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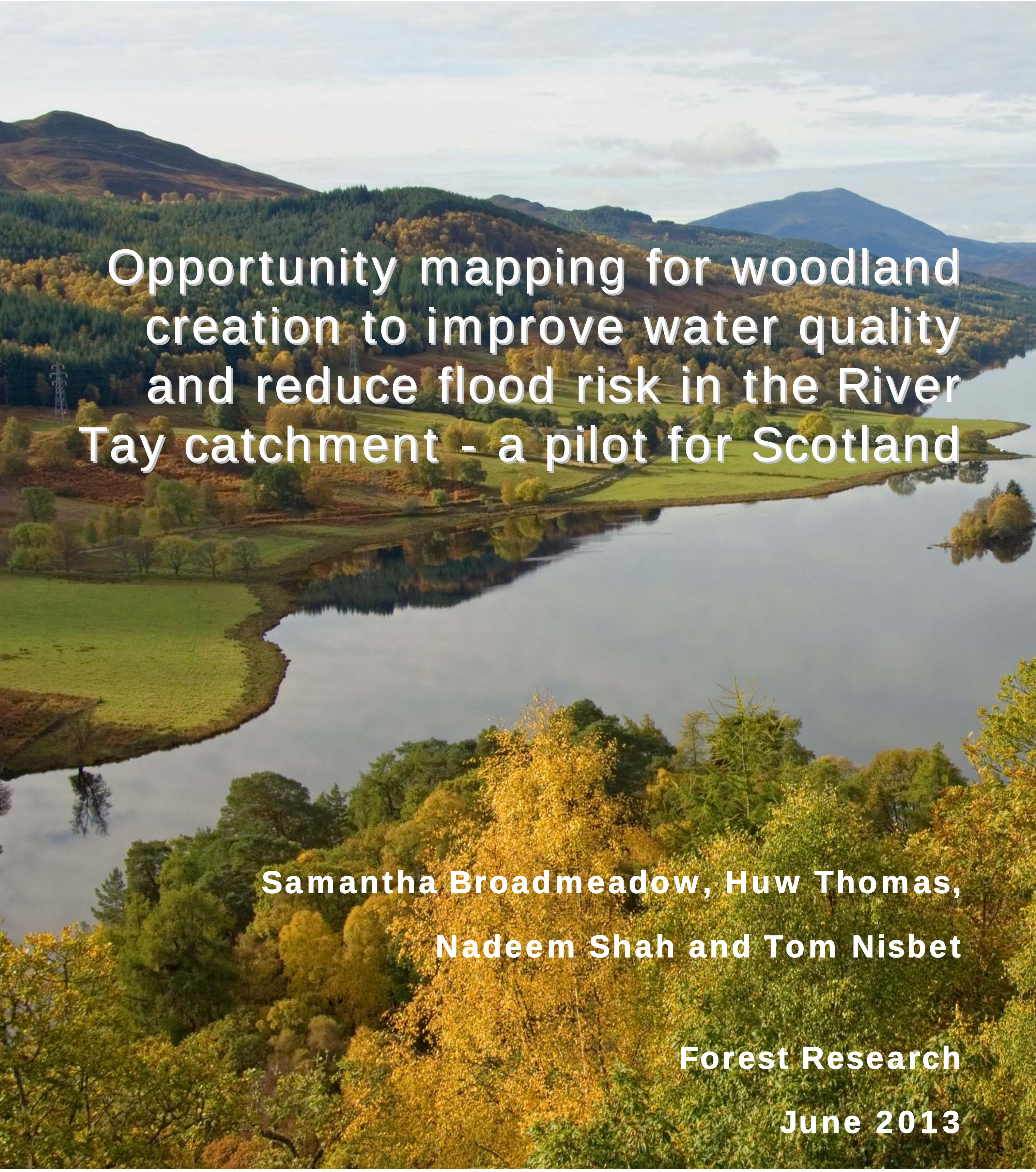

Opportunity mapping for woodland creation to improve water quality and reduce flood risk in the River Tay catchment - a pilot for Scotland

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Executive Summary

The River Tay is one of fourteen Priority Catchments in Scotland identified by the Scottish Environment Protection Agency (SEPA) and partner organisations for restoration and protection. It is impacted by a number of major water issues, with over 1,300 residential and 270 non-residential properties vulnerable to flooding and 26% of river and loch water bodies currently failing to meet the required Good Ecological Status (GES) due to diffuse pollution. A recent review of relevant research provides strong evidence of the ability of woodland creation to mitigate these pressures by reducing and delaying flood waters, limiting pollutant loadings and retaining diffuse pollutants. Commissioned by SEPA and Forestry Commission Scotland (FCS), the objective of this study was to identify priority areas for woodland creation and the improved management of existing woodlands to reduce downstream flood risk and help restore damaged waters.

A wide range of spatial datasets were accessed from partners, particularly SEPA, and used to generate a large number of maps and supporting GIS shapefiles showing priority areas for planting. The results provide a strong basis for developing and refining regional strategies, initiatives and plans to deliver new woodlands where they can best contribute to flood risk management (FRM) and Water Framework Directive (WFD) targets, in addition to generating many other benefits for society. Woodland creation, however, is not without risks and care will be required in site selection to ensure that planting does not increase flood risk by synchronising, rather than desynchronising downstream flood flows.

There are extensive opportunities within the catchment for woodland creation or the improved management of existing woodlands to mitigate downstream flood risk and improve water quality, including:

- 2,851 km^2 (57% of catchment) of priority sites for woodland planting to reduce downstream flood risk, comprising 2,550 km^2 of wider woodland, 204 km^2 of riparian woodland and 97 km^2 of floodplain woodland (Map 38)

- 561 km^2 (11% of catchment) of priority land in failing or vulnerable water body catchments subject to one or more diffuse agricultural pollution pressures (phosphate, nitrate, pesticides and sediment) (Map 38)

- 284 km^2 (6% of catchment) of priority land with opportunities for woodland planting to tackle both flood risk and one or more diffuse agricultural pollution pressures; 32% (94 km^2) of this land is free from all sensitivities (Map 39)

- 1,734 ha of priority land with opportunities for woodland planting to reduce both flood risk and all four identified diffuse agricultural pollution pressures; 63% (1,099 ha) of this land is free from all sensitivities

- 39 river water bodies containing sub-catchments with >20% conifer forest cover where the scale of felling could potentially increase local flood risk or reduce water

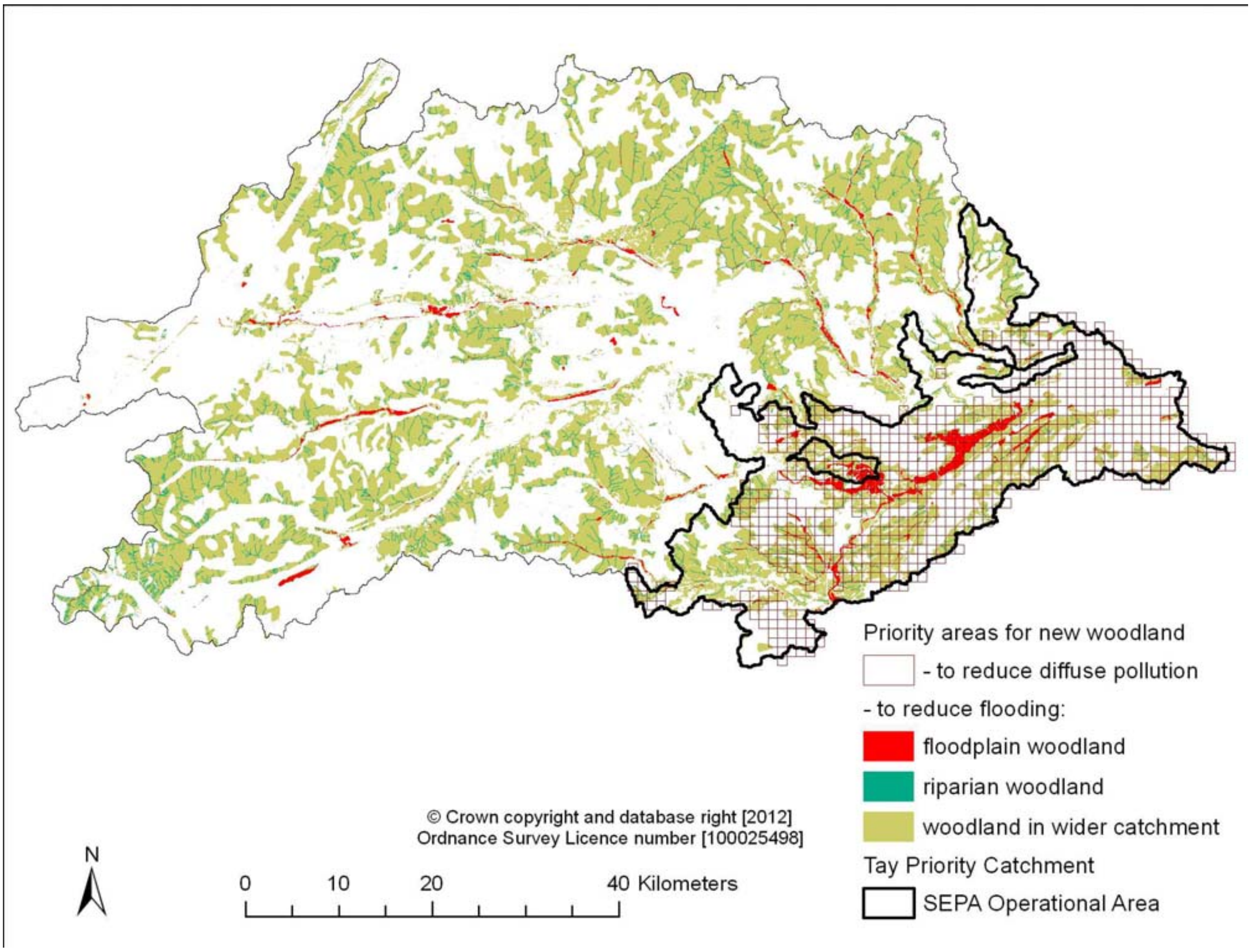
quality; two loch water bodies where felling and restocking might contribute to acidification (subject to confirmation of vulnerability); 2,952 ha of riparian land where conifer woodland remains within 20 m of the river network; and an extensive area where large-scale planting of conifer or short rotation forestry crops could potentially pose a risk to future water resources due to the higher water use of trees.

These opportunities are not evenly distributed across the catchment, being particularly skewed to the lowland southeast part of the Tay. The scope for multiple water benefits are concentrated in this agricultural dominated area. Locally, dual water benefits for FRM and reducing one or more diffuse pollutants are greatest in the catchments of the Dean Water, Coupar Burn, Ordie Burn, St Martins Burn and the lower part of the River Ericht. There is a large degree of overlap between the identified priority land for woodland creation and existing regional strategies, plans and projects designed to promote land use change or improve land management to mitigate flooding and diffuse pollution, including SEPA's ten Potentially Vulnerable Areas for flooding and Operational Area to address diffuse pollution pressures.

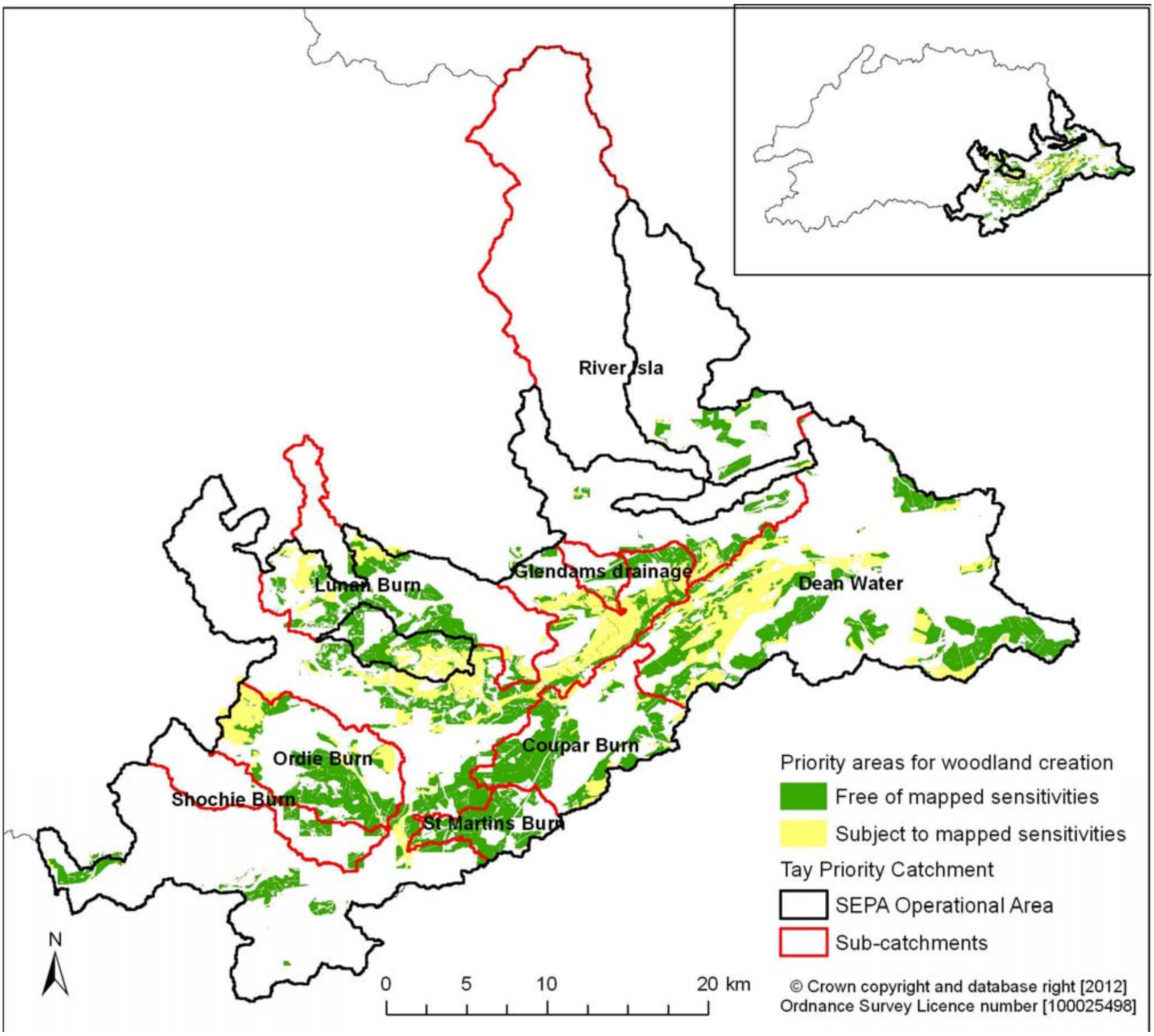
It is recommended that partners and other regional stakeholders use these maps and spatial data to target locations where woodland planting can provide the greatest benefits to water at the sub-catchment scale. This includes using the identified opportunities to better integrate woodland into existing 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 the provision of recreation and carbon, so that opportunities to further widen the range of benefits from planting can be realised.

The study notes that changes will be required to the Scottish Rural Development Programme to promote better targeting of woodland creation for water and achieve a sufficient level of planting to make a difference at the sub-catchment scale. This includes raising the value of woodland grants and supporting smaller planting schemes, the latter being especially important for tackling agricultural diffuse pollution pressures, which tend to be greatest on arable land. While land values and crop prices will greatly constrain the scope for woodland creation on such land, it is thought that small scale planting targeted to riparian buffers and along pollutant pathways could make a significant difference, while having a limited impact of agricultural incomes. 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 for water.

Finally, it is recommended that one or more case studies are established within the catchment to demonstrate and help communicate the value and benefits of woodland creation for water. A number of good candidate sites are available where it should be possible to achieve a sufficient level of woodland creation to enable the benefits for FRM and mitigating diffuse pollution to be quantified. On paper, the Dean Water sub-catchment appears to offer the greatest potential as it has the largest extent (18,966 ha; 79%) of priority land, with a total of 3,660 ha (15%) that could address all four diffuse pollutants and 7,466 ha (31%) both diffuse pollution and FRM. However, there may be greater scope for making a difference in the smaller sub-catchment of St Martin's Burn, which has the greatest proportion of land for addressing both WFD and FRM (1,242 ha; 53%), as well as 209 ha (9%) available for planting to reduce the four diffuse pollutants.



Map 38 Combined map of priority areas for woodland creation to address FRM or WFD



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List of Abbreviations

BAP: Biodiversity Action Plan

DWPAs: Drinking Water Protection Areas

EA: Environment Agency

F&WG: Forests and Water Guidelines

FCS: Forestry Commission Scotland

FRM: flood risk management

GES: Good Ecological Status

GIS: Geographical Information System

GWB: Groundwater body

HOST: Hydrology Of Soil Types

LCA: Land Capability for Agriculture

LFRMPs: Local Flood Risk Management Plans

LWB: Loch water body

LWD: Large Woody Debris

NFI: National Forest Inventory

NFM: natural flood management

NIRAMS: Nitrogen Risk Assessment Model for Scotland

NVZ: Nitrate Vulnerable Zone

PSI: Proportion of Sediment-sensitive Invertebrate index

PSYCHIC: Phosphorus and Sediment Yield Characterisation in Catchments

PVAs: Potentially Vulnerable Areas

RBMPs: River Basin Management Plans

RWB: River water body

SAC: Special Area of Conservation

SEPA: Scottish Environment Protection Agency

SPA: Special Protection Area

SPR: Standard Percentage Runoff

SRDP: Scotland Rural Development Programme

SSSI: Site of Special Scientific Interest

WFD: Water Framework Directive

1. Objective

To provide GIS spatial datasets and maps which identify opportunities for woodland creation and improved management of existing woods to reduce diffuse pollution and flood risk in the River Tay Priority Catchment.

2. Background

Scotland is endowed with an abundance of high quality water, the preservation of which is vital for the well-being of the nation's people and all other life forms, from the fish living within the waters to the birds that thrive in its surroundings. However, a range of anthropogenic pressures damage and threaten the water environment in some areas and work needs to be done to restore and protect this key resource. The Scottish Government has embodied its commitment to water protection through its legislative and regulatory regimes, a major component of which is implementation of the European Union Water Framework Directive (WFD). Transposed into Scots Law in 2003, it provides a framework for the protection of all water bodies including rivers, canals, lochs, estuaries, wetlands, groundwaters and coastal waters. Key aims are to prevent the deterioration of water quality and resources, promote the sustainable use of water, mitigate the effects of floods and droughts, and achieve good chemical and/or ecological status in all surface and ground waters. Implementation is facilitated by River Basin Management Plans (RBMP), supported by programmes of measures to tackle pressures.

Whilst significant progress has been made towards improving the condition of affected water bodies across Scotland, assessments indicate that about 40% continue to fail the environmental standards required to support good ecology, with diffuse pollution identified as one of the most important water management issues (SEPA, 2012a).

The main diffuse pollutants affecting waters are phosphorus, nitrate, pesticides, sediment, ammonia and faecal microorganisms. Agriculture is the primary source and thought to be responsible for nearly half of water bodies across Scotland failing due to diffuse pollution, a total of 495 water bodies (SEPA, 2007). Commercial forestry can also act as a pressure on the water environment if poorly designed and managed. It is thought to contribute to 75 failing water bodies, mainly due to conifer crops having been planted too close to watercourses.

Scotland's approach to addressing diffuse pollution is described in the Rural Diffuse Pollution Plan (DPMAG, 2011). This identifies over one hundred catchments with failing waters that require catchment-based solutions. Fourteen of these, including the River Tay catchment, have been prioritised for attention in the first RBMP due to risks posed to human health (by impacting on drinking and bathing waters) and designated sites.

The primary aim of the Priority Catchment approach is to implement a range of land-based measures to reduce diffuse pollution, either by tackling pollutant sources or interrupting delivery pathways. A key measure recommended by the Scotland RBMP is to install buffer zones, including of woodland, to intercept and treat nutrient and pesticide pollutants from adjacent agricultural land (SEPA, 2009a). The beneficial role that woodland can play in this regard is highlighted by Nisbet *et al*. (2011a & b) in a review of the subject commissioned by the Environment Agency (EA) and Forestry Commission (FC). The review concluded that there is strong evidence to support woodland creation in appropriate locations to mitigate diffuse pollution and help achieve other WFD related objectives.

Woodland can help prevent or reduce diffuse pollution through a number of mechanisms, including:

- Substitution: woodland is a much less intensive land use compared to agriculture, with very infrequent and small inputs of fertiliser and pesticides, and low levels of site disturbance.
- Interception: woodland canopies can provide a barrier to airborne pollutants such as ammonia and pesticides, while the well-structured nature of woodland soils help to receive and retain dissolved or suspended pollutants in runoff (e.g. nitrate, phosphate and sediment), reducing delivery to watercourses.
- Immobilisation: complex chemical interactions take place in organic-rich woodland soils that can help to immobilise pollutants.
- Uptake: root uptake is the first step in a number of remedial processes, for example contaminant uptake followed by transpiration into the atmosphere (phytovolatilisation) or translocation within the plant itself (phytoextraction).
- Biodegradation: biodegradation of contaminants may be enhanced within the root zone, including nitrate removal by microbial-mediated nitrate reduction; this can be a particularly important process in the hyporheic zone, where ecological and hydrological processes occur at the interface between groundwater and surface water.
- Woodland is also recognised as having an important contribution to make to flood mitigation. The Flood Risk Management (Scotland) Act 2009 introduced a new, more sustainable approach to managing flood risk that requires greater consideration to be given to the role of natural flood management (NFM). According to Nutt (2012), woodland offers a number of NFM techniques that can help to mitigate downstream flooding, including upland afforestation, gully planting, riparian planting, floodplain planting and the artificial placement of large woody debris (LWD) dams within streams. These act in various ways to reduce and/or delay the downstream passage of flood flows, including through increased water use, promoting rainfall infiltration into the soil, stabilising river banks and increasing channel and floodplain hydraulic roughness.

Other water related benefits provided by woodland creation include:

- Temperature regulation: the provision of riparian shade can reduce thermal stress to sensitive freshwater life (e.g. salmonid fish), and thereby help to reduce the threat posed by climate warming.
- River morphology: a multi-layered canopy of native riparian woodland and associated inputs of dead wood and leaf litter can improve channel form and river function. Riparian woodland can also help to protect river banks through tree rooting and by excluding livestock.
- Habitat connectivity: fragmented habitats can increase species isolation and extinction leading to reduced biodiversity; woodland can provide effective corridors along which species can move from the watercourse throughout the wider catchment.

Opportunities for woodland creation to benefit water are constrained by many factors, not least economics. It is therefore imperative that planting is targeted to the most effective locations where it can best benefit society. 'Opportunity mapping' has been developed to help identify these locations and promote more integrated catchment management. The method can be applied across a range of scales, from assessing opportunities for planting at a strategic regional or river basin level down to the practical farm/field scale.

This report describes how opportunity mapping was used to assess opportunities for woodland creation to reduce diffuse pollution and flood risk within the River Tay Priority Catchment in Scotland. The approach comprised three strands: identifying constraints and sensitivities to woodland creation; assessing the scope for woodland planting to reduce flood risk; and identifying opportunities for woodland creation to address diffuse pollution pressures affecting surface water bodies and groundwater resources. Account was also taken of potential water trade-offs associated with woodland creation and where changes to the design and management of existing woodland could benefit flood risk management (FRM) and WFD objectives. A series of maps and tabulated data are provided that identify priority areas for woodland creation to benefit water. The report also provides a number of recommendations on next steps to try and deliver benefits on the ground.

3. Study Area

The River Tay catchment (Map 1) covers an area of 4,970 square kilometres and is the largest river catchment in Scotland, stretching 193 km from the northern slopes of Ben Lui to the Firth of Tay. It is drained by a total of 180 rivers and 27 lochs, among the largest of which are the Rivers Tay, Tummel, Garry and Isla, and Lochs Ericht, Lyon, Rannoch, Tay, and Tummel. The majority of rivers rise in the mountainous high plateau of the Grampian Highlands and flow south east across the Highland Boundary Fault to the East Central Lowlands (Map 2).

The geology of the catchment (Map3) is split by the Highland Boundary fault. To the north-west are the uplands formed by hard, acid igneous and metamorphic rocks, dominated by granites, psammites, pelites and quartzite. This contrasts sharply with the broad flat plains of softer sedimentary rocks to the south-east, mainly comprising sandstones overlain by glacial and alluvial drifts. Soil types reflect the variation in geology and topography, with the uplands covered by acid peats, peaty podzols and peaty gleys, the valley basins by humus-iron podzols, and the lowlands by deeper, more fertile, brown forest and alluvial soils (Map 4).

Land capability for agriculture (LCA) is dictated by the soils and geology. The uplands are dominated by rough grazing with improved grassland in valley bottoms, while the best land is centred in the south-east, where there are large areas of intensive arable cropping (Maps 5 & 6). Woodland and plantation forestry extend over 15% of the catchment and occupy the steep valley side slopes and lower hills (Map 7). Heath, bog and montane habitats cover the hill tops and higher mountains. A number of the lochs and rivers are used for hydroelectricity generation, while upland areas are attracting increasing attention for major windfarm developments. Population density is very low throughout most of the catchment and concentrated in the lowlands of the south-east in the towns of Blairgowrie, Kirriemuir, Forfar and Perth, along with the associated road and rail network (Map 8).

There are a total of 206 individual water bodies in the catchment, a significant proportion of which are impacted by abstraction, flow regulation, morphological alterations and point or diffuse source pollution (SEPA, 2010). Diffuse pollution is the dominant issue in the lowland, south-east part of the catchment, where fifteen rivers, six lochs and two groundwaters have been degraded by a range of diffuse pollutants (SEPA, 2012b). This area has been classified as a special ‘Operational Area’ by SEPA as a way of focusing resources to tackle diffuse pollution in the most impacted catchments. Local surveys by SEPA staff of ~1000 km of the River Tay and its tributaries within the operational area identified over 950 breaches of diffuse pollution control legislation, the majority of which were associated with agricultural activities, in particular, land cultivation and livestock poaching and erosion.

The River Tay catchment is heavily designated, comprising 13 Drinking Water Protection Areas (DWPAs), 18 Special Areas of Conservation (SACs) and 9 Special Protection Areas (SPAs). It is also designated under the EU Freshwater Fish Directive and as a Natura 2000 site for Atlantic salmon, sea lamprey, river lamprey, brook lamprey, clear-water lochs and otters; freshwater pearl mussel is another important protected species. There are 106 nationally important Sites of Special Scientific Interest (SSSIs), including Rannoch Moor, which is the most extensive area of western blanket and valley mire in Britain. Most of the lower Tay is designated under the Nitrates Directive as a Nitrate Vulnerable Zone (NVZ) for groundwaters.

The recent National Flood Risk Assessment shows that there are a number of communities at risk of flooding throughout the River Tay catchment, stretching from Tyndrum in the west to the major town of Perth in the east (SEPA 2011a; 2011b). A total of 10 Potentially Vulnerable Areas (PVAs) have been identified, containing 1,342 residential and 275 non-residential properties vulnerable to flooding (Map 9). These figures are expected to rise significantly in the next 50 to 100 years due to climate change.

4. Methods

4.1 Approach to GIS mapping

Opportunities for woodland planting to contribute to flood mitigation and a reduction in diffuse pollution within the River Tay catchment were identified using a GIS mapping assessment. This was based on the approach originally developed for FRM 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 to incorporate the benefits of woodland for reducing diffuse water pollution (Broadmeadow & Nisbet, 2010c; Broadmeadow & Nisbet, 2011) and further developed for this study.

The current project draws heavily on spatial datasets prepared by SEPA under their FRM and WFD programmes. It also uses modelled datasets of pollution loss to water derived from the Diffuse Pollution Screening Tool developed for SEPA by ADAS, JHI and HR Wallingford (SNIFFER, 2006).

4.2 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 or in appropriate locations on Scheduled Ancient Monuments. Their inclusion reflects their highly sensitive nature and restricted scope for woodland planting to play a significant part of any flood mitigation or water quality improvement scheme. The list of constraints comprised the following:

- Urban areas, including villages, towns and cities
- Roads
- Railway infrastructure
- Scheduled Ancient Monuments
- National Grid gas pipelines
- National Grid overhead cables
- Open water

- Existing woodland
- Deep peat (>50 cm depth)

The combined dataset was used to remove areas that would be unsuitable for significant woodland planting (Map 10). Scheduled Ancient Monuments were protected by adding a fixed buffer (30 m), as recommended by the FC's Forests and Historic Environment Guidelines (FC, 2011a). Wider buffer zones may be required to preserve the setting of a particular scheduled monument, which would be determined during specific site assessments. Deep peat soils were included to reflect potential issues over the impact of planting on soil carbon stocks, depending on the nature of planting and woodland management.

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, sites close to flood defence and urban infrastructure, and areas scheduled or recognised for their nature conservation, historic or cultural importance. The full list is as follows:

- Best agricultural land (LCA grade 1 & 2)
- Floodplain buffer around urban centres and along roads
- Land protected by flood defences
- Sites of proposed windfarms
- Ministry of Defence land
- RAMSAR sites
- SAC
- SPA
- SSSI
- National Nature Reserves
- RSPB Reserves
- Battlefields
- National Parks
- National Scenic Areas
- Land above the natural tree line (>500 m AOD)

- Undesignated Biodiversity Action Plan (BAP) Habitats (e.g. Wetlands, Upland Heath & Moor, and Blanket Bog)

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 (Map 11). 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.

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 or adjacent to the floodplain 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 when an application is made.

There are several sensitivities which were not included in the combined dataset because the available spatial data did not define the location of the feature with sufficient precision. This includes land protected by existing or proposed flood defences as these features were only available as a point dataset. Such land should be considered as a sensitivity to reflect the reduced scope for woodland planting to mitigating downstream flooding (due to having little effect on flood conveyance). These areas would not normally be considered a priority for planting for FRM unless there were plans to remove or breach the flood defences to increase flood storage and promote interactions with any planted woodland. This factor will need to be taken into account at the local level when considering individual applications for woodland creation. 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.

No information was available on the location of any flood storage washlands, which would normally be considered a sensitivity because planting here would provide no FRM benefit and could actually reduce the actual volume of flood storage (although the impact is likely to be small). If planting was proposed within washlands for water quality or biodiversity gains, an important issue would be the likely frequency and depth of flooding. Some tree species are more sensitive than others to inundation and care would be required in the design and management of these woodlands to secure establishment and sustain growth. Guidance on this issue is provided by FOWARA (2006).

Finally, the constraints and sensitivities for which spatial data are available were brought together in Map 12 to show the distribution of land potentially available for woodland planting in the region.

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

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.

4.3.1 Floodplain

Planting within floodplains is thought to offer the greatest potential for downstream flood mitigation and therefore the first step was to define the extent of the floodplain where woodland could interact with flood flows. SEPA's indicative floodplain maps were selected for this purpose. Map 9 delineates the fluvial flood zones defined for flood events with a 1% (1:100) and a 0.1% (1:1000) probability of occurring in any year. The 1:1000 Flood Zone was selected as the boundary of the floodplain to better represent the potential area at risk from inundation if new woodland was effective at raising upstream flood levels due to a backwater effect.

The next step was to remove areas affected by the constraints defined in Section 4.2, resulting in a map showing areas within the Flood Zone that are potentially suitable for planting floodplain woodland for flood mitigation (Map 13). 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). Map 14 shows the distribution of small (<2 ha), medium (2-50 ha) and large (>50 ha) parcels of land with potential for planting floodplain woodland.

4.3.2 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 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 the flood storage capacity of river channels.

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 (Map 15). 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.

4.3.3 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 and sealing. Following the removal of the listed constraints, the identification of priority locations for planting was based on an assessment of the hydrological properties of soils and the susceptibility of soils to structural degradation by livestock poaching.

This drew on the following datasets:

- The Hydrology Of Soil Types (HOST) (Boorman *et al*., 1995)
- Standard Percentage Runoff (SPR) based on the HOST classification
- Poach Class based on the HOST classification

These are described below:

HOST: The HOST system was developed to classify soils according to their hydrological behaviour (Map 16; Table 1). HOST is a conceptual representation of the hydrological processes in the soil zone. All soil types (Soil Series) 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 <2 m depth)
- a soil (or soil and substrate) which contains an impermeable or semi-permeable layer <1 m 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.

Soil Series	HOST Class	SPR (%)	Area (km^2)	% of catchment	Physical Soil Description
43, 165	4	2.0	29	1	Free draining brown forest soils
97, 98, 100, 186, 273	5	14.5	299	6	Humus iron podzols
44, 276, 492, 493, 495	6	33.8	48	1	Brown forest soils; humus iron podzols with gleys
1	7	44.3	109	2	Free draining alluvial soils
29, 127, a32, 507, 523, 3D, 3E	12	60	224	1	Peaty gleys, podzols and rankers
20	13	2.0	28	1	Humus iron podzols with impermeable layer within 100 cm
19, 116, 241, 497	14	25.3	242	5	Peaty and humic gleys
9, 10, 11, 21, 22, 23, 26, 28, 30, 31, 101, 117, 118, 119, 123, 126, 131, 135, 154, 182, 185, 244, 245, 246, 253, 499, 500, 501, 502, 504, 506, 509, 510, 518, 521, 522, 524, 527	15	48.4	1,448	29	Peaty soils over slowly permeable substrate
239	16	29.2	82	2	Humus iron podzols
6, 12, 14, 25, 27, 96, 122, 125, 134, 136, 147, 193, 195, 251, 255, 256, 257, 472, 475, 498, 503, 505,508, 520, 525, 530, 532, 533, 534	17	29.2	1,094	22	Peaty and subalpine soils on impermeable substrate
41, 237, 274, 368, 414, 490	18	47.2	398	8	Brown forest soils
33, 34, 35, 474, 488, 512, 514, 551	19	60.0	327	7	Shallow & slowly permeable peaty subalpine soils
15, 36, 137, 195, 258, 515	22	60.0	88	2	Impermeable alpine rankers and lithosols
41, 149, 238, 275, 488, 491	24	39.7	56	1	Slowly permeable, peaty and humic gleys
4E	28	60	98	2	Impermeable (gleying <40cm from surface)
513	29	60	286	6	Subalpine peat

Table 1. The hydrological properties of the soils of the catchment

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 that are likely to make an increasing contribution to the generation of flood flows (Map 17).

Poach class: The HOST classification deals primarily with water movement but since the basis of the classification is the physical structure and configuration of the soil profile, it can also be used to underpin other physical and hydrological models. Harrod (1998) used HOST to classify the vulnerability of lowland grassland soils to poaching by livestock and this system was applied to the River Tay catchment (Map 18). Poaching leads to surface compaction and waterlogging, increasing the risk of rapid surface runoff.

A combination of SPR and vulnerability to poaching was used to classify soils in terms of their propensity to generate rapid runoff and thus to prioritise areas for woodland planting in the wider catchment to aid flood management (Table 2; Map 19).

Priority for planting	HOST - SPR	Sensitivity to structural degradation: Poach Risk Class	Proportion of catchment
Low	L <25% L <25%	L – Slight to Moderate M - High	10%
Medium	M >25% M >25% L <25%	L – Slight to Moderate M - High H – Very High to Extreme	27%
High	M >25% H >50% H >50% H >50%	H – Very high to Extreme L – Slight to Moderate M - High H – Very High to Extreme	63%

Table 2. Classification of soils by their propensity to generate rapid surface runoff

4.3.4 Prioritising floodplain and riparian zone for woodland creation

Floodplain and riparian land were prioritised for planting for downstream flood mitigation where this comprised soils with a high propensity to generate rapid runoff. Map 20 shows the distribution of the priority areas for planting floodplain, riparian and wider woodland within the catchment.

4.3.5 Combined map

Map 21 relates the priority areas for planting floodplain, riparian and wider woodland to the location of PVAs and hydropower dams, which will influence the effectiveness of planting for FRM. It is important to note that in some locations planting could have the opposite outcome of increasing flood risk where the delaying effect of woodland synchronises, rather than desynchronises downstream flood peaks. This factor would need to be checked during the assessment of individual woodland planting applications.

4.4 Identification of suitable areas for woodland creation to reduce diffuse pollution

The mapping of woodland opportunities to address diffuse pollution in the catchment was based on SEPA WFD datasets and modelled assessments of pollution loads to watercourses. Priority was given to land draining to failing river and loch water bodies (RWBs & LWBs) and groundwater bodies (GWBs). Individual water bodies are attributed with a unique identifier, which allows the spatial data to be linked directly to other WFD data sources such as classification and typology, risks and pressures, designations, current status and proposed objectives.

Priority locations for woodland creation were considered to be land draining to failing water bodies in which the reason for failure has been identified as diffuse pollution from agricultural sources, either through direct measurement or an assessment of risk. A recently published assessment of the WFD water bodies in the River Tay catchment identified 15 RWBs, 2 GWBs and 12 LWBs that have been degraded by diffuse pollution, with another 13 RWBs at risk (SEPA 2012). Attention was confined to those diffuse pollutants that could be potentially reduced by woodland planting, namely phosphate, nitrate, sediment and pesticides (Nisbet *et al*., 2011a).

The identification of priority areas for individual pollutants drew on the best available information on agricultural pollution sources and pathways, and the effects of diffuse pollution on the aquatic ecology. Spatial data for modelled losses of pollutants (nitrogen, phosphorus and suspended sediment) from agricultural land to watercourses were used to determine the distribution of pollutant sources draining to failing water bodies. This relied on the Diffuse Pollution Screening Tool developed for SEPA by ADAS, JHI and HR Wallingford (SNIFFER, 2006). The tool utilises a range of simple models informed by more complex models such as PSYCHIC (Phosphorus and Sediment Yield Characterisation in Catchments) and NIRAMS (Nitrogen Risk Assessment Model for Scotland) to provide estimates of pollutant pressures and annual loads delivered to waters on a 1 km^2 grid scale across Scotland. Diffuse pollutant loads are generated for individual pollutants for a range of land uses. The mapping work described below used the estimated pollutant loads associated with agricultural land use.

4.4.1 Identification of areas failing WFD due to diffuse pollution pressures

PHOSPHORUS

Map 22 illustrates the annual modelled loss of phosphorus in kg/ha/y across the catchment derived from agricultural land use via surface runoff, drain flow and seepage to groundwater. Values were then regrouped into low, medium and high classes for the purpose of identifying priority areas for woodland creation (Map 23). Thresholds of 0.5 kg P/ha/y and 1.0 kg P/ha/y were selected as class boundaries based on WFD phosphate concentration standards.

Phosphorus is a physico-chemical quality element that is directly measured in surface waters and contributes to the WFD assessment of ecological status by comparing with environmental quality standards set for catchment typology. SEPA has identified 15 RWBs and 6 LWBs that are currently failing Good Ecological Status (GES) due to phosphate plus another four RWBs with rising trends in P concentration indicative of a future threat. Map 24 shows the distribution of these failing and at risk water bodies in the catchment and Map 25 the component 1 km grid squares predicted by the screening tool to have the highest phosphorus losses to watercourses (>1 kg/ha/yr). The latter were defined as priority areas for woodland creation to address diffuse P pollution from agriculture. Despite the modelled high phosphorus losses in the southwest of the catchment (Maps 22 & 23), diffuse pollution is not an issue in the area (Map 24); this apparent discrepancy is thought to be due to the screening tool giving too high a weighting to connectivity/delivery factors.

SEDIMENT

The distribution of annual total sediment loss in kg/ha/yr is illustrated in Map 26 and grouped by low, medium and high classes in Map 27 for the purpose of identifying priority areas for woodland creation. Thresholds of 250 kg/ha/yr and 500 kg/ha/yr were selected for low-medium and medium-high class boundaries, respectively. A sediment delivery rate of 500 kg/ha/y was used by the EA to define RWBs in England at risk from diffuse sediment pollution in their initial catchment characterisation.

Environmental standards remain undefined for sediment and this element is not included in the WFD assessment of GES for surface water bodies. However SEPA have developed the PSI (Proportion of Sediment-sensitive Invertebrate) Index as an assessment tool to determine the degree to which riverine sites are impacted by sediment. The PSI tool is based on a classification of macroinvertebrate groups by their known vulnerability to fine sediment (Seal, 2012). This identifies four RWBs as being impacted by sediment pollution and another 11 at risk (Map 28). The 1 km grid squares with the highest sediment losses (>500 kg/ha/yr) lying within these water bodies were selected as priority areas for woodland creation to address diffuse sediment pollution from agriculture (Map 29).

NITRATE

There is currently no environmental quality standard for nitrate in surface waters and thus it does not directly contribute to the assessment of water body status. However, it remains a serious issue for drinking water supplies with much of the lower catchment classified as a NVZ. Map 30 shows the modelled nitrogen loss from agricultural land in surface runoff and drain flow plus seepage to groundwaters, while Map 31 regroups the data into low, medium and high classes using class boundary thresholds of 5 kg N/ha/y and 10 kg N/ha/y, respectively.

Three GWBs currently fail GES due to their chemical classification (Map 32), two of which are degraded due to high nitrate concentrations (SEPA 2012b). The extent of the nitrate vulnerable area is shown in Map 32; within the NVZ there are 28 RWBs failing GES due to a biological element where the cause of failure is unknown. In the absence of more specific data on individual RWBs failing due to diffuse nitrate pollution, the catchments of these failing RWBs and the two identified GWBs were selected as the areas at greatest risk (Map 33). The component 1 km grid squares exerting the highest nitrate pollution pressure (>10 kg/ha/y) defined the priority area for woodland creation to address diffuse agricultural nitrate pollution.

PESTICIDES

Generally, pesticide concentrations found in surface waters from 'normal agricultural use' are insufficient to affect ecological status but they remain a very important concern for the protection of drinking water supplies. Robust standards are set for drinking waters and pesticide levels are regularly monitored to assess compliance. No spatial data for pesticide losses were available for this project but historical chemical sampling shows the presence of pesticides commonly used in agriculture in the rivers of the lower catchment. SEPA have identified six RWBs as being impacted by pesticides and another ten plus two LWBs at risk (Map 34). All of the 1 km grid squares lying within the catchments of these water bodies were identified as a priority for woodland creation to address diffuse pesticide pollution (Map 35).

MULTIPLE POLLUTANTS

The priority areas identified for woodland creation to help reduce each of the four individual pollutants derived from agriculture are combined in Map 36 to show where land use change could tackle multiple diffuse pollutants. The location of DWPAs is also displayed. Constraints to planting are removed in Map 37 to show opportunities for woodland creation within the priority areas in relation to the Tay Priority catchment Operational Area and key sub-catchments.

COMBINED PRESSURES

Map 38 shows the distribution of the priority areas for woodland creation for FRM in relation to those for reducing one or more diffuse pollutant pressures to surface waters or groundwater. Opportunities for planting to benefit both are displayed in Map 39, along with mapped sensitivities, the Operational Area and key sub-catchments.

4.5 Identification of areas where changes to the design and management of existing woodland could benefit FRM and WFD

Forestry and conifer plantations in particular can exert a number of pressures on the water environment. Some of these need to be addressed through changes to forest design and management at the catchment scale, including the potential for clearfelling and restocking to increase surface water acidification, and the risk of clearfelling contributing to higher peak flows and promoting nutrient release. Others require action at the local scale, such as the need to improve bankside morphology and riparian habitat by clearing back conifer crops from streamsides. The FC's Forests and Water Guidelines (F&WG) describe a range of measures to address these issues. The following maps were developed to aid targeting of the measures:

Map 40 – river water bodies failing GES due to acidification. The F&WGs place restrictions on the extent of new planting, restocking and felling of both conifer and broadleaved woodland within surface water bodies that are failing or at risk of failing GES due to acidification. Work is ongoing to revise the methodology for addressing new planting and restocking but the method for felling is largely agreed. This requires that no more than 20% of the catchment of individual permanent watercourses (deminimis of 100 ha) within failing or at risk water bodies is to be felled within any three-year period. No RWBs are affected by acidification in the River Tay catchment but there is uncertainty over the status of up to six LWBs. These remain to be sampled to confirm their condition but in the interim a 10 m DTM was used to define boundaries for the catchments (>100 ha in area) of all permanent watercourses draining to the lochs and the extent of forest cover determined from the National Forest Inventory (NFI). Map 40 shows the distribution of component catchments with >20% woodland cover; those with >20% conifer cover are more likely to pose an issue due to shorter rotations and larger scale of felling. If the LWBs are found to be at risk, these locations will merit closer attention to determine whether the planned timing of felling (based on forest plans) is likely to breach the threshold rate and thus require amending.

Map 41 – river water bodies with sub-catchments with >20% woodland cover. The F&WGs also recommend the application of a 20% threshold on the extent of clearfelling in any three-year period to control the potential impact on peak flows and phosphate runoff within vulnerable areas. This map shows the location of sub-catchments with >20% woodland cover in relation to PVAs identified in the National Flood Risk Assessment and catchments of water bodies impacted or at risk from P pollution. These were derived using the 10 m DTM and NFI. Once again, the likelihood of clearfelling breaching the 20% threshold will be greatest for conifers.

Map 42 – watercourses with existing conifer forest within 20 m of bankside. The F&WGs recommended that conifers should be cleared from stream banks to create a riparian native woodland buffer zone when access allows. This work is likely to be programmed within existing forest plans but the map provides a check showing the areas that may require attention. Early clearance is recommended within water bodies vulnerable to acidification to promote ecological recovery.

Map 43 – water bodies potentially at risk from the higher water use by trees. The F&WGs recommend avoiding large-scale planting of conifer or short rotation forestry crops in areas where the water supply is being, or is planned to be, fully exploited or in catchments which fail to sustain adequate environmental flows. This map identifies the areas at greatest risk in terms of catchments exploited for hydroelectric power generation, as well as GWBs failing WFD objectives due to poor quantitative status and RWBs with poor hydrological status due to abstraction or flow regulation for hydropower.

5. Results

Calculated values for the extent and distribution of priority areas for woodland creation to help tackle downstream flooding and selected diffuse pollutant pressures within the River Tay catchment and a number of individual sub-catchments are included in this section to highlight key opportunities for woodland planting to benefit water.

5.1 Constraints and sensitivities to woodland creation

A total of 1,897 km^2 or 38% of the catchment is excluded from woodland planting due to the constraints listed in Section 4.2. In addition to the constraints, a further 2,188 km^2 or 44% of the catchment is subject to sensitivities that may restrict the scale and character of any woodland creation. Details of the individual constraints and sensitivities are listed in Table 3.

The extent of deep peat (almost 20% of the catchment) and existing woodland cover (15%) represent the dominant constraints to woodland planting. Population density is very low, particularly in the west, and together with the road and rail network affect only 3% of the land area. Most of the urban infrastructure is concentrated within the lowlands in the southeast of the catchment.

A large proportion of the catchment, 73%, is identified as potentially sensitive to woodland creation. The largest individual sensitivity is land above 500 m, affecting almost a third of the catchment. Much of the area is subject to some form of national or international designation to protect the culturally important landscape, habitats and species of national and international conservation value. Some 36% of the catchment lies within a National Park or National Scenic Area and another 21% is covered by European designations. Although only just over 2% comprises Grade 2 agricultural land this is all concentrated in the southeastern lowlands.

In terms of the fluvial floodplain, a total of 136 km^2 or 51% of the Flood Zone (area at risk from a 1 in 1000 year flood event) is excluded from woodland planting due to constraints. However open water including lochs and reservoirs occupies 106 km^2 of this, leaving 161 km^2 of the floodplain not under permanent water. Around 18% of this is affected by constraints, 9% due to existing woodland cover. A further 65% is subject to sensitivities, mainly arising from the buffer zone applied to urban areas and roads. This indicates that most planting proposals within the floodplain are likely to require detailed consideration of the impact of the backing-up of flood waters on local buildings and transport, which is likely to influence the scale and nature of planting.

Constraint or sensitivity	Area (km^2)	%
Deep Peat	993	19.9%
Existing Woodland	765	15.3%
Open Water	106	2.1%
Road and rail network	112	2.2%
Urban infrastructure	50.1	1.0%
Gas pipeline & Wayleaves under overhead electrical cable	25.6	0.5%
Sites of Antiquity [NMR no spatial data]	N = 11,350 sites	na
Total area of all constraints for which spatial data are available:		
Catchment	1,897	38.0%
Floodplain (excluding open water)	28.8	17.9%
International conservation designations:	Combined – 1,030	20.6%
RAMSAR	18.2	<1%
SPA	773.8	15.5%
SAC	511.4	10.2%
National conservation designations:		
SSSI	802	16.1%
NNR	56.9	1.1%
Protected and culturally important landscapes:		
National Scenic Areas	800	16.0%
National Parks	1010	20.2%
Battlefield	4.5	<1%
Grade 2 agricultural land	113.5	2.3%
Land above 500m	1,520	30.5%
Undesignated BAP Habitats:		
Wet heath and moor	27.9	<1%
Dry Heath and moor	503.9	10.1%
Upland heath and moor	999.2	20.0%
Blanket bog	517.2	10.4%
Wetlands	2.9	<1%
Buffers for roads and urban areas in the floodplain.	109.7	2.2%
Area of all combined sensitivities for which spatial data are available:		
Catchment	3,633	72.8%
Floodplain (excluding open water)	104.8	65%

Table 3. Constraints and sensitivities to woodland planting in the catchment (note that several of the features overlap)

5.2 Opportunities for woodland creation to reduce downstream flood risk

A total of 2,851 km^2 or 57% of the River Tay catchment is identified as a priority area for woodland creation to reduce downstream flood risk (Map 20). This land is relatively evenly distributed across the catchment, with the majority comprising heath and montane upland habitats, but also a significant area on arable and improved grassland in the lower Tay (Map 6). Most of the priority land (89% or 2,550 km^2) involves potential wider woodland, targeting soils with a high propensity to generate rapid runoff or extreme/high vulnerability to livestock poaching (Maps 17 & 18). Around 204 km^2 comprises priority riparian woodland, which is similarly well distributed throughout the catchment. Priority floodplain woodland totals 97 km^2, most of which (56%) is concentrated within the River Isla catchment.

Map 21 shows the distribution of priority land in relation to the PVAs identified by the National Flood Risk Assessment (SEPA, 2011a). The catchment contains 10 areas at risk from flooding for which Local Flood Risk Management Plans (LFRMPs) are being prepared (SEPA, 2011b). Spatial data for the PVAs was not available for this project but using images available on the SEPA website, the WFD RWBs which equate to the PVAs were selected and used to define the upstream catchment draining to each.

A breakdown of the extent of woodland creation opportunities upstream of consecutive PVAs is provided in Table 4. All PVAs include significant areas of priority land for woodland creation to aid FRM. The greatest opportunities lie within the River Isla catchment draining to the PVA centered on Stanley, Luncarty and Bankfoot, although most of the affected 441 residential and 37 non-residential properties are flooded by the River Tay below the confluence with the River Isla. The next PVA with the largest area of upstream priority land is at Aberfeldy on the main stem of the River Tay, where 379 residential and 80 non-residential properties are at risk. Once again, the flooding here appears to be from the main river and sizeable upstream areas of woodland creation would be required to exert a significant impact on flood risk.

Attention may therefore be better directed at providing flood protection through planting within the PVAs where smaller communities are at risk within upstream reaches of the Tay or within tributary catchments (e.g. within the Blair Atholl, Blairgowrie, Alyth or Crianlarich PVAs or at Coupar Angus within the River Isla catchment). It would be easier to achieve the required level of woodland creation to make a difference in these locations and the communities are more likely to be undefended by traditional flood defences due to economics. As an example, extensive areas or priority land are potentially available in the River Garry catchment above Blair Atholl, including 19,080 ha of wider woodland and 270 ha of floodplain woodland. Similarly, there are extensive opportunities for planting wider woodland (20,991 ha) and floodplain woodland (956 ha) on priority areas upstream of Blairgowrie within the River Ericht catchment.

Spatial data were not available to assess the influence of existing water transfers, flow diversions and water storage associated with the numerous hydroelectric power schemes in the wider catchment. The impact of the operation of these on river flows would need to be taken into account when considering the suitability of any priority sites for planting to reduce downstream flood risk. The role of any lochs and reservoirs within individual catchments would also need to be considered.

Catchment draining to Potentially Vulnerable Area	Area of PNW (ha)	Area of PNFW (ha)	Priority area for flood risk management (ha)		
			PFW	PRW	PWW
1. Crianlarich	5,736	364	45	888	4,803
2. Aberfeldy [1]	45,471	2,465	921	4,156	40,394
3. Loch Rannoch	13,500	409	313	821	12,367
4. Blair Atholl	20,703	335	270	1,354	19,080
5. Pitlochry [3 & 4]	56,917	1,454	1,045	3,814	52,058
6. Dunkeld [2 & 5]	113,518	5,527	2,703	8,712	102,102
7. Forfar & Kirriemuir	520	433	58	5	457
8. Alyth	14,162	738	558	953	12,651
9. Blairgowrie	23,410	1,088	956	1,463	20,991
10. Stanley [7, 8 & 9]	171,597	11,767	6,947	11,730	152,921
11. Perth [all of the above ≡ Tay catchment]	17,374	1,499	1,047	3,920	11,000

Table 4. Extent and distribution of opportunities for woodland creation to reduce flood risk within the upstream catchments of Potentially Vulnerable Areas in the River Tay catchment (numbers in brackets indicate nested catchments, the areas of which are also included in the row total)

PNW: potential new woodland

PNFW: potential new floodplain woodland

PFW: priority floodplain woodland for FRM

PRW: priority riparian woodland (outside the floodplain) for FRM

PWW: priority wider woodland for FRM

The LFRMPs are due to be completed by December 2013. Woodland creation is a potentially effective NFM measure and consideration should be given to the scope for planting on the identified priority areas to help reduce flood risk for affected communities. The ambition in these areas should be to encourage land owners to plant woodland in appropriate locations to slow runoff and reduce/delay flood flows, thereby helping to restore natural flood attenuation processes.

5.3 Opportunities for woodland creation to reduce diffuse pollution

A total of 56,062 ha or 11.3% of the catchment comprises opportunities within priority areas for planting to reduce one or more diffuse pollutants (Table 5). Maps 25, 29, 33 and 35 show that diffuse pollution is primarily an issue in the lowland southeast part of the catchment, where arable cropping and livestock grazing are the dominant land uses. Assessments by SEPA indicate that around two-thirds of the total phosphorus load, 95% of sediment, 76% of nitrogen and almost all pesticides are derived from agriculture, mostly via surface runoff (although losses for nitrate are also important to groundwater). This area presents extensive opportunities for woodland creation to reduce multiple diffuse pollution pressures on the water environment (Maps 36 & 37). A total of 5,677 ha of land is a priority for all four diffuse pollutants, the majority of which is free from constraints (4,975 ha; 88%) and sensitivities (3,905 ha; 69%) (Table 5).

DWPAs have been established by SEPA to highlight the vulnerability of local water supplies and to help manage activities that could have a detrimental impact. Although only impacted by one diffuse pollutant (pesticides), planting would be particularly beneficial for improving drinking water quality within two DWPAs in the lower Tay.

Number of diffuse pollutants	Potential for woodland creation (ha) in priority areas to reduce multiple diffuse pollutants		
	Total free from constraints (ha), [% of Catchment]	Area (ha) subject to sensitivities	Area (ha) free from sensitivities
1	26,776 [5.4 %]	8,842	17,934
2	18,196 [3.7 %]	5,146	13,049
3	6,116 [1.2 %]	1,381	4,735
4	4,975 [1.0 %]	1,070	3,905
Total	**56,062 [11.3 %]**	**16,439**	**39,623**

Table 5. Extent of priority land for planting to reduce one or more diffuse pollution pressures within the River Tay catchment.

Table 6 provides a breakdown of opportunities for woodland creation on priority land within the Tay Priority Catchment Operational Area, including a number of key sub-catchments known to be impacted or at risk from diffuse pollution. A large proportion (51%) of the operational area is potentially available for planting to reduce at least one diffuse pollutant (Map 37). The same applies to most of the sub-catchments, five of which (Glendams, Dean Water, Ordie Burn, St Martins Burn and Coupar Burn) have between a 77-81% cover of priority land free from constraints (ranging between 825-18,966 ha). These provide good candidates for achieving a sufficient level of woodland creation to demonstrate/quantify through a programme of monitoring the benefits for mitigating diffuse pollution. On paper, the Dean Water sub-catchment would appear to be the best site as it has the largest extent of priority land (22,563 ha), covering over 95% of the catchment, most of which (18,966 ha) is free from constraints to woodland planting (however 5,077 ha (21%) comprise LCA Grade 2 agricultural land). There are also extensive (3,660 ha) opportunities for woodland creation to address all four diffuse pollutants. However, the large size of the catchment would require relatively extensive planting to exert an impact at this level, although there is likely to be greater scope within individual tributary catchments. A better candidate could be the smaller sub-catchment of St Martin's Burn, which has the greatest proportion of land for addressing both WFD and FRM (53%), as well as 209 ha (9%) available for planting to reduce the four diffuse pollutants.

SEPA WFD management catchment	Area (ha)	Opportunities for woodland planting on priority land (ha and %)		
		to reduce one or more diffuse pollutants	to reduce four diffuse pollutants	for both WFD (at least one diffuse pollutant) and FRM
Catchment	497,122	56,062 (11.3%)	4,975 (~1%)	28,444 (5.7%)
Operational area	103,949	55,149 (53%)	4,936 (4.8%)	26,699 (25.7%)
Sub-catchments within the operational area of the Tay Priority Catchment				
Coupar Burn	6,793	5,221 (77%)	0	2,835 (42%)
Dean Water	24,110	18,966 (79%)	3,660 (15%)	7,466 (31%)
Glendams drainage	1,023	825 (81%)	0	330 (32%)
Lunan Burn	9,509	5,216 (55%)	119 (1.3%)	2,451 (26%)
Ordie Burn	6,472	5,100 (79%)	0	2,863 (44%)
River Isla	36,528	4,305 (11.8%)	32 (<1%)	1,453 (3.9%)
Shochie Burn	3,819	401 (10%)	0	383 (10%)
St Martins Burn	2,358	1,805 (77%)	209 (8.9%)	1,242 (53%)

Table 6. Extent of opportunities for planting on priority land to reduce one or more diffuse pollution pressures within the Tay Priority Catchment Operational Area.

The main sensitivity affecting the scope for new planting to address diffuse pollution in the Operational Area is the highly valued nature of the Grade 2 agricultural land (Map 11). Farm economics will make it difficult to achieve any sizeable planting within this area but there is significant potential for more targeted, smaller scale planting to make a difference. In particular, planting within riparian and across slope edge of field buffers, on infiltration basins and along pollutant pathways can provide a barrier to and help intercept and remove pollutants in runoff, reducing their delivery to watercourses. Action is required to try and persuade land owners to use these opportunities to integrate more woodland into their farm units to provide water and other environmental benefits. For riparian planting, an additional sensitivity that needs to be taken into account is the floodplain buffer assigned to protecting roads and urban centres from the possible backing-up of floodwaters, although this is more of an issue for larger-scale floodplain planting.

5.4 Consideration of opportunities in relation to existing strategies, projects and plans

There are a number of national land use and land management based strategies and plans that help to shape and guide the use of woodland to reduce flood risk and improve water quality in the River Tay catchment. One of the Key Themes of the Scottish Forestry Strategy (SE, 2006) is to protect the environmental quality of the nation's natural resources and the strategy recognises the positive contribution that well planned and managed woodland can make in this regard. The strategy supports the development of SEPA's RBMPs and the use of woodland measures to improve water quality as well as aid FRM.

The Scottish Government's Land Use Strategy (SG, 2011), Forestry Commission's Rationale for woodland expansion (FC, 2009a) and recent report of the Woodland Expansion Advisory Group (FC, 2012) all promote woodland creation for multiple benefits, but also highlight the importance of minimising the loss of prime agricultural land (Grades 1, 2 & 3.1; Map 5). This is a key issue for the lower Tay and other intensively farmed catchments as it is the agricultural management of this land that is the primary source of diffuse pollution and often acts to increase rapid runoff and reduce flood storage. Opportunities for woodland planting to benefit water are therefore usually greatest here. The solution is to focus on smaller-scale, targeted planting on prime land and all documents call for more effective integration of woodlands and farming in this regard (e.g. by providing woodland buffers and shelterbelts along field margins and watercourses).

The Scotland Rural Development Programme (SRDP) has a key role to play in helping to deliver more targeted woodland planting for water benefits. The current Rural Development Contracts – Rural Priorities scheme provides funding support for a number of woodland options to help address Regional Priorities, which in the case of the Tay includes reducing diffuse pollution, protecting against erosion and contributing to sustainable flood management. However, there are restrictions on funding support for small-scale planting which will need to be addressed if opportunities are to be realised. There is also a strong case for better integrating the scheme with River Basin and FRM Plans, which will hopefully be addressed by the next 2014-2020 SRDP programme.

The Tay Forest District Strategic Plan (2009-13) (FC, 2009b) and Draft Perth and Kinross Forest Plan (2012-2032) (PKC, 2012) recognise the potential contribution that forestry can make to sustainable flood management and achieving RBMP objectives, although their focus is more on the management of existing woods and forests, rather than on woodland creation. There is a need to incorporate the identified priority areas for planting into the Draft Forest Plan and then integrate this with the next Tay Area Management Plan (2015-21) to help prioritise planting opportunities to deliver WFD objectives. The current Tay Area Management Plan (2009-15) (SEPA, 2009b) provides a time line for the percentage of surface water bodies achieving good or high status to increase from the present 48% to the target of 95% by 2027. The mapping project should be used to inform the planned improvements required to meet this goal.

Similarly, there is a need to link forest plans with the Strategic Flood Risk Assessment (TAYplan, 2011) and forthcoming Local Flood Risk Management Plans (SEPA, 2011b). The TAYplan calls for action to find sustainable solutions to mitigate flood risk that allow for climate change and are 'no regret', such as planting trees to assist with managing surface runoff. There is a good case to further raise awareness of how woodland creation can contribute to FRM, including as part of sustainable drainage systems. It would also be helpful to include information on the scope for NFM measures such as woodland planting to reduce flood risk on the 'Datasheets' for each PVA identified by the National Flood Risk Assessment (Section 8, Tay; SEPA (2011b)).

A number of local projects have already been established to help deliver woodland benefits for water. The identified priority riparian and floodplain areas will inform the current two-year FC Perth & Argyll Conservancy/SEPA project on promoting riparian woodland planting along the River Isla. The mapping project should also help to build on SNH's Natural Care Scheme Lunan Lochs project (SNH, 2006) by showing where woodland planting could be effective for reducing nutrient loadings to these sensitive waters.

There is scope to influence a number of wider planting initiatives in the River Tay catchment to increase water services. This includes the Hill Sheep and Native Woodland project (Morgan-Davies *et al*., 2008) aimed at better integrating farming and forestry in the western part of the Tay, and the National Trust for Scotland project to expand native woodland in the Ben Lawers National Nature Reserve. Likewise, the Tayside Local Biodiversity Action Plans (Tayside Biodiversity Partnership, 2002) for native pinewoods and upland oakwoods should take account of the identified opportunities.

5.5 Priority areas for woodland creation to provide both FRM and WFD benefits

Map 39 shows that opportunities for woodland creation to benefit both FRM and WFD are concentrated within the lowland southeast of the catchment. Opportunities are relatively evenly distributed across this area, although with a number of distinct clusters. Locally, the greatest scope for the dual water benefits arise in the catchments of the Dean Water, Coupar Burn, Ordie Burn, St Martins Burn and the lower part of the River Ericht. There are a total of 28,444 ha of land (5.7% of the Tay catchment) where planting could benefit FRM and at least one diffuse pollutant pressure, and 1,734 ha both FRM and all four diffuse pollutants. Sensitivities affect 32% of the dual area for one diffuse pollutant and are dominated by Grade 2 land and floodplain buffers, as described in Section 5.3.

5.6 Opportunities for the re-design and management of existing woodland to benefit FRM and WFD

5.6.1 River water bodies failing GES due to acidification

Map 40 shows the location of the six LWBs in the River Tay catchment potentially impacted by acid deposition. Two of the six are partly afforested and the map also displays where the existing level of forest cover may exceed 20% of any tributary sub-catchment (>100 ha in area) within these. Approximately half of the identified sub-catchments comprise broadleaved or mixed woodland, which will typically be managed under a low impact silviculture regime and thus unlikely to breach the 20% threshold for felling in any three year period. The greatest risk of breaching this threshold will be in the 54 sub-catchments with extensive conifer cover. If subsequent measurements show the two LWBs to be impacted by acidification, the forest management plans covering the component forest blocks (around Loch Tummel and Loch Errochty in the Tay Forest Park) will require checking to ensure that planned felling does not pose a significant acidification pressure on local waters. They would also need to be checked to see whether forest restocking presents a risk, as described by the Forest and Water Guidelines (FC, 2011).

5.6.2 River water bodies with sub-catchments with >20% woodland cover

Map 41 shows the distribution of vulnerable RWBs with forested sub-catchments (>20% woodland cover), where the scale of felling could pose an increased risk of downstream flooding or phosphate enrichment. As was the case for acidification, those sub-catchments dominated by broadleaved or mixed woodland are likely to present a low risk of felling exceeding the 20% threshold in any three-year period. The main issue will concern those sub-catchments with significant conifer cover within PVAs or RWBs vulnerable to nutrient enrichment. For FRM, much will depend on the location of properties or other assists at risk of flooding, as this will determine the size of the upstream catchment and therefore whether the scale of felling could pose a risk. The forest management plans for these forest blocks need to be checked and amended where the felling threshold is likely to be exceeded for vulnerable assets, habitats or watercourses.

5.6.3 Watercourses with existing conifer forest within 20 m of bankside

Map 42 illustrates the distribution and extent of conifer stands within 20 m of the river network. There are a large number of sites across the catchment amounting to a total area of 2,952 ha. Individual woodland management plans relating to these should be reviewed and opportunities taken to restore sites to native broadleaved woodland at the earliest opportunity. Priority should be given to sites where conifer forest has been planted up to the waters edge, especially if downstream waters are shown to be vulnerable to acidification. Consideration should be given to retaining a few conifer trees (where these are likely to be stable) to provide some shade and shelter until the riparian zone re-vegetates.

5.6.4 Water bodies potentially at risk from the higher water use by trees

The flow of water draining from nearly the whole catchment is impacted by either impoundment for use in hydroelectric power generation, or abstraction for drinking water supply, industry and agriculture (Map 43). In the lower Tay, 20 RWBs, one LWB and four GWBs have been degraded due to overabstraction and/or changes to the natural flow (SEPA, 2012b). Planting could exert a significant additional pressure on water flows in these areas due to the potentially higher water use by trees, especially of conifers (Nisbet, 2005). Consequently, consideration needs to be given to the impact on future water yield, including the effects of climate change, before carrying out large scale planting of conifers or short rotation forest crops upstream of affected water bodies.

6. Conclusions

The River Tay is one of fourteen Priority Catchments in Scotland identified by the Scottish Environment Protection Agency (SEPA) and partner organisations for restoration and protection. It is impacted by a number of major water issues, with over 1,300 residential and 270 non-residential properties vulnerable to flooding and 26% of river and loch water bodies currently failing to meet the required Good Ecological Status (GES) due to diffuse pollution. A recent review of relevant research provides strong evidence of the ability of woodland creation to mitigate these pressures by reducing and delaying flood waters, limiting pollutant loadings and retaining diffuse pollutants. Commissioned by SEPA and Forestry Commission Scotland (FCS), the objective of this study was to identify priority areas for woodland creation and the improved management of existing woodlands to reduce downstream flood risk and help restore damaged waters.

A wide range of spatial datasets were accessed from partners, particularly SEPA, and used to generate a large number of maps and supporting GIS shapefiles showing priority areas for planting. The results provide a strong basis for developing and refining regional strategies, initiatives and plans to deliver new woodlands where they can best contribute to flood risk management (FRM) and Water Framework Directive (WFD) targets, in addition to generating many other benefits for society. Woodland creation, however, is not without risks and care will be required in site selection to ensure that planting does not increase flood risk by synchronising, rather than desynchronising downstream flood flows.

There are extensive opportunities within the catchment for woodland creation or the improved management of existing woodlands to mitigate downstream flood risk and improve water quality, including:

- 2,851 km^2 (57% of catchment) of priority sites for woodland planting to reduce downstream flood risk, comprising 2,550 km^2 of wider woodland, 204 km^2 of riparian woodland and 97 km^2 of floodplain woodland

- 561 km^2 (11% of catchment) of priority land in failing or vulnerable water body catchments subject to one or more diffuse agricultural pollution pressures (phosphate, nitrate, pesticides and sediment)

- 284 km^2 (5.7% of catchment) of priority land with opportunities for woodland planting to tackle both flood risk and one or more diffuse agricultural pollution pressures; 49% (144 km^2) of this land is free from all sensitivities
- 1,734 ha of priority land with opportunities for woodland planting to reduce both flood risk and all four identified diffuse agricultural pollution pressures; 63% (1,099 ha) of this land is free from all sensitivities
- 39 river water bodies containing sub-catchments with >20% conifer forest cover where the scale of felling could potentially increase local flood risk or reduce water quality; two loch water bodies where felling and restocking might contribute to acidification (subject to confirmation of vulnerability); 2,952 ha of riparian land where conifer woodland remains within 20 m of the river network; and an extensive area where large-scale planting of conifer or short rotation forestry crops could potentially pose a risk to future water resources due to the higher water use of trees.

These opportunities are not evenly distributed across the catchment, being particularly skewed to the lowland southeast part of the Tay. The scope for multiple water benefits are concentrated in this agricultural dominated area. Locally, dual water benefits for FRM and reducing one or more diffuse pollutants are greatest in the catchments of the Dean Water, Coupar Burn, Ordie Burn, St Martins Burn and the lower part of the River Ericht. There is a large degree of overlap between the identified priority land for woodland creation and existing regional strategies, plans and projects designed to promote land use change or improve land management to mitigate flooding and diffuse pollution, including SEPA's ten PVAs for flooding and Operational Area to address diffuse pollution pressures.

It is recommended that partners and other regional stakeholders use these maps and spatial data to target locations where woodland planting can provide the greatest benefits to water at the sub-catchment scale. This includes using the identified opportunities to better integrate woodland 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 the provision of recreation and carbon, so that opportunities to further widen the range of benefits from planting can be realised.

The study notes that changes will be required to the Scottish Rural Development Programme to promote better targeting of woodland creation for water and achieve a sufficient level of planting to make a difference at the sub-catchment scale. This includes raising the value of woodland grants and supporting smaller planting schemes, the latter being especially important for tackling agricultural diffuse pollution pressures, which tend to be greatest on arable land. While land values and crop prices will greatly constrain the scope for woodland creation on such land, it is thought that small scale planting targeted to riparian buffers and along pollutant pathways could make a significant difference, while having a limited impact of agricultural incomes. 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 for water.

Finally, it is recommended that one or more case studies are established within the catchment to demonstrate and help communicate the value and benefits of woodland creation for water. A number of good candidate sites are available where it should be possible to achieve a sufficient level of woodland creation to enable the benefits for FRM and mitigating diffuse pollution to be quantified. On paper, the Dean Water sub-catchment appears to offer the greatest potential as it has the largest extent (18,966 ha; 79%) of priority land, with a total of 3,660 ha (15%) that could address all four diffuse pollutants and 7,466 ha (31%) both diffuse pollution and FRM. However, there may be greater scope for making a difference in the smaller sub-catchment of St Martin's Burn, which has the greatest proportion of land for addressing both WFD and FRM (1,242 ha; 53%), as well as 209 ha (9%) available for planting to reduce the four diffuse pollutants.

7. Recommendations

The following recommendations would help to secure the identified opportunities for woodland creation and the improved management of existing woodland to deliver flood risk management and Water Framework Directive benefits:

1 SEPA and partner organisations use the maps and supporting datasets to help target future woodland creation within priority areas to make a difference at the sub-catchment scale. It is timely to incorporate the opportunities into the draft Perth and Kinross Forest Plan (2012-2032) and in due course to inform the next WFD Tay Area Management Plan (2015-2021), forthcoming Local Flood Risk Management Plans and future revisions to the Strategic Flood Risk Assessment (2011) and TAYplan (2012). One or more regional dissemination events should be held to promote the findings of this work and to discuss how to pool available resources to achieve implementation.

2 The maps should continue to be refined as new monitoring data become available. In particular, there is significant scope for improved targeting of woodland creation to reduce agricultural diffuse pollutant pressures by incorporating information gained from recent catchment surveys/walks.

3 There is a good case for updating the application of the diffuse pollution screening tool to capitalise on improvements in modelling (e.g. PSYCHIC). This would improve the accuracy of modelled data and aid the mapping of diffuse pollutant pressures at the field scale.

4 The impact of existing water transfers, flow diversions and water storage associated with the numerous hydroelectric power schemes in the River Tay catchment need to be taken into account when considering the suitability of any of the identified priority sites for planting to reduce downstream flood risk.

5 The vulnerability of affected properties and scope for upstream woodland creation to protect these should be examined for the ten Potentially Vulnerable Areas. This should include an assessment of the potential for planting 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. These assessments would help to refine the large area of identified priority land for planting to reduce flood risk.

6 FCS should use the maps showing sub-catchments with >20% woodland cover to check that felling plans will not breach thresholds set for the protection of water quality and to minimise the risk of increasing flood flows. Woodland plans should also be reviewed where conifer stands remain within 20 m of the river network and opportunities taken to restore sites to native riparian broadleaved woodland at the earliest opportunity

7 Further work is needed to raise the value of and improve the synergy between available incentives to secure land management change in desired locations. This includes working with partners to evaluate the full range of woodland ecosystem services and explore other sources of funding for investing in woodland creation.

8 The maps should be used to facilitate the establishment of one or more demonstration woodlands 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 future water management.

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