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Opportunity mapping for woodland creation to reduce flood risk in Northern Ireland

Flooding on the River Bann near Portadown, January 2016

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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The Forest Service is an Executive Agency within the Department of Agriculture, Environment and Rural Affairs (DAERA). The aims of the Agency set out in the Framework Document are: “to contribute to the economic development of the entire forestry sector in Northern Ireland, whilst at the same time promoting the sustainable management of forests for multiple use and conserving and enhancing the rural environment”.

Executive Summary

The objective of this project was to provide GIS spatial datasets and maps which identify priority areas for woodland creation to benefit flood risk management in Northern Ireland

A wide range of spatial datasets were accessed from partners and used to generate a set of maps and supporting GIS shapefiles showing priority areas for planting. The results provide a strong basis for developing and refining catchment strategies, initiatives and plans to deliver new woodlands where they can best contribute to flood risk management (FRM). Consideration should also be given to where planting could help tackle other issues, such as reducing diffuse pollution and meeting Water Framework Directive (WFD) objectives. Woodland creation, however, is not without risks and care will be required in planting the right tree in the right place to avoid woodland acting as a pressure on the water environment.

There are extensive opportunities in Northern Ireland for woodland creation to mitigate downstream flood risk (Map 14) including:

- 2,493 km^2 of priority areas for woodland planting to reduce downstream flood risk, comprising 1,721 km^2 for wider woodland, 110 km^2 for riparian woodland and 663 km^2 for floodplain woodland.

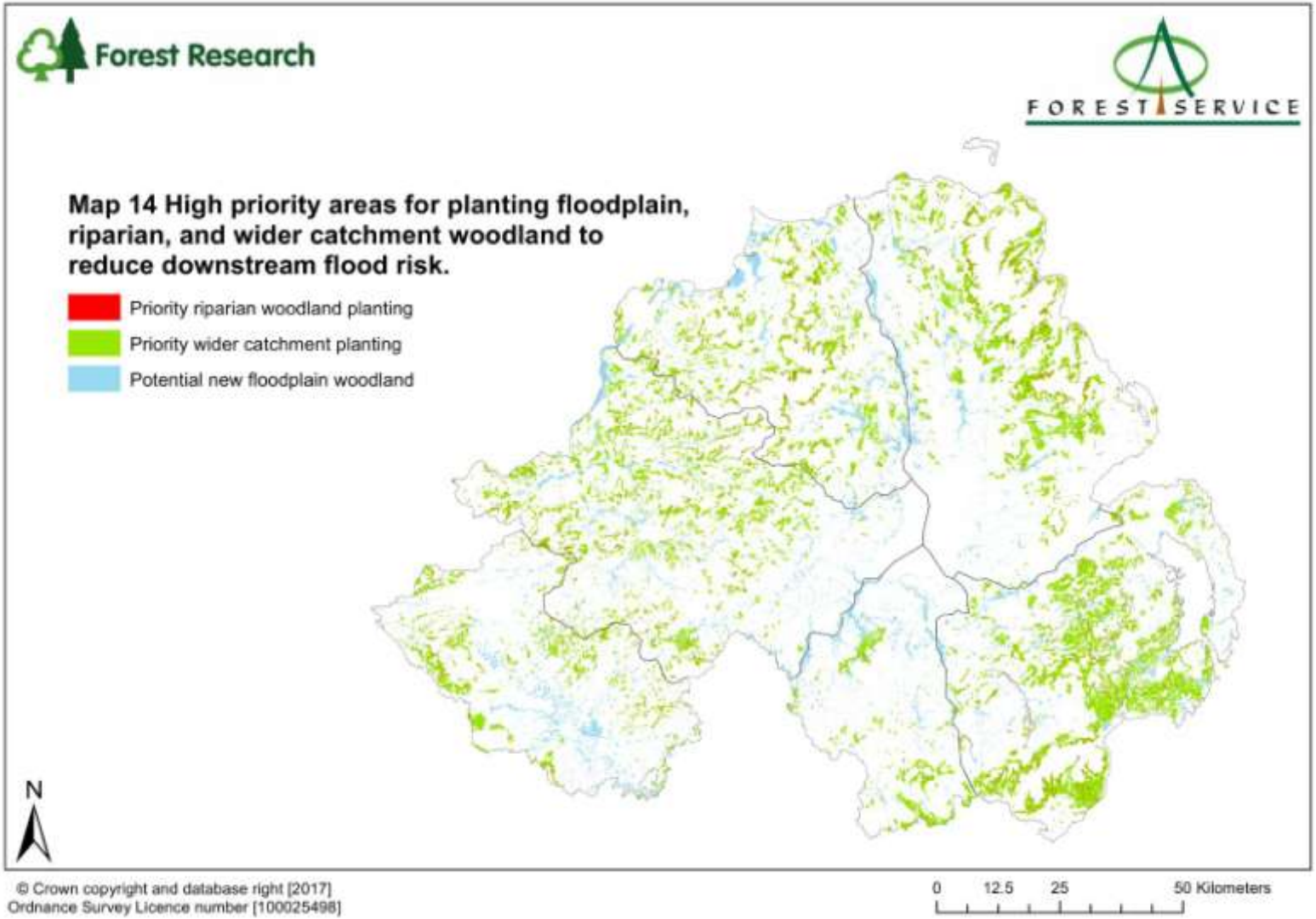
Opportunities for woodland creation to reduce flood risk are relatively evenly distributed across the country. Opportunities for larger scale new woodland planting may be more possible in the east of the country, while opportunities for existing woodland expansion and connection of more fragmented pockets of existing woodland may exist in the western areas.

It is recommended that partners and other stakeholders use these maps and spatial data to inform Flood Risk Management Plans. It would help to further prioritise the target areas at the sub-catchment scale in terms of communities at risk and where opportunities for woodland planting to make a difference are greatest. This includes better integrating woodland opportunities into existing and new catchment initiatives to improve the chances of success and help secure longer-term performance. There is also significant scope to overlay the maps with those of other woodland values such as for reducing diffuse pollution or the provision of recreation and carbon, so that opportunities to widen the range of benefits from planting can be realised.

Achieving a sufficient area of planting to make a difference will require long-term planning, coordination and an appropriate level of grant support

under future afforestation programmes. There is a good case for better integrating available incentives to secure greater land use change, as well as exploring other funding options for woodland creation to reduce flood risk.

Care is required with the design and management of existing woodland to ensure that flood risk management benefits are maintained. The greatest risk is posed by large-scale clearfelling, which can be controlled by limiting the scale of felling to <20% of the catchment upstream of vulnerable communities within any three year period.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Map 14 High priority areas for planting floodplain, riparian, and wider catchment woodland to reduce downstream flood risk.
Priority riparian woodland planting
Priority wider catchment planting
Potential new floodplain woodland
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Note: Only a selection of maps have been used in the main body of the report. For the full list of maps, please refer to the separate Maps Section included with this report.

1. Objective

To provide GIS spatial datasets and maps which identify priority areas for woodland creation to benefit flood risk management in Northern Ireland.

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 is increasing 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, 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 increased by about one thousand hectares each year part of which was grant aided and part occurred naturally, probably as a result of some landowners neglect, which resulted in a gradual increase in woodland area.

Today there are 122,000 hectares of woodland and Government policy continues to support woodland creation to deliver multiple benefits for society, including public access for health and well being, 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 reduce downstream siltation, both of which can help alleviate flood risk. 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 Flood Risk 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 we 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 a number of catchments and regions in England, Scotland and Wales in recent years.

This project will provide GIS spatial datasets and maps displaying opportunities and priorities for woodland creation to help reduce flood risk in Northern Ireland. These maps will inform Flood Risk Management Plans and facilitate shared learning and development so that the contribution of forestry to mitigating flood risk – and the consequences for wider land use decisions - are considered in tandem.

3. Methods

3.1 Approach to GIS mapping

Opportunities for woodland planting to contribute to flood mitigation in Northern Ireland were identified using a GIS mapping assessment. This was based on the approach originally developed for flood risk management in the River Parrett Catchment in Somerset (Nisbet & Broadmeadow, 2003) and subsequently applied to other parts of England (Broadmeadow & Nisbet, 2010a & b). It has since been extended and further developed in recent applications to the whole of England (Broadmeadow & Nisbet, 2011), to the Environment Agency's Midlands (Broadmeadow *et al*., 2012) and Yorkshire & North East Regions (Broadmeadow *et al*., 2013a), and to the Tay Priority catchment in Scotland (Broadmeadow *et al*. (2013b), as well as in Wales for Natural Resources Wales' Integrated Natural Resource Management Pilot Catchments (Thomas *et al*., 2014).

3.2 Identification of constraints and sensitivities to woodland creation

The first step in determining the extent and scale of woodland creation opportunities was to identify constraints to woodland planting. These are locations where the creation of sizeable areas of woodland is either not possible or very unlikely due to existing land use, land ownership or the presence of vulnerable assets. They should not all be seen as absolute barriers to planting as some will provide local opportunities, such as part of Sustainable Urban Drainage Systems within urban areas. Their inclusion reflects their highly sensitive nature and restricted scope for woodland planting to play a significant part of any flood mitigation scheme. The list of constraints comprised the following:

- Urban areas, with a population above 500
- Roads

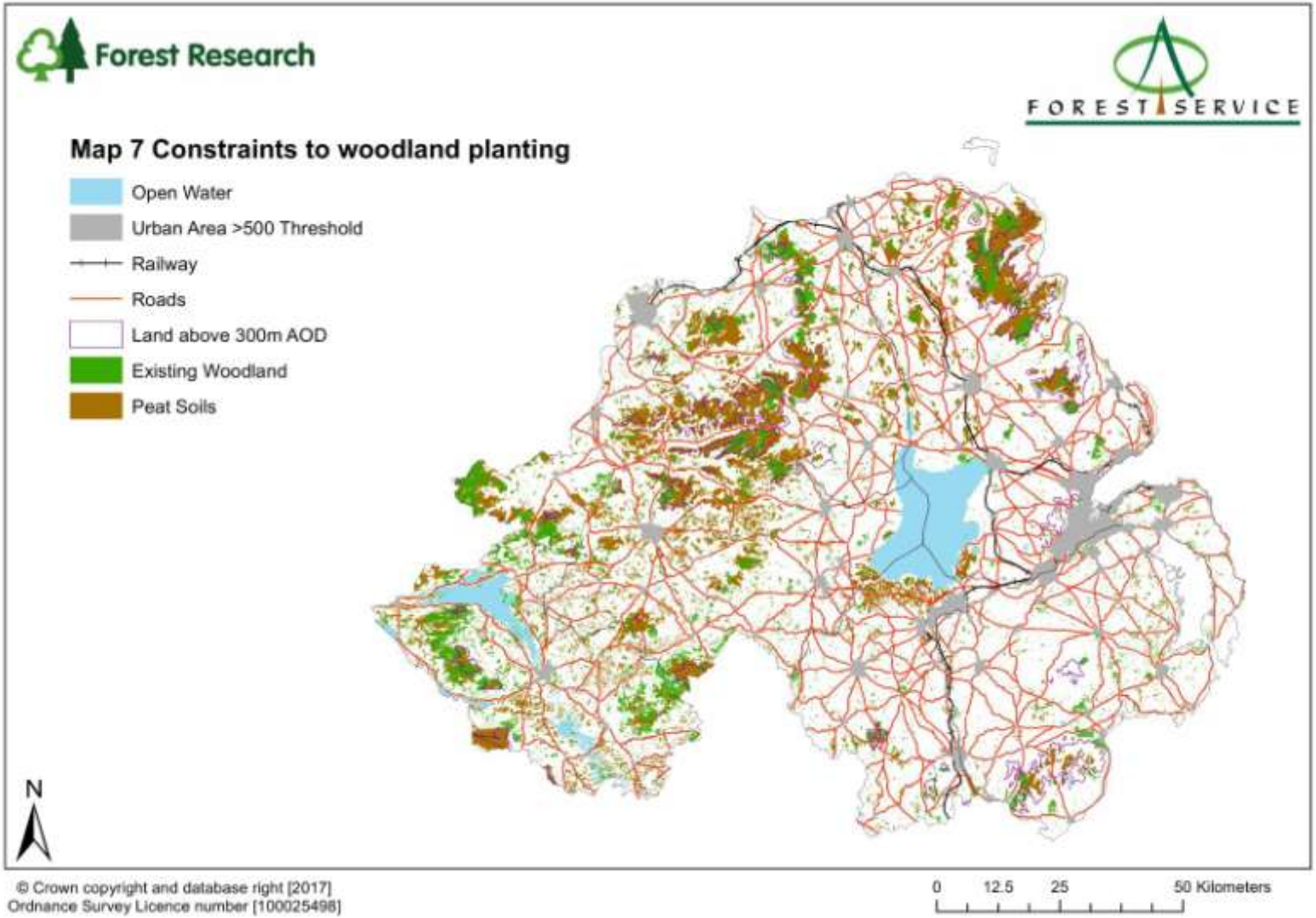
- Railway infrastructure
- Land above 300m AOD
- Open water
- Existing woodland
- Peat soils

The combined dataset was used to remove areas that would be unsuitable for significant woodland planting (Maps 7). Peat soils were included as a constraint to reflect potential issues over the impact of planting on soil carbon stocks, depending on the nature of planting and woodland management. Northern Ireland Forest Service implement the UKFS good forest practice guideline to "avoid establishing new forests on soils with peat exceeding 50cm depth and on sites that would compromise the hydrology of adjacent bog habitats".

There are additional factors that will influence the scale, type and design of any planting. These are termed sensitivities and would require careful consideration on an individual site basis in consultation with relevant agencies. This would be undertaken as part of the normal assessment and approval process for woodland planting applications. Sensitivities include the most valuable agricultural land and areas scheduled or recognised for their nature conservation, historic or cultural importance. The full list is as follows:

- RAMSAR, SAC, SPA and ASSI
- National Nature Reserves
- Agricultural Land Class 3 (Cruickshank, 1997)
- Areas of Outstanding Natural Beauty (AONB)
- Floodplain buffer around urban centres and along roads
- World Heritage Sites

The above features were combined to form a single GIS layer, showing where woodland creation would be possible providing the scheme was appropriately designed to protect and enhance the value of the existing habitat, landscape or assets on the site (Maps 8). Most of the sensitivities are self-explanatory and well defined by formal designated boundaries. The selection of others is explained below, particularly those that required some processing, such as the floodplain buffers.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Map 7 Constraints to woodland planting
Open Water
Urban Area >500 Threshold
Railway
Roads
Land above 300m AOD
Existing Woodland
Peat Soils
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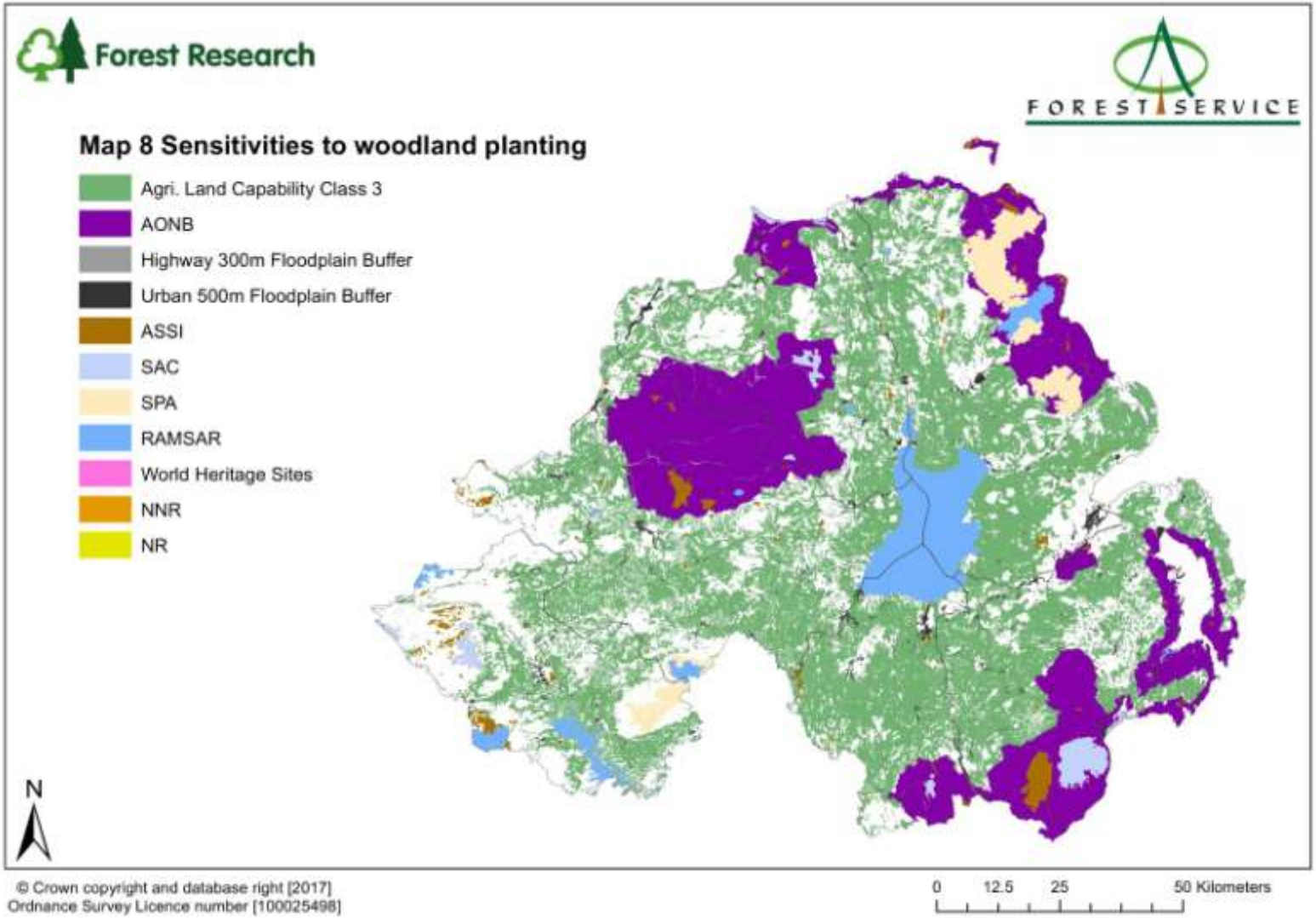
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Map 8 Sensitivities to woodland planting
Agri. Land Capability Class 3
AONB
Highway 300m Floodplain Buffer
Urban 500m Floodplain Buffer
ASSI
SAC
SPA
RAMSAR
World Heritage Sites
NNR
NR
N
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It was thought appropriate to include a buffer around urban areas and roads (railways were excluded on the basis that they were expected to be embanked and therefore less at risk) within the floodplain. This was in view of the potential sensitivity of these assets to the backing-up of floodwaters upstream of any planted floodplain woodland, or the blockage of downstream culverts or bridges by the washout of woody debris. The buffer acts as a flag to check for these issues when a planting application is made; this may require reach-scale modelling of flood levels and an assessment of the vulnerability of local pinch points to blockage.

Uniform fixed width buffers were created, principally guided by the results of previous modelling work which showed the backwater effect to be largely confined to a distance of 300-400 m upstream. Consequently, a 500 m wide buffer was delineated around urban areas and a 300 m buffer along both sides of roads. It is important to note that an allowance has not been made for the protection of isolated buildings and farmsteads, which would need to be assessed on an individual site by site basis during the application process.

There are several categories of land that were not included in the combined dataset but could be considered as 'sensitivities'. These comprise land protected by flood defences and areas identified for proposed new flood defences. The restricted scope for woodland planting to affect flood flows within these areas (due to being 'offline') means that they would not normally be considered a priority for planting for flood risk management (FRM), unless there were plans to remove or breach the flood defences to increase flood storage and promote interactions with any planted woodland. The same applies to the planting of trees close to rivers where there may be a need to preserve access to maintain flood embankments or protect these from tree rooting and windblow.

Finally, the constraints and sensitivities for which spatial data are available were brought together in Maps 9 to show the distribution of land potentially available for woodland planting in the region.

3.3 Identification of suitable areas for woodland creation to reduce downstream flood risk

Woodland creation is increasingly viewed as making an effective and sustainable contribution to NFM. Woodland can help alleviate flooding in three main ways: through the potentially high water use of trees increasing available soil water storage and reducing the generation and volume of flood water; by the typically high infiltration rates of woodland soils reducing direct surface runoff and delaying the passage of water to streams; and by the greater hydraulic roughness created by woodland vegetation, acting to increase above ground flood water storage and delay the downstream passage of flood flows (Nisbet et al., 2011a). These

mechanisms are to varying degrees location dependent and considered to be greatest where there is most contact between water and woodland, such as along runoff pathways and on floodplains. Consequently, the focus of mapping is to identify preferred locations where woodland planting is likely to be most effective. The catchment was divided into three zones for this purpose: floodplain, riparian and wider catchment.

3.3.1 Floodplain at risk from fluvial flooding – Northern Ireland Flood Maps

Planting within floodplains is thought to offer the greatest potential for downstream flood mitigation and therefore efforts focused on defining the extent of the floodplain where woodland could potentially interact with flood flows. Use was made of Flood Maps, Northern Ireland, using the 1 in 1000 year (0.1% annual exceedance probability (AEP)) modelled Fluvial Flood Hazard extent for Northern Ireland, modelled at strategic rather than detailed scale. The flood maps were first published by the Rivers Agency in November 2008. The 1 in 1000 year extents are from the 2008 Strategic dataset. For the purpose of this project, attention was restricted to identifying where woodland creation could help to reduce flooding from rivers. Most engineering, development and planning issues on the floodplain relate to the 1 in 100 year flood or more frequent floods, however using the 1 in 1000 year flood extent in this case ensures that woodland is planted across the full potential width of the floodplain.

It must be noted that additional woodland planting alone is unlikely to have a significant impact on such an extreme flood event, and it must be stressed that the 1 in 1000 year flood extent was chosen for this project (and other similar projects in Wales, England and Scotland) for floodplain delineation purposes only.

Areas of constraints to woodland creation (see Section 3.2), where tree planting would not be possible or appropriate, were removed from consideration. This generated maps showing areas within the fluvial flood zone that were suitable for potential new floodplain woodland (Map 10).

The efficacy of floodplain woodland in retarding flood flows and mitigating downstream flooding is dependant on the size of the woodland in relation to the scale of the floodplain (Thomas and Nisbet, 2006). Clearly, woodland spanning the entire floodplain will generate a greater impact compared to an isolated, small block of woodland on one side or on the margin of the floodplain. However, modelling shows that it is not necessary to plant a continuous stretch of woodland either across the full width or an extended length of the floodplain to achieve a significant delay in flood flows; a series of smaller blocks spread out across the floodplain may be just as effective at flood attenuation, depending on location and overall extent (Nisbet and Thomas, 2008).

3.3.2 Riparian zone

The close proximity between woodland and water in the riparian zone also makes this a very effective location for woodland planting to aid FRM, as well as to deliver other significant water benefits. A key attribute is the formation of large woody debris (LWD) dams from fallen trees and the input and collection of dead wood. These dams impede water flow and promote out of bank flows, increasing flood storage and delaying flood flows. Additionally, riparian woodland can reduce sediment delivery from the adjacent land and protect riverbanks, reducing downstream siltation and helping to maintain channel conveyance.

The riparian zone and therefore the potential to plant riparian woodland was defined as a 30 m wide area along both banks of the river network. This width was selected as the zone most likely to interact with and provide woody debris to the river channel. The preference was to exclude sections of the river channel that were too wide (e.g. >5 m) to establish stable debris dams but unfortunately no data were available on river channel width. Another factor that is left for local consideration is the valley or hydraulic gradient. The ability of planting to enhance floodplain storage and the associated stability of LWD dams reduces with increasing channel gradient and thus steeper reaches tend to be less effective for holding back flood waters. However, this factor needs to be weighed against the other FRM benefits of planting riparian woodland along steeper reaches and side slopes, such as reducing bank erosion and sediment delivery, as well as potentially reducing rapid runoff from the adjacent land.

All areas affected by constraints to riparian planting were then removed to generate a map showing areas suitable for potential new riparian woodland (Map 11).

3.3.3 Adjacent land

Woodland in the wider catchment can be most effective at reducing flood flows when targeted to soils that are prone to generating rapid runoff or the pathways along which water flows to streams. Such areas include naturally wet soils subject to seasonal waterlogging or surface ponding, and sensitive soils at risk of surface compaction, sealing and poaching. The identification of priority locations for planting was based on an assessment of the hydrological properties of soils.

This drew on the following spatial datasets:

- National soil map of Northern Ireland – Published by Agri-Food and Biosciences Institute (AFBI)
- The Hydrology Of Soil Types (HOST) (Boorman et al., 1995)

- Standard Percentage Runoff (SPR) based on the HOST classification

3.3.3.1 HOST

The HOST system was developed to classify soils according to their hydrological behaviour. HOST is a conceptual representation of the hydrological processes in the soil zone. All soil series (map units) in the UK have been grouped into one of 29 hydrological response models or 'HOST classes'. Allocation to a HOST class is by a hierarchical classification. Soils are first allocated to one of three physical settings:

- a soil on a permeable substrate in which there is a deep aquifer or groundwater (i.e. at >2 m depth)
- a soil on permeable substrate in which there is normally a shallow water table (i.e. at <2m depth)
- a soil (or soil and substrate) which contains an impermeable or semi-permeable layer <1m from the surface.

Each physical setting is sub-divided into response models, which describe flow mechanisms and identify groups of soils that are expected to respond in the same way to rainfall. Finally there are sub-divisions of some of these models according to the rate of response and water storage within the soil profile.

3.3.3.2 SPR

Calibrated values of SPR for each HOST class were derived from multiple regressions between the proportion of each response model within a number of UK river catchments and the SPR values derived from river gauging data. The SPR represents the percentage of rainfall that contributes to quick response runoff. HOST classes with a SPR >25% represent seasonally waterlogged and flashy soils (i.e. soils which have a rapid response to rainfall and runoff) that are likely to make a significant contribution to the generation of flood flows.

3.3.4 Prioritising areas for woodland creation to reduce flood risk

The following land was defined as priority areas for woodland planting to reduce flood risk: land comprising soils with a high propensity to generate rapid surface runoff (>40% SPR, termed 'priority wider woodland'); riparian land abutting land with a high propensity for generating rapid surface runoff ('priority riparian woodland'); and all suitable floodplain land ('priority floodplain woodland'). These areas are favoured either in view of their proximity to sources of flood generation of their ability to reduce the conveyance of flood flows downstream. The distribution of high, medium and low priority areas using the >40%, 35 – 40%, and

<35% SPR thresholds respectively are shown in table 1, along with the area of potential land available for planting.

	SPR %	Total Area km^2	% NI	Available Land km^2	% NI
Low	<35	3,642	26	3,033	21
Medium	35 – 40	5,518	39	5,109	36
High	>40	3,494	25	2,493	13

Table 1 Distribution of high, medium and low priority planting areas for Northern Ireland (Note: available land under "High" priority areas includes *all* available floodplain)

It is important to note that this prioritisation should not be seen as a barrier to woodland planting on other land, where there could be significant local opportunities for woodland creation to reduce downstream flood risk. This is particularly the case with the adjacent land and soils with SPR values of just under 40%, which would still benefit from planting. Maps 14 shows the distribution of the high priority areas for planting floodplain, riparian and wider woodland within Northern Ireland as well as those land areas with SPR values between 35 – 40% in Map 15 (i.e. medium priority).

Another important caveat is that planting in some locations could have the opposite outcome of increasing flood risk, where the delaying effect of woodland synchronises, rather than desynchronises downstream flood peaks (Nisbet *et al*., 2011a). This is more likely to be a problem with planting in the lower reaches of catchments closer to assets at risk (Broadmeadow *et al*., 2013a) and would need to be checked (possibly involving modelling) during the assessment of individual woodland planting applications.

4. Results

Calculated values for the extent and distribution of priority areas for woodland creation to help tackle downstream flooding are presented below for Northern Ireland.

4.1 Constraints to woodland creation

A total of 4,149 km^2 or 29.3 % of the country is excluded from woodland planting due to the constraints listed in Section 4.2 (Table 2). Peat soil cover represents the dominant constraint, affecting 13.6% of the area. Open water (10.6%) is the other main constraint and existing woodland

covers 7.9% of the country. The constraints are distributed throughout the country, with the areas above 300m being dominant features in the northwest, northeast and southeast of the country. The main open water features are Lough Neagh in the central area, and the upper and lower Lough Erne in the southwest. Peat soils are more dominant in the north and western areas. Existing woodland is scattered across the country but with larger unbroken areas in the southwestern, west and along the northeast of the country (Map 4).

In terms of the fluvial floodplain, a total of 1,515 km^2 or 10.7% of the country is at risk from a 1 in 1000 year flood event. Just over 56% of the floodplain is excluded from woodland planting due to constraints. Just under 5% of the floodplain is already covered by woodland.

Constraints	**Area km^2**	**%**
Peat	1,926	13.6
Existing Woodland	1,121	7.9
Open Water inc. Estuary	1,497	10.6
Road and rail network	153	1.1
Urban infrastructure	640	4.5
Treeline (land above 300m)	744	5.3
Actual area of all merged constraints for which spatial data are available: Total: Floodplain (FP):	 4,149 852	 29.3 56.3 of FP

Table 2 Constraints to woodland planting in Northern Ireland (Note: total area does not equate to the sum of each individual Constraint as some features overlap)

4.2 Sensitivities to woodland creation

Some 10,137 km^2 or nearly 72% of Northern Ireland is identified as potentially sensitive to woodland creation, which may restrict the scale and character of any planting (Table 3). Much of this area (7,077 km^2) is Grade 3 agricultural land spread over the lower lying areas of the country. The inclusion of Grade 3 agricultural land as a sensitivity is due to the land having a potentially high yield in productivity and profitable returns under agricultural use, and therefore less likely to be favoured and used for woodland creation. The next largest individual sensitivities are the 8 Areas of Outstanding Natural Beauty covering over 24% of the country. Almost 45% of land is subject to a national or international conservation designation.

Over 76% of the floodplain is subject to sensitivities, especially the buffer zone for roads and urban areas. This indicates that most planting proposals within the floodplain may require detailed consideration of the impact of the backing-up of flood waters on local buildings and transport infrastructure, which is likely to influence the scope for planting.

Sensitivities	Area km^2	%
International conservation designations:		
RAMSAR	881.8	6.2
SPA	1,140.3	8.1
SAC	859.1	6.1
National conservation designations:		
ASSI	0.2	<1
NNR	49.8	<1
AONB	3,411.8	24.1
Grade 3 agricultural land	7,077.1	50
World Heritage Site	2.4	<1
Buffers for roads and urban areas in the floodplain.	447.9	3.2
Actual area of all merged sensitivities for which spatial data are available:	10,137.3	71.6

Table 3 Sensitivities to woodland planting in Northern Ireland (Note: total area does not equate to the sum of each individual Sensitivity as some features overlap. Areas off the mainland have also been removed from totals for country)

4.3 Opportunities for woodland creation to reduce downstream flood risk

A total of 2,493 km^2 or 17.6% of Northern Ireland is identified as being available as a high priority area for woodland creation to reduce downstream flood risk on soils with a SPR of 40% or above (Map 13). Only 7.9% of Northern Ireland is currently covered in woodland. Planting opportunities in the country are fairly scattered across the country, with opportunities for larger new woodland planting areas in the east of the country, but more opportunities for woodland expansion to existing woodland areas in the west and northeast of the country (Map 14). Some 110 km^2 (6% of the total priority area potentially free of constraints to planting) forms priority land for riparian woodland.

Currently, only 4.7% of Northern Ireland's floodplain is covered with woodland. Almost 44% of the floodplain is free from constraints to woodland planting, highlighting very real opportunities to significantly

increase the floodplain woodland cover in Northern Ireland, from 71 km^2 to 663 km^2.

Much of Northern Ireland (39%) is covered with surface and ground water gley soils. Despite these soils having potentially high runoff figures, they did not fall under the area for priority planting as the SPR value for these soils were just below the 40% SPR threshold used. It is worthy of note that in reality, these areas would also benefit woodland planting to help reduce rapid runoff, and have therefore been included in Map 15. Some 5,110km^2 is free from constraints to woodland planting and is potentially available for planting within this zone.

5. Conclusions

The objective of this project was to provide GIS spatial datasets and maps which identify priority areas for woodland creation to benefit flood risk management in Northern Ireland

A wide range of spatial datasets were accessed from partners and used to generate a set of maps and supporting GIS shapefiles showing priority areas for planting. The results provide a strong basis for developing and refining catchment strategies, initiatives and plans to deliver new woodlands where they can best contribute to flood risk management (FRM). Consideration should also be given to where planting could help tackle other issues, such as reducing diffuse pollution and meeting Water Framework Directive (WFD) objectives. Woodland creation, however, is not without risks and care will be required in planting the right tree in the right place to avoid woodland acting as a pressure on the water environment.

There are extensive opportunities in Northern Ireland for woodland creation to mitigate downstream flood risk (Map 14) including:

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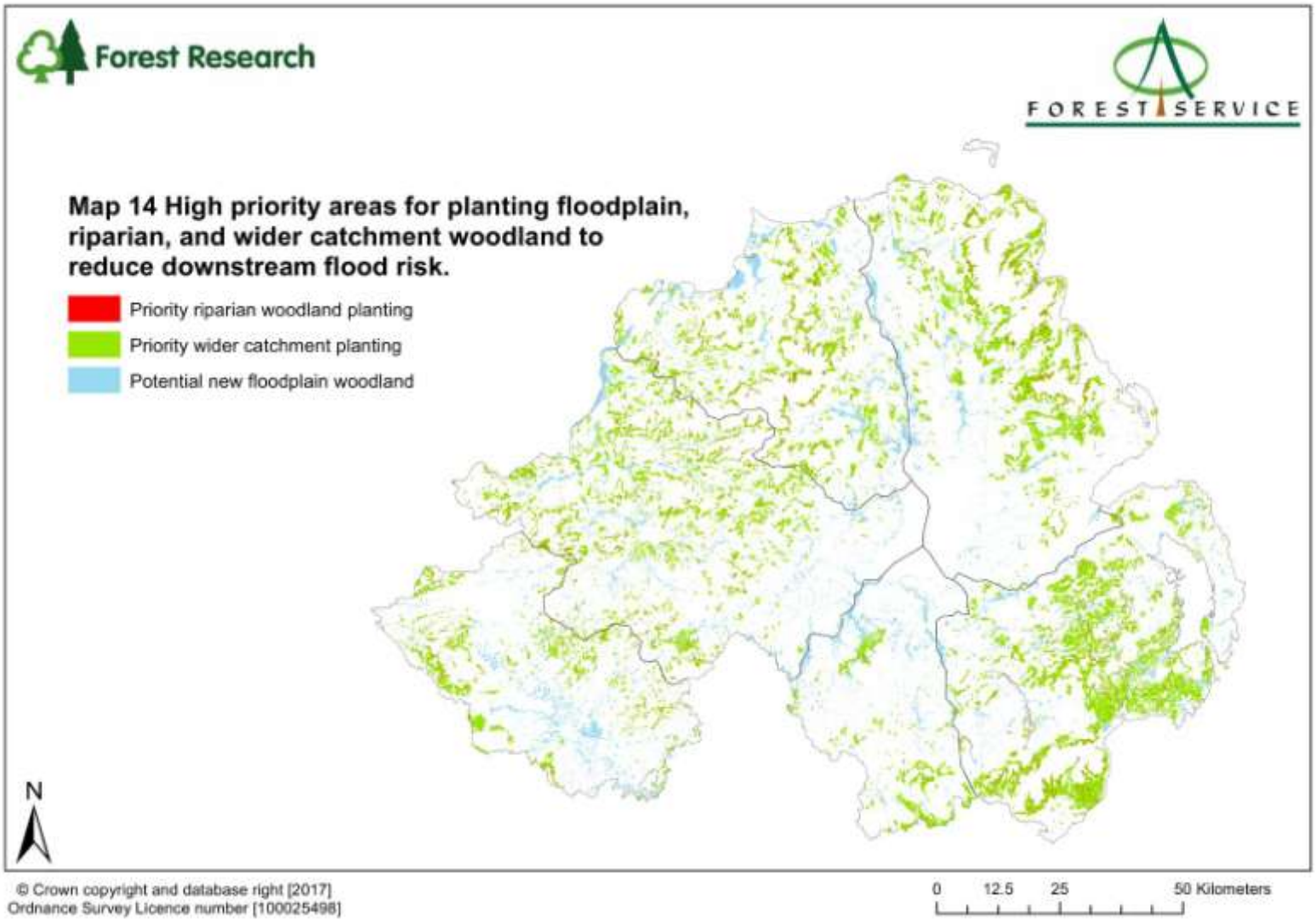
Opportunities for woodland creation to reduce flood risk are relatively evenly distributed across the country. Opportunities for larger scale new woodland planting may be more possible in the east of the country, while opportunities for existing woodland expansion and connection of more fragmented pockets of existing woodland may exist in the western areas.

It is recommended that partners and other stakeholders use these maps and spatial data to inform catchment flood management plans. It would

help to further prioritise the target areas at the sub-catchment scale in terms of communities at risk and where opportunities for woodland planting to make a difference are greatest. This includes better integrating woodland opportunities into existing and new catchment initiatives to improve the chances of success and help secure longer-term performance. There is also significant scope to overlay the maps with those of other woodland values such as for reducing diffuse pollution or the provision of recreation and carbon, so that opportunities to widen the range of benefits from planting can be realised.

Achieving a sufficient area of planting to make a difference will require long-term planning, coordination and an appropriate level of grant support under future afforestation programmes. There is a good case for better integrating available incentives to secure greater land use change, as well as exploring other funding options for woodland creation to reduce flood risk.

Care is required with the design and management of existing woodland to ensure that flood risk management benefits are maintained. The greatest risk is posed by large-scale clearfelling, which can be controlled by limiting the scale of felling to <20% of the catchment upstream of vulnerable communities within any three year period.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Priority wider catchment planting
Potential new floodplain woodland
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6. Recommendations

The following recommendations would help to secure the identified opportunities for woodland creation to assist the management of flood risk for affected communities:

1. The Department of Agriculture, Environment and Rural Affairs and Northern Ireland Forest Service and partner organisations use the maps and supporting datasets to help target woodland creation within priority areas to make a difference at the catchment scale. This would be assisted by a more detailed assessment of communities at risk, including defining upstream catchments and opportunities for planting within these.

2. Assessment should include the use of flood models to predict the effects of planting some or all of the identified land on downstream flood risk, including the potential to increase flood risk by synchronising, rather than desynchronising downstream flood flows, and the vulnerability of any key 'pinch points' to blockage by woody debris.

3. Identified catchments where modelling predicts that woodland creation could help reduce flood risk for affected communities should be taken forward for further consideration, including assessing landowner support, managing any sensitivities and identifying potential win-wins for planting to meet other water and related objectives. Securing planting opportunities in desired locations may require additional incentives and would benefit from exploring other potential sources of funding for investing in woodland creation.

4. Dissemination events could be held to promote the findings of this work and to discuss how to pool available resources to achieve implementation.

5. The maps could be used to facilitate the establishment of a demonstration test catchment to monitor and quantify the benefits of woodland creation for water. This would provide a local evidence base and help communicate the need for and success of using woodland as part of a more integrated catchment-based approach to flood risk management.

7. Acknowledgements

We would like to thank Northern Ireland Forest Service for funding this work and for providing a number of the spatial datasets used in the opportunity mapping.

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