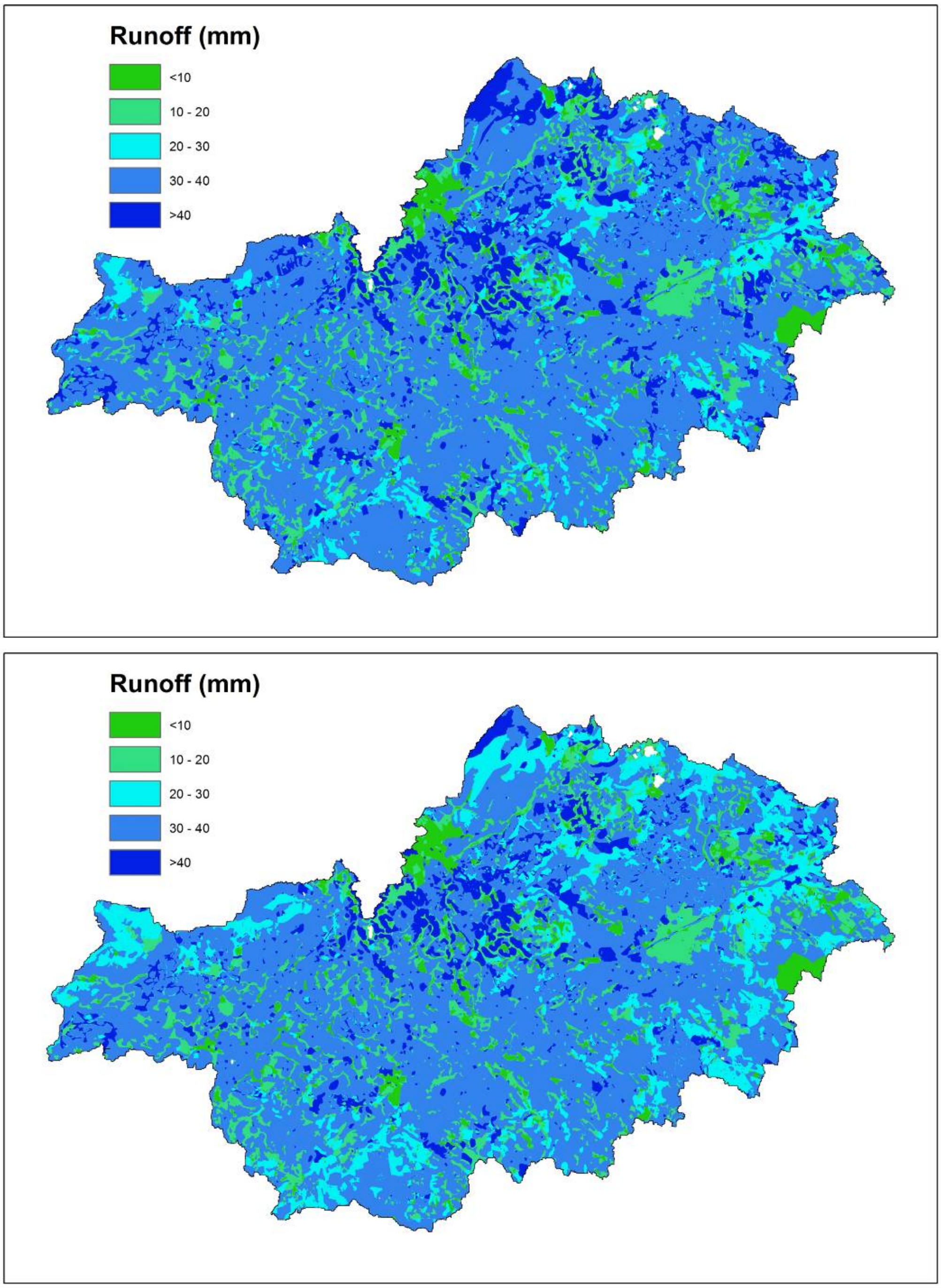


Figure 14 Spatial variation in modelled runoff for a 1 in 100 year rainfall event for the existing baseline land use scenario (top) and woodland creation in Scenario 3

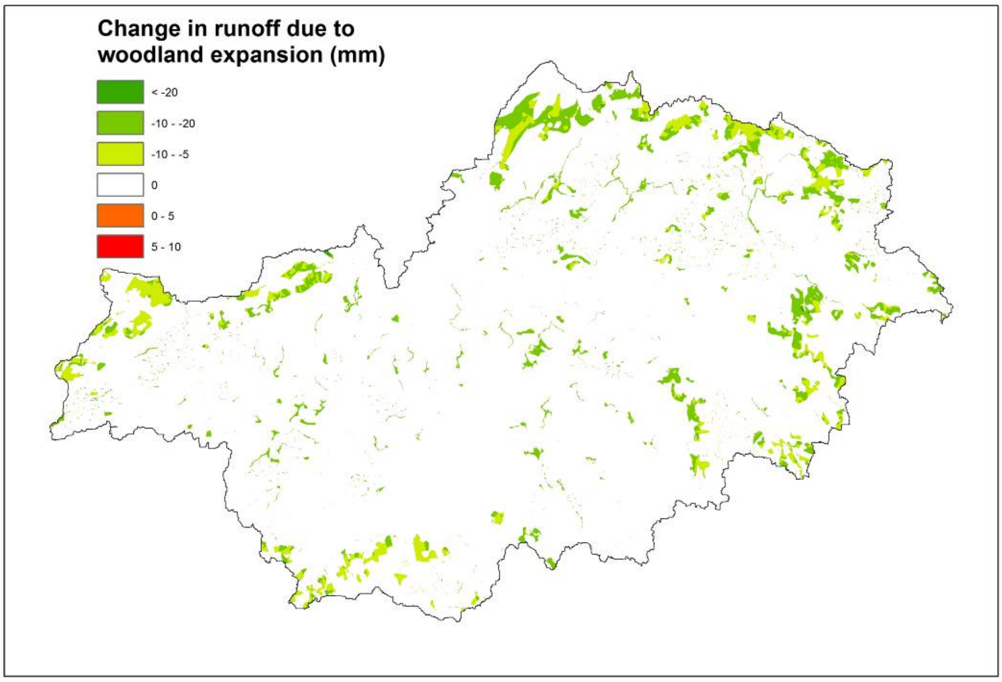


Figure 15 Predicted change in runoff from woodland expansion identified in Scenario 3.

10. Conclusions

A rainfall-runoff model based on the Soil Conservation Service (SCS) Runoff Curve Number method has been applied to the catchments draining to Omagh, Northern Ireland, to assess the potential effect of woodland creation on flood flows. Realistic woodland creation targets that would extend woodland cover to 13.8% of the catchment was predicted to reduce more frequent flood events (1 in 5 year) at Omagh by 13%, reducing to 8% for more extreme storms (1 in 100 year). The existing 6% woodland cover was predicted to be making a relatively small contribution to flood alleviation, decreasing peak flows by between 1% and 3% (for the 100 year and 5 year flood, respectively).

Modelled runoff maps were created for the different land use scenarios to allow identification of areas which generate largest amounts of runoff. Unfortunately, the scope for woodland planting in these target areas was often constrained, requiring investigation of opportunities for improved management or suitability for other natural flood management measures. Where woodland creation is not possible, management of the existing land cover should be considered in order to help reduce runoff. This is particularly relevant on upland heather and heather-grassland for example, since woodland creation opportunities are very small on both land areas. Heather cover itself is effective at reducing runoff, having a high surface area, thus increasing evapotranspiration rates, and its root systems allows increased infiltration, compared to other landuses.

As with all modelling, the results need to be treated with caution since the SCS method remains to be validated for UK conditions. However the potential reductions in flood peak predicted lie within the range of values generated by other modelling studies and therefore add to the growing body of evidence that woodland creation and management may have a significant role to play in flood risk management. The SCS method provides a potentially powerful tool for evaluating the impact of land use change and management on runoff, as well as for identifying areas where such measures could be most effective.

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