Case study 8

Woodlands for Water opportunity mapping - national

Tom Nisbet and Samantha Broadmeadow (Forest Research)

1. Catchment summary

Study location

Opportunity maps have been developed by Forest Research at several scales:

- national – England
- regional – Lake District, Midlands, Yorkshire and North East
- catchment scale:
- England – Rivers Derwent, Avon, Frome and Piddle
- Scotland – Rivers Clyde, Tay plus 13 other priority catchments
- Wales – Rivers Rhondda, Tawe and Dyfi

A field scale opportunity map was also generated for a theoretical 'farm estate'.

Study summary

Woodlands for Water, a joint initiative by the Forestry Commission and the Environment Agency, aims to promote the creation of new woodland where it can best help to reduce downstream flood risk and rural diffuse pollution. Opportunity mapping is used to identify priority locations for planting and grant support. It is underpinned by the review of Nisbet et al. (2011) which describes how woodland can exert a significant impact on a range of catchment processes. As well as contributing to EU Water Framework Directive and flood and coastal erosion risk management (FCERM) targets, woodland creation can also deliver a range of other environmental, social and economic benefits. These include greenhouse gas reduction, climate change adaptation and growing the rural economy.

The maps produced have been used to promote woodland creation for a range of water services. This includes targeting locations where planting could help to:

- reduce flood risk for downstream properties (for example, at Pickering in north Yorkshire)
- reduce sediment and nutrient loads to impacted waters (for example, Bassenthwaite Lake in the Lake District)
- protect steep slopes from slippage and soil erosion (for example, as part of the Clough Woodlands project in the Peak District)
- provide riparian shade to reduce thermal stress to fish (for example, in the River Avon in Hampshire)
- improve the condition of priority aquatic and riparian habitats (for example, in the River Frome in Dorset)

Planting was supported under the previous Forestry Commission English Woodland Grant Scheme by an enhanced grant rate, which had delivered around 1,800ha of new woodland in priority locations across England by the end of 2013. Funding for targeted planting is now provided by Countryside Stewardship.

Woodland creation, however, is not without risks and care is required in planting the right tree in the right place to avoid woodland acting as a pressure on the environment. Opportunity mapping supports this process by identifying constraints and sensitivities to planting.

Geographical information system (GIS) filtering approaches are used within Woodlands for Water projects to determine the possibilities for woodland creation in a first phase of understanding catchment issues and opportunities. The national maps could therefore be identified as a necessary step in any business process. The maps help to generate an understanding of how the catchment works (sources, pathways, receptors) and enable catchment managers to assess the feasibility of mitigating the catchment issues.

Community involvement

Woodlands for Water relies on a strong partnership approach to:

- identify synergies and prioritise sites
- integrate funding support
- reach agreement with local landowners
- achieve the required level of planting to make a difference at the catchment scale

The Forestry Commission works closely with the Environment Agency and catchment partnerships to inform the development of river basin, catchment and flood risk management plans. Forest Research provides scientific support.

2. Data summary

Datasets and analysis techniques used

The following national datasets were used:

- National Soil Map
- Hydrology of Soil Types (HOST) dataset
- Environment Agency's Detailed River Network
- ADAS Phosphorus and Sediment Yield Characterisation In Catchments for Phosphorus (PSYCHIC-P) and National Environment and Agricultural Pollution – Nitrate (NEAP-N) modelled rates of pollutant loss/usage (based on 2010 agricultural statistics)
- pesticide usage (GfK Kynetec Limited)
- faecal indicator organism (FIO) risk (Centre for Research in Environment and Health, University of Wales)
- bathing and shellfish waters datasets
- National Forest inventory map 2013
- Ordnance Survey (OS) national coastline dataset
- OS Strategi 1: 250 000 scale inland water
- OS Strategi 1:250 000 scale urban
- Natural England Peat Map (October 2008)
- FC_Peat Map created by Forest Research for Forestry Commission Wales in 2011
- Environment Agency's fluvial Flood Zone 2 map (January 2014)
- 50m gridded dataset of the riparian zones across England and Wales
- National Soils Resources Institute (NSRI)/National Soil Map of England and Wales (NATMAP) vector soil data
- Environment Agency Water Framework Directive river basin boundaries

The most important outputs of this study are GIS based opportunity maps identifying locations that are most suitable for and which would benefit most from woodland planting. These utilise a large number of spatial datasets (some model derived) from a range of partners, most of which are subject to licence agreements.

Woodland for Water also draws on supporting modelling studies aimed at quantifying the impact of woodland creation on diffuse pollution (for example, PSYCHIC and NEAP-N) and flood risk such as OVERFLOW, the US Army Corp of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) and its Hydrologic Modelling System (HMS).

Data restrictions

Most of the datasets used in the opportunity mapping work require a licence and some will attract a fee. Enquiries should be directed to the Environment Agency (email: data.info@environment-agency.gov.uk).

3. Model summary

Catchment processes investigated

This study explores the following catchment processes:

- Run-off generation - Woodland can increase interception and, in some instances it is believed reduce effective run-off, as well as protect vulnerable soils. The approach considers catchment descriptors such as HOST, standard percentage run-off (SPR) and soil vulnerability to structural degradation.
- Sediment sources, pathways and receptors - Woodland can stabilise sediment sources, interrupt the delivery pathway and protect receptors. The approach has used various datasets including soil erosion vulnerability, connectivity, extent of bare ground and PSYCHIC sediment model outputs.
- In-channel barriers - These are potentially vulnerable to blockage by woody debris. Datasets on the location of critical pinch points can be used to inform the approach.
- Longitudinal barriers - These affect the scope for woodland to interact with flood flows. The location of barriers is used to prioritise areas for planting both in terms of avoiding or targeting, depending on local objectives.
- Catchment change - Woodland can affect (usually benefit) river hydromorphology. This is addressed in a number of ways including targeting ‘damaged’ lengths of river channel, areas lacking shade, or areas with excessive shade.
- Sources, mobilisation and delivery of diffuse pollutants - Woodland creation is generally associated with low pollutant loads and an ability to intercept and retain pollutants draining from adjacent/upslope land. Models are used to classify sources of 5 diffuse pollutants – sediment, phosphate, nitrate, pesticides and FIOs.

Model assumptions

‘Backing up effects’ were also considered because riparian and floodplain woodland can slow down flood flows, potentially increasing flood risk to local upstream properties. A ‘standard’ buffer area is identified around all vulnerable assets as a potential sensitivity and flag for further consideration.

The Woodlands for Water opportunity mapping projects generally begin by focusing on locations with known water issues including flood risk and diffuse pollution. A GIS filtering approach is employed as a screening technique to generate opportunity maps showing where woodland creation could deliver maximum benefits (details below). Constraints and sensitivities are identified to help ensure the right tree is planted in the right place.

By overlaying and stacking different water services plus spatial data on other environmental benefits it is possible to generate combined opportunity maps to show where there is greatest synergy. These maps can then be informed by data on site vulnerability and cost-effectiveness (for example, the value of assets at risk of flooding or scope for achieving water status targets) to prioritise locations and catchments for planting and grant support. Stakeholder involvement and catchment planning are crucial to putting in place sufficient change on the ground to make a difference. Demonstration woodlands have been used to convey the value and benefits of woodland creation for water.

Environment Agency Water Framework Directive and flood risk management (FRM) spatial datasets (for example, significant water management issues and updated flood risk maps) were utilised in the production of opportunity maps. These included the following.

A range of constraints and sensitivities to planting – in the case of regional and catchment mapping – were mapped. Constraints are factors that make sizeable planting of woodland not possible or very

unlikely due to existing land use, land ownership or the presence of vulnerable assets. Sensitivities comprise factors that could influence the scale, type and design of woodland creation. For the national mapping work, only core constraints were considered. These consisted of:

- existing woodland – based on the National Forest Inventory Map 2013 (Woodland canopy – Interpreted Forest type – selected) owned by the Forestry Commission GB
- open water – OS Strategi 1: 250 000 scale Inland water (lake, reservoir, and pond) outer limit was used to define areas of open water
- urban areas – OS Strategi 1:250 000 scale urban areas (large and small) outer limit was used to define the boundary of urban areas
- deep peat (peat >40cm deep) – in England, the Natural England (October 2008) Peat Map was used and, in Wales, the FC_Peat Map created by Forest Research for Forestry Commission Wales in 2011(selected areas of deep peat and eroded deep peat) was used

The four datasets were combined using the UNION tool (Figure 1) to create a single dataset called CONSTRAINT. This was then converted to a 50m raster grid and the OS national coastline dataset was used as an analysis mask to re-class the dataset. Next the area with no data (that is, free from constraints) was exported to generate a new dataset called Potential New Woodland (PNW).

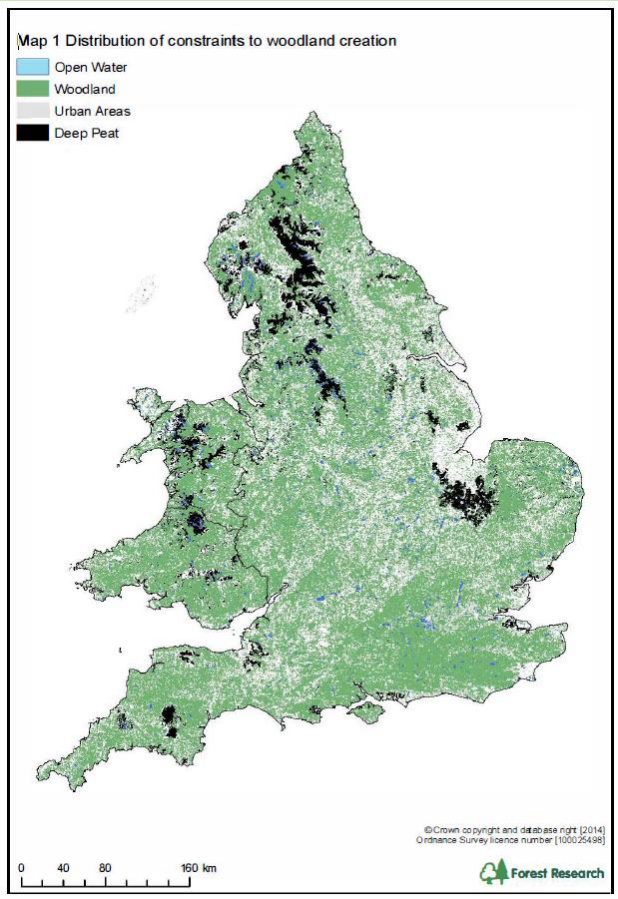

Figure 1: Distribution of constraints to woodland creation

Source: Broadmeadow et al. (2014)

Opportunity maps for woodland planting to mitigate diffuse pollution were based on Environment Agency Water Framework Directive datasets of modelled pollutant loads or pressure at a 1km2 scale for each of phosphate, sediment, nitrate, total pesticides and faecal indicator organisms (FIOs). The data were derived from a range of models addressing pollutant loads to land and/or loss and delivery to watercourses from agriculture and rural land management. Appropriate thresholds were selected to define the target area for woodland creation.

Various models were used. PSYCHIC, a diffuse phosphorus and sediment broad scale model, used 2010 agricultural census data for England and Wales to estimate the annual losses of each pollutant to water (Figure 2). NEAP-N (a soil nitrate leaching model) was used to estimate nitrate concentrations in drainage waters.

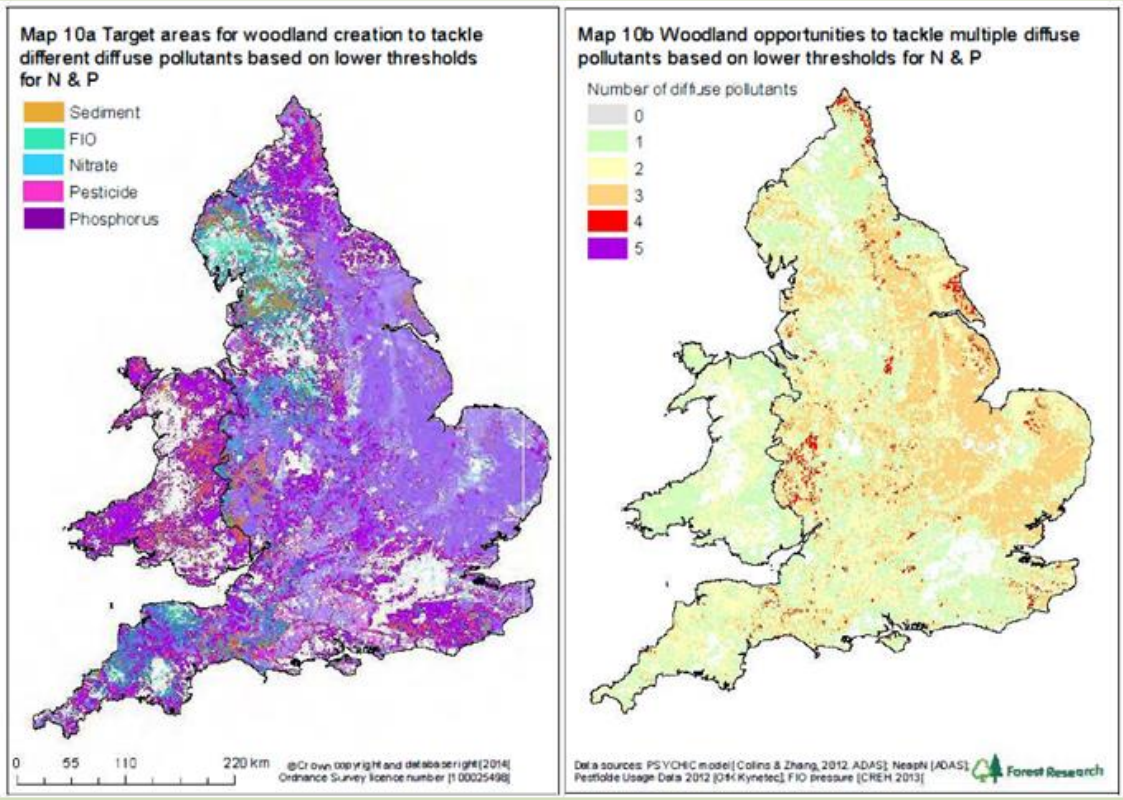

Figure 2: Example of diffuse pollution modelling and mapping

Source: Broadmeadow et al. (2014)

Information on pesticide usage was obtained from a dataset (2012) with a 1km grid containing values for the total amount of pesticide usage based on typical application rates for each of 12 key pesticides.

As there is no national dataset for FIOs, the Centre for Research in Environment and Health (CREH) statistical model was used to predict FIO risk to support the Catchment Sensitive Farming (CSF) initiative. This utilised:

- the ADAS 2010 land use database at a 1km grid scale to estimate the relative risk of pollution from agriculture
- bathing and shellfish waters datasets and applied a threshold (top 10% of FIO values for both receptors) to identify target areas where woodland creation could help reduce diffuse pollution

The maps for the individual pollutants were overlain and constraints removed to identify locations where woodland planting could help to reduce one or more diffuse pollutants (Figure 3).

Opportunity maps for woodland creation to reduce flooding from rivers divided catchments into three zones:

- floodplain
- adjacent land
- riparian zone

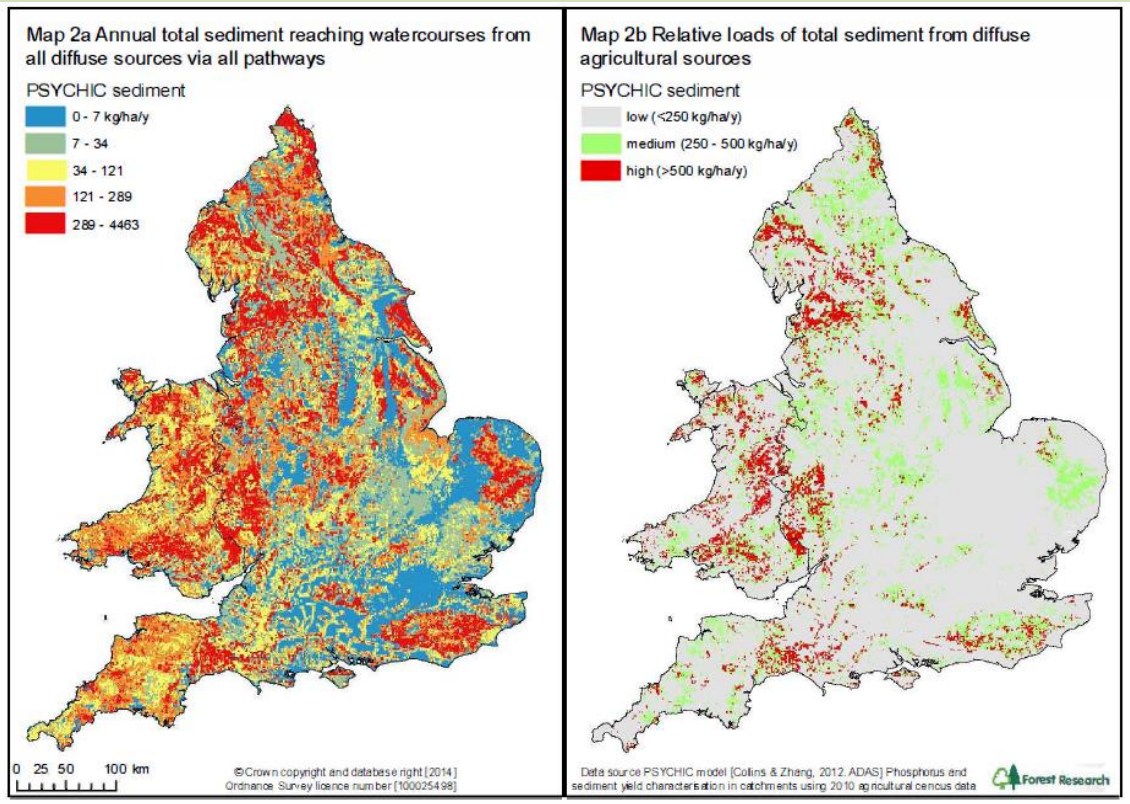

Figure 3: Example of opportunity maps for woodland creation based on diffuse pollution mapping

Source: Broadmeadow et al. (2014)

The approach for the floodplain utilised the field ‘TYPE’ in the Environment Agency’s Flood Zone 2 map (January 2014), with an applied selection ('Fluvial Model', 'Fluvial Event', 'Fluvial Model and Fluvial Event', 'Undefined Event', 'Fluvial/Undefined Event', 'Fluvial Model and Fluvial/Undefined Event', 'Fluvial Model and Undefined Event') to generate a new dataset called ‘fluvial flood zone’. The CONSTRAINT dataset was used to remove unsuitable locations, leaving target areas for planting floodplain woodland. Areas already benefiting from flood protection were identified (Figure 4).

For the adjacent land, mapping identified soils prone to generating rapid run-off where woodland planting could best help by reducing and slowing down surface flows. This utilised the following datasets:

- NSRI
- HOST
- SPR based on HOST classification
- revised SPR values derived from the study by Packman et al. (2004)
- poach class – reflects the risk of structural damage to the soil by poaching (Harrod 1998)

Target locations for woodland creation were defined as soils with an SPR >50% (Figure 5), with constraints removed.

For the riparian zone, the Environment Agency’s Detailed River Network was used to generate a 50m gridded dataset of riparian zones across England and Wales. The riparian zone raster was merged with the woodland creation target areas as determined by the soil classification dataset minus constraints to identify target areas for riparian woodland creation to benefit flood risk management. The zone was not mapped at A4 size due to small size of zones.

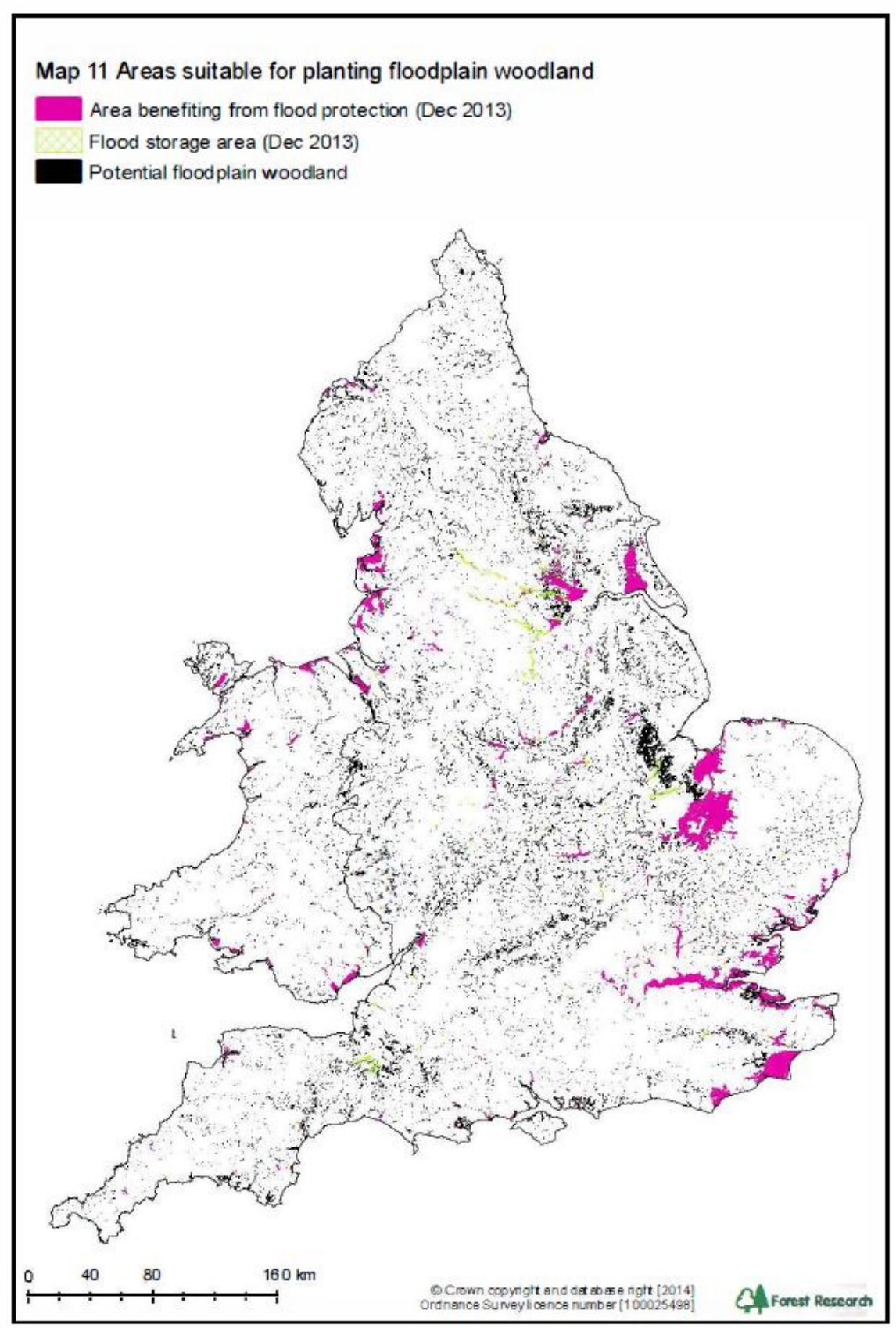

Figure 4: Map showing areas suitable for floodplain woodland planting based on Fluvial Flood Risk mapping

Source: Broadmeadow et al. (2014)

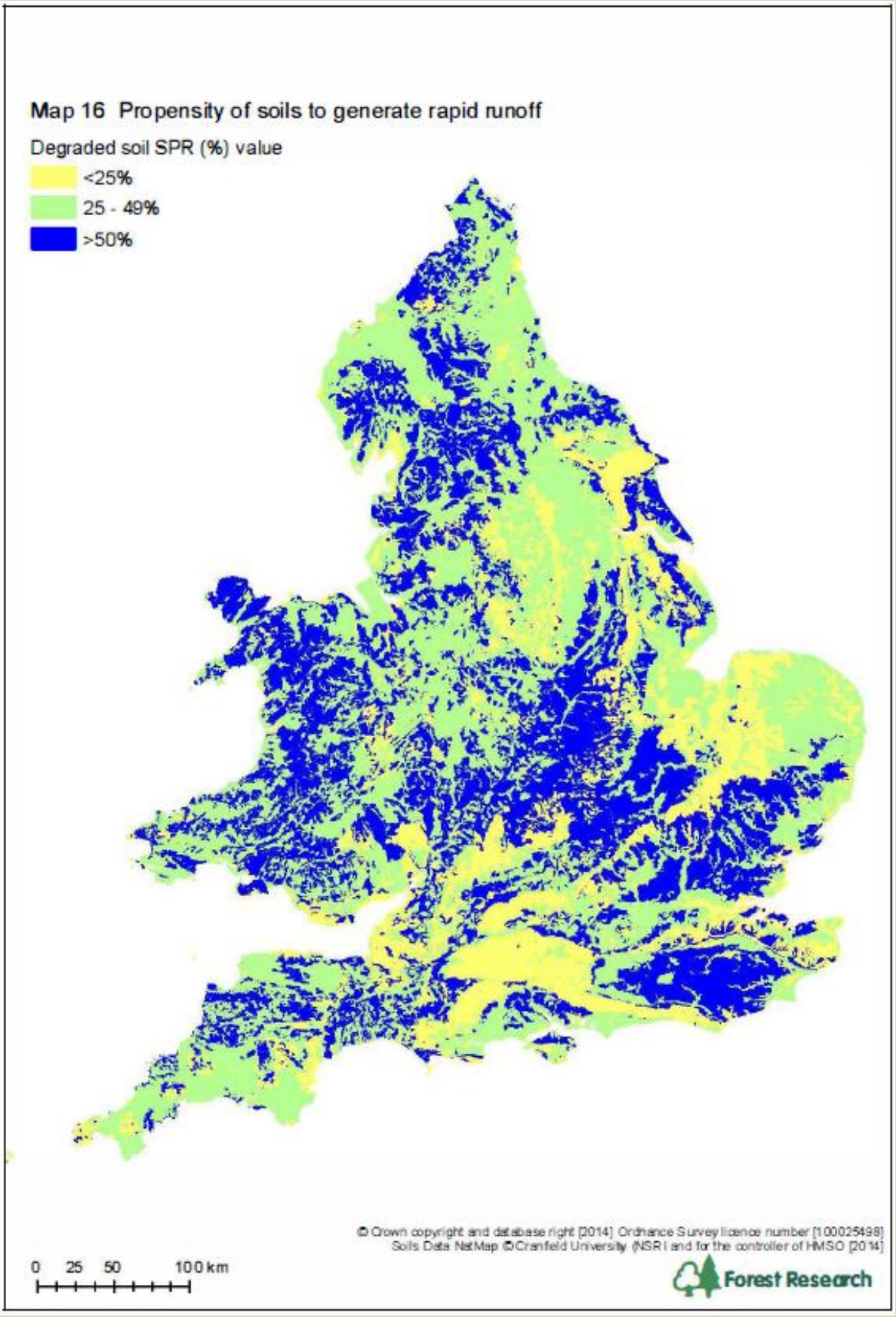

Figure 5: Map showing potential target areas for woodland planting to reduce flood generation as identified by soil classification analysis

Source: Broadmeadow et al. (2014)

Combined opportunities were identified by overlaying target areas for planting floodplain, riparian and wider woodland to reduce flood risk and then overlaying target areas for flood risk with those for reducing one or more diffuse pollutants.

Flood risk was not directly quantified within this case study. However, the opportunity maps generated in the Woodland for Waters projects can be used as a screening tool to assist targeting of flood risk management measures that can then be modelled in more detail. An example of this approach was at Pickering in north Yorkshire, where Durham University's OVERFLOW model was used to assess the impact of planting within identified target areas on flood risk to the town (Odoni et al. 2010). The modelling also showed where planting could increase flood risk by synchronising flood flows. Primarily fluvial and surface water flooding were considered using the existing national flood maps.

ISIS and ReFH (Revitalised Flood Hydrograph) modelling was used to conduct a sensitivity analysis of identified locations for woodland creation to reduce flooding in the River Derwent catchment in Cumbria (Atkins 2012). Other hydrological models (for example, ISIS, ISIS TUFLOW) have been applied to predict the impact of woodland creation (see McIntyre and Thorne 2013).

Data and model outputs

Opportunities for planting floodplain woodland target Flood Zone 2 (national Environment Agency maps of 1 in 1000 year return period) and include a nominal buffer around vulnerable assets so potential backing up effects can be checked for. A limit is also applied to the width of floodplain, with areas wider than 1km excluded because of the reduced likelihood of achieving a sufficient width of planting to make a difference. Consideration was also given to using available spatial datasets on the vulnerability of assets to blockage.

Priority can be given to locations where measures are expected to exert the greatest effects, such as by targeting soils with a high propensity to generate rapid run-off. There is also potential to consider this indirectly, for instance, by only targeting non-maintenance regimes for riparian woodland in the headwaters of catchments or where there are fewer bridges that could give rise to debris blockage.

Opportunity mapping is well suited to identifying multiple benefits and synergies by overlaying datasets for different woodland services such as for flood risk, diffuse pollution control, shade provision and habitat connectivity. While opportunity mapping does not try to quantify the physical benefits, it can stack these (for example, for the individual diffuse pollutants of sediment, phosphate, nitrate, pesticides and FIOs) to inform the prioritisation process.

Model performance

A range of models have been used to assess the interactions between woodland and water, although GIS opportunity mapping is the main spatial analysis tool applied within this case study. The work assumes that the right tree will be planted in the right place within the identified target areas to deliver water benefits. Guidance has been developed to aid this process and underpin financial incentives to encourage appropriate planting (Forestry Commission England 2012).

The maps are limited by the accuracy of the spatial data and require ground-truthing as part of the normal assessment and approval process for individual woodland planting applications. In some cases there will be a need for modelling to check that planting will not increase flood risk due to the backing up of floodwaters or the synchronisation of flood flows.

It is assumed that local consideration will be given to the risk of the washout of woody debris blocking downstream structures, especially where the construction of large woody debris dams is planned.

4. Lesson learnt

Choice of tools

A range of GIS filtering techniques and datasets have been used to identify and prioritise locations to focus on when considering whole catchment WWNP. The approach also facilitates shared learning and development so that the contribution of woodland creation to mitigating flood risk and diffuse

pollution, and the consequences for wider land use decisions, are considered in tandem.

The wider Woodlands for Water work also highlights how woodlands can affect a number of catchment processes and the need for these interactions to be better incorporated and represented within catchment models. For example, woodlands can contribute to flood risk management by their greater water use, the typically higher infiltration rates of woodland soils, their greater hydraulic roughness, and by their ability to protect soils and reduce sediment delivery to watercourses. Most of these factors are often ignored in the application of hydrology and/or hydraulic models or insufficient care is taken in their parameterisation.

The opportunity maps are based on broad scale assumptions and sound knowledge of how woodland can alter and improve flood attenuation, drawn from research on catchment processes. The strategic approach is useful for prioritising the search for Working with Natural Processes (WWNP) and uncertainties can then be reduced through more detailed modelling.

Catchment scale and typology

Opportunity mapping identifies the scope for woodland creation and WwNP to contribute to flood risk management and meeting Water Framework Directive objectives across a range of catchment scales. Studies such as the application of OVERFLOW at Pickering in north Yorkshire (Odoni et al. 2010) show how this can inform the application of catchment models to predict and upscale the effects of woodland creation on flood risk, including where planting could make things worse by synchronising flood flows.

The approach takes into account different broad scale factors influenced by typology such as landform, soil characteristics and pollutant loads. Scale issues are not explicitly handled; for instance, for larger catchments it is not clear if partial planting in different watersheds would deliver a net improvement to flood risk. However, this is partly addressed by the prioritisation process to make it more likely that sufficient woodland will be planted to make a difference.

Wider benefits

This tool combines different datasets to highlight locations where woodland creation can provide multiple water and other services, including:

- reducing flood risk, diffuse pollution and soil erosion
- improving habitat condition and connectivity
- keeping rivers cool for climate change adaptation

Future research needs

The Woodlands for Water opportunity mapping is a useful approach for screening areas with potential for whole catchment approaches to WwNP that can help prioritise areas for more detailed investigation. The wider study also highlights the need for woodland processes to be better incorporated and represented in catchment hydrology and hydraulic models.

The results of site and catchment process studies have informed model development and application, which underpins the opportunity mapping approach and targeting of financial incentives to implement woodland creation for multiple water and other benefits. Process understanding is sound, but there remains a need to improve the representation of these within models and for better models to upscale and integrate the effects of different FCRM measures at the larger catchment scale.

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Project background

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Project manager: Lydia Burgess-Gamble, Evidence Directorate

Research contractors: Barry Hankin (JBA), Sebastian Bentley (JBA), Steve Rose (JBA), Keith Beven (Lancaster University), Trevor Page (Lancaster University), Mark Wilkinson (James Hutton Institute), Paul Quinn (Newcastle University) and Greg O'Donnell (Newcastle University).

For more information contact: fcerm.evidence@environment-agency.gov.uk