Forest Research

Demonstrating a rapid biodiversity assessment methodology to facilitate the management of multiple forest ecosystem services

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Forest Management Adaptation (AdaFor) Project

AdaFor is a two year (2013 – 2015) collaborative project between research organisations and local authorities in northern France and southern England under the Interreg IVA France (Channel) England Cross-border Cooperation Programme 2007-2015. The cross-border collaboration seeks to integrate a broad knowledge base and expertise to facilitate forest adaptation and improve forest resilience. The forestry sector today is under increasing pressure to adapt to an expanding demand for timber and woodfuel, the impacts of climate change, the conservation requirements for woodland ecosystems and the need to reduce management costs. Forest Research's principal contributions to the project are:

- To assess the influence of climate change on forests and provide advice on appropriate management practices
- To investigate ecosystem services provided by woodland and establish methods to enhance these services through management

The ADAFOR project is part funded by the European Union (European Regional Development Fund ERDF) within the framework of the European INTERREG IVA France (Channel) England Cross-border Cooperation Programme 2007-2015, under the priority to: 'Ensure a sustainable environmental development of the common space'; with the objective to 'Ensure a balanced management of the environment and raise awareness about environmental issues'. The Forest Research component is being provided through matched funding from the Forestry Commission through the climate change adaptation and biodiversity research programmes. We would like to acknowledge here also the co-operation of UMP Tilhill and the owners of our two case study woods Colin Hall (Land of Nod) and Penny Raynor (Hartley Mauditt).

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1. Background

Woodlands have the potential to provide a wide range of ecosystem services. These are typically categorised into provisioning, regulating, cultural and supporting services (Quine *et al*., 2011). Table 1 provides a list of the key ecosystem services in UK woodlands, including related goods and benefits. Woodland biodiversity, including genetic diversity, is recognised as a supporting service that underpins the other three groups of ecosystem services. Below-ground organisms carry out essential biogeochemical processes leading to the renewal of soil, plant nutrients and fertility, while above-ground organisms influence woodland dynamics and natural woodland regeneration. Where biodiversity is threatened, these essential processes are negatively impacted, compromising the quality and quantity of provisioning, regulating and cultural services. In a recent attempt to assign monetary value to woodland ecosystem services, biodiversity was among the highest valued for its environmental benefits (Table 2). The priority list of ecosystem services for England, Scotland and Wales following recent discussion with forestry policy officers (and FC Corporate and Forestry Support - C&FS) is indicated in Table 1.

Many woodland managers are interested to manage their woods for multiple purposes, thereby delivering a suite of ecosystem services. A questionnaire (Appendix 1) recently circulated among woodland owners at a meeting organised by the Institute of Chartered Foresters and Forestry Commission England (i.e. UK Forestry Society and Woodland Management Workshop – 27, February, 2014), revealed that more than 90 of 127 respondents confirmed a significant interest to manage their woods for not only timber, but also for biodiversity conservation, flood protection, carbon sequestration, soil protection, aesthetic appeal in the wider landscape and/or for the preservation of the woodlands historical value (Figure 1). All of the respondents also indicated that they were prepared to spend time assessing the biodiversity potential of their woodland, in some cases (27% of respondents), for more than three days if required (Figure 2). This implies an interest to follow-up on a biodiversity survey in order to make necessary management changes to protect and enhance the supporting role of biodiversity; this may include improving conditions for wildlife which is a primary concern.

Table 1: List of the key ecosystem services in UK woodlands, including related goods and benefits. A priority list of these is indicated based on consultations by the *Land Use and Ecosystem Services Research Group* at Forest Research with FC Corporate and Forestry Support (C&FS) and forest policy advisors in Wales, England and Scotland.

			Priority list of ecosystem services as defined by LUES steering group			
Type of Ecosystem Service	**Service**	**Goods & benefits**	**England**	**Scotland**	**Wales**	**GB (C&FS)**
Provisioning	Trees & other woodland vegetation (including peat)	Food for humans and livestock				
		Fibre				
		Fuel				
		Drugs/ chemicals				
		Ornamental				
	Woodlands and water supply	Supply/ storage				
	Animal products	Food / non-food				
Regulating	Climate	Mitigation e.g. carbon				
		Moderation e.g. shade				
		Adaptation (resilience/diversification)				
	Hazard	Flood control				
		Soil and water protection				
	Detoxification & purification	Noise reduction				
		Water quality				
		Air quality				
		Soil quality				
	Pests & disease	Predators/ competitors/ non-natives				
	Pollination					
Cultural	Environmental settings	Physical well-being				
		Mental restoration / escape and freedom				
		Recreation, enjoyment & fun				
		Sense of place; catalyst for social activity & cohesion				
		Livlihoods; contribution to the local economy				
		Sensory stimulation				
		Education / learning				
		Landscape improvements				
		Nature connectedness				
	Wild species diversity; biodiversity					
Supporting	Biodiversity					
	Nutrient cycling					
	Soil formation					
	Water cycling					
	Oxygen production					

Table 2: Valuation of social and environmental benefits of forests in Great Britain (2010 prices)

Environmental and social benefits	Annual value (£ millions)
Recreation	484
Landscape	185
Biodiversity	476
Carbon sequestration*	115
Air pollution absorption*	0.5
Total	**1,261**

* An approximation, since carbon sequestration, and probability of death and illness due to air pollution, varies over time. More carbon is sequestrated in early rotations than in later rotations, resulting in an annuity stream that is inconsistent over multiple rotations. Similarly for air pollution, that results in an individual's life being shortened by a few days or weeks at the end of the individual's life at some point in the future. More recent work puts a much higher value on the carbon sequestration benefits (Read et al. 2009).

Figure 1: Prioritisation of a range of woodland ecosystem services by forest managers (*N*=127 questionnaire respondents attending UK Forestry Society and Woodland Management Worksop – 27, February, 2014). Rating of each ecosystem service is high, medium, low or not an aim.

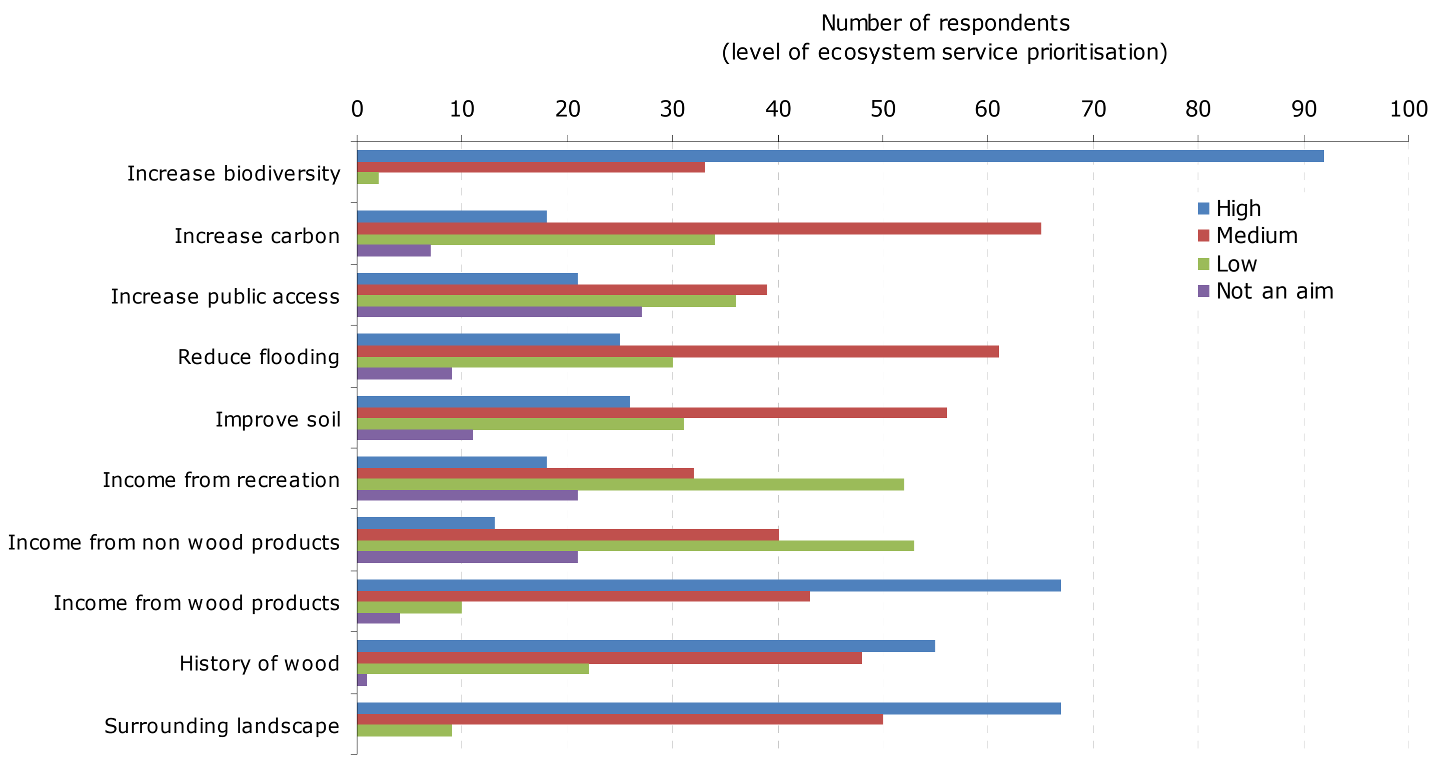
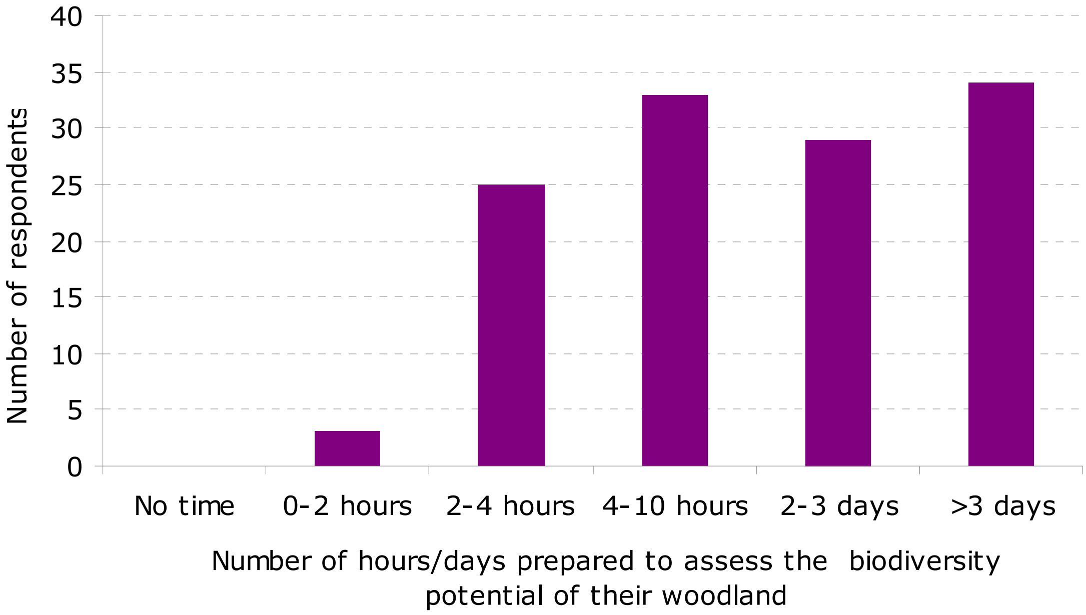


Figure 2: Time that forest managers are prepared to spend assessing the biodiversity potential of their woodland (*N*=127 questionnaire respondents attending UK Forestry Society and Woodland Management Worksop – 27, February, 2014).



However, for forest managers there is a balance to strike between the provision of ecosystem services and the management costs involved. In order to evaluate the costs and determine trade-offs, there is a need to be able to 1) evaluate the current status of ecosystem service delivery against target levels and 2) identify specific management action and possible changes in silvicultural practice that will allow for target ecosystem service delivery. Also, while an evaluation of the status of ecosystem service delivery is ideally conducted at large spatial scales (i.e. at least at the Forest Management Unit scale - FMU), management action is typically planned at the compartment and sub-compartment scales. Thus, there is a need for assessments of ecosystem service delivery to be transferable into management action at both the FMU and sub-compartment levels.

In this report we describe a methodology for evaluating the current 'potential' biodiversity status of woodland FMU's using two case study woodlands. The methodology includes presenting the results of biodiversity assessments in a manner that allows for easy interpretation to identify required management action for effective improvements in biodiversity at both the sub-compartment and FMU scales. We also explore in this report how the proposed changes in management activity for biodiversity gains might influence the delivery of two other ecosystem services (carbon sequestration and timber/woodfuel production).

Assessing Woodland Biodiversity

Assessing the current biodiversity status of a woodland and, consequently, determining where improvements might be made, is difficult to achieve (Lawton *et al*., 1998). Measuring biodiversity in its entirety is not feasible and as a result, biodiversity indicators are generally used instead as indirect, surrogate measures of 'potential' rather than actual levels of biodiversity. Biodiversity indicators such as deadwood volume or native tree species richness have proven, measured relationships with levels of specific associated biodiversity. When combined, these biodiversity indicators effectively provide a measure of the heterogeneity of the woodland environment. As a general rule of thumb, there is evidence to show that the more heterogeneous the environment the greater the variety of niche spaces that are available for colonisation by a greater diversity of individuals and species with unique habitat and resource requirements (Tews *et al.,*2004; Stevens & Tello, 2011). Some woodlands have inherent heterogeneity just based on their physical setting (Burnett *et al*., 1998). We also know that the more continuously wooded (through time), the more connected and the larger a woodland is, the greater the prospects for harbouring higher levels of biodiversity than less well connected, smaller and younger woodlands (Bailey, 2007; Lawton *et al*., 2010; Hodgson *et al*., 2009; 2011). Keystone structures such as veteran trees are also recognised to play a valuable role (Tews *et al*., 2004). While management of the woodland is at the compartment scale, attempting to improve conditions for biodiversity should additionally be considered at the whole woodland scale. In this way heterogeneity can be considered and maximised across the entire woodland, rather than simply at the stand scale.

In order to be of practical use to forest managers, biodiversity indicators need to be easy to assess, repeatable, inexpensive and ecologically meaningful (Ferris & Humphrey, 1999). Also, it is most useful if a suite of indicators are used for a combined assessment of potential biodiversity. This provides a more accurate means of assessing the comparative value of different woodlands for biodiversity (McElhinney *et al*., 2006) and facilitates the monitoring of the effectiveness of any forest management interventions. A number of authors have proposed such composite indices that are applicable at the FMU scale (Van Den Meersschaut & Vandenkerkhove, 1998; McElhinney *et al*., 2006; Larrieu & Gonin, 2008). Amongst these is the Indice de Biodiversité Potentielle (IBP) [Potential Biodiversity Index] (Larrieu & Gonin, 2008). While other indices often involve complex and time-intensive recording that requires some degree of specialist knowledge, the IBP is quick and easy to use and requires no specific level of expertise beyond the knowledge of native tree genera. The index includes a wide range of biodiversity indicators, many of which (e.g. deadwood) are recognised in international agreements as being important to forest biodiversity. It notably also includes context-specific indicators, such as woodland continuity and associated habitats (Larrieu & Gonin, 2008), which can greatly enhance woodland biodiversity but are frequently overlooked. The scores for the individual indicators, and their graphical depiction in radar diagrams, also assist with long-term monitoring and the easy identification of areas requiring improvement (Larrieu & Gonin, 2008). The IBP has the added advantage of having been widely tested and refined by its authors in woodlands throughout France (Larrieu & Gonin, 2011) and, though the authors state that it is applicable in Atlantic, continental and even European boreal regions (Larrieu & Gonin, 2008), we are unaware of its application in woodlands outside France.

The use of the IBP by forest managers has been reviewed using a questionnaire approach (Emberger, 2013). The outcome of this review work has highlighted areas for improvement and some key weaknesses (e.g. invasive species not included, scale of application is not clearly defined, vocabulary too technical). In this report we describe a biodiversity assessment methodology that is partly based on the IBP and that is designed to evaluate the current biodiversity potential of a woodland not only at the FMU scale, but also at the compartment and sub-compartment scales. We take account of the critiques of the IBP in developing our own woodland biodiversity assessment methodology.

2. Aims and Objectives

In this report we detail a survey methodology (i.e. the Rapid Woodland Biodiversity Assessment - RWBA) that allows for a rapid assessment of the current potential of a woodland, or given FMU, to provide habitat for biodiversity. A range of biodiversity indicators are used to gauge potential levels of biodiversity. These biodiversity indicators are rapid and inexpensive to assess and do not require any specific expertise beyond the ability to identify native and non-native tree and shrub species. Since actual biodiversity is not measured, the assessment can only describe 'potential' rather than 'actual' levels of biodiversity. The RWBA feeds back to the forest manager specific management steps that could be taken to further enhance biodiversity. Two case study woodlands with contrasting levels of management intervention and tree species composition were assessed using the RWBA methodology to demonstrate how biodiversity information is collected and interpreted. Furthermore, we demonstrate how specific changes in management for improved biodiversity provision impact on the delivery of other ecosystem service's such as timber or woodfuel production and carbon sequestration in the two case study woodlands.

Specific Objectives:

1) Devise an easy-to-use biodiversity survey methodology that will provide management advice on actions that can improve the biodiversity potential of a woodland at the sub-compartment and FMU scales.
2) Demonstrate the application of the rapid woodland biodiversity assessment methodology and interpretation of survey results on 2 case study woodlands with different levels of management activity.
3) Undertake an analysis of how proposed changes in the woodland management plans of the two case study woodland's influences timber/ woodfuel production and amount of carbon sequestered.

3. Methods

3.1 Case Study Woodlands

Two case study woodlands situated in southeast England close to the villages of Oakhanger in Hampshire and Churt in Surrey were used in this study. These were Hartley Mauditt Woodland (SU751 345; $51^0$07' N, $0^0$55' W), a 59 hectare FMU mostly comprising neglected mixed broadleaf coppice and Land of Nod Woods (SU848 374; $51^0$08' N, $0^0$47' W), a 37 hectare actively managed FMU comprising areas of pine plantation, chestnut coppice, thinned beechwood and mixed broadleaf. Hartley Mauditt FMU lies at approximately 100m a.s.l. on a poorly drained strip of Gault Clay situated between calcareous outcrops on one side and Lower Greensand on the other. The soil is heavy and seasonally waterlogged, often not drying in the summer in enclosed woodland areas. Land of Nod FMU lies at 150m a.s.l. on Cretaceous and Tertiary sand. The soils are well-drained with a bleached subsurface horizon and with areas of well-drained sandy and coarse loamy soils. Table 3 provides a list of all of the separate compartments making up these FMU's and includes details for each of these including the compartment area, main canopy tree species, planting spacing, planting year, yield class and Windthrow Hazard Classification (WHC) (UPM Tilhill, 2010a; b). There are 17 sub-compartments in Hartley Mauditt FMU and 32 in the Land of Nod FMU.

Table 3: Details of the Hartley Mauditt and Land of Nod FMU's by compartment and subcompartment (UPM Tilhill, 2010a; b).

Woodland/ FMU	Compartment	Sub-compartment	Area (ha)	Dominant Tree Species	Spacing	Planting year	Yield Class	WHC
Hartley Mauditt	1	A1	1.2	POK	1.8	1900	4	3
		A2	1.8	SB	2	1995	4	1
		B	1.4	SP	1.5	1956	12	1
		C	1.1	MB	1.2	1920	6	1
		D	1.1	JL	1.3	1958	12	1
		E	1.1	MB	3	2004	4	2
		F	1.0	BE	1.8	1961	12	1
		G1	0.2	OK	1.2	1890	8	1
		G2	1.1	JL	1.8	1958	12	1
	2	A	6.4	MB	1.8	1920	8	1
	3	A	11.2	MB	1.2	1920	8	3
	4	A	11.1	MB	1.8	1920	8	3
	5	A	6.6	MB	1.8	1920	8	3
	6	A	7.8	MB	1.8	1920	8	3
	7	A	2.7	MB	1.8	1920	8	1
		A2	1.0	OK	1.8	1983	6	1
		B	2.1	OK	3	1983	12	1
Land of Nod	1	A1	1.8	BE	2	1960	6	2
		A2	0.6	JL	2	1960	12	2
		B	0.9	EL	2	1977	12	2
		C	1.4	SCC	2.5	2000	6	2
		D1	2.2	MB	2	1900	4	2
		D2	1.4	MB	3	1987	6	2
		E	0.8	MC	2	1960	14	2
		F	0.7	EL	2	1971	12	2
		G1	1.3	SCC	2.5	2004	6	2
		G2	0.2	SP	2	1971	14	2
		H1	2.5	SP	2	1977	14	2
		H2	0.4	WH	2	1965	16	2
		I	0.4	MB	2	1900	4	2
		J1	0.4	WH	2	1966	16	2
		J2	2.0	SP	2	1966	14	2
		K	2.6	SP	2	1964	14	2
		L	1.4	SP	2	1966	14	2
		M	2.3	CP	2	1977	16	2
		N1	0.1	SP	2	1963	14	2
		N2	0.0	NS	1.8	1963	14	2
		N3	0.1	RC	2	1963	12	2
		P	1.1	CP	2	1983	16	2
	2	A	1.9	CP	2	1977	16	2
		B1	0.4	SP	2	1964	14	2
		B2	0.5	SP	2	1971	14	2
		C	0.9	SP	2	1966	14	2
		D	1.1	MB	2	1900	4	2
		E1	0.4	EL	2	1971	12	2
		E2	0.2	SCC	2.5	1971	6	2
	3	A	4.3	SP	2	1966	14	2
	4	A	0.3	BR	?			
		B	3.0	CP	2	1991	16	2

3.2 Rapid Woodland Biodiversity Assessment (RWBA)

3.2.1 RWBA Protocol

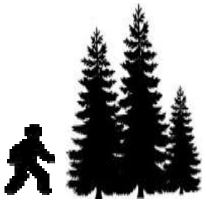
The rapid woodland biodiversity assessment (RWBA) involves a walk through the woodland, or FMU under assessment; biodiversity indicator information is collected during the course of the walk and also at fixed stopping points from temporary survey plots. The protocol and proposed list of biodiversity indicators used in the RWBA have been drawn up by combining elements of three different woodland survey methodologies that also require the collection of biodiversity indicator information. These are the National Forest Inventory UK (2014), the Index of Biodiversity Potential (IBP) (Larrieu & Gonin, 2008; 2011; Forêt Privée Française, 2014) and the Woodland Conservation Condition Survey (Lush *et al*., 2012). The RWBA has also been developed considering UK Forestry Standard recommendations for enhancing and protecting woodland biodiversity (FC, 2011).

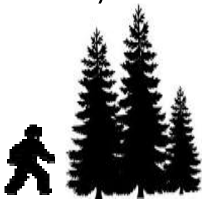
The route for the FMU walk and the location and number of fixed stopping points are planned in advance using a map and/or aerial photographs of the woodland and knowledge of the range of different woodland habitats present. The goal is to collect biodiversity indicator information from the existing range of woodland habitat, covering also examples of the range of distinct forest management units (i.e. forest compartments) present in the woodland. The route should pass, therefore, through the main areas of woodland habitat variation and the fixed stopping points should be located in representative examples of each type of woodland habitat. Where separate woodland compartments have very similar woodland habitat (e.g. mid-rotation monocultures of oak), it is only necessary to make a stopping point in one of these. As a general guide, ten fixed stopping points evenly marked along the route through the woodland is considered adequate in a moderately varied 30 hectare woodland (Lush *et al*., 2012). The number of fixed stopping points will inevitably vary, however, depending on the size of the woodland and level of variation in woodland habitat. A minimum of 5 stopping points is recommended in small and/or homogeneous woodlands and for larger, more heterogeneous woodlands, the number of stops should be capped at the number that can be surveyed in 1-2 days. Where survey plots are set up at predetermined stopping points to provide information for a given compartment or sub-compartment, it is important that the survey plot is located in an area that is representative of the compartment, or where this is not possible multiple survey plots may be needed to provide a clearer picture of the biodiversity potential of the compartment. For example, if standing deadwood and/or regeneration of native tree species have a very patchy distribution, multiple survey plots may be needed in areas of high abundance or no deadwood/ regeneration. Ideally, for best results, the assessment should be conducted at two different times of the year in order to collect biodiversity indicator information when most easily assessed. For example, lying deadwood is most visible in the winter/early spring.

A total of 19 biodiversity indicators are proposed to provide information about the biodiversity potential of the FMU being surveyed. These are listed in Table 2, along with definitions, assessment methods and the ideal time of year for assessment of each of the biodiversity indicators. As highlighted in Table 2, in some cases information about a particular biodiversity indicator is collected during the course of a woodland walk, with no need to set up survey plots, while in others a temporary survey plot is required. Six of the biodiversity indicators are context specific and cannot readily be manipulated by changes in management practice. They define, in other words the 'inherent' biodiversity value of the FMU. These biodiversity indicators are: Topographical variation, woodland connectivity, abundance of veteran trees, the presence of wetland habitat and rocky habitat and woodland continuity. The remaining thirteen biodiversity indicators are related to the structure and management of the woodland and can be altered with changes in management practice. These are: Temporary open space coverage, native tree species abundance, native tree species richness, native shrub species richness, regeneration abundance of native tree species, regeneration abundance of non-native tree species, vertical vegetation structure, variation in stem sizes, large standing deadwood abundance, lying deadwood volume, coarse woody debris (CWD) volume (multiple types), invasive species abundance and browsing pressure. All of the biodiversity indicators selected for inclusion in the RWBA are recognised as being positively associated with woodland biodiversity. The justification for the selection of many of these biodiversity indicators is outlined in detail by Larrieu & Gonin (2008) and is underpinned by evidence published research and the authors' expert opinion.

The information derived for each of the biodiversity indicators can be used to provide an assessment of biodiversity potential at the whole FMU scale. A selection of the indicators can additionally provide an assessment of biodiversity potential at the smallest woodland management scale (i.e. compartment, or sub compartment); these are primarily the indicators for which information is collected using survey plots. A system of scoring each of the biodiversity indicators has been devised (Table 4), where the highest score is 3 points and the lowest 0 points. These scores are based on published, accepted thresholds and expert opinion and references for each are given in Table 2. Where biodiversity indicator information is collected using a series of temporary survey plots set up during the course of the woodland walk (e.g. native tree species richness), biodiversity indicator scores are attributed at the plot level; these survey plot scores can be averaged across survey plots to get a single FMU score. It is not expected that high scores are received for all biodiversity indicators at the survey plot scale. There is an expectation, however, that an FMU with high biodiversity potential will receive high scores for all biodiversity indicators at the FMU scale. For those biodiversity indicators for which information is derived only after completing a circuit of the FMU and/or via a desktop study (e.g. topographical variation, woodland connectivity), a single whole FMU score is given. Forest managers can collect as many or as few of the proposed biodiversity indicators as they wish; however, the more indicators that information is collected for, the higher the resolution of the survey. Examples of the survey forms to be completed when collecting biodiversity indicator information on the woodland walk (i.e. whole FMU scale and survey plot scale) are given in Appendix 6

Table 4: List of biodiversity indicators, definitions, assessment methods and the scoring system. Graphic indicates if survey plot or walk through survey method is required.

Biodiversity Indicators	Definitions	Assessment method and timing	Score
Context-specific indicators			
(A) Topographical variation 	• Three slope categories are recognised (Burnett *et al.*, 1998): o <3% or no slope (flat terrain) o 3%-16.5% slope o >16.5% slope • Eight aspect categories are recognised (where slope of >3%): o North o Northwest o Northeast o South o Southwest o Southeast o West o East	**Method:** At each stopping point on the woodland walk note which slope and aspect category applies. A compass will help determine aspect and a clinometer or a hypsometer can be used to determine slope (see FR's SOP0348). **Timing:** Winter, early spring	0 = Flat terrain 1 = 2-3 slope categories, but only 1 aspect category 2 = 1-2 slope categories with ≥3% slope and 2 aspect categories 3 = 3 slope categories and 2+ aspect categories

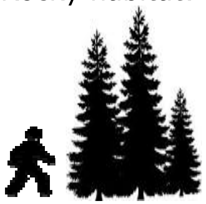
(B) Woodland connectivity 	A woodland is considered to be connected to other woodland where the border of the FMU runs into other woodland, or a hedgerow runs directly up to the border of the FMU. A woodland becomes 'isolated' where other woodland and 'corridors' or 'stepping stones' such as hedgerows and veteran trees are >3km away from the border of the FMU (Davies & Pullin, 2007; Humphrey & Bailey, 2012).	**Method:** Note the level of connectivity of the FMU using a combination of aerial photographs, maps and/or a walk around the perimeter of the FMU. **Timing:** Any time of year	0 = Isolated. No neighbouring woodland or hedgerow/ veteran trees within 3km. 1 = Some woodland or hedgerow/ veteran trees within 3km, but no directly connecting woodland. 2 = <50% of woodland is connected to other woodland 3 = >50% of woodland is connected to other woodland

(C) Abundance of veteran trees: 	• Veteran trees can be best identified (Lush *et al*., 2012) by: 1) their circumference at 1.5 m height which differs according to tree species[1]. Circumference can also be measured in terms of 'hugs'[2]. 2) the presence of particular features as listed below. Each tree should have at least three of these features to be classified as a veteran tree. o Major trunk cavities or hollowing. o Water pools in tree crevices. o Small holes in the trunk, larger branches or larger roots caused by decay. o Missing or loose bark. o Large quantities of dead wood in the canopy. o Areas where sap is seeping through the bark. o Crevices sheltered from direct rainfall. o Fungi on the trunk or larger branches. o Plants growing on the trunk or branches (not including mosses or lichens). • A localised distribution of veteran trees is when the majority of veteran trees occupy a single quarter of the woodland where the woodland is roughly split into four even parts. Veteran trees are widely distributed across a woodland where they are present across >25% of the woodland, occupying >1 quarter of a woodland.	**Method:** On a map of the woodland, note the location and number of veteran trees counted during the woodland walk. Additionally, record on the map any other known veteran trees present in the woodland. **Timing:** Any time of year	0 = <1 ha^{-1} 1 = 1-3 ha^{-1} 2 = >3 ha^{-1} but veteran trees have only a localised distribution 3 = >3 ha^{-1} and widely distributed across entire woodland (Humphrey & Bailey, 2012)

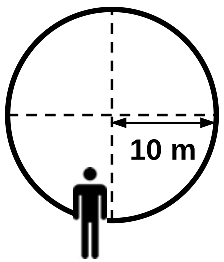
[1] Veteran tree circumference at 1.5m height according to tree species (note that in upland areas, veteran trees may not reach large stem circumferences):
≥150cm (1 hug): aspen, birch, hawthorn, hazel
≥225cm (1.5 hugs): Cherry, field maple, goat willow, grey willow, holly, hornbeam, rowan
>250cm (1.75 hugs): Alder, Scots pine
>300cm (2 hugs): Ash, oak, yew
>450cm (3 hugs): Beech, elm, Horse chestnut, limes, poplars, sweet chestnut, sycamore, other willows, other conifers

[2] An approximate guideline to measure the circumference of tree trunks 1.5m from the ground is in the form of 'hugs'. A hug is where an average adult can reach around the tree trunk and their fingers just meet. One hug is approximately equivalent to a trunk circumference of 150cm. One and a half hugs would be equivalent to a circumference of 225cm, whilst half a hug (i.e. where it is possible to reach around the tree with one arm and touch your chest) is equivalent to a circumference of 75cm. It may be useful to measure the first few trees using a tape to help calibrate the size of a surveyors hug.

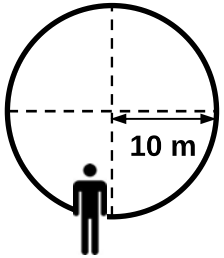
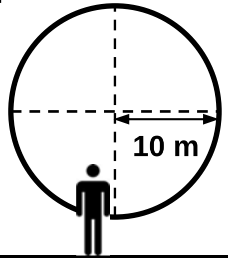
(D) Wetland habitat: 	• Types of wetland habitat include (Larrieu & Gonin, 2011; Lush *et al*., 2012): o Pool - a body of standing water less than 25 m². o Pond – a body of standing water 25 m² to 2 ha in area which usually holds water for at least 4 months of the year. o Lake - any inland water body larger than 2 ha. o River - running water more than 2.5 m wide. o Stream – running water less than 2.5 m wide. o Wet ditch - a man-made water body more than 20 times longer than it is wide, containing water at the time of survey. o Dry ditch – as above, but dry at the time of survey. o Bog/marsh or swamp – areas of ground permanently or seasonally saturated with water o Natural spring – water source naturally flowing from the ground • Wetland habitat can be within or immediately bordering woodland. • A localised distribution of wetland habitat is when the majority of wetland habitat occupies a single quarter of the woodland where the woodland is split into four even parts. Wetland habitat is widely distributed across a woodland where it is present across >25% of the woodland, occupying >1 quarter of a woodland.	**Method:** Note the types of wetland habitat present during the woodland walk and mark these on a map of the woodland. **Timing:** Winter/early spring	0 = absent 1 = 1+ type present. When combined, these have only a localised distribution. 2 = 1 type present and widely distributed across the woodland 3 = 2+ types present and at least 2 types are widely distributed across the woodland.

(E) Rocky habitat: 	• Types of rocky habitat include (Larrieu & Gonin, 2011): o Rocky ridge or rock face o Scree o Blocks > 20 cm/slabs/piles of stones; o Stone wall or ruin o Chasm, cave, or large rock fracture • Rocky habitat can be within or immediately bordering woodland. • A localised distribution of rocky habitat is when the majority of rocky habitat occupies a single quarter of the woodland where the woodland is roughly split into four even parts. Rocky habitat is widely distributed across a woodland where it is present across >25% of the woodland, occupying >1 quarter of a woodland.	**Method:** Note the types of rocky habitat present during the woodland walk and mark these on a map of the woodland. **Timing:** Winter/early spring	0 = absent 1 = 1+ type present. When combined, these have only a localised distribution. 2 = 1 type present and widely distributed across the woodland 3 = 2+ types present and at least 2 types are widely distributed across the woodland
(F) Woodland continuity:	Old woodland is considered here to be woodland that has not been cleared for at least 120 years. The composition of the woodland may change over time through selective felling types ofactivity, but continuity of woodland cover remains.	**Method:** Review records from old maps (e.g. http://www.old-maps.co.uk) what proportion of the FMU is likely to have been wooded for at least 120 years **Timing:** N/A	0 = <5% of FMU has been continuously wooded for 120+ years 1 = 5-20% of FMU has been continuously wooded for 120+ years 2 = 21-50% of woodland has been continuously wooded for 120+ years 3 = >50% of woodland has been continuously wooded for 120+ years

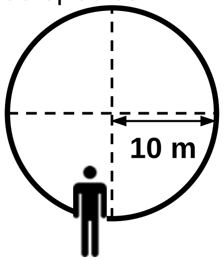
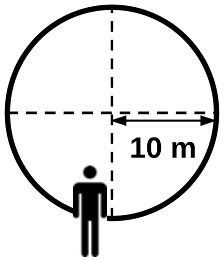
Structure and management indicators

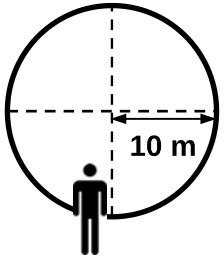
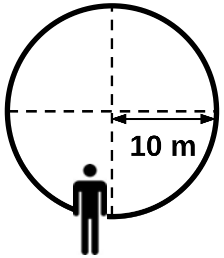
(G) Temporary open space (TOS) 	• This is open space in which trees can be expected to regenerate (e.g. glades, rides, footpaths, areas of clearfell). This differs from permanent open space where tree regeneration is not possible (e.g. tarmac, concrete, buildings, rivers). (NFI Manual UK, 2014) • Area between 0.01ha to 0.25ha (10 m^2 to $50m^2$) and at least 10m wide. Less than 20% wooded (Lush *et al*., 2012). • A localised distribution of TOS is when the majority of TOS's occupy a single quarter of the woodland where the woodland is roughly split into four even parts. TOS's are widely distributed across a woodland where they are present across >25% of the woodland, present in >1 quarter of a woodland.	**Method:** Note areas of TOS on a map of the woodland during the woodland walk. In addition, highlight on a map of the woodland any other known and/or potential areas of TOS according to any available recent aerial photographs of the woodland. Visit potential areas of TOS where confirmation is required. **Timing:** Late spring/summer	0 = >50% (25%)[3] of woodland has areas of TOS 1 = ≤10% (5%) or 25-50% (10-25%) of woodland has areas of TOS 2 = 10-25% (25%) of woodland has areas of TOS but these are found only in a localised area of the woodland 3 = 10-25% (25%) of woodland has areas of TOS and these are widely distributed across the entire woodland (FC, 2011)
(H) Native tree species abundance[4]:  	• See list of native tree species in Appendix 2, including precisions on any differences in native status between England, Scotland and Wales. • Live trees only; ht>50 cm Note: The Forestry Standard proposes that in each FMU there is a minimum of 5% native broadleaved trees or shrubs. This is less important in small (<10ha) woods where the adjacent landscape provides habitat diversity and in native woods (e.g. yew).	**Method:** Percentage of uppermost canopy cover in 10m radius circular survey plot that is attributable to native tree species. **Timing:** Late spring/summer	0 = <10% of the uppermost canopy contains native tree species 1 = ≥10 and <50% of the uppermost canopy contains native tree species 2 = ≥50 and <80% of the uppermost canopy contains native tree species 3 = ≥80% of the uppermost canopy contains native tree species

[3] For woodlands over 10 ha (number in brackets for woodlands less than 10ha)

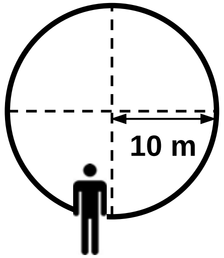
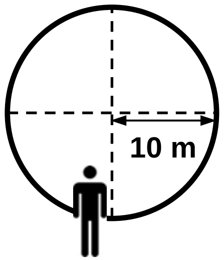
(I) Native tree species richness 	• See list of native tree species in Appendix 2, including precisions on any differences in native status between England, Scotland and Wales. • Live trees only; ht>50 cm • Score capped at 1 if cover of native tree species is less than 10%	**Method:** Number of native tree species occurring in 10m radius circular survey plot. **Timing:** Late spring/summer	0 = No native tree species 1 = 1-2 native tree species 2 = 3-4 native tree species 3 = 5+ native tree species
(J) Native shrub species richness 	• See list of native shrub species in Appendix 4. • Live shrubs only	**Method:** Number of native shrub species occurring in 10m radius circular survey plot. **Timing:** Late spring/summer	0 = No native shrub species 1 = 1-2 native shrub species 2 = 3-4 native shrub species 3 = 5+ native shrub species

[4] In Scotland and Wales, it may be of interest to set the threshold for native tree species abundance lower than in England. This is because in Scotland and Wales for a woodland to qualify as 'native' woodland, ≥50% of the tree species making up the canopy layer should be native tree species compared to a threshold of ≥80% in England.

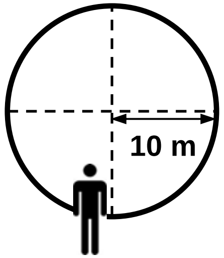
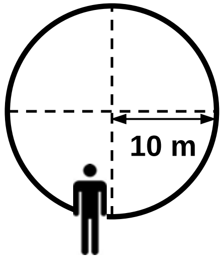
(K) Regeneration abundance: native tree species 	• See list of native tree species in Appendix 2, including precisions on any differences in native status between England, Scotland and Wales. • Seedlings are defined as <50 cm height; Saplings are defined as ≥50cm tall and <4cm DBH. (NFI Manual UK, 2014) • Live recruits only. • Regeneration of each given tree species is 'infrequent' where it occurs in 1 of 4 quarters of the survey plot and 'abundant' where it occurs in >1 of the 4 quarters of the survey plot.	**Method:** Record the number of different native tree species that are regenerating naturally in each quarter of a 10m radius circular survey plot. **Timing:** Late spring	0 = No regeneration of native tree species 1 = Regeneration of ≥1 native tree species 'infrequent' 2 = Regeneration of ≥1 native tree species, 1 of which is 'abundant' 3 = Regeneration of >1 native tree species >1 of which is 'abundant'
(L) Regeneration abundance: non-native tree species 	• See list of non-native tree species in Appendix 3. • Seedlings are defined as <50 cm height; Saplings are defined as ≥50cm tall and <4cm DBH. (NFI Manual UK, 2014) • Live recruits only. • Regeneration of each given tree species is 'infrequent' where it occurs in 1 of 4 quarters of the survey plot and 'abundant' where it occurs in >1 of the 4 quarters of the survey plot.	**Method:** Record the number of different non-native tree species that are regenerating in each quarter of a 10m radius circular survey plot. **Timing:** Late spring	0 = Regeneration of > 1 non-native tree species, >1 of which is 'abundant' 1 = Regeneration of ≥1 non-native tree species, 'abundant' 2 = Regeneration of non-native tree species 'infrequent' 3 = Regeneration of non-native tree species absent

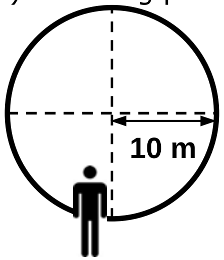
(M) Vertical vegetation structure:  	• Four vegetation layers are recognised (Larrieu & Gonin, 2011): 1. Herbaceous and non-woody 2. Low woody (< 7 m high) 3. Intermediate woody (7-20 m high) 4. High woody (>20m high) • Layers are not counted if covering less than 10% of the survey plot (Larrieu & Gonin, 2011)	**Method:** Record the number of vegetation layers occurring in a 10m radius circular survey plot. **Timing:** Late spring/summer	0 = 1 vegetation layer 1 = 2 vegetation layers 2 = 3 vegetation layers 3 = ≥4 vegetation layers
(N) Variation in stem sizes  	• Four stem circumference size classes are recognised[5] (Lush *et al*., 2012): 1. >225cm or >1.5 hugs 2. 150-225.9cm or 1-1.5 hugs 3. 75–149.9cm or 0.5–1 hug 4. 22–74.9cm • Assess circumference of stems 1.5m above ground level http://www.treeregister.org/measuringtrees.shtml	**Method:** Record the number of stem circumference size classes for the most common tree species occurring in a 10m radius circular survey plot. Record only for trees with trunk circumferences >22cm. **Timing:** Winter/ early spring	0 = 1 tree circumference size class 1 = 2 tree circumference size classes 2 = 3 tree circumference size classes 3 = 4 tree circumference size classes

[5] Diameter at Breast Height (DBH) can also be assessed as an alternative to trunk circumference or 'hugs'. It is typically measured 1.3m from the forest floor. The equivalent DBH categories are as follows: 1). >71.5cm, 2). 47.6-71.5cm, 3). 23.6-47.5cm, 4). 7-23.5cm

(O) Large standing deadwood abundance:  	• These are >1m tall and, where leaning, <45^0 departure from the vertical. Diameter is measured at the narrowest point on the stem. Minimum diameter of 10cm (Humphrey & Bailey, 2012).	**Method:** Record the number of snags present in a 10m radius circular survey plot to derive an estimate of the number of snags per hectare (i.e. no. of snags x 31.85m^2 = no. of snags ha^{-1}).[6] **Timing:** Summer	0 = <10 snags ha^{-1} 1 = >10 snags ha^{-1} with minimum stem diameter range of 10-20cm 2 = >10 snags ha^{-1} with minimum stem diameters range of 10-20cm and/or 1-14 snags ha^{-1} with stem diameter >20cm 3 = >10 snags ha^{-1} with minimum stem diameters range of 10-20cm and/or >14 snags ha^{-1} with stem diameter >20cm
(P) Fallen deadwood volume:  	• Logs and large fallen branches: >45^0 departure from the vertical. • >10cm diameter at narrowest point and >50cm long (Lush *et al*., 2012).	**Method:** Record the number of fallen deadwood pieces present in a 10m radius circular survey plot to derive an estimate of the number of fallen deadwood pieces per hectare (i.e. no. of snags x 31.85m^2 = no. of fallen deadwood pieces ha^{-1}). **Timing:** Winter/ early spring	0 = No logs or fallen branches present 1 = <20 m^3 ha^{-1} 2 = 20-40 m^3 ha^{-1} 3 = >40 m^3 ha^{-1} Humphrey & Bailey (2012) propose 20m^3 as a minimum

[6] Area of circle is pi x r2; 3.14 x100=314; 1 ha = 10,000m2, so 10,000/314=31.85m2

(Q) Coarse woody debris (CWD) volume:  	• CWD includes: o Large standing deadwood/snags: >1m tall and <45^0 departure from the vertical; minimum diameter of 10 cm. o Logs and large fallen branches: >45^0 departure from the vertical; >10cm diameter at narrowest point and >50cm long (Lush *et al*., 2012) • CWD does not include stumps (i.e. standing deadwood <1m tall). Humphrey & Bailey (2012)	**Method:** Record the approximate volume of CWD in a 10m radius circular survey plot. As a rule of thumb, consider that 1 piece of deadwood with dimensions 10 cm diameter x 1 m long represents 0.26 m3 of deadwood per ha. Use this estimate to derive the volume of CWD per hectare (i.e. volume in 10m radius survey plot x 31. 85m^2 = volume of CWD ha^{-1}). **Timing:** Winter/ early spring for logs; summer for standing deadwood.	0 = No CWD present 1 = <20 m3 ha^{-1} 2 = 20-80 m3 ha^{-1} 3 = >80 m3 ha^{-1} Humphrey & Bailey (2012) propose 20m^3 as a minimum
(R) Invasive species abundance  	• See Appendix 5 for a list of plant species considered to be invasive in British woodlands. • Each invasive species is ‘infrequent’ where it occurs in 1 of 4 quarters of the survey plot and ‘abundant’ where it occurs in >1 of the 4 quarters of the survey plot.	**Method:** Record the number of different listed invasive woodland plant species in each quarter of a 10m radius circular survey plot. **Timing:** Late spring/ summer	0 = $\geq$ 1 invasive plant species ‘abundant’ 1 = >1 invasive plant species ‘infrequent’ 2 = 1 invasive plant species ‘infrequent’ 3 = No invasive plant species

(S) Browsing pressure  	• Three type of browsing pressure are recognised (adapted from Lush *et al*., 2012): o Browse line (BL): Lower branches and shoots of trees and shrubs are browsed back so that leaves no longer occur within reach of livestock. o Bark stripping (BS): Recognised here where it is due to grazers/browsers rather than squirrels, so it occurs up to a height of 2m on the trunk. o Damaged or absent shoot tips (ST): Includes damage to shoots present at the base, on the trunk or on the lower branches of trees and taller shrubs. • Browsing pressure is considered to be 'low intensity' where <20% of vegetation in the survey plot shows damage by any type of browsing pressure. It is 'high intensity' where >20% of vegetation shows damage from any type of browsing pressure.	**Method:** Record the number of different listed types of browsing pressure in a 10m radius circular survey plot and whether browsing pressure is high or low. **Timing:** Late spring/ summer	0 = ≥1 type of browsing pressure present, 'high intensity' 1 = >1 type of browsing pressure present, 'low intensity' 2 = 1 type of browsing pressure present, 'low intensity' 3 = No evident grazing or browsing pressure

3.2.2 Application of the RWBA in two case study woodlands

Woodland walks were completed twice in each of the case study woodlands in 2014 by a Forest Research staff member. The first woodland walk took place in early spring on the 25th of March in Hartley Mauditt Woods and on the 31st of March in the Land of Nod Woods, taking 4.5 and 3.75 hours, respectively in each of the woodlands. The second woodland walk took place in late summer (i.e. 27th of August in Hartley Mauditt and 20th of August in the Land of Nod, taking approximately 2.5 hours in each of the woods). The second woodland walk was added to recover additional information when the trees and shrubs were fully in leaf and vegetation layers more clearly defined. Stops for assessments in circular survey plots were completed at 11 locations on the Hartley Mauditt woodland walks and at 12 locations on the Land of Nod woodland walks. The route taken and stopping points where survey plots were assessed are indicated on the woodland maps in Figures 3 & 4.

Figure 3: Hartley Mauditt FMU with route taken on woodland walk and survey plot stopping points

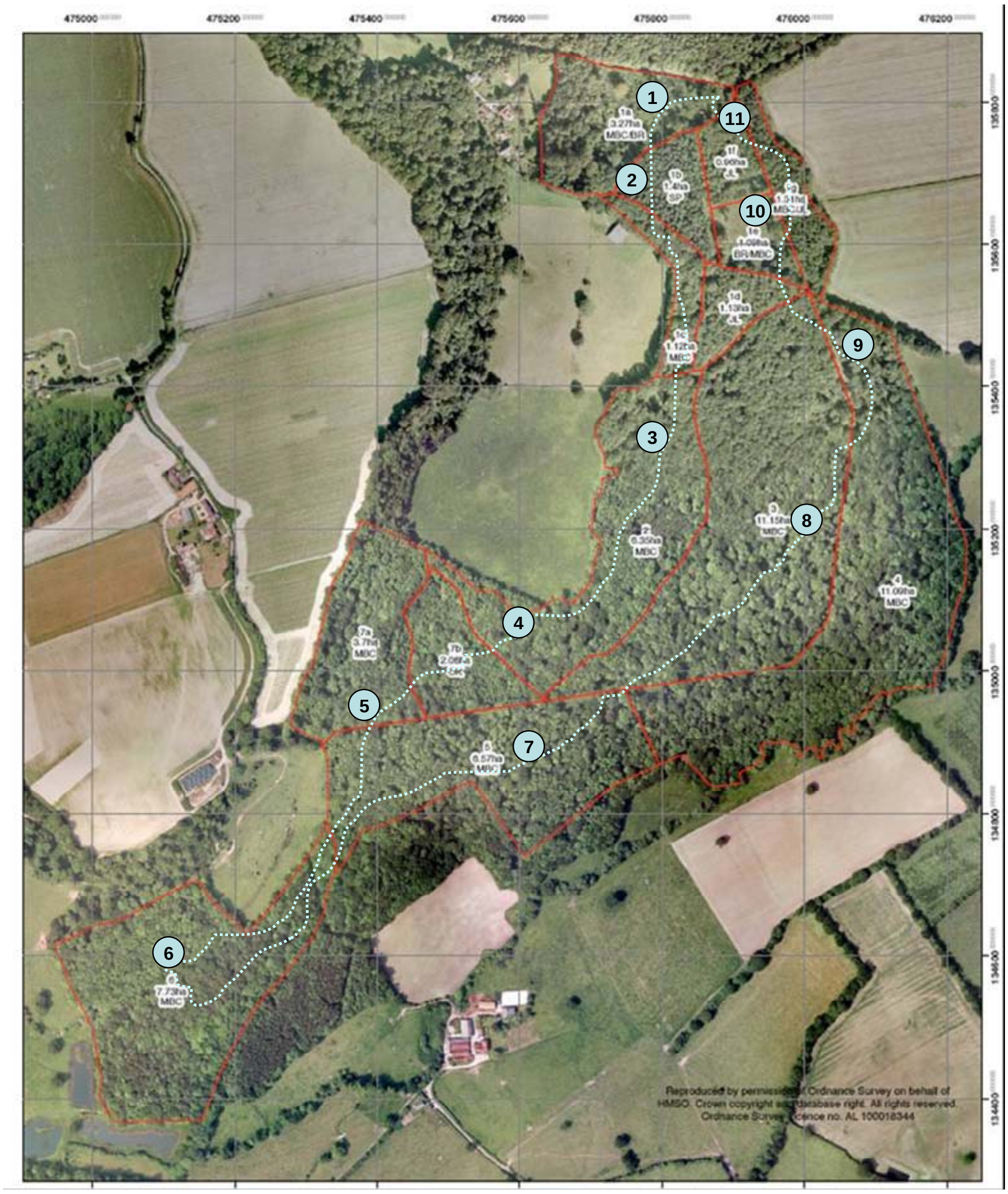
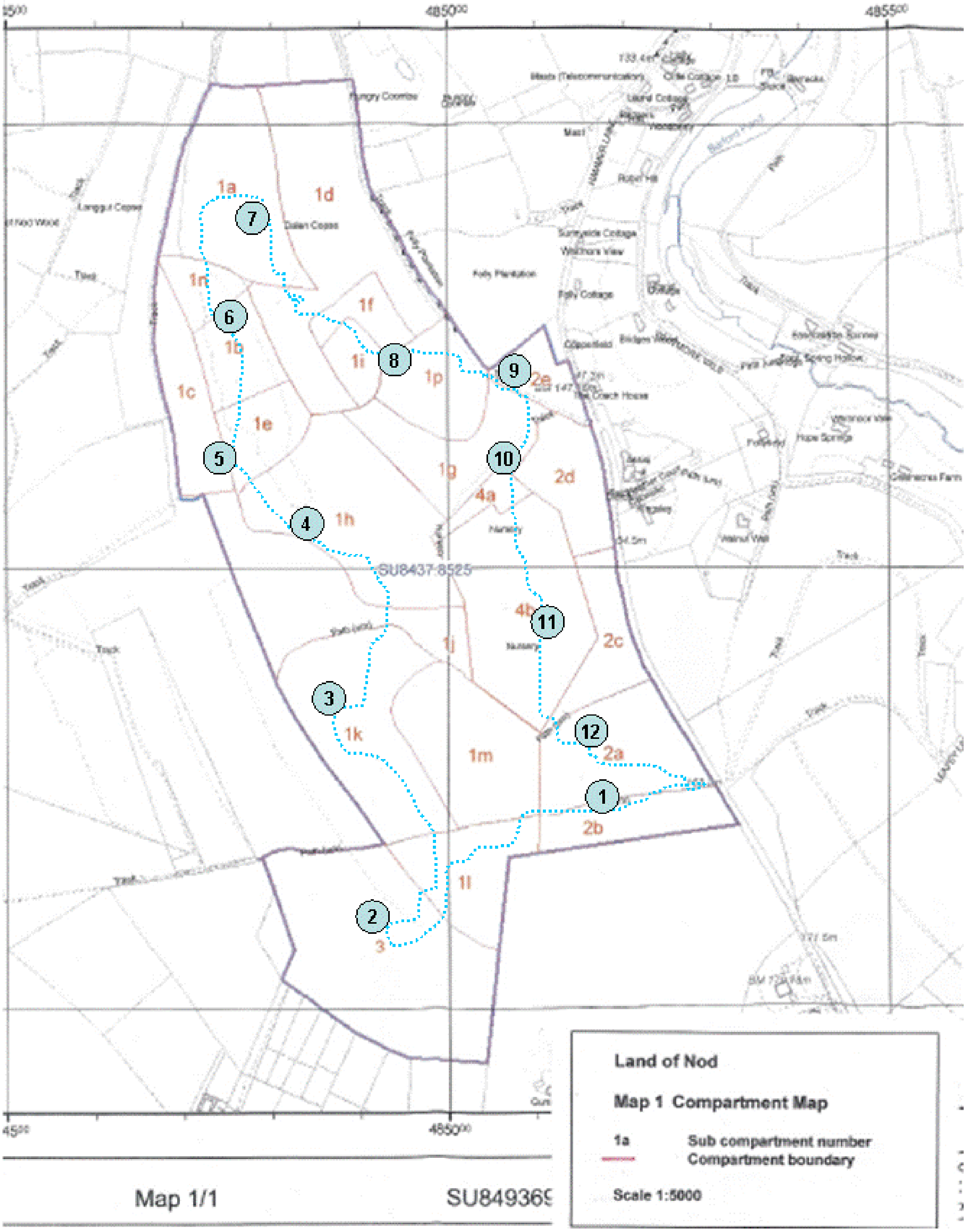


Figure 4: Land of Nod FMU with route taken on woodland walk and survey plot stopping points



3.3 Carbon component calculation methodology

The calculation methods used to make initial estimates for the two case study woods of timber and woodfuel volume and biomass, but also of carbon, are the same as described in the FC Woodland Carbon Code (WCC) Carbon Assessment Protocol (Jenkins *et al*., 2011). The subsequent forecast changes in volume, biomass and carbon over time based on the RWBA recommended management changes, have been produced for the case study forests using a methodology consistent with the WCC Carbon Lookup Tables. However the level of detail is generally far greater and the processing was considerably more 'bespoke'.

3.3.1 Data Input

The first step in the carbon calculation methodology was to translate the inventory and stand data for the two case study woodlands into sub-compartment-level information including both description (i.e. 'what is there') and intent (i.e. how is the sub-compartment going to be managed).

There were a number of inconsistencies and uncertainties in the data provided, in terms of exactly what was actually there and what management action was intended for each sub-compartment. UPM-Tilhill, as the managing agents who provided the base inventory and management plan information, were contacted for further clarification to ensure the data were interpreted appropriately.

Once the sets of input information for each sub-compartment were finalised the second step was to enter these data into the Forestry Commission "M1" yield model. This process involves specification of the stand characteristics – species, yield class, spacing etc. and specification of the thinning and felling interventions – timing, intensity, target volume to remove etc. The majority of the Land of Nod Management Plan assumed fairly 'standard' management, i.e. assuming the stand is managed to the most appropriate yield table for the particular species, yield class and spacing. These models were available through M1 and, for the Management Plan scenario, were used where this had been specified. The forecasting of some sub-components were further 'refined' by including thinning and felling events and using target volumes as a guide where these had been specified in the Management Plans (mainly in the Harvesting Plan or the Product Assortment tables provided).

The structure and proposed Management Plan for Hartley Mauditt was very different to that of Land of Nod, where around 85% of the area is classified as mixed broadleaf coppice. The M1 yield model is essentially a high forest growth and yield model and was not designed to model coppice stands. To allow an estimate and forecast of the carbon in the coppice at Hartley Mauditt, the inputs to the M1 growth model were modified and eight 'cohorts' of areas in the early stages of high forest stand development were used to represent the coppice being managed on a rotation of 40 years with a 5 yearly cutting cycle, as specified in the Management Plan.

The methodology outlined above allowed the estimation of 'year zero' in each scenario and a forecast of the development of (volume, biomass and carbon for) each Woodland Management Plan scenario. For the "RWBA informed" scenarios, the input files/ information sets for each forest were modified, to attempt to reflect and represent the specific activities selected to improve biodiversity, such as restocking conifer stands/sub-compartments with native (broadleaved) species, felling small patches of sub-compartments and/or increasing thinning intensity to encourage regeneration and more varied stand structure. Changes such as harvesting a proportion of branch material for wood fuel or leaving some felled stem wood in the forest were also made in the RWBA informed scenarios . The prescriptions for the modelling in both the Management Plan (baseline) and RWBA informed scenarios are given for each sub-compartment in Appendix 7.

It should be noted that in translating the RWBA recommendations at the sub-compartment level into 'sensible' instructions for modelling in the M1 model, some interpretation was necessary to ensure a balance was struck between reflecting the changes in management suggested by the RWBA recommendations on the one hand, and not 'over modelling' by adding complexity and splitting sub-compartments into smaller and smaller components on the other. This is particularly the case where it was deemed that this would have increased the amount of time needed to process and analyse outputs without necessarily significantly improving the forecast.

3.3.2 Spin up of the model

The models used in the WCC were designed for the establishment of new woodlands on previously arable or pasture land. However, the Hartley Mauditt and Land of Nod sites are already established woodlands. Results in this report are therefore presented for 2010 onwards, using the forest composition at that date. In order to achieve a stable 'woodland' basis including accumulated debris on the ground, the simulations were initialised prior to 2010. This type of activity is often known as 'spinning up the model' In order to achieve stability, a spin-up period of around 40 years is often required for sub-compartments established some time before 2010 and where the woodland was planted, grown and managed in a conventional manner. In sub-compartments established more recently, stability would not be reached, so an entire prior rotation was used as spin-up.

3.3.3 Timber volume

The outputs from the M1 yield model were essentially in the form of annual volume estimates, both standing and felled, for each sub-compartment, based on the specified management. The volume estimates from M1 were for the stemwood only, to a top (minimum) diameter of 7 cm. This is defined by convention as the 'timber volume' of a stand of trees in Great Britain (Matthews and Mackie, 2006). The volume of stem wood less than 7 cm in diameter and of the branches (and roots) was not included in the M1 outputs. However, the timber volume estimates from M1 were used to derive estimates of the mass of these other components, along with the mass of the stemwood in the next step of the process. Both the standing volume and the volume harvested in thinning and clear-felling events were estimated.

3.3.4 Biomass

The stand development characteristics and stem volume estimates generated from M1 were used as input data for the Forest Research BSORT biomass model. This model uses the data produced by the M1 yield model to calculate estimates of biomass in a number of tree components (e.g. branches, sawlogs, roundwood, roots, stumps, foliage). The oven dry mass of stemwood components were estimated by multiplying the volume estimates by the basic density (specific gravity) of the particular species being considered (see Section 5 of Jenkins *et al*., 2011). The masses of the other components were estimated using a series of allometric equations within the BSORT model (see Section 5 of Jenkins et al., 2011). As with the volume estimates from M1, the biomass estimates were generated at annual time steps to allow the changes in biomass over time to be forecast.

3.3.5 Carbon

The stock of carbon in the tree biomass was estimated by multiplying the biomass by a value for average carbon content of wood material. This value was set at 0.5 in the models (see for example Matthews, 1993). Because the biomass estimates were generated at annual time steps, this allowed the change in carbon stock over time to be forecast.

The results for carbon stocks are presented in two categories:

1. Standing – Total live carbon in standing trees including roots, foliage and timber
2. Debris – Carbon stocks originating from harvesting residues, litterfall and standing dead trees

The results for harvested products are presented in three categories:

1. Sawlogs – Larger diameter timber lengths from the lower parts of the tree, generally used for producing sawn timber
2. Roundwood – Smaller diameter timber lengths from the upper parts of larger trees and sometimes whole stems of small trees, usually used for producing panel products like particle board, fencing and sometimes for paper production.
3. Fuel wood – Wood remaining after sawlogs and roundwood have been removed, may include a proportion of branchwood. Also includes 'co-products' from sawmills, i.e. the offcuts and residues from the production of sawn timber.

<u>All harvested wood products from coppice, particularly relevant to</u> management in Hartley Mauditt, were classed as fuel wood.

4. Results

4.1 RWBA scores and related management recommendations

4.1.1 Estimated biodiversity potential at the whole FMU scale

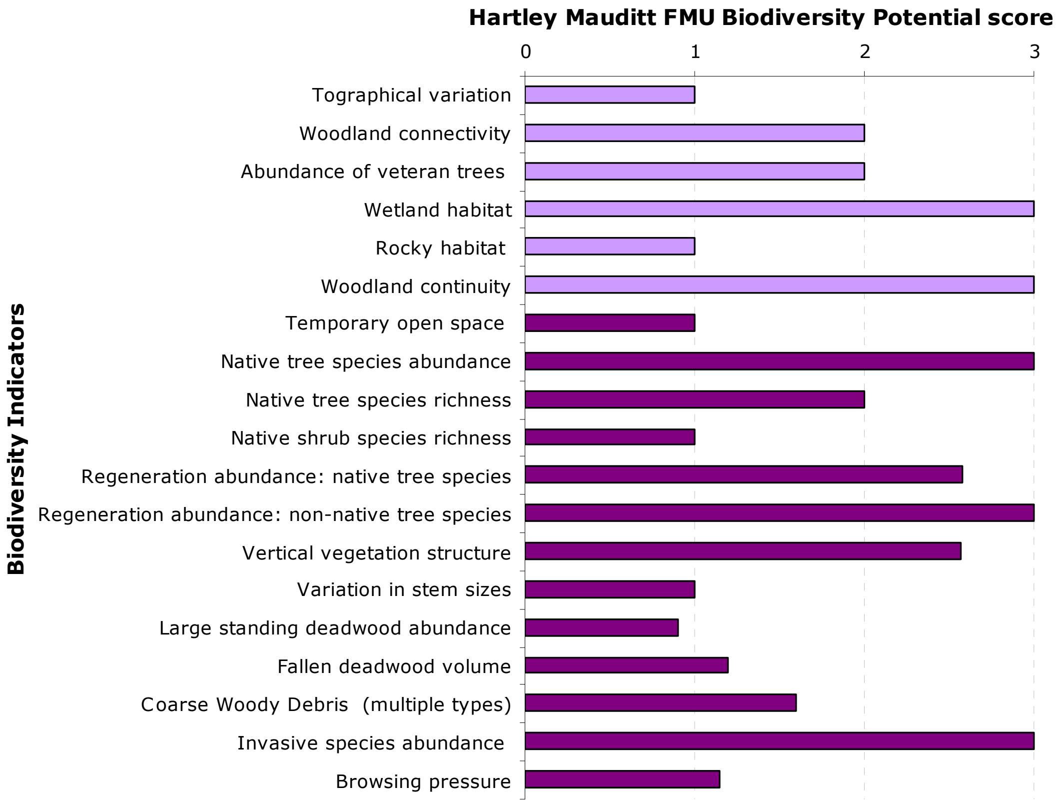
Hartley Mauditt FMU

When considering biodiversity indicators representing variables that cannot easily be improved by forest management, Hartley Mauditt FMU received high scores for many of these (Figure 5). High scores in particular were attributed for the prevalence of wetland habitats. Veteran trees were also present in high numbers per ha, but appeared to mostly be present in one sector of the FMU; veteran trees thus having a localised rather than a widespread distribution which would otherwise be of greater benefit to biodiversity. It is recommended to select and manage suitable trees elsewhere in the FMU as veteran trees for the future. Regarding all existing veteran trees, these should be maintained; this can include taking measures to maintain tree vigour and health such as pollarding and/ or haloing around the veteran trees to reduce competition for light (Humphrey & Bailey, 2012). The FMU does not directly border other woodland over more than 50% of its outer edge. Old maps reveal, however, significant periods of woodland continuity within the majority of the FMU since at least 1870; nearby woodlands less than 3km away, also have similar levels of woodland continuity. Reducing somewhat the inherent biodiversity potential of the FMU were a limited abundance and diversity of rocky habitat types. The FMU is also not situated on an area of significant topographical relief, so there will not have been the advantage of a greater diversity of niche spaces created by a complex physical terrain.

Hartley Mauditt FMU had high biodiversity potential scores for variables that can be altered by forest management, in some cases receiving top scores (Table 5). Native tree species were abundant in the canopy across the FMU, occupying at least 80% of the canopy and most often 100% of the upper canopy in temporary survey plots. Native tree species richness was also high, with an average of 3.7 (s.d.= 1.0) native (including 'naturalised') tree species present in each temporary survey plot; native tree species present in the FMU included hazel, beech, oak, silver birch, wild cherry, ash, sweet chestnut, aspen and field maple. Regeneration of native tree species was also in evidence throughout the FMU, with limited competition from invasive vegetation species or from the regeneration of non-native tree species. The biodiversity potential of Hartley Mauditt FMU was compromised, however, by high levels of herbivory as indicated by the low scores associated with browsing pressure. Native shrub species richness was also poor across the entire FMU, with on average only 1 (s.d.= 0.8) native shrub species (mostly holly or hawthorn) present in survey plots. In addition, while vertical vegetation structure generally had all four layers described (i.e. herbaceous, low, intermediate and high woody), the age structure of the most common native tree species was often poor as evidenced by the low plot score for variation in stem sizes. This is due to management for coppice in most of the stands. A system of coppice with standards and a greater mixed native tree species coppice crop are proposed to improve the age class distribution of the dominant tree species in each stand (see sub-compartment scale management recommendations in the following section).

Temporary open space that was encountered on the woodland walk covered an estimated total area of 5,300 m^2 of the FMU. Even where this value is doubled to account for rides and other areas of open space not encountered on the woodland walk, temporary open space is still estimated to occupy less than 10% of the total FMU area which is the minimum threshold coverage proposed in the UK Forestry Standard (FC, 2011). Another 5 hectares of temporary open space should be created throughout the FMU; this could be achieved by creating glades, or opening out rides. The following references provide advice on how open areas can be created and maintained, including points to consider before creating temporary open spaces (Blakesley & Buckley, 2010; FC England, 2005). The biodiversity indicators for deadwood revealed that some improvements could also be made, particularly by increasing the amount of large standing and fallen deadwood in the FMU. The average score for volume of deadwood across all temporary survey plots was $50.4m^3ha^{-1}$ (s.d.= 57.8). This is above the minimum threshold recommended of $20m^3ha^{-1}$, but could be improved further. Some snags were observed, but these were frequently of small stem diameter ($\leq$20cm diameter at the narrowest point). This was also true for fallen deadwood, which was frequently <40cm in diameter.

Figure 5: Whole woodland biodiversity indicator scores for Hartley Mauditt and Land of Nod FMU's. Biodiversity indicators for variables that are independent of forest management are presented in light purple and biodiversity indicators for variables that can be altered by forest management are presented in dark purple.



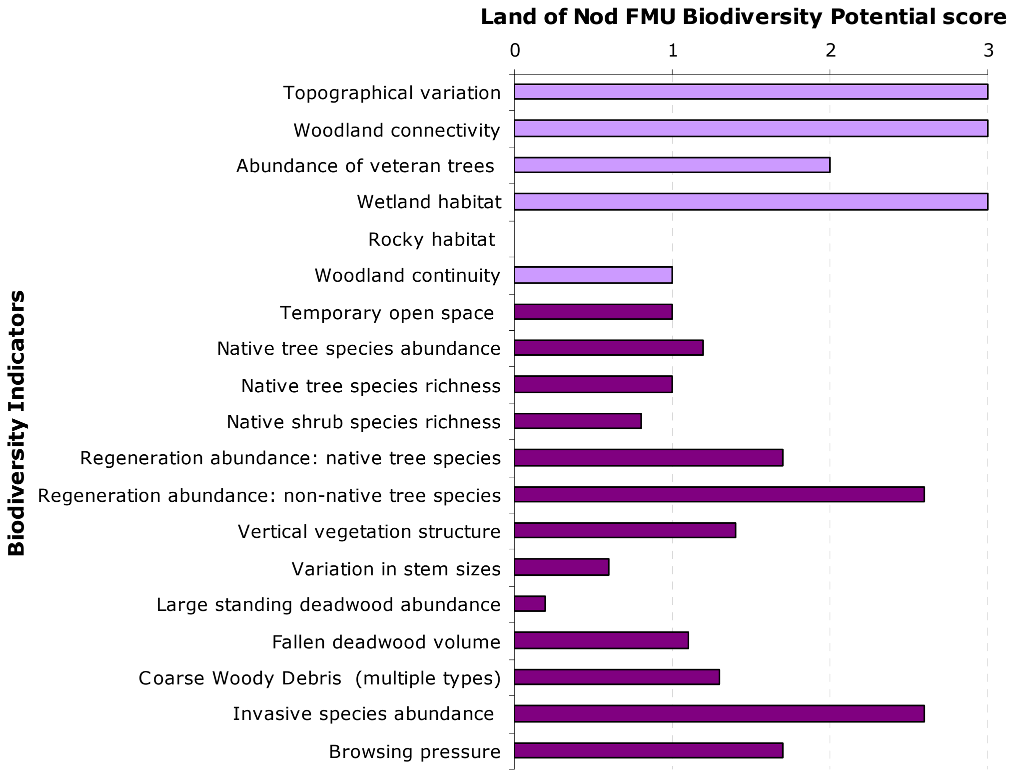


Table 5: Biodiversity indicator results for Hartley Mauditt FMU from woodland walk, survey plots and desktop study.

	Survey Plots											
	Stop number	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9	Stop 10	Stop 11
	Sub-compartment number	1A(1/2)	1B	2A	2A	7A	6A	5A	3A	4A	1E	1F
	Main canopy species	POK/SB	SP	MB	MB	MB	MB	MB	MB	MB	MB	BE
Biodiversity Indicators	Planting Year	1900/1995	1956	1920	1920	1920	1920	1920	1920	1920	2004	1961
	Sub-compartment area (ha)	1.2/1.8	1.5	6.4	6.4	2.7	7.8	6.6	11.2	11.1	1.1	1
	Grid reference	SU 757 358	SU757 356	SU 758 355	SU 757 353	SU 754 350	SU 751 345	SU 756 349	SU 760 352	SU 760 354	SU 759 356	SU 759 357
Topographical variation	Slope	<3%	<3%	<3%	<3%	3-16.5%	3-16.5%	<3%	<3%	<3%	3-16.5%	3-16.5%
	Aspect	Flat	Flat	Flat	Flat	various	NW	Flat	Flat	Flat	Flat	East
Woodland connectivity	FMU does not directly border other woodland over more than 50% of its outer edge											
Abundance of veteran trees	9 veteran trees were observed on the woodland walk. These had a localised distribution.											
Wetland habitat	4 wetland habitat types were observed on the woodland walk. These were a stream, wet and dry ditches and areas that could be described as bog, swamp, or marsh. These were widely distributed across the woodland.											
Rocky habitat	1 rocky habitat type was observed on the woodland walk. This included blocks>20cm, slabs and stones.											
Woodland continuity	Old maps reveal significant periods of woodland continuity within the majority of the FMU since at least 1870.											
Temporary open space	On walk six open space areas were encountered, widely distributed across the woodland. 1) 50x30m, 2) 20x15m, 3) 30x30m, 4), 30x30m, 5) 30x30m, 6) 40mx40m. Total area 5,300 m2. Does not include open space associated with											
Native tree species abundance	Percentage cover	100%	80%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Plot score	3	3	3	3	3	3	3	3	3	3	3
Native tree species richness	No. of spp	4	3	4	4	4	4	3	6	4	3	2
	Native tree species	HAZ, OK, SBI, WCH	AH, BE, HAZ	AH, BI, HAZ, OK	AH, HAZ, OK, SC	AH, HAZ, OK, SC	AH, BI, HAZ, OK	BE, HAZ, OK	AH, ASP, BI, FM, HAZ, OK	AH, BE, HAZ, OK	AH, ASP, HAZ	BE, HAZ
	Plot score	2	2	2	2	2	2	2	3	2	2	1
Native shrub species richness	No. of species	0	0	0	0	1	1	2	0	2	1	1
	Shrub species	0	0	0	0	HOL	HW	HAW, HOL	1	HAW, HOL	ER	HAW
	Plot score	0	0	0	0	1	1	1	1	1	1	1
Regeneration abundance: native tree species	No. of plot quarters with regen	4	4	4	2	4	4	4	4	4	Could not see	2
	Species regenerating	HAZ, OK	AH	AH	Could not see	AH, HAZ	AH, HAZ	AH, HAZ	HAZ	AH, HAZ	Could not see	HAZ
	Plot score	3	2	2	2	3	3	3	2	3	?	2
Regeneration abundance: non-native tree species	No. of plot quarters with regen (spp)	0	0	0	0	0	0	0	0	0	Could not see	0
	Species										Could not see	
	Plot score	3	3	3	3	3	3	3	3	3	?	3
Vertical vegetation structure	Vegetation layers present	3,4	2,3,4	1,2,3,4	2,4	1,2,3,4	1,2,3,4	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,4
	Plot score	1	2	3	1	3	3	2	2	3	3	2
Variation in stem sizes	Stem size classes present	4	3	4	Could not see	2,3,4	2,3,4	1, 2, 3, 4	2,3,4	4	2, 3	3, 4
	Main tree species	HAZ	BE	AH	Mixed	Mixed	Mixed	Mixed	Mixed	OK, BE	Mixed	BE
	Plot score	0	0	0	?	2	2	3	2	0	1	1
Standing deadwood	Number of snags in plot	0	2	1	1	1	1	0	3	1	0	1
	Estimated no. of snags ha^{-1}	0	63.7	31.85	31.85	31.85	31.85	0	95.55	31.85	0	31.85
	Plot score	0	2	2	1	1	1	0	1	0	0	1
Fallen deadwood volume	Volume of deadwood pieces in plot	0.691	0.141	0.330	5.027	4.524	0.628	0.000	0.982	0.314	0.393	0.141
	Estimated volume (m^3) of fallen	22.0	4.5	10.5	160.1	144.1	20.0	0.0	31.3	10.0	12.5	4.5
	Plot score	2	1	1	3	3	2	0	2	1	1	1
CWD volume (multiple types)	Volume of CWD in plot (m^3)	0.691	1.555	2.215	5.278	4.542	0.805	0.000	1.484	0.314	0.393	0.141
	Estimated volume (m^3) of deadwood ha^{-1}	22.0	49.5	70.5	168.1	144.6	25.6	0.0	47.3	10.0	12.5	4.5
	Plot score	2	2	2	3	3	2	0	2	1	1	1
Invasive species abundance	No. of plot quarters with invasive spp	0	0	0	0	0	0	0	0	0	0	0
	Plot score	3	3	3	3	3	3	3	3	3	3	3
Browsing pressure	Types of damage	BS, ST	ST	no damage	no damage	ST	ST	no damage	BS, ST	BS, ST	ST	BS
	% damage by type	10%, 90%	80%	no damage	no damage	50%	90%	no damage	5%, 5%	5%, 80%	15%	5%
	Plot score	0	0	3	3	0	0	3	1	0	2	2

General management practice for enhancing deadwood in the FMU as recommended in Humphrey & Bailey (2012) are listed in a series of bullet points below.

- Retain all existing standing and fallen dead trees (including major branches) occurring in each compartment except in those cases where there are overriding safety concerns, or concerns over tree disease[7].
- Favour natural processes (e.g. wind, riverbank erosion, competitive shading out) to create deadwood.
- Where there is no, or insufficient amounts of deadwood created by natural processes, deadwood can be created by artificially injuring, ring barking or felling mature trees especially during thinning and harvesting operations to reduce costs. Artificial snags can be created by using a harvester to cut the upper part of the tree. Ideally snags should be approximately 1-3m high and created in clusters (minimum of 10 ha^{-1}) to benefit hole-nesting birds (Humphrey *et al*., 2002).
- During thinning, leave trees of no commercial value that are likely to die through shading, but also allow some larger wind-firm trees that are likely to survive for at least 50-100 years to age and hollow.
- Maximise the diversity of deadwood by retaining snags of variable height and deadwood at varying stages of decay, replenishing the supply of deadwood where needed to maintain continuity of deadwood habitat.
- Native deadwood is thought to provide more valuable habitat than non-native deadwood and should be retained preferentially.
- Retaining deadwood in different light conditions will enhance the diversity of decay rates and deadwood habitat types.
- Where timber or firewood is stacked in piles for collection, these should be removed as soon as possible before they are colonised by invertebrates as this can interfere with invertebrate life cycles and population structures.

The creation and retention of deadwood can be undertaken on a sub-compartment by sub-compartment basis, with recommended volumes guided by biodiversity indicator scores for deadwood. However, it is also important to assess the distribution of deadwood across the FMU to ensure connectivity of deadwood habitat and to help prioritise management action for deadwood creation and retention. A uniform distribution of deadwood across sub-compartments and the wider FMU should be avoided. Instead, the positioning of deadwood in either sun-exposed or shaded conditions should be varied both within and from one compartment to the next. Also, lying deadwood should be grouped in association with wetland habitat and/or live stems of native trees, shrubs and other semi-natural vegetation. Where choices must be

[7] There is a balance to strike between deadwood retention and bark beetle or fungal infestation that will threaten living trees. Pest and pathogen infection from deadwood is mostly not an issue, however (FC, 2008; Humphrey & Bailey, 2012). A bark beetle that can be problematic and occurs in the UK is the Great spruce bark beetle (*Dendroctonus micans*). This species moves onto living trees when very high bark beetle population numbers develop. Fungal pathogens such as *Heterobasidion annosum* on pines can be controlled effectively using a biological control agent, the saprophytic fungus, *Phlebiopsis gigantean*.

made, biodiversity associated with deadwood is least likely to benefit from recent deadwood creation/retention in newly established woodland stands (<50 years) with no continuity of habitat (e.g. clearfell and restock areas of both native and non-native tree species areas such as compartment 1b in Hartley Mauditt FMU). Woodland sub-compartments that are most likely to benefit from deadwood creation and retention include those comprising broadleaved woodland managed historically as high forest or coppice, but where stands are aging (e.g. 100-120 years).

Land of Nod FMU

Biodiversity indicators that were independent of forest management action showed mixed results in describing the biodiversity potential of the Land of Nod FMU (Figure 5). A heterogeneous terrain with frequent encounters of wetland habitat and high connectivity to other woodland resulted in high biodiversity potential scores. However, rocky habitat and veteran trees were absent or scarce across most of the FMU. Continuity of woodland habitat was also poor in most sub-compartments of the FMU.

Land of Nod FMU had low biodiversity potential scores for many of the biodiversity indicators representing variables that can be changed by woodland management (Table 6). Native tree and shrub species were scarce with on average one native tree species (s.d.= 1.3) and one or no native shrub species (s.d.= 0.5) present in each sub-compartment. Using the sub-plots to obtain an estimate, native tree species occurring in the FMU covered approximately 5.2 ha, or 7% of the FMU and included birch, sweet chestnut, rowan, beech and oak. This is just above the minimum threshold of 5% native tree species proposed for individual FMU's by the UK Forestry Standard. The vertical structure of vegetation in many of the sub-compartments was poor (e.g. 8 out of 12 compartments assessed had no ground vegetation layer) and single age classes were commonly found amongst the dominant tree species in each sub-compartment. Regeneration of native tree species was observed, however, in many sub-compartments suggesting that there is scope for increasing the proportion of native tree species in the FMU in gaps created for this purpose. Indicators for levels of herbivory and levels of competition from invasive vegetation species and non-native regeneration revealed that baseline levels in most sub-compartments are low, although this could change where the canopy is opened up.

The average score for volume of deadwood across all temporary survey plots was $24.1 m^3 ha^{-1}$, although there was significant variation among sub-compartments (s.d.= 57.8) with 9 out of the 12 sub-compartments assessed having less than the minimum recommended volume of deadwood (i.e. $20 m^3 ha^{-1}$). Snags were frequently of small stem diameter (<20cm diameter at the narrowest point) and rarely encountered, occurring in only 5 of the 12 sub-compartments assessed. Similarly fallen deadwood was mostly smaller pieces with a diameter <40cm at the narrowest point.

The scope to transform some sub-compartments or sections of sub-compartments to a lower impact silviculture system should be considered to increase the biodiversity potential of the FMU.

Table 6: Biodiversity indicator results for Land of Nod FMU from woodland walk, survey plots and desktop study.

	Survey Plots												
	Stop number	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9	Stop 10	Stop 11	Stop 12
	Sub-compartment number	2B(1/2)	3A	1K	1H(1)	1C	1B	1A(1)	1P	2E(2)	1G(1)	4B	2A
	Main canopy species	SP	SP	SP	SP	SC	EL	BE	CP	SC	SC	CP	CP
Biodiversity Indicators	Planting Year	1964/71	1966	1964	1977	2000	1977	1960	1983	1971	2004	1991	1977
	Sub-compartment area (ha)	0.4/0.5	4.3	2.6	2.5	1.4	0.9	1.8	1.1	0.2	1.3	3	1.9
	Grid reference	SU851367	SU850365	SU849367	SU848371	SU847372	SU847373	SU848374	SU849373	SU850372	SU850371	SU851370	SU852368
Topographical variation	Slope	<3%	3-16.5%	>16.5%	3-16.5%	3-16.5%	3-16.5%	<3%	3-16.5%	<3%	3-16.5%	<3%	<3%
	Aspect	Flat	SW	SW	NE	SW	NW	Flat	W	Flat	NW	Flat	Flat
Woodland connectivity	>50% of the woodland is connected to other woodland												
Abundance of veteran trees	4 veteran trees observed on the woodland walk.												
Wetland habitat	3 wetland habitat types were observed on the woodland walk. These were wet and dry ditches and areas of that could be described as bog, swamp, or marsh.												
Rocky habitat	No rocky habitat types were observed on the woodland walk.												
Woodland continuity	Continuity of woodland habitat was poor in most sub-compartments of the FMU. No more thann 20% of the woodland has been continuously wooded for >120 years												
Temporary open space	On walk three sections of open space were encountered. 1) 15x10m, 2) 20x10m, 3) 30x30m Total area of 1250m2 This does not include open space elsewhere in woodland associated with rides and clear												
Native tree species	Percentage cover	0%	10%	2%	5%	95%	0	100%	50%	100%	100%	0	0
abundance	Plot score	0	1	0	0	3	0	3	2	3	3	0	0
Native tree species richness	No. of spp	0	2	3	2	1	0	2	4	1	1	0	0
	Native tree spp	0	BI, SC	BI, SC, ROW	BE, ROW	SC	0	BE, BI	BE, OK, ROW, SC	SC	SC	0	0
	Plot score	0	1	2	1	1	0	1	2	1	1	0	0
Native shrub species	No. of spp	1	1	1	1	0	0	1	1	1	0	1	1
	Shrub spp	HOL	HOL	HOL	HOL	0	0	HOL	HOL	HOL	0	HOL	HOL
richness	Plot score	1	1	1	1	0	0	1	1	1	0	1	1
Regeneration abundance: native tree species	No. of plot quarters with regen	1	1	1	2	4	1	4	1	3	4	3	1
	Native tree spp recruits	OK	BI	ROW, SC	OK, ROW	SC	BI	BE	SC	SC	SC	OK, ROW, SC	OK
	Plot score	1	1	1	3	2	1	2	1	2	2	3	1
Regeneration abundance: non-native tree species	No. of plot quarters with regen	0	0	0	1	0	0	2	0	0	4	0	0
	Species				F			RC			RC		
	Plot score	3	3	3	2	3	3	1	3	3	1	3	3
Vertical vegetation	Vegetation layers present	1,2,4	1,2,3,4	1,3,4	1,2,3,4	2,3,4	3,4	4	2,3,4	2,3	2,3	3	4
structure	Plot score	2	3	2	3	2	1	0	2	1	1	0	0
Variation in stem sizes	Stem size classes present	3	3	3	3,2	3, 4	3, 4	3, 4	1, 2, 3, 4	4	4	4	4
	Main tree species	SP	SP	SP	SP	SC	EL	BE	mixed spp	SC	SC	CP	CP
	Plot score	0	0	0	1	1	1	1	3	0	0	0	0
Standing deadwood	Number of snags in plot	0	1	2	1	2	0	0	0	0	0	1	0
abundance	Estimated no. of snags ha^{-1}	0.0	31.9	63.7	31.9	63.7	0.0	0.0	0.0	0.0	0.0	31.9	0.0
	Plot score	0	0	0	2	0	0	0	0	0	0	0	0
Fallen deadwood volume	Number of deadwood pieces in plot	0.652	0.188	0.153	0.503	0.016	0.024	1.178	0.259	0.236	0.000	0.047	0.039
	Estimated no. of deadwood pieces	20.8	6.0	4.9	16.0	0.5	0.8	37.5	8.3	7.5	0.0	1.5	1.3
	Plot score	2	1	1	1	1	1	2	1	1	0	1	1
CWD volume (multiple types)	Volume of CWD in plot (m^3)	0.652	0.259	0.202	6.158	0.016	0.024	1.178	0.259	0.236	0.000	0.047	0.039
	Estimated volume (m^3) of	20.8	8.3	6.4	196.1	0.5	0.8	37.5	8.3	7.5	0.0	1.5	1.3
	Plot score	2	1	1	3	1	1	2	1	1	0	1	1
Invasive species abundance	No. of plot quarters with invasive	0	2 (Rhod)	0	0	1 (Rhod)	0	0	0	1 (Rhod)	0	0	0
	Plot score	3	0	3	3	2	3	3	3	2	3	3	3
Browsing pressure	Types of damage (% damage)	BS	BS	ST	BS, ST	BS, ST	BS	no damage	BS	BS, ST	ST		
	% damage	1%	2%	10%	5%,10%	30%, 10%	5%	no damage	10%	5%, 50%	80%	no damage	no damage
	Plot score	2	2	2	1	0	2	3	2	0	0	3	3

4.1.2 Estimated biodiversity potential at the sub-compartment scale

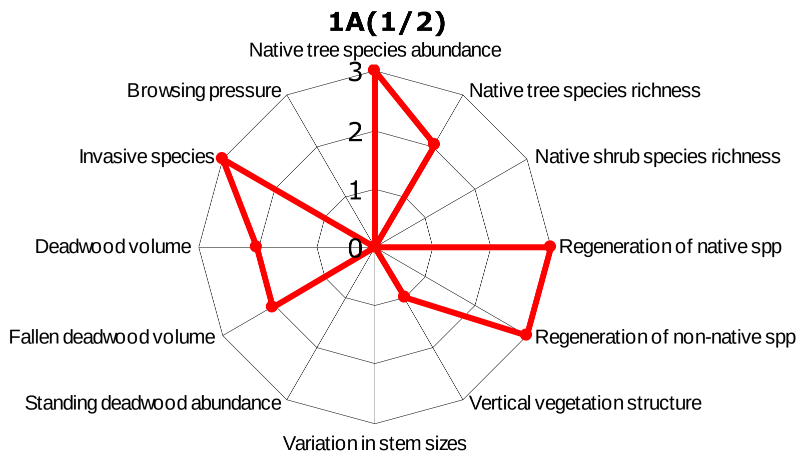
Hartley Mauditt FMU

Survey plots were assessed in the majority of the sub-compartments, covering 52.1ha (88.7% of the FMU). In the remaining, 6.6 ha of 'unvisited' sub-compartments, many of these had comparable counter-parts amongst the assessed sub-compartments; management advice is likely to be transferable between such comparable sub-compartments. For the remaining unvisited sub-compartments, no specific management advice is available following the RWBA. See Table 7.

Table 7: Summary of sub-compartments visited and comparable 'unvisited' ones in FMU

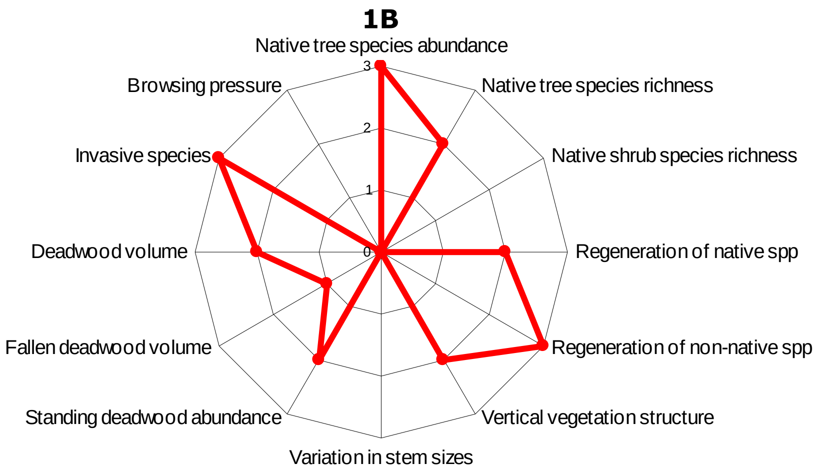
Compart-ment	Sub-compartment	Area (ha)	Dominant Tree Species	Planting year	Survey Plot Assessment? (stop number)	Comparable surveyed plot that can be used for management advice?
1	A1	1.2	POK	1900	√ (1)	
	A2	1.8	SB	1995	√ (1)	
	B	1.4	SP	1956	√ (2)	
	C	1.1	MB	1920	X	See results for sub-cmpt's 2, 3, 4, 5, 6, 7A
	D	1.1	JL	1958	X	See results for sub-cmpt 1B and Land of Nod FMU sub-cmpt 1B
	E	1.1	MB	2004	√ (10)	
	F	1.0	BE	1961	√ (11)	
	G1	0.2	OK	1890	X	No comparable results
	G2	1.1	JL	1958	X	See results for sub-cmpt 1B and Land of Nod FMU sub-cmpt 1B
2	A	6.4	MB	1920	√ (3, 4)	
3	A	11.2	MB	1920	√ (8)	
4	A	11.1	MB	1920	√ (9)	
5	A	6.6	MB	1920	√ (7)	
6	A	7.8	MB	1920	√ (6)	
7	A	2.7	MB	1920	√ (5)	
	A2	1.0	OK	1983	X	No comparable results
	B	2.1	OK	1983	X	No comparable results

<u>Sub-compartment 1A (1/2) POK/SB (PY 1900/1995) 3.3ha</u>: **Stop 1**



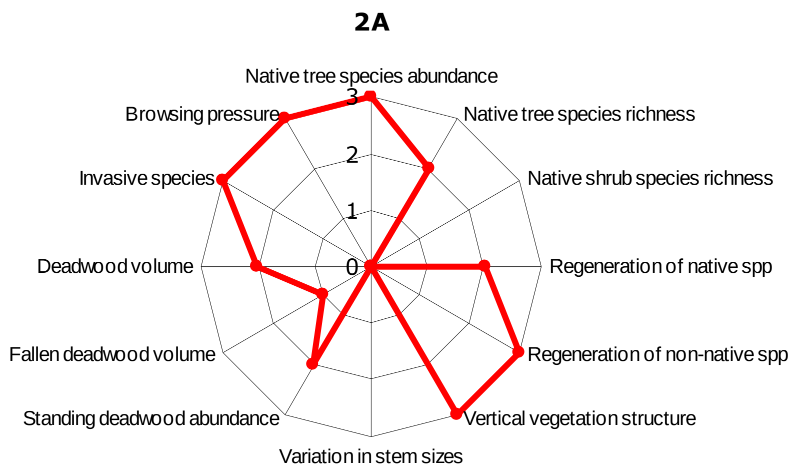
The native tree species component is high in this sub-compartment. Hazel, oak (*Q. robur*), silver birch and wild cherry were found sharing the canopy layer in the temporary survey plot. The herbaceous and lower woody layers are mostly missing, resulting in a poor vertical vegetation structure. Contributing to the poor vertical structure is a limited variation in stem sizes of the dominant native tree species, hazel, indicative of a single age class represented. Native shrub species are also absent and while there is evidence of natural regeneration of hazel (from coppice) and oak (seedlings), the grazing/browsing pressure is very high with approximately 90% of shoot tips showing signs of browsing. It is recommended that during the next coppice cycle, sufficiently large areas are opened up to allow natural regeneration of a greater diversity of native tree and shrub species and the development of a ground vegetation layer. Some seeding/planting may be required to diversify the native tree and shrub species components. Native tree species that could be encouraged to regenerate in this sub-compartment include field maple, beech, sweet chestnut and ash; these tree species are already present in the wider woodland area. Among these and the other native tree species already present in the stand, beech, ash, birch, oak and sweet chestnut would coppice well and could be used as an additional source of coppice, although ash, birch and beech have a shorter coppicing life-span than sweet-chestnut and oak. Regenerating trees and shrubs will require some protection from browsing. Hazel stools can be 'thinned' to provide openings by stump removal or premature cutting to prevent rapid re-growth (Blakesley & Buckley, 2010). A system of coppice with standards would contribute to an increased variation in stem sizes. It is recommended that up to 25 standard trees per hectare are sufficient, according to their canopy size (Blakesley & Buckley, 2010). The overall estimated volume of deadwood in the sub-compartment ($22m^3ha^{-1}$) reaches the minimum recommended volume of deadwood per hectare; this could be improved further for wildlife by retaining approximately another $60m^3$ ha^{-1} in addition to what is already present. Standing deadwood in particular is not in evidence and can be created by leaving behind trees that are unlikely to survive due to shading. Large pieces of standing deadwood (diameter>20cm) are particularly valuable. Invasive species and non-native regeneration are not problematic in this compartment at present and so should not affect tree/shrub species regeneration and the development of ground flora.

Sub-compartment 1B SP (PY 1955) 1.4ha: **Stop 2**



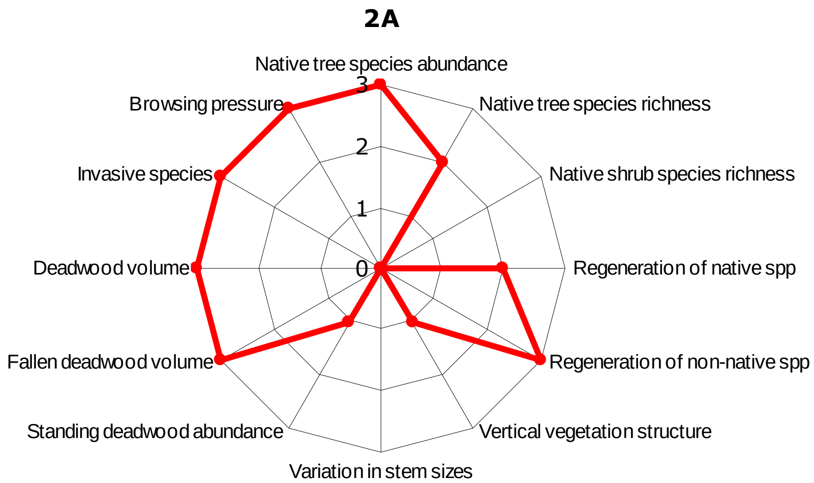
Although Scots pine is the main crop species in this sub-compartment, the native tree species component is high, with three different native tree species found sharing the upper canopy with Scots pine in the temporary survey plot. There is, however, no clear variation in stem sizes of either Scots pine or of any of the native tree species to indicate the occurrence of mixed age classes; the most common native tree species, beech, occurs mostly in stem size class 2 (DBH 24-47cm). A ground vegetation layer is mostly missing and native shrub species are also not in evidence. Regeneration is mostly of ash (seedlings and saplings). There is also a heavy browsing pressure with 80% of shoot tips showing signs of damage in the sample plot. In order to produce a skewed distribution of size classes of both the main crop species, Scots pine, and native tree species that are sharing the canopy, the most appropriate method considering a low risk of windthrow, but high risk of damage to young recruits from browsers, is a shelterwood system using group selection. This involves the gradual removal of the mature canopy by group selection at each thinning interval so that by the end of the second or third thinning cycle a third of the mature canopy has been removed leaving a shelterwood of 75-120 trees ha^{-1} if light-demanding trees are to be regenerated or planted, or more dense (150–200 trees per hectare) for shade-bearers (Blakesley & Buckley, 2010). Fencing or tree guards may be required to protect regenerating trees in the different age cohorts. Opening up the canopy by group selection will also encourage ground flora and native shrub species to develop, although the forest manager should subsequently be vigilant of any potential influx of invasive vegetation species and regeneration of non-native tree species which are currently not a problem in this compartment. Additional tree species that could be encouraged to regenerate include oak, sweet chestnut, hornbeam, wild cherry and field maple; some of these species are present already elsewhere in the wider woodland. The current estimated volume of deadwood (49.5m^{3}ha^{-1}) is sufficiently high to be valuable for wildlife, although it could be increased further by approximately 30m^{3}ha^{-1}. Large pieces of lying deadwood with a diameter >40 cm and large snags (minimum diameter of >20cm) are missing and could be favoured to reach the higher target volume of deadwood.

<u>Sub-compartment 2A MB (PY 1920) 6.4ha</u>: **Stop 3**



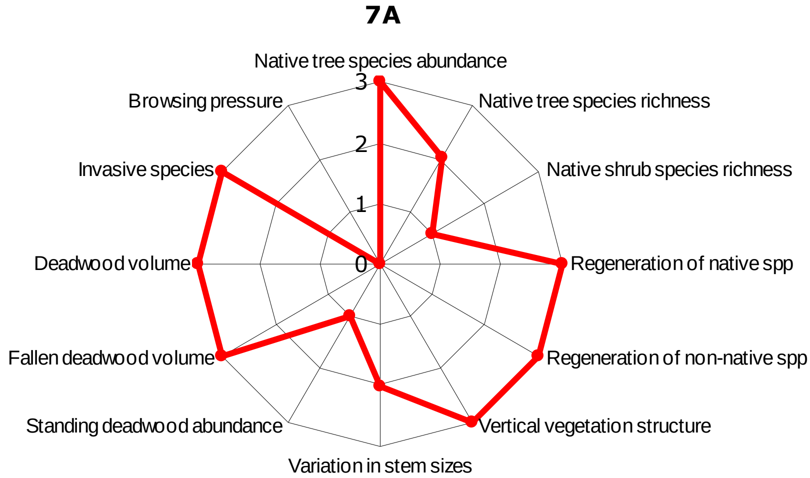
The biodiversity potential in this sub-compartment is high with top scores received for many of the biodiversity indicators. Vertical vegetation structure is very good, with all vegetation layers represented and there are no indications of browsing pressure, or stifled growth due to invasive vegetation species or non-native tree species regeneration. Native tree species richness could be improved further and particular attention should be paid to introducing some native shrub species to the stand where none were found in the temporary survey plot. There is no variation in stem sizes, with only a single age class for individual species represented. Recommendations on how to diversify the range of stem sizes are similar to those given for sub-compartment 1A. The volume of deadwood (70.5m^{3}ha^{-1}) is sufficiently high to be valuable for wildlife, although it could be increased further by approximately 10m^{3}ha^{-1}. Large pieces of lying deadwood with a diameter >40 cm are missing and could be favoured to reach the higher target volume of deadwood.

<u>Sub-compartment 2A MB (1920) 6.4ha</u>: **Stop 4**



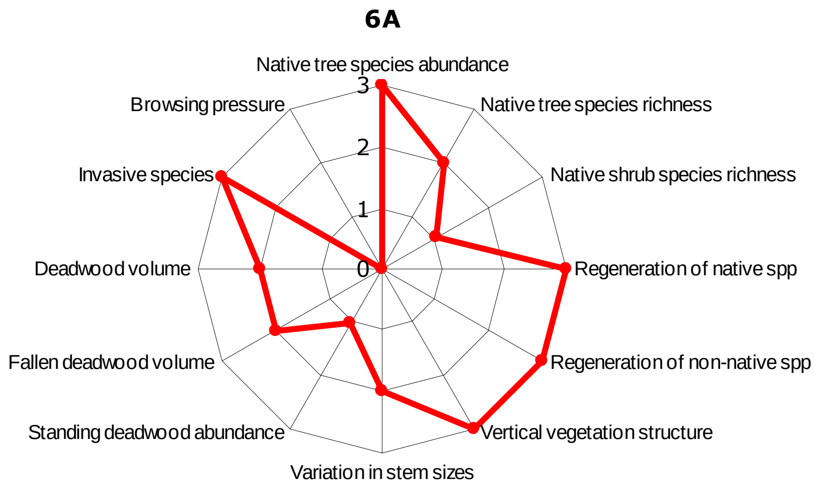
Overall, the biodiversity potential in this sector of the sub-compartment is high, judging from the survey plot scores. The number of native tree species making up the canopy layer could be increased by encouraging, for example, beech, birch, or wild cherry to regenerate. Some opening up of the canopy is desirable also to encourage a ground vegetation layer and regeneration of native shrub species which are both absent. Variation in stem sizes is very poor indicating a limited age class distribution. Some of the more mature trees can be retained as standards to enhance the vertical and horizontal structure of the stand. The volume of deadwood (70m^{3}ha^{-1}) is sufficiently high to be beneficial to biodiversity, although the number of snags could be increased further and especially larger snags (minimum diameter >20cm). Another 10m^{3}ha^{-1} of deadwood is recommended to maximise biodiversity potential.

Sub-compartment 7A MB (1920) 2.7ha: **Stop 5**



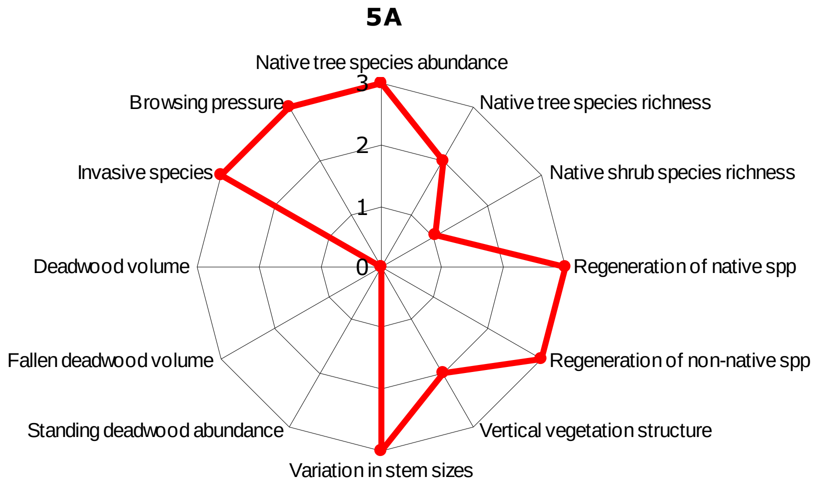
The biodiversity potential in this sector of the sub-compartment is high with top scores received for almost all of the biodiversity indicators. Improvements could, nevertheless, still be made. The number of native tree species making up the canopy layer could be increased by encouraging, for example, beech, birch and wild cherry to regenerate. Only one native shrub species (holly) was present in the survey plot, which may in part be due to the relatively high browsing pressure as evidenced by 50% of shoot tips in the survey plots showing signs of damage. Encouraging a more diverse shrub layer by direct seeding is recommended, although some action will need to be taken to stem the browsing pressure. Promoting trees in the largest age class (DBH>71.6cm), for example as standards, is recommended. The volume of deadwood (144m^3ha^{-1}) is sufficiently high to be beneficial to biodiversity, although snags were scarce and large snags (minimum diameter >20cm) were completely absent; more deadwood of this type is needed for wildlife that specifically uses it as habitat (e.g. woodpeckers) (Bütler *et al*., 2004).

Sub-compartment 6A MB (1920) 7.8ha: **Stop 6**



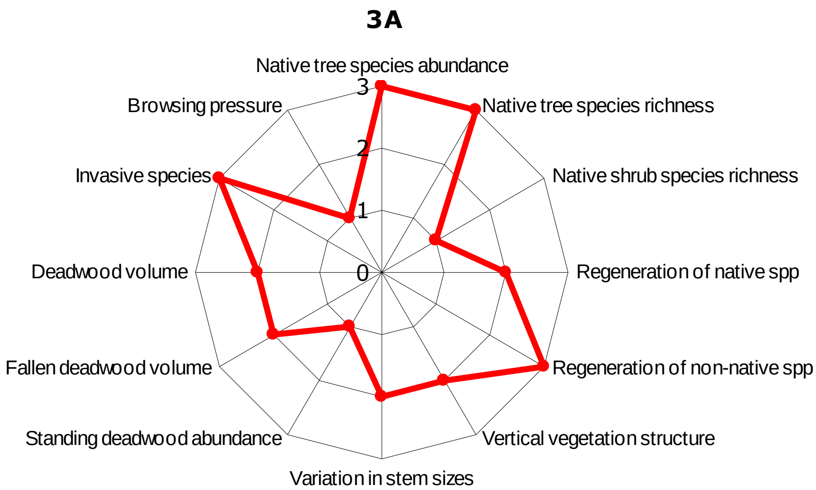
The management recommendations for this sub-compartment are very similar to those proposed for compartment 7A. Deadwood volume at 25.6m^3ha^{-1} is lower in this compartment, however, with no large fallen deadwood (minimum diameter>40cm) or large snags (minimum diameter >20cm) present in the survey plot. Deadwood volume could be improved by retaining approximately another $55m^3\ ha^{-1}$ in addition to what is already present (i.e. $25.6m^3ha^{-1}$).

Sub-compartment 5A MB (1920) 6.6ha: **Stop 7**



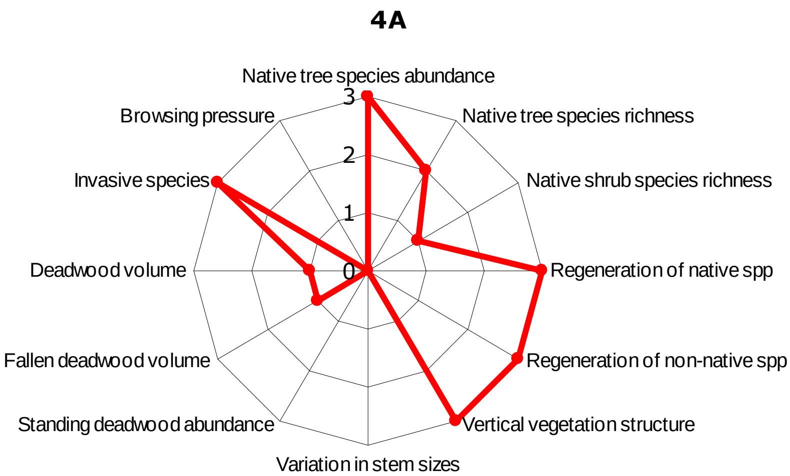
The biodiversity potential in this sub-compartment is high with top scores received for many of the biodiversity indicators. There is a good mixture of stem sizes of the most common native tree species indicating the presence of a range of age classes. Regeneration of tree species appears to be high with no damage in evidence from browsers, although only two native shrub species were present in the shrub layer and there was no ground vegetation layer. It is recommended that during the next planned thinning intervention, some open space is left to encourage a ground vegetation layer and the regeneration of more native tree and shrub species. Removal of some of the coppice stools of the most common tree species may be necessary to create sufficient space. Some seeding/planting may be required to increase the diversity of woody species. Tree species that could be planted to increase species diversity include sweet chestnut, wild cherry, ash, field maple and birch. Also, as no deadwood was in evidence in the survey plot, it is recommended that at least $80m^3\ ha^{-1}$ of deadwood is planned for retention on site, particularly of large fallen deadwood (minimum diameter>40cm) or large snags (minimum diameter >20cm).

Sub-compartment 3A MB (1920) 11.2ha: **Stop 8**



The biodiversity potential in this sub-compartment is high with high scores received for many of the biodiversity indicators. As for many other sub-compartments in Hartley Mauditt FMU with a similar management and composition, a ground vegetation layer is missing, requiring some open space to be left at the next thinning, potentially by the removal of some coppice stools to create space. This management action might also help to promote the natural regeneration of native shrub species which were otherwise completely absent from the survey plot. Some action may be required to help stem the browsing pressure which was observed to be relatively high in the temporary survey plot. While some deadwood was present (47 m^3 ha^{-1}) the overall volume could be increased further by 33 m^3 ha^{-1} and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot.

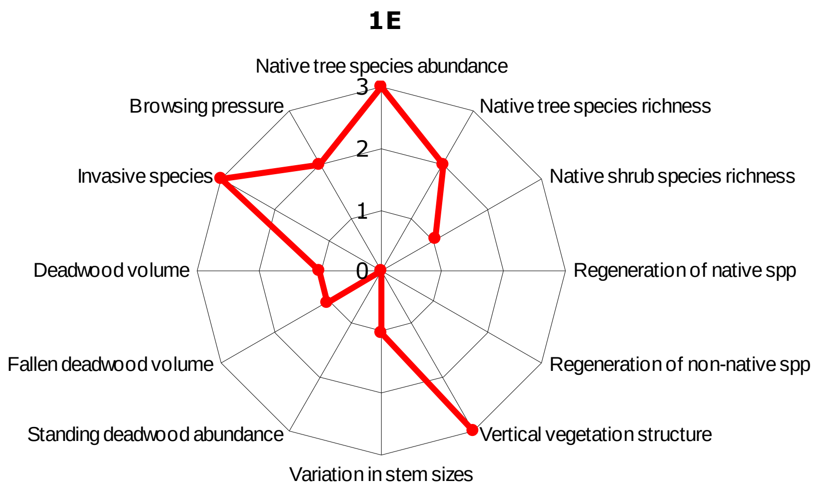
Sub-compartment 4A MB (1920) 11.1ha: **Stop 9**



The biodiversity potential in this sub-compartment is high with high scores received for many of the biodiversity indicators. Improvements that could be made include increasing further the number of native tree species making up the canopy layer by encouraging, for example, field maple, birch and wild cherry to regenerate. A single stem size category for the coppice species, hazel, reflects a poor age structure.

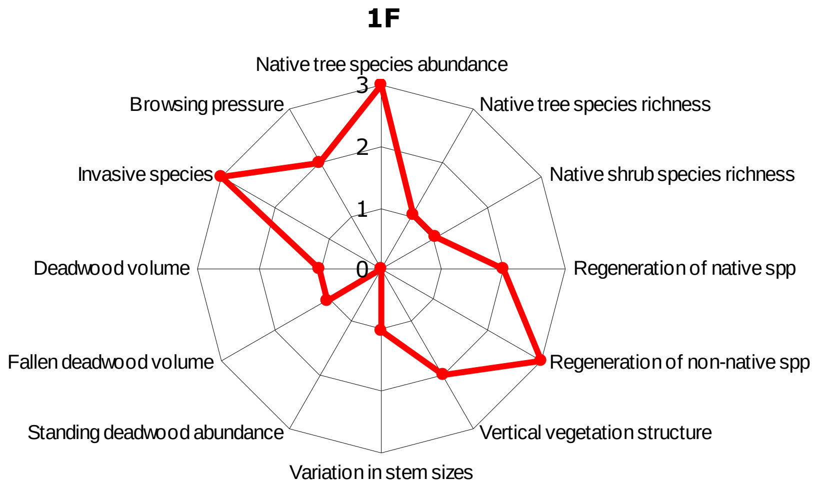
Recommendations on how to improve this are similar to those given for compartment 1A. Encouraging a more diverse shrub layer by direct seeding is recommended, although action will need to be taken to stem the heavy browsing pressure as evidenced by 80% of shoot tips in the survey plots showing signs of damage. Promoting large trees as standards in the largest age class (DBH>71.6cm) is also recommended. Deadwood volume (10 m^3ha^{-1} could be substantially improved by retaining approximately another 70m^3 ha^{-1} in addition to what is already present (i.e. 10.3m^3ha^{-1}) and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot.

Sub-compartment 1E MB (2004) 1.1ha: **Stop 10**



Although this coppice stand has only recently been established, the biodiversity potential is high, although not all of the biodiversity indicators could be assessed in a temporary survey plot because of dense undergrowth. Improvements could be made in particular to the number of stem size classes of the coppice crop and it is recommended that the number of native tree and shrub species is increased further. See sub-compartment 1A for suggestions on how this might be achieved. Promoting large trees as future standards in the largest age class (DBH>71.6cm) is also recommended as no trees in this age class were found in the survey plot. Deadwood volume could be substantially improved by retaining approximately another 67.5m^3 ha^{-1} in addition to what is already present (i.e. 12.5m^3ha^{-1}) and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot.

<u>Sub-compartment 1F BE (1961) 1.0ha</u>: **Stop 11**



The management recommendations for this sub-compartment are similar to those proposed for sub-compartment 1A. While biodiversity potential is fairly high according to many of the biodiversity indicator scores, tree species richness and the age class structure of the main coppice species could be improved. As beech dominates the canopy and is a heavy shade-bearing tree, for additional tree species to regenerate, the sizes of any openings will need to be considered carefully. Deadwood volume (4.5m^3 ha^{-1}) could be substantially improved by retaining approximately another 75.5m^3 ha^{-1} in addition to what is already present (i.e. 4.5$m^3 ha^{-1}$) and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot.

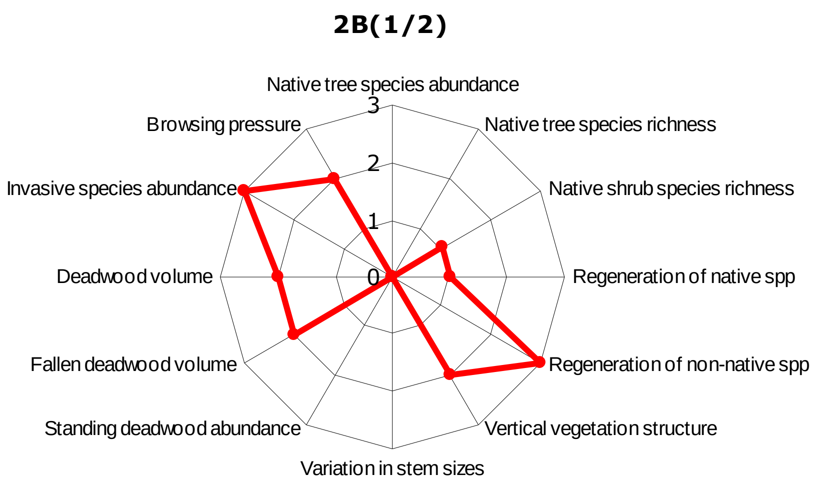
Land of Nod FMU

Survey plots were assessed in sub-compartments covering a combined area of 21.9ha (58% of the FMU). See Table 8.

Table 8: Summary of sub-compartments visited and comparable 'unvisited' ones in FMU

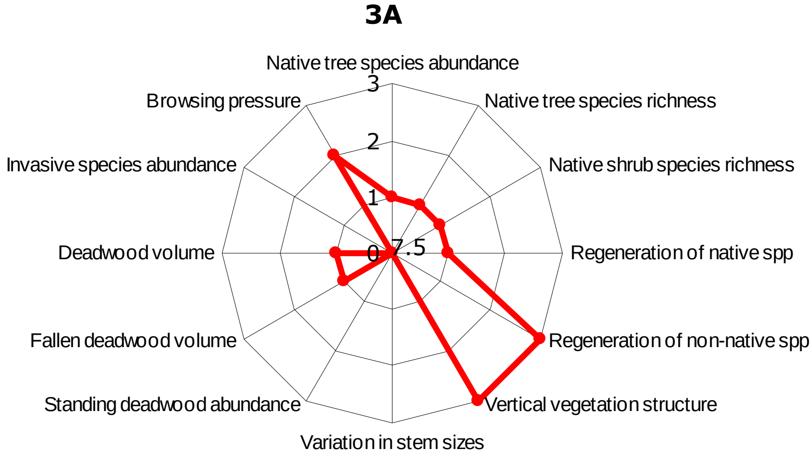
Compart-ment	Sub-compartment	Area (ha)	Dominant Tree Species	Planting year	Survey Plot Assessment? (stop number)	Comparable surveyed plot that can be used for management advice?
1	A1	1.8	BE	1960	√ (7)	
	A2	0.6	JL	1960	X	See results for sub-cmpt 1B
	B	0.9	EL	1977	√ (6)	
	C	1.4	SCC	2000	√ (5)	
	D1	2.2	MB	1900	X	No comparable results
	D2	1.4	MB	1987	X	No comparable results
	E	0.8	MC	1960	X	No comparable results
	F	0.7	EL	1971	X	See results for sub-cmpt 1B
	G1	1.3	SCC	2004	√ (10)	
	G2	0.2	SP	1971	X	See results for sub-cmpt's 1H, 1K, 2B(1), 2B(2), 3A
	H1	2.5	SP	1977	√ (4)	
	H2	0.4	WH	1965	X	No comparable results
	I	0.4	MB	1900	X	No comparable results
	J1	0.4	WH	1966	X	No comparable results
	J2	2.0	SP	1966	X	See results for sub-cmpt's 1H, 1K, 2B(1), 2B(2), 3A
	K	2.6	SP	1964	√ (3)	
	L	1.4	SP	1966	X	See results for sub-cmpt's 1H, 1K, 2B(1), 2B(2), 3A
	M	2.3	CP	1977	X	No comparable results
	N1	0.1	SP	1963	X	See results for sub-cmpt's 1H, 1K, 2B(1), 2B(2), 3A
	N2	0.0	NS	1963	X	No comparable results
	N3	0.1	RC	1963	X	No comparable results
	P	1.1	CP	1983	√ (8)	
2	A	1.9	CP	1977	√ (12)	
	B1	0.4	SP	1964	√ (1)	
	B2	0.5	SP	1971	√ (1)	
	C	0.9	SP	1966	X	See results for sub-cmpt's 1H, 1K, 2B(1), 2B(2), 3A
	D	1.1	MB	1900	X	No comparable results
	E1	0.4	EL	1971	X	See results for sub-cmpt 1B
	E2	0.2	SCC	1971	√ (9)	
3	A	4.3	SP	1966	√ (2)	
4	A	0.3	BR		X	Poorly defined composition in FMU management plan
	B	3.0	CP	1991	√ (11)	

<u>Sub-compartment 2B (1/2) SP (PY 1964/71) 0.4/0.5ha</u>: **Stop 1**



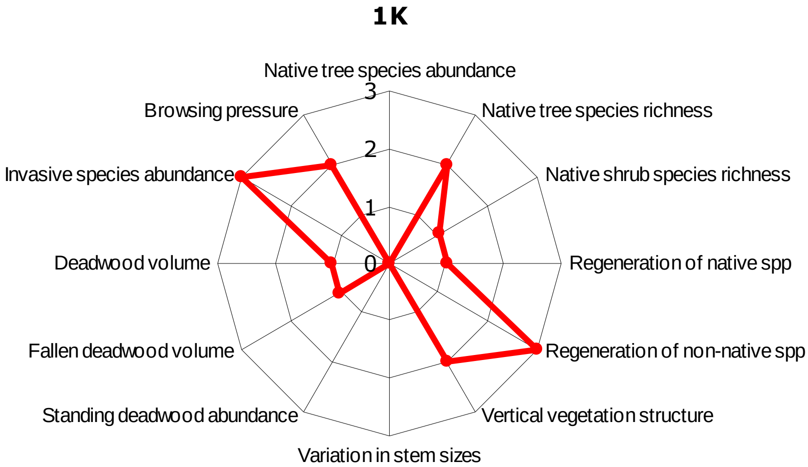
Low scores for most of the biodiversity indicators assessed in the survey plot suggest that the biodiversity potential of this sub-compartment is poor. There are, however, a number of management changes that could be made to improve this sub-compartment's biodiversity potential. No native tree species share the canopy at present with the main crop species, Scots pine and Scots pine only occurs in one stem class size. For increased biodiversity potential, native tree species could be encouraged to regenerate in spaces that are opened up during thinning cycles so that there is a goal of at least 10% of the canopy comprising native tree species (e.g. creation of an oak-Scots pine mixture). A new generation of Scots pine should also be encouraged to regenerate in gaps. Where these new recruits do not reach the canopy layer by the end of the crop cycle, they will at least contribute to an intermediate woody vegetation layer (which is missing at present) and help to create a mixed age structure. Currently oak (likely to be sessile oak) is regenerating naturally in this sub-compartment and other native tree species that occur in the FMU that could be encouraged to regenerate naturally or by seeding/planting include sweet chestnut, beech, rowan and birch. Other native tree species that are likely to cope with the sandy soils include small-leaved lime, whitebeam and aspen. The diversity of native shrub species is very poor, comprising only one species at present, holly; native shrub species richness could be increased by encouraging regeneration in gaps or by direct seeding. The small size of the sub-compartment precludes the possibility of creating large gaps. In this case, more shade tolerant native tree species should be prioritised to create a more complex vertical structure. Very positive points for the biodiversity potential of this sub-compartment are the low levels of browsing pressure and no visible competition from invasive vegetation species or from regeneration of non-native conifers. The manager should remain vigilant of these threats, however, following the creation of gaps in the canopy. The estimated volume of deadwood in this sub-compartment (22 m^3ha^{-1}) reaches the minimum recommended level which is $20m^3ha^{-1}$ and some large fallen deadwood (diameter >40cm at narrowest point) is present. However, no snags were observed and where more deadwood is generated either artificially or naturally, large snags (diameter >20cm at narrowest point) and more large lying deadwood pieces should be prioritised with recommended increases in volume of $60m^3ha^{-1}$.

Sub-compartment 3A SP (PY 1966) 4.3ha: **Stop 2**



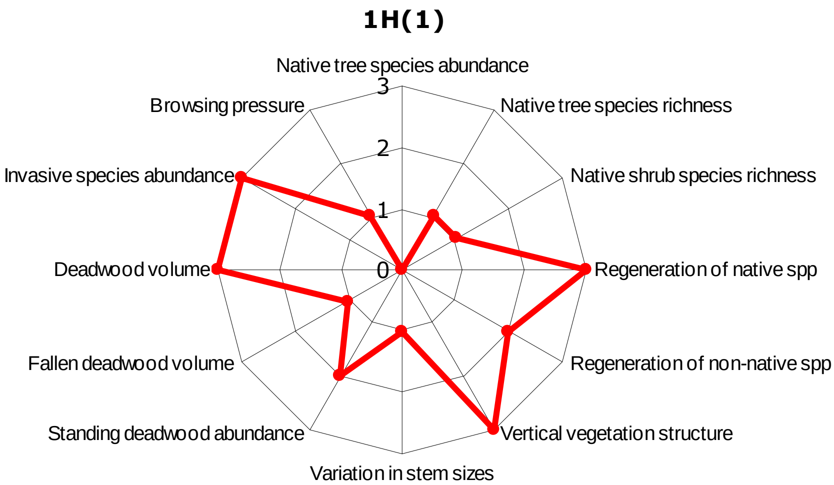
Although this sub-compartment is chiefly a Scots pine plantation with the main crop present in a single stem class size, 10% of the canopy comprises native tree species (i.e. birch and sweet chestnut). To improve the biodiversity potential of the sub-compartment in terms of tree species composition, the recommendation would be to increase the native tree species component still further to create a mixed species crop. One option is to consider during the next thinning operations to introduce more sweet chestnut in gaps that are opened up. This naturalised broadleaf species is tolerant of moderate shading and should thrive on the sandy loams present in the Land of Nod FMU. Natural regeneration of birch only was observed in the temporary survey plot, so planting of sweet chestnut in gaps may be required to facilitate the recruitment process. Where other native tree species and/ or Scots pine emerge in gaps through natural regeneration, these should be retained to increase species richness and to diversify the age structure of the stand. Suggestions of other native tree species to encourage growing in gaps have been given already for sub-compartment 2B. Gap creation by group selection should be staggered through time as another mechanism to diversify the age structure of the tree species occupying the stand. Native shrub species richness was poor (i.e. only holly present), so could also be improved by direct seeding where natural regeneration does not occur. It is likely that some intervention is needed to control the levels of competition for space and light from rhododendron. While this invasive species shows a heavy presence in this sub-compartment, a good vertical vegetation structure is nevertheless present, with all defined layers present. The volume of deadwood in this sub-compartment (8.3 m^3ha^{-1}) is below the minimum threshold of $20m^3ha^{-1}$. 1 snag and only small (<40cm diameter at narrowest point) fallen deadwood pieces were observed in the temporary survey plot. The generation of more deadwood (as much as 70 m^3ha^{-1}) is suggested during thinning intervals, and particularly of large snags (>20 cm at narrowest point) and large fallen deadwood pieces (minimum diameter >40cm).

Sub-compartment 1K SP (PY 1964) 2.6ha: **Stop 3**



This sub-compartment has much in common with sub-compartment 3 and the management recommendations would be very similar. Regeneration of sweet chestnut and rowan are in evidence, although a low score indicates that this natural recruitment of native tree species is infrequent. Unlike sub-compartment 3, rhododendron does not show a significant presence in this sub-compartment and therefore should not be problematic for the process of enhancement of native tree and shrub species components. The volume of deadwood in this sub-compartment (6.4 m^3ha^{-1}) is below the minimum threshold of $20m^3ha^{-1}$. Although snags and fallen deadwood were observed in the survey plot, the quantity should ideally be increased by 75 m^3ha^{-1} and include some large pieces of fallen deadwood (minimum diameter >40cm) and large snags (>20 cm at narrowest point).

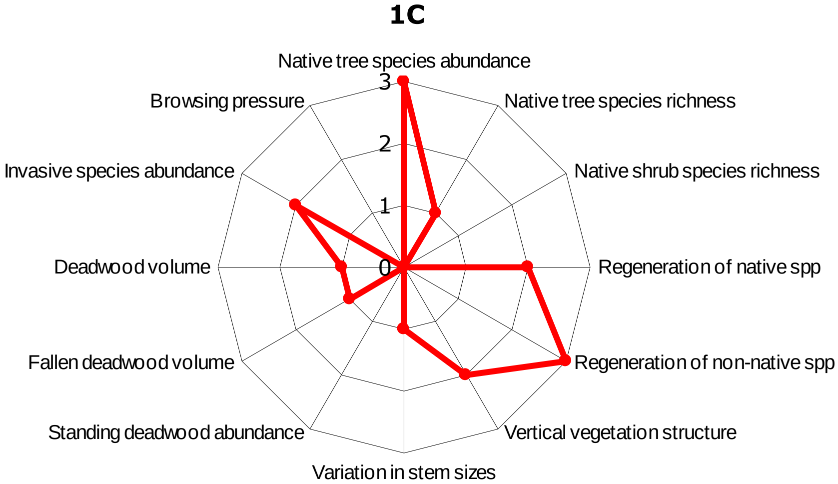
Sub-compartment 1H (1) SP (PY 1977) 2.5ha: **Stop 4**



A single aged Scots pine crop dominates this sub-compartment, although some rowan and beech are also present making up a small fraction of the canopy (5%). The biodiversity potential of this pine monoculture is fairly limited as the low scores for many biodiversity indicators in the survey plot reveal. It is recommended that this sub-compartment is diversified in terms of species composition and/or in terms of the age structure of the dominant tree species. Diversifying the Scots pine crop can be achieved by 1) undertaking a heavy thinning at the point where the Scots pine is at or near its maximum mean annual volume increment, or 2) by carrying out group fellings at periodic intervals to allow a mixed age structure to develop as new recruits replace Scots pine in the gaps. Group felling is preferable to avoid disturbance to ground vegetation layers and associated biodiversity. It could also reduce the potential for competitive exclusion of woodland species from invasive ground vegetation species and herbivores that proliferate following an opening of the canopy. Natural regeneration by native tree species may be possible considering the high numbers of oak and rowan recruits recorded in the temporary survey plot. Both of these species require fairly open canopy conditions for good growth, so large gaps would need to be created and maintained. As sweet chestnut is already a key component of the canopy layer in three other sub-compartments in the Land of Nod FMU (making up a combined area of 2.9ha or 9% of the FMU), it is recommended that other native tree species that are likely to be tolerant of the well-drained soils in Land of Nod FMU, such as beech, small-leaved lime, birch, whitebeam and sessile oak (*Q. petraea*), are favoured for the regeneration of the gaps in the stand. All of these apart from beech require intermediate to high levels of light for good growth. More native shrub species such as dogwood, privet, or dogrose should also be encouraged to regenerate in gaps. Only holly was found to be present in the temporary survey plot. Group felling is likely to be the most sensitive management approach to help minimise disturbance to existing wildlife, while also preserving in some sections of the stand the benefits of the good vertical vegetation structure that already exists. As the stand is quite large it should be possible to create sufficiently large gaps for regeneration and good growth.

While no invasive vegetation species were observed in the survey plots and only some limited regeneration of non-native tree species (a fir), browsing pressure was high so some protective measures may be required to shield young trees and native shrubs species from browsers. The volume of deadwood in this sub-compartment (196 m^3ha^{-1}) is very high. Where diversification of the stand ensues, standing and lying deadwood of native tree species will be preferential to Scots pine deadwood.

Sub-compartment 1C SC (PY 2000) 1.4ha: **Stop 5**

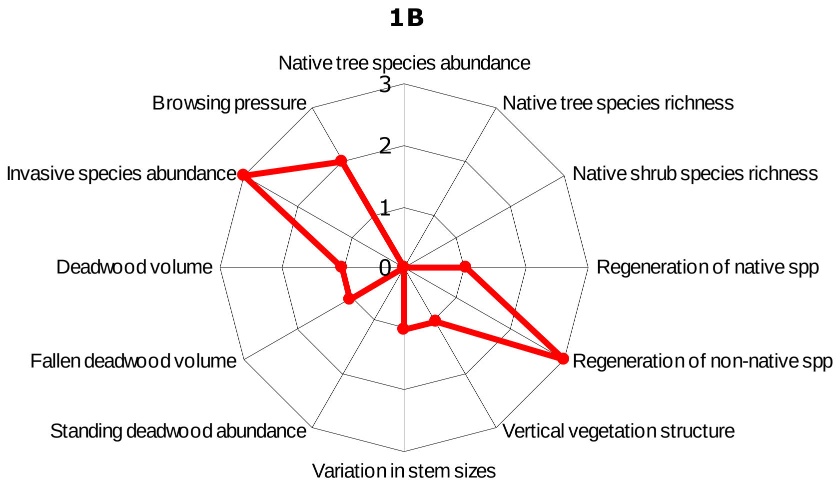


Although this sub-compartment is dominated by the naturalised native broadleaf species, sweet chestnut, the biodiversity potential of this sub-compartment is compromised by the young age and single species composition of the stand. A ground vegetation layer and native shrub species are missing which could be improved through the management of rhododendron which is present, although not yet dominant in the undergrowth. Also, a ground vegetation layer could be encouraged to develop where the density of sweet chestnut coppice stools is reduced. It is recommended that a system of coppice with standards is introduced as a minimum means to diversify the stand in the long term. This will contribute to an increased variation in stem sizes, improved vertical vegetation structure and increased native tree species richness. Oak and beech could be planted as standards (these species are present in the wider FMU) and these should be 'recruited' gradually over a period of time in order to establish standards representing a number of age cohorts. Some sweet chestnut standards could also be encouraged to develop, by reducing a number of coppice stools to a single dominant stem. It is recommended that up to 25 standard trees per hectare are sufficient, according to their canopy size. When the standards grow into mature trees they could occupy 20–40% of the overhead cover, but if scarce butterfly species are present, a lower cover density of 20% or less may be appropriate (Blakesley & Buckley, 2010). Tree species with relatively open canopies, such as oak, ash and birch, will allow more light through, while beech will cast a dense shade. For even greater diversification of the stand, it is recommended that some of the sweet chestnut coppice is removed in order to create space for the development of a ground vegetation layer and natural regeneration or planting of some native shrub species which are absent at present. As a 'naturalised' native tree species, the number and variety of different taxa associated with sweet chestnut is lower than that of native tree and shrub species (Buckley & Howell, 2004). Stools can be 'thinned' by stump removal or premature cutting to prevent rapid re-growth (Blakesley & Buckley, 2010).

The young age and broadleaf component of this stand have clearly attracted herbivores as evidenced by the low biodiversity potential score against the browsing pressure biodiversity indicator. Some herbivore protection measures are likely to be needed.

The volume of deadwood in this compartment (0.5 m^3ha^{-1}) is well below the minimum recommended threshold of $20m^3ha^{-1}$. Where some sweet chestnut is removed to make space for other tree species, these stools and/or the poles from them should be left *in situ*. In the longer term, where standards are introduced, these should provide a supply of deadwood in the form of large branches, especially where tree crowns are thinned. Also, as standards develop and their canopies expand fewer will be needed. Those in excess can be ring barked and left as standing deadwood, ideally when the DBH is at least 20cm.

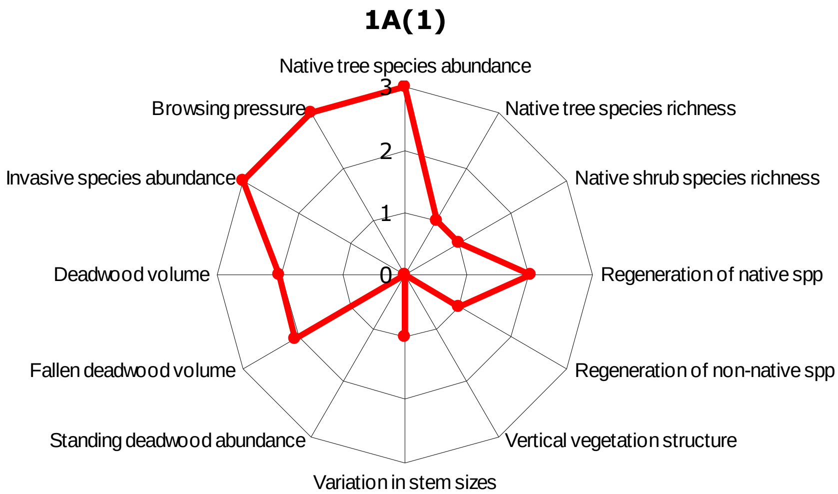
<u>Sub-compartment 1B EL (PY 1977) 0.9ha</u>: **Stop 6**



The biodiversity potential of this European larch monoculture is very limited as revealed by the low scores for most biodiversity indicators. Added to this is the potential vulnerability of European larch to *Phytophthora ramorum* which makes its future as a source of timber uncertain, especially as there is no alternative tree species in the compartment to replace it should crop failure occur. Diversifying the European larch crop can be achieved by 1) undertaking a heavy thinning at the point where the larch is at or near its maximum mean annual volume increment, or 2) by carrying out group fellings at periodic intervals to allow a mixed age structure to develop as new recruits replace larch in the gaps. The second option is unlikely to work well, however, in this stand because of its small size. Management action to diversify the stand should consider promoting the development of ground vegetation and lower woody layers which are missing at present. The removal of any larch should progress gradually in order to create and then retain a complex vertical structure.

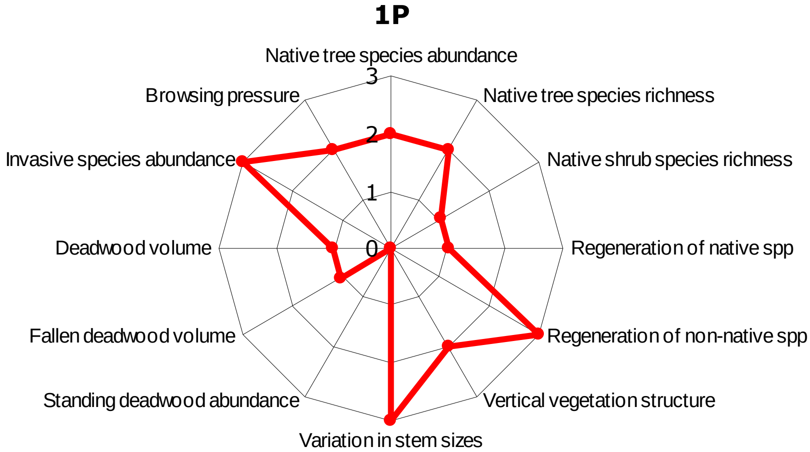
The volume of deadwood in this sub-compartment (0.8 m^3ha^{-1}) is well below the minimum recommended threshold of $20m^3ha^{-1}$. Where diversification of the stand ensues, standing and lying deadwood of native tree species will eventually be preferential to European larch deadwood, although European larch can act as an initial source of standing and lying deadwood.

Sub-compartment 1A(1) BE (PY 1960) 1.8ha: **Stop 7**



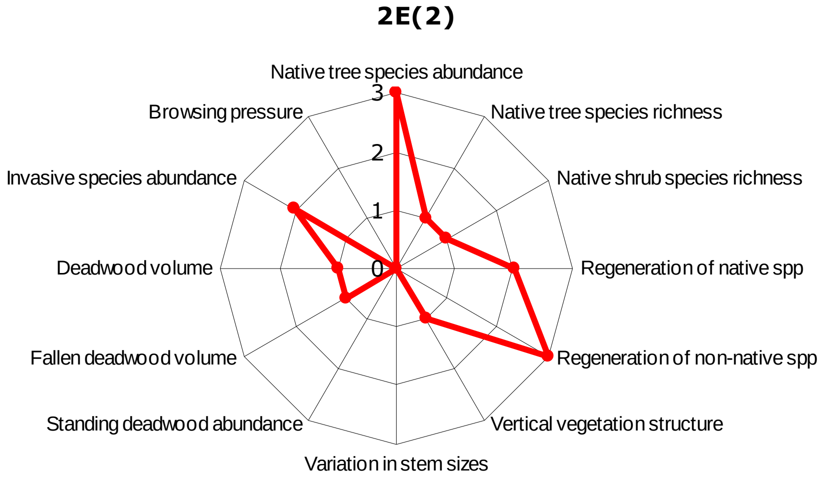
While the native tree species abundance score is high, this stand comprises only two native tree species (i.e. mostly beech, with some birch) and vertical vegetation structure is restricted to one layer (i.e. a high woody vegetation layer). This sub-compartment would benefit from the introduction of other native broadleaf woodland species, such as sessile oak (*Q. petraea*), rowan, whitebeam, small leaved lime, aspen and/ or birch. Diversifying the beech crop can be achieved by 1) undertaking a heavy thinning at the point where the beech is at or near its maximum mean annual volume increment, or 2) by carrying out group fellings at periodic intervals to allow a mixed age structure to develop as new recruits replace beech in the gaps. Where new generations of beech and other native tree species do not reach the canopy layer by the end of the crop cycle, the younger trees will at least contribute to an intermediate woody vegetation layer which is missing at present. Currently beech is regenerating abundantly in this sub-compartment showing good potential for the development of a mixed age structure, at least for this species. The diversity of native shrub species is very poor, comprising at present only one species, holly; native shrub species richness should also be increased by encouraging regeneration in gaps or by direct seeding. Opening up the canopy will also encourage ground flora to develop, although the forest manager should subsequently be vigilant of any potential influx of invasive vegetation species and regeneration of non-native tree species; at present red cedar seedlings were found to be fairly prolific in the temporary survey plot. The volume of deadwood in this sub-compartment (37.5 m^3ha^{-1}) is above the minimum recommended threshold of $20m^3ha^{-1}$. There is, however, no standing deadwood and no large pieces of fallen deadwood (diameter of >40cm at narrowest point). These categories of deadwood should be prioritised where more deadwood is generated during the process of opening up the beech canopy. Another 60 m^3ha^{-1} of deadwood is recommended for retention.

Sub-compartment 1P CP (PY 1983) 1.1ha: **Stop 8**



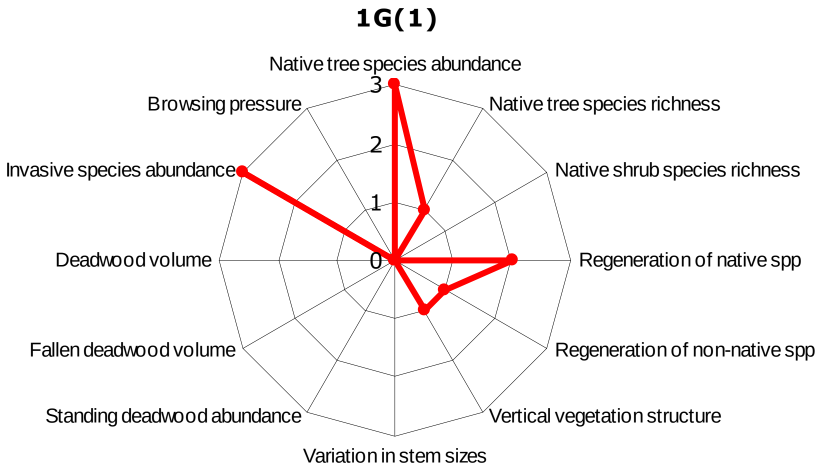
The biodiversity potential of this sub-compartment is high and can be improved further without significant changes required to the composition of the stand. based on a an estimate from the survey plot, a young single aged Corsican pine crop presently shares approximately 50% of the canopy with rowan, oak, sweet chestnut and beech resulting in a diversified canopy layer. The uncertain future of Corsican pine (see comments for sub-compartment 4b) suggests that this species could be removed at the next thinning interval to create space for the regeneration of more native tree species such as birch. More native shrub species such as dogwood, privet, or dogrose should also be encouraged to regenerate in gaps created with the removal of Corsican pine. Only holly was found to be present in the temporary survey plot. The volume of deadwood in this sub-compartment (8.3 m^3ha^{-1}) is below the minimum recommended threshold of $20m^3ha^{-1}$. Deadwood volume could be substantially improved by retaining approximately another 72 m^3ha^{-1} and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm). Standing and lying deadwood of native tree species will be preferential to Corsican pine deadwood, although Corsican pine can act as an initial source of standing and lying deadwood.

<u>Sub-compartment 2E(2) SC (PY 1971) 0.2ha</u>: **Stop 9**



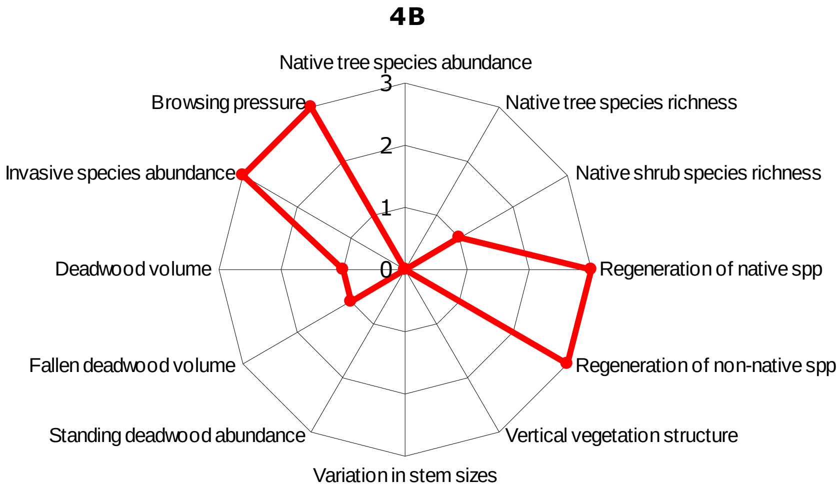
This sweet chestnut coppice monoculture has low biodiversity potential as it presents a fairly homogenous stand structure with no variation in stem size classes and only two vegetation layers (low and intermediate woody layers). There was no ground vegetation layer in the survey plot with only sweet chestnut regenerating and holly present as a native shrub species. Browsing pressure is high and rhododendron is present. Most of the management recommendations given for sub-compartment 1C also apply in this stand. The volume of deadwood in this sub-compartment (7.5 m^3ha^{-1}) is below the minimum recommended threshold of $20m^3ha^{-1}$. It is proposed that deadwood amounting to 73 m^3ha^{-1} should be created/retained in this sub-compartment.

<u>Sub-compartment 1G(1) SC (PY 2004) 1.8ha</u>: **Stop 10**



The biodiversity potential of this young single-aged sweet chestnut coppice stand is very low according to the majority of biodiversity indicators. There are potential additional problems in this sub-compartment of high levels of browsing and regeneration of red cedar seedlings in high numbers which may impact on the regeneration of native tree species. Sweet chestnut is the only 'native' tree species regenerating at present in high numbers and there is otherwise no ground vegetation layer. Most of the observations and management recommendations given for sub-compartment 1C also apply in this stand. No deadwood of any kind was present in the survey plot, although some old coppice stools were present potentially providing microhabitats for wildlife. It is proposed that deadwood amounting to 80 m^3ha^{-1} should be created/retained in this sub-compartment.

Sub-compartment 4B CP (PY 1991) 3.0ha: **Stop 11**

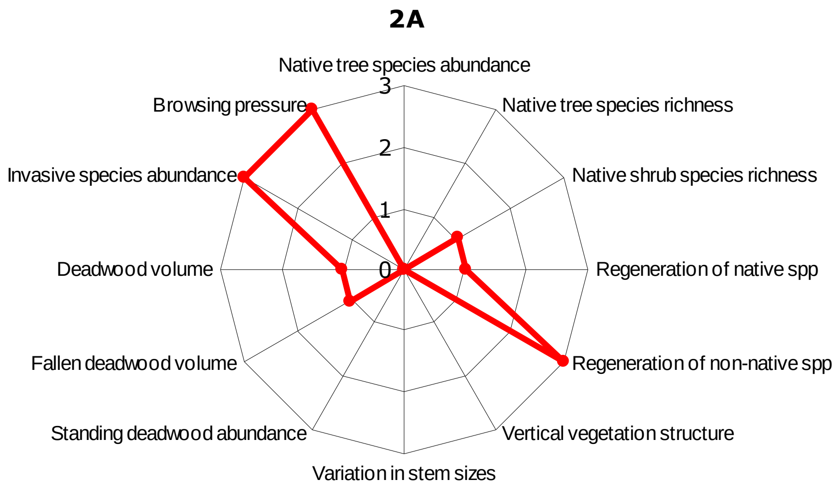


The biodiversity potential of this pine monoculture is fairly limited as the low scores for many biodiversity indicators in the survey plot reveal. Added to this is the vulnerability of Corsican pine to red band needle blight (*Dothistroma*) which makes its future as a source of timber very uncertain, especially as there is no alternative tree species in the sub-compartment to replace it should there be crop failure. A young Corsican pine crop dominates the canopy and occupies a single vertical vegetation layer (the intermediate woody layer). Native tree species do appear, nevertheless, to be regenerating naturally and in abundance including species such as rowan, oak and sweet chestnut. It is recommended that this stand is at the very least diversified, although harvesting the stand and replanting with native tree species is preferential for greatest gains in terms of both a more secure source of timber and/or woodfuel as well as for significant improvements in the biodiversity potential of the stand. Diversifying the Corsican pine crop can be achieved by 1) undertaking a heavy thinning at the point where the Corsican pine is at or near its maximum mean annual volume increment, or 2) by carrying out group fellings at periodic intervals to allow a mixed age structure to develop as new recruits 9e.g. oak and rowan) replace Corsican pine in the gaps. Large gaps would need to be created and maintained for oak and rowan to grow well. More native shrub species such as dogwood, privet, or dog rose should also be encouraged to regenerate in gaps. Only holly was found to be present in the temporary survey plot.

Deadwood volume could be substantially improved by retaining approximately another 78m^3 ha^{-1} in addition to what is already present (i.e. 2.3m^{3}ha^{-1}) and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot.

Where diversification of the stand ensues, standing and lying deadwood of native tree species will be preferential to Corsican pine deadwood.

<u>Sub-compartment 2A CP (PY 1977) 1.9ha</u>: **Stop 12**



The biodiversity potential of this mature Corsican pine monoculture is very low with poor scores for almost all biodiversity indicators. Poor light levels within the stand remove the possibility of any successful natural regeneration and other understory vegetation development (apart from the occurrence of holly as a shade-tolerant species); this in turn reduces the likelihood of high levels of browsing or colonisation by invasive vegetation species, which explains the high biodiversity potential scores for these biodiversity indicators. As for the other Corsican pine monocultures (e.g. compartment 4b), it is recommended that the Corsican pine is gradually harvested and replaced with native tree species mixtures, or at the very least that a mixed age and/or mixed species composition is introduced. See sub-compartment 4b for suggestions on how these options might be achieved.

The volume of deadwood in this sub-compartment (1.3 m^{3}ha^{-1}) is well below the minimum recommended threshold of 20m^{3}ha^{-1}. Deadwood volume could be substantially improved by retaining approximately another 78m^3 ha^{-1} and particularly for large fallen deadwood (minimum diameter>40cm) and large snags (minimum diameter >20cm) which were absent in the temporary survey plot. Where diversification of the stand ensues, standing and lying deadwood of native tree species will eventually be preferential to Corsican pine deadwood, although Corsican pine can act as an initial source of standing and lying deadwood.

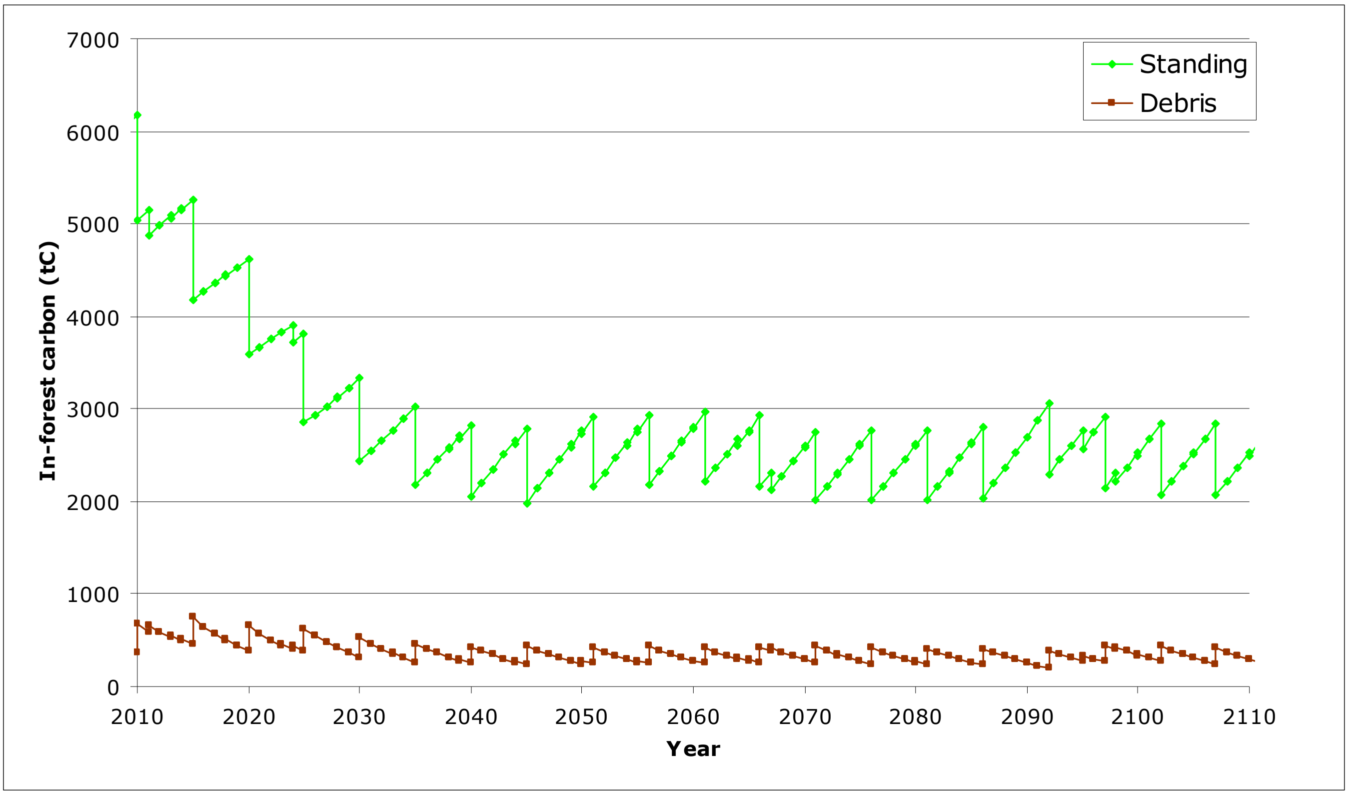
4.2 Estimates of carbon stocks in the forest and biomass of harvested wood products for the current and RWBA-informed management plans

All results are presented as forecast estimates for a 100 year period between 2010 and 2110. It should be noted that it is usual practice to review and revise forest and woodland management plans every 10 years. Therefore, the forecasts presented are likely to become less representative with time. All estimates are based on the net productive area of each forest. In line with Forestry Commission convention, UPM-Tilhill, who manage both case study woodlands, set this net productive area at 85% of gross area, i.e. 15% of each sub-compartment within the woodland is assumed to be unproductive (in terms of tree growth). These non-productive areas include features such as rides, roads, bare rock etc.

4.2.1 Hartley Mauditt – Carbon stocks in the forest: Management plan

The estimates of above ground carbon in the tree components of the forest and of debris (i.e. lying deadwood) are based on the original management plan and are shown in Figure 6 for the period 2010 to 2110.

Figure 6: Illustration of forecast (2010-2110) carbon stocks in standing trees and debris based on the original management plan for Hartley Mauditt FMU.



The carbon stocks in the standing live trees showed a reduction from around 6000 tonnes of carbon over the productive net area of the 59 hectares of woodland, falling to around 2500 tonnes by around 2035. It must be noted that this reduction in standing carbon is balanced, to some extent, by the carbon in the harvested wood products shown in Figure 7. The carbon stocks in the debris were relatively constant over the one hundred year period of the forecast at around 400 tonnes. The 'saw tooth' pattern in Figure 6 is largely a consequence of 85% of the woodland being managed as broadleaf coppice on a five-year cycle.

4.2.2 Hartley Mauditt – Harvested wood products: Management plan

The estimated out-turn of the three product categories; saw logs, round wood and fuel wood, for each year in the forecast, based on the original management plan, are shown in Figure 7.

Figure 7: Chart showing forecast (2010-2110) of harvested products based on the original management plan for Hartley Mauditt FMU.

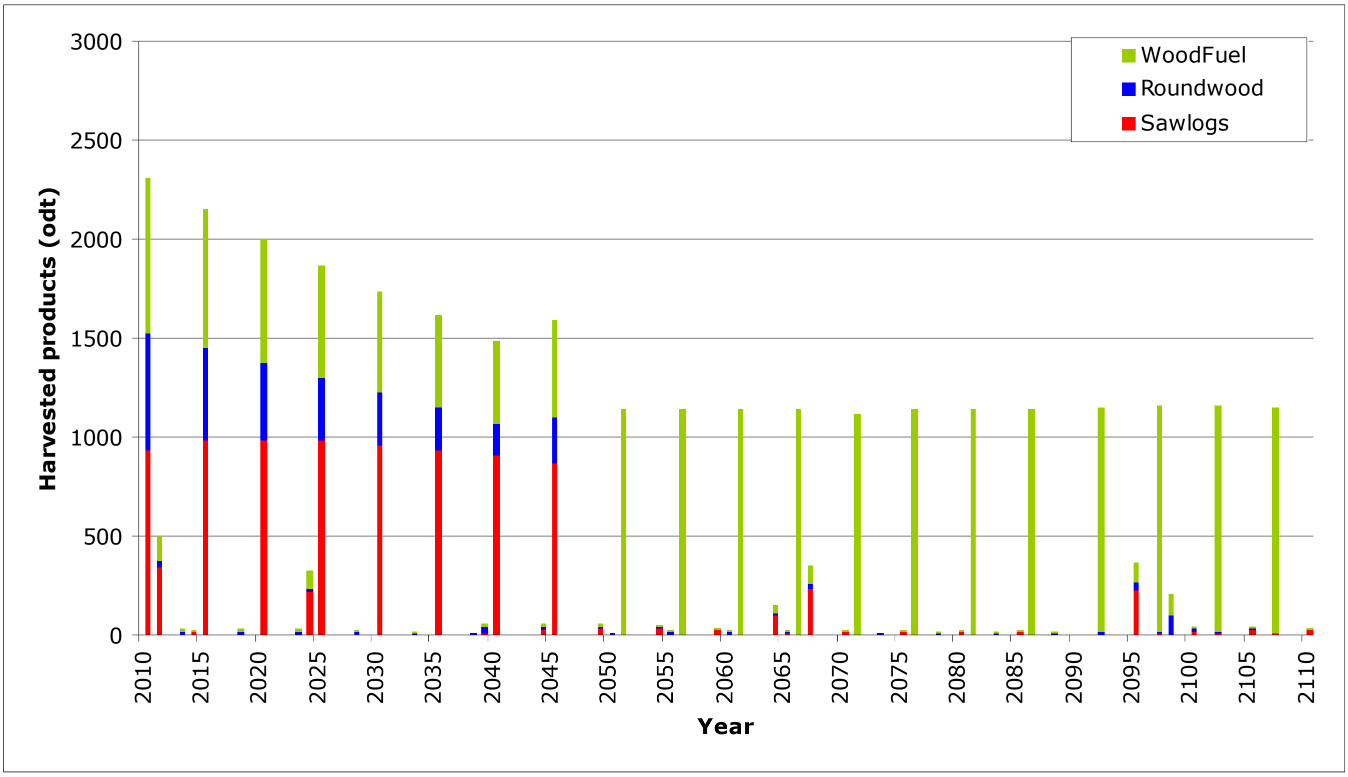
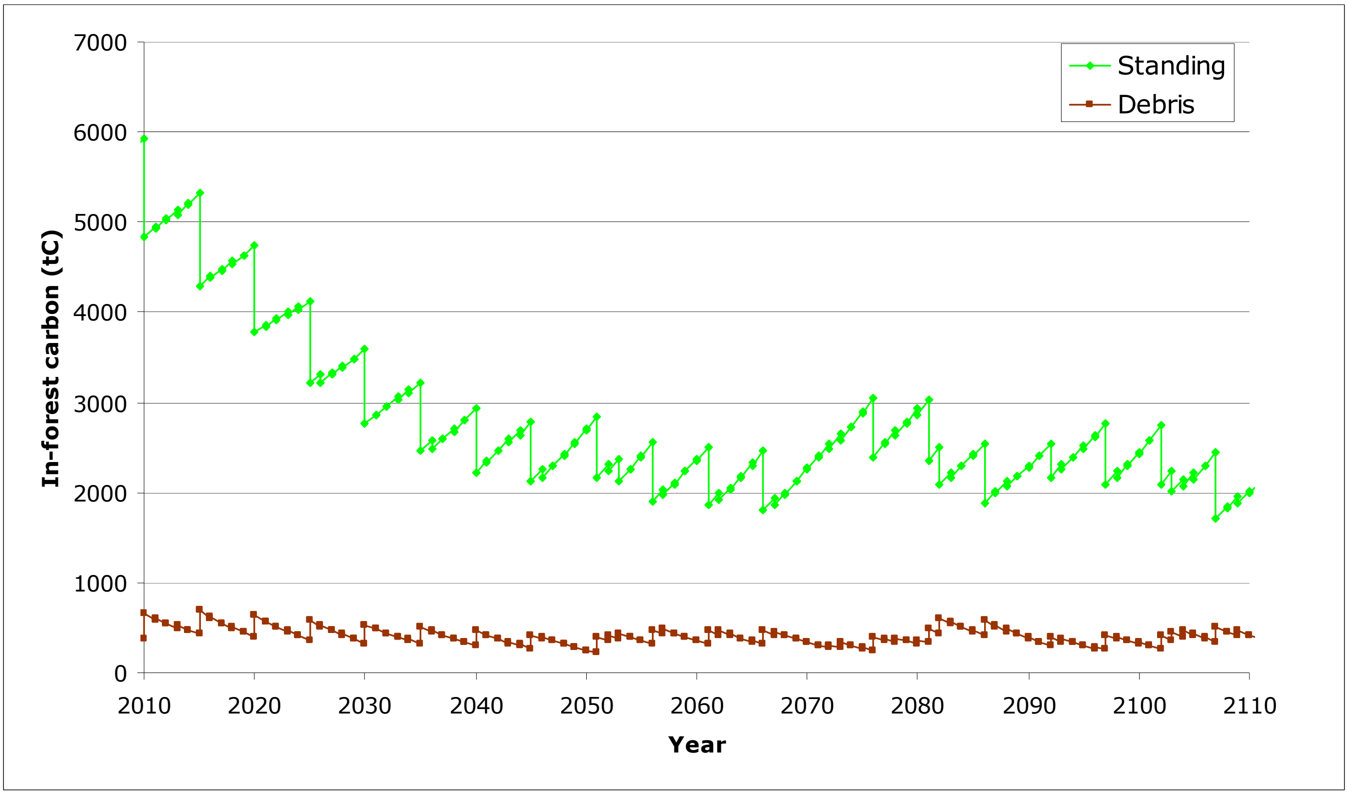


Figure 7 shows that the quantities of saw logs and round wood produced fall to virtually nothing by 2046. This is a consequence of switching the management of 85% of the woodland to coppice on a 40-year rotation. Effectively most of the woodland would be on a 40-year rotation by 2045. This means the trees would only grow to limited size, which at the stand level is less than the 'optimum' in terms of volume production. The consequence being that the harvested wood products from 2045 would be smaller trees producing mainly fuel wood. As noted above, because the larger trees were removed in the first half of the forecast, the standing carbon stocks declined during this period as shown in Figure 6, but this carbon was still sequestered in the harvested wood products like saw logs and round wood, some of which would be relatively long-lived as a stock of carbon.

4.2.3 Hartley Mauditt - Carbon stocks in the forest: RWBA informed scenario

The estimates of carbon in the tree components of the forest and the debris for the period 2010 to 2110, based on the rapid woodland biodiversity assessment (RWBA) informed management plan are shown in Figure 8.

Figure 8: Illustration of forecast (2010-2110) carbon stocks in standing trees and debris based on the RWBA informed management plan for Hartley Mauditt FMU.

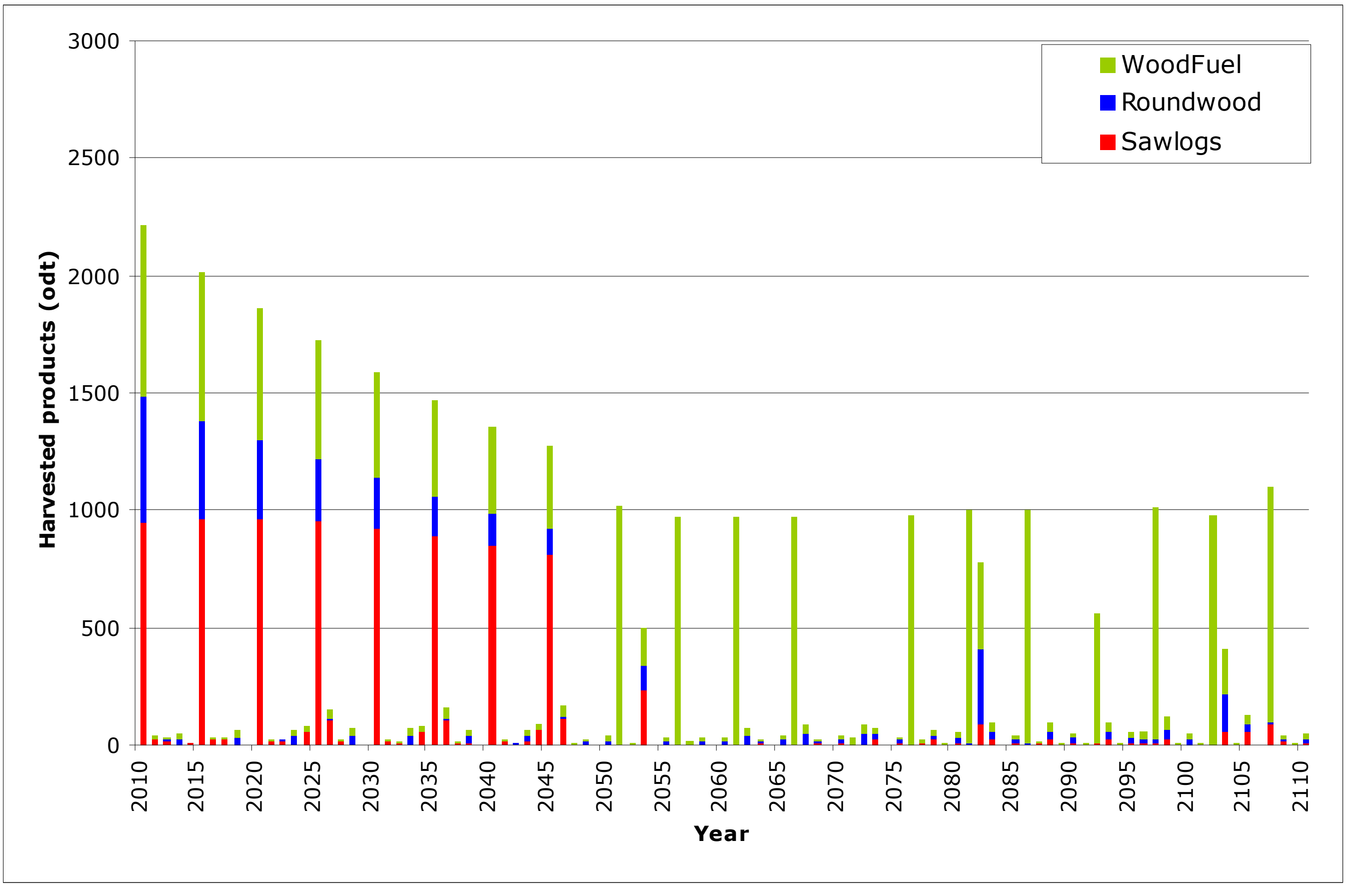


The RWBA recommended the creation of coppice with standards as the management prescription for many of the sub-compartments in Hartley Mauditt to improve vertical and horizontal structure. This was probably the reason there is a little more variation in the standing tree carbon stocks than found in the forecast from the original management plan. The quantity of debris for the RWBA informed scenario was on average slightly higher than for the original management plan. This may again relate to the presence of standards, though the difference in carbon stocks in debris between the two scenarios is small.

4.2.4 Hartley Mauditt – Harvested wood products: RWBA informed scenario

The estimated out-turn of the three product categories; saw logs, round wood and fuel wood, for each year in the forecast, based on the RWBA informed management plan is shown in Figure 9.

Figure 9: Chart showing forecast (2010-2110) of harvested products based on the RWBA informed management plan for Hartley Mauditt FMU.

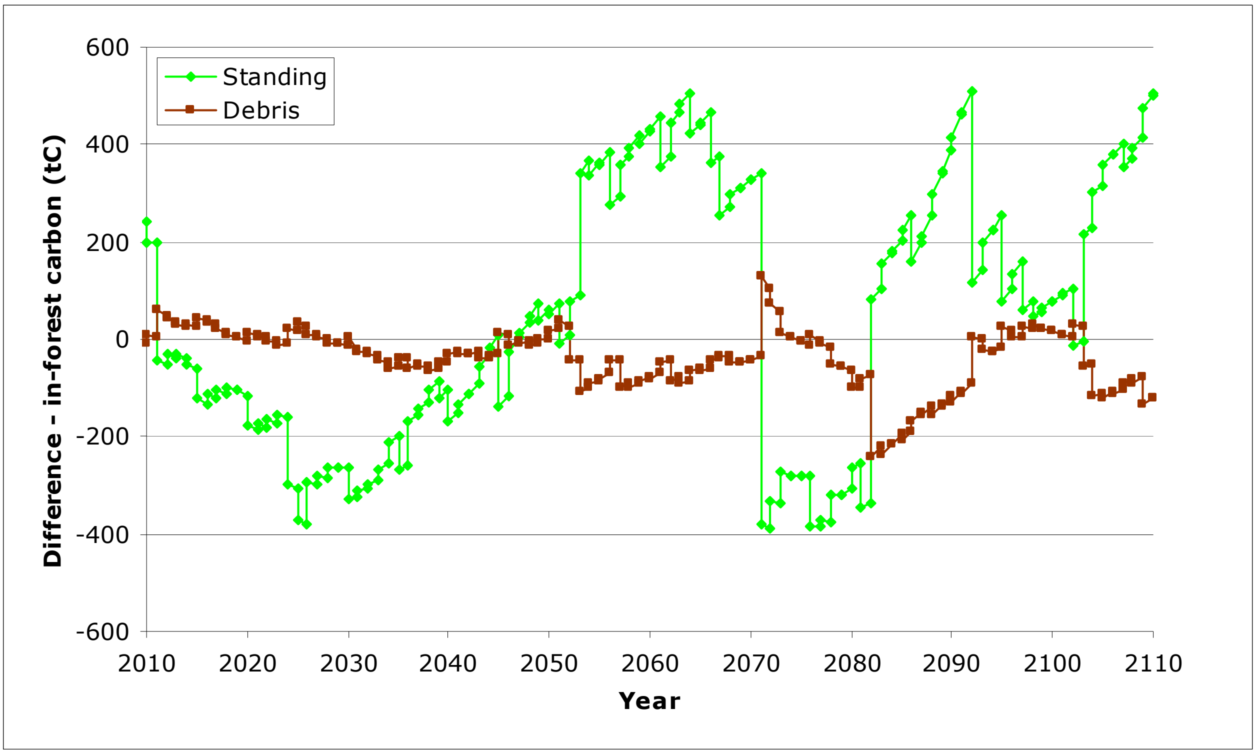


The RWBA scenario forecast predicted slightly lower quantities of harvested wood products than the original management plan. However, the average differences for the period 2010 to 2110 were very small; for example, the mean *annual* difference in fuelwood between the two scenarios was only around 12 oven dry tonnes (odt). For comparison, the total predicted fuel wood production for the RWBA informed scenario over the one hundred year forecast was more than 16,000 odt.

4.2.5 Hartley Mauditt – Difference in carbon stocks in the forest between scenarios

To help clarify the differences between the original management plan and RWBA informed management plan scenarios, Figure 10 shows the differences in carbon stocks between the two scenarios expressed in terms of the original management plan carbon stock minus the RWBA informed plan (i.e. these are essentially the differences between figures 6 and 8). This means that positive numbers indicate higher carbon stocks for a year in the forecast from the original management plan and negative numbers indicate higher carbon stocks for a year in the RWBA informed scenario. As Figure 10 shows the differences between the carbon stocks, note that the scale of the Y-axis is considerably smaller with a range of 1200, whereas figures 6 and 8 have a scale of 7000 (tonnes carbon).

Figure 10. Difference in carbon stocks forecasted (2010-2110) between the original management plan and the RWBA informed management plan scenarios for Hartley Mauditt FMU.



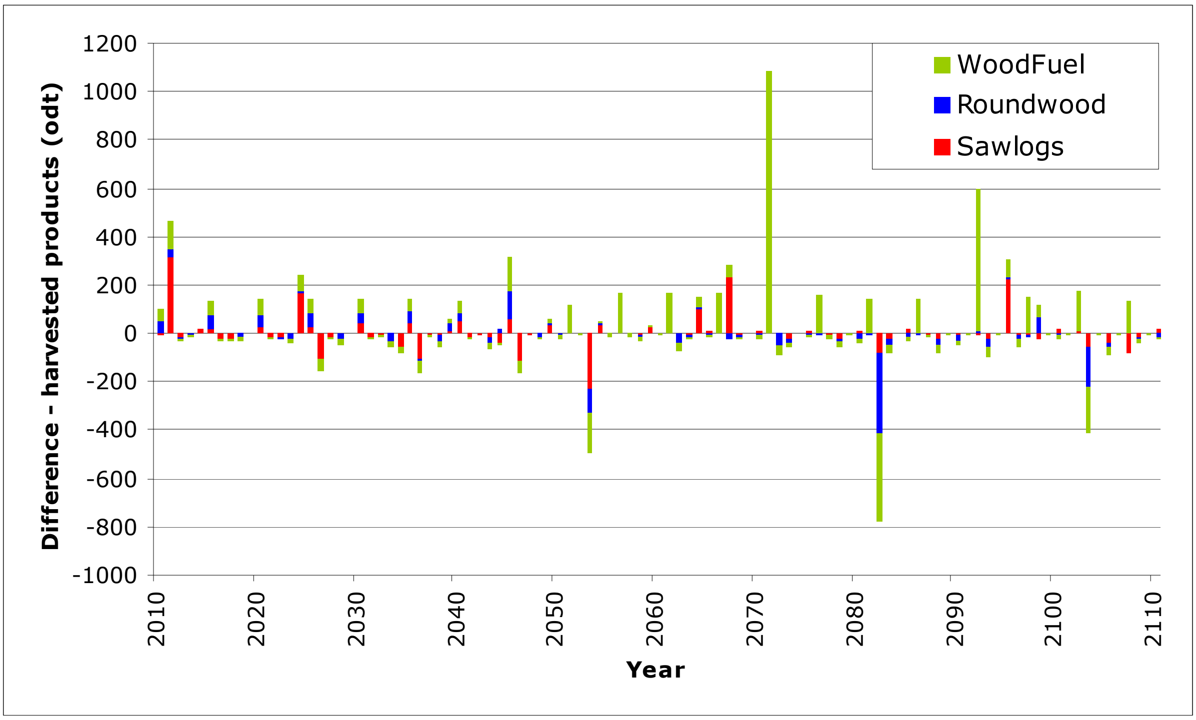
The RWBA informed scenario exhibits a slightly higher standing carbon stock for the first 35 years of the forecast. For the remainder of the forecast period, the sign of the difference between the scenarios varies. However, on average, the standing carbon stocks are slightly higher in the original management plan scenario.

The differences in carbon stocks in the debris ‘pool’ between the two management scenarios are considerably smaller than those for the standing stocks, as would be expected given their differences in overall magnitude. The pattern of differences seems to be broadly opposite to that for the standing carbon stocks, i.e. when the standing carbon is higher in the forecasts for the original management plan; the debris carbon stocks are higher in the RWBA informed scenario forecast.

4.2.6 Hartley Mauditt – Difference in harvested wood products between scenarios

As with the predicted carbon stock differences in Figure 10, to help to clarify the differences between the original management plan and RWBA informed management plan scenarios, Figure 11 shows the differences in harvested products between the two scenarios expressed in terms of the original harvested products minus the products produced from the RWBA informed plan, essentially the differences between figures 7 and 9. This means that positive numbers indicate more harvested wood products for a year in the forecast from the original management plan and negative numbers indicate more harvested wood products for a year in the RWBA informed scenario.

Figure 11: Difference in harvested wood products forecasted (2010-2110) between the original management plan and the RWBA informed management plan scenarios.

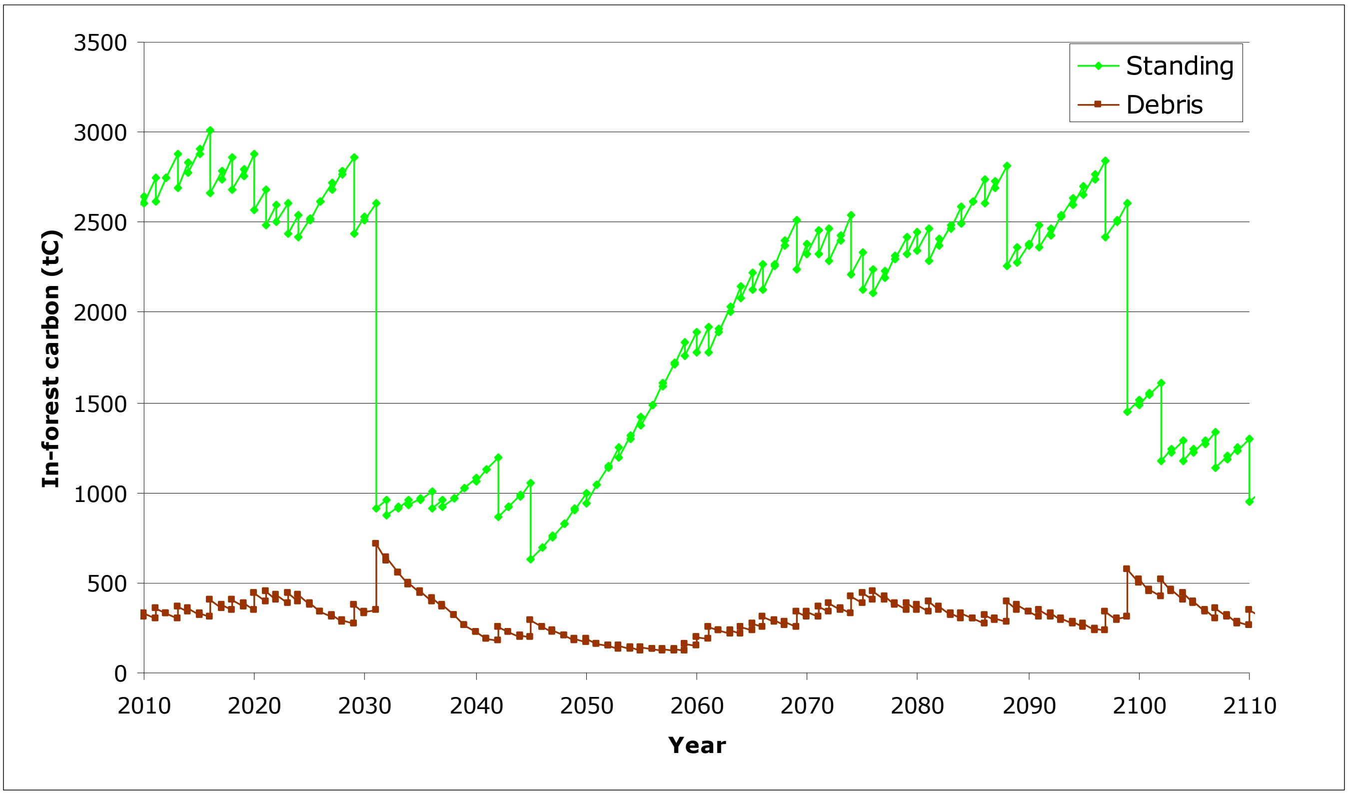


In general, the modelling suggests that the original management plan is producing more harvested wood products than the RWBA informed scenario. In particular, there is more wood fuel material being produced in the second half of the forecast. This is likely to be due to the original plan being managed on a coppice only basis, whereas the RWBA informed management is specified as coppice with standards, suggesting at least a portion of the material being produced will be large dimensions of timber suitable for Saw logs and round wood. This effect can be seen in the years where the RWBA informed scenario produces more harvested wood products than the original management plan scenario. In particular 2053, 2082 and 2103.

4.2.7 Land of Nod - Carbon stocks in the forest: Management plan

The estimates of (above ground) carbon in the tree components of the forest and the debris (effectively lying deadwood) for the period 2010 to 2110, based on the original management plan are shown in Figure 12.

Figure 12: Illustration of forecast carbon stocks (2010-2110) in standing trees and debris based on the original management plan for Land of Nod FMU.



The carbon in the standing live trees show a reasonably constant stock of around 2750 tonnes of carbon over the productive net area of the 37 hectares of woodland, falling sharply in 2031 to around 1000 tonnes. This suggests the woodland is currently not 'normally' structured, i.e. the age classes are not balanced to give broadly equal areas/volumes of harvesting in each year or period. The forecast shows a steady increase in standing carbon stocks with re-growth between 2030 and 2100 (an implied rotation of around 70 years). The reduction in standing carbon stocks around 2100 is smaller than in 2031, suggesting that the structure of the forest is becoming more 'normal'.

4.2.8 Land of Nod – Harvested wood products: Management plan

The estimated outturn of the three product categories; saw logs, round wood and fuel wood, for each year in the forecast, based on the original management plan are shown in Figure 13.

Figure 13: Chart showing forecast (2010-2110) of harvested products based on the original management plan for Land of Nod

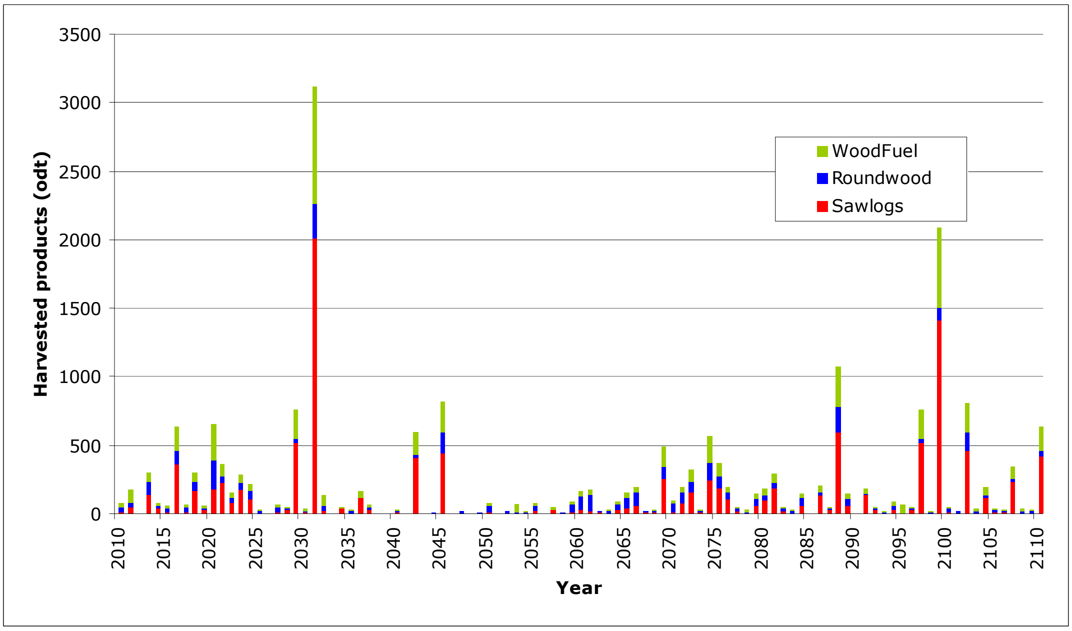
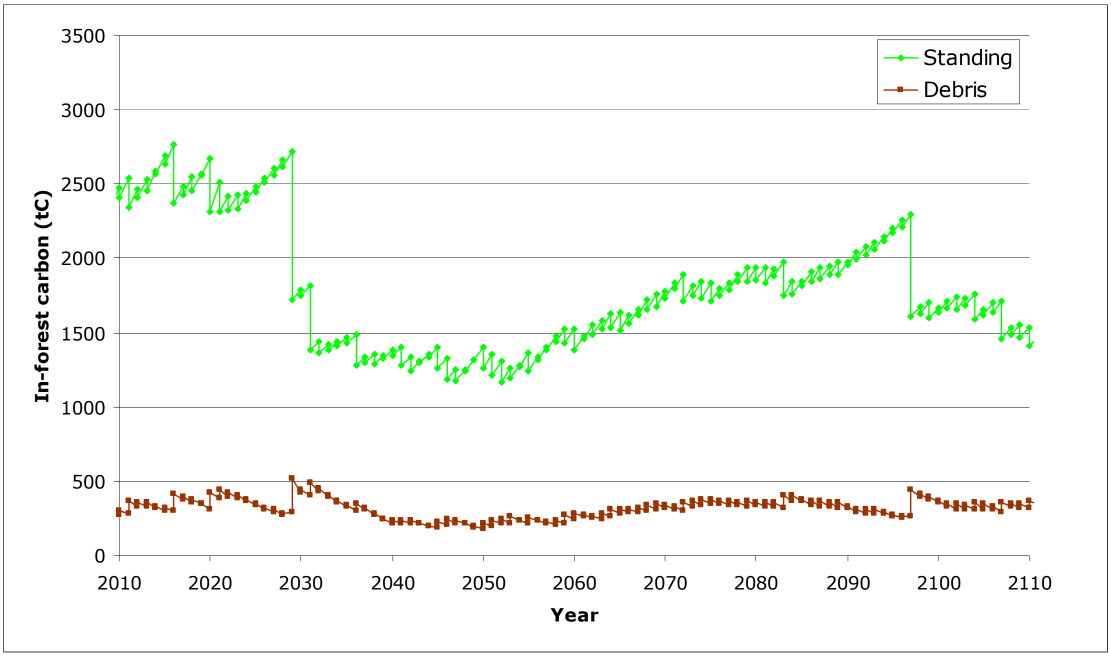


Figure 13 shows that, unlike Hartley Mauditt, the original management plan for Land of Nod produces a large proportion of saw logs, as would be expected given the more traditional, high-forest silviculture of the woodland. There are also peaks in harvested products around 2030 and 2100, mirroring the reductions in standing carbon stocks.

4.2.9 Land of Nod - Carbon stocks in the forest: RWBA informed scenario

The estimates of carbon in the tree components of the forest and the debris for the period 2010 to 2110, based on the rapid woodland biodiversity assessment (RWBA) informed management plan is shown in Figure 14.

Figure 14: Illustration of forecast (2010-2110) carbon stocks in standing trees and debris based on the RWBA informed management plan for Land of Nod FMU.

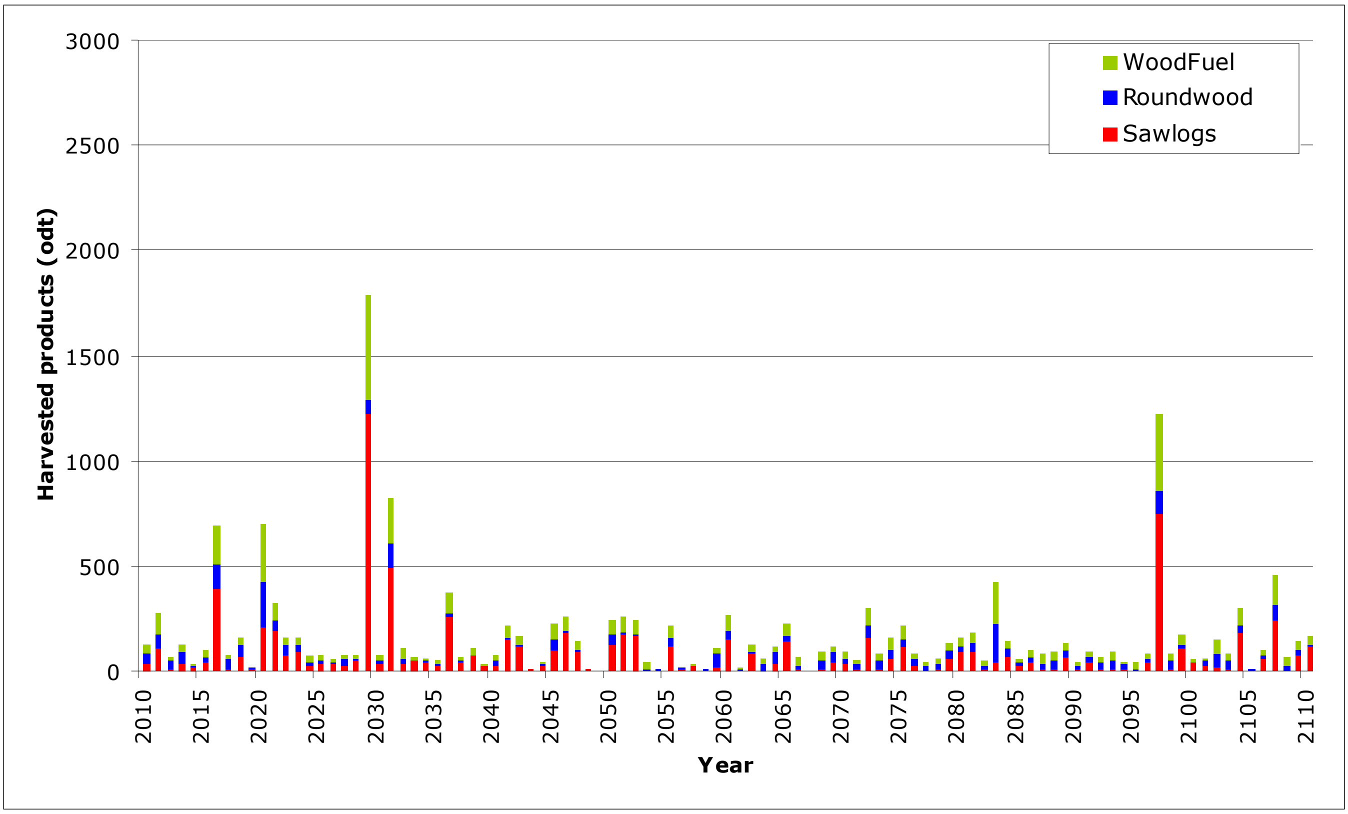


The RWBA recommended group felling or heavy thinning as the management prescription for many of the sub-compartments in Land of Nod to improve biodiversity. This has the effect of reducing the individual reductions in standing carbon stock as felling events are more evenly spread over the forecast period. The quantity of debris for the RWBA informed scenario is more constant and on average very slightly higher than for the original management plan, which was a specified prescription in the RWBA informed scenario.

4.2.10 Land of Nod – Harvested wood products: RWBA informed scenario

The estimated outturn of the three product categories; saw logs, round wood and fuel wood, for each year in the forecast, based on the RWBA informed management plan is shown in Figure 15.

Figure 15: Chart showing forecast (2010-2110) of harvested products based on the RWBA informed management plan for Land of Nod FMU.

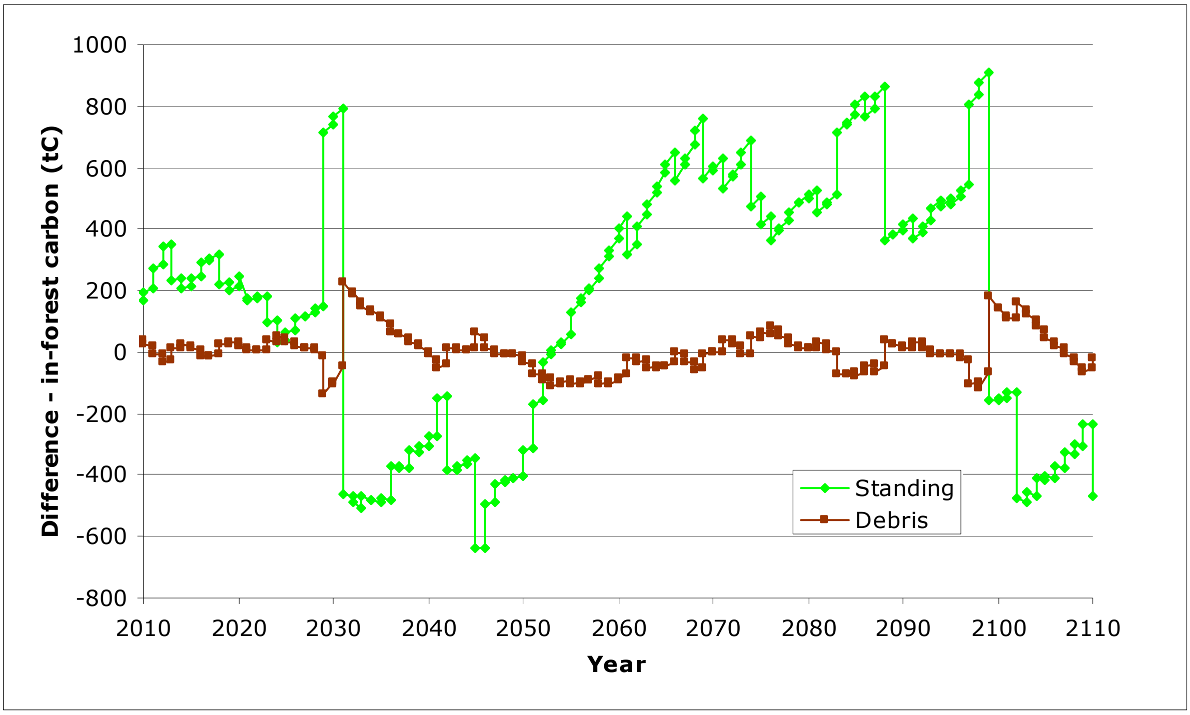


The RWBA scenario forecast predicts a more even distribution of harvested wood products than the original management plan throughout the forecast period. This is consistent with the carbon stocks, as the harvesting events are occurring every five years for around two-thirds of the sub-compartments in the forest. The maximum annual quantities of harvested wood products are considerably lower for the RWBA informed scenario than for the original management plan. For example, in 2031 where there is a peak of production in the original management plan forecast, the total for the three wood product categories is more than 3100 oven dry tonnes (odt); for the RWBA scenario a similar peak occurs in 2029, but is just under 1800 odt.

4.2.11 Land of Nod – Difference in carbon stocks in the forest between scenarios

To assist in clarifying the differences between the original management plan and RWBA informed management plan scenarios, Figure 16 shows the differences in carbon stocks between the two scenarios expressed in terms of the original management plan carbon stock minus the RWBA informed plan, essentially the differences between figures 12 and 14. This means that positive numbers indicate higher carbon stocks for a year in the forecast from the original management plan and negative numbers indicate higher carbon stocks for a year in the RWBA informed scenario. As Figure 16 shows the differences between the carbon stocks, note that the scale of the Y-axis is narrower with a range of 1800, whereas figures 12 and 14 have a scale of 3500 (tonnes carbon).

Figure 16: Difference in carbon stocks forecasted (2010-2110) between the original management plan and the RWBA informed management plan scenarios for Land of Nod FMU.



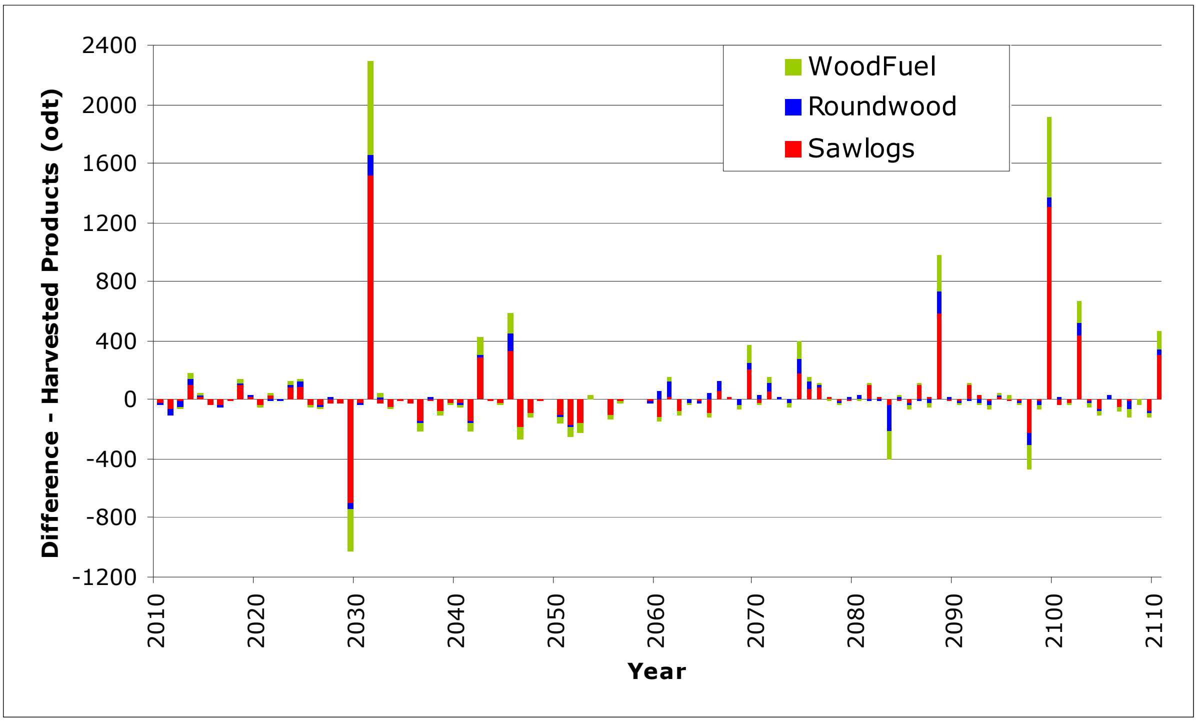
The original management plan scenario generally exhibits higher standing carbon stocks than the RWBA informed scenario, except during the 20 year period from around 2030 when a large area is felled in the original plan and takes time to 're-grow'.

The overall differences in carbon stocks in the debris 'pool' between the two management scenarios are very small.

4.2.12 Land of Nod – Difference in harvested wood products between scenarios

As with the predicted carbon stock differences in Figure 16, to help to clarify the differences between the original management plan and RWBA informed management plan scenarios, Figure 17 shows the differences in harvested products between the two scenarios expressed in terms of the original harvested products minus the products produced from the RWBA informed plan, essentially the differences between figures 13 and 15. This means that positive numbers indicate more harvested wood products for a year in the forecast from the original management plan and negative numbers indicate more harvested wood products for a year in the RWBA informed scenario.

Figure 17: Difference in harvested wood products forecasted (2010-2110) between the original management plan and the RWBA informed management plan scenarios: Land of Nod FMU.



In general, the modelling suggests that the original management plan is producing, on average, more harvested wood products than the RWBA informed scenario. As noted already, the peaks around 2030 and 2100 relate to the rotations assigned to many of the sub-compartments in the original management plan.

4.2.13 Summary of differences in carbon stocks and harvested products for both case study woodlands

Table 9 summarises the estimates of standing and debris carbon stocks forecast for each of the two scenarios and the differences between the scenarios, relative to the management plan.

Table 9: Summary of **annualised** carbon stocks for each woodland and management scenario.

	Standing (tC)	Debris (tC)
Hartley Mauditt (59 ha)		
Management plan scenario	2819.7	367.3
RWBA informed scenario	2774.2	406.6
Difference (% of original)	45.5 (1.6)	-39.2 (10.7)
Land of Nod (37 ha)		
Management plan scenario	1,951.7	317.3
RWBA informed scenario	1,789.9	314.3
Difference (% of original)	161.8 (8.3)	3.0 (0.95)

All results assume 85% productive (net) area

The predicted results in Table 9 suggest that, for Hartley Mauditt, the original management plan results in very slightly higher annualised standing carbon stocks over the period of the forecast (2010-2110), while the annualised debris carbon stocks are higher (10.7%) for the RWBA informed management scenario. For the Land of Nod forecast, the annualised standing carbon stocks for the original management scenario are predicted to be just over 8% higher than those for the RWBA informed scenario. However, the difference in annualised debris carbon stocks over the one hundred years of the forecast is less than 1%, which cannot be considered significant in the context of this study. The quantities of harvested (wood) products for the two case study woodlands and management scenarios, along with the differences relative to the original management plan, are summarised in Table 10.

Table 10: Summary of harvested product **totals** for each woodland and management scenario.

	Sawlogs (odt)	Roundwood (odt)	Fuel wood (odt)
Hartley Mauditt (59 ha)			
Management plan scenario	8,969.3	3,194.3	18,955.6
RWBA informed scenario	8,812.8	3,777.5	16,478.5
Difference (% of original)	156.5 (1.7)	-583.2 (18.3)	2477.0 (13.1)
Land of Nod (37 ha)			
Management plan scenario	11,172.6	3,858.9	5,878.2
RWBA informed scenario	8,221.2	3,235.6	5,065.0
Difference (% of original)	2951.4 (26.4)	623.2 (16.1)	813.3 (13.8)

All results assume 85% productive (net) area

The predicted results in Table 10 suggest that, for Hartley Mauditt, the original management plan results in very slightly higher total saw log production over the period of the forecast (2010-2110), fuel wood production is more than 10% higher in the original scenario compared to the RWBA informed scenario, in part because the area of coppice is lower due to the adoption of 'coppice with standards' management. The total quantity of round wood produced is higher for the RWBA informed scenario than the original management plan. This may relate to the way that coppice with standards management is being represented and this increasing the average rotation length leading to larger trees being harvested on average.

The predicted results for Land of Nod suggest that the RWBA informed management scenario produces lower total quantities of all three categories of harvested wood products. In particular, the change in management suggested by the RWBA leads to an overall reduction of around 25% in the quantity of saw log material (somewhat less for the other two product categories). This is not unexpected as the RWBA informed scenario increases the frequency and reduces the size of individual clear-felling events (see Figure 17), leading to a 'little and often' flow of material compared to the two or more large spikes of production from the original management plan.

5. Discussion

Rapid Woodland Biodiversity Assessment

Recognition of the need to protect and enhance woodland biodiversity is reflected in numerous global agreements that have emerged from the United Nations Conference on Environment and Development (UNCED; the 'Earth Summit'), held in Rio de Janeiro in 1992. These include the 'Forest Principles' (United Nations, 1992) and Agenda 21 (United Nations, 1993), which deal with sustainable forest management and sustainable development respectively, and the Convention on Biological Diversity (CBD) (1992; 2010). The need for reporting progress under such international agreements has led to the development of indicators to assist signatories to monitor not only the status quo, but also the effects of policy measures that have been put in place for the conservation and sustainable management of woodlands and woodland biodiversity (Puumalainen *et al*., 2003; Boutin *et al*., 2009; Lamb *et al*., 2009). However, the use of indicators for reporting is not an end in itself. Ultimately, these indicators must also serve to inform decisions that will make a difference in practice. Many of the indicators developed to report on woodland biodiversity and sustainable forest management are applicable at both the national and woodland scales (Newton & Kapos, 2002; Chirici *et al*., 2012) (e.g. vertical and horizontal vegetation structure, deadwood volume, regeneration). However, for woodland managers, additional 'supplementary' woodland biodiversity indicators are needed to describe woodland scale rather than landscape scale features, thereby allowing indicator information to be used to guide action on the ground (Ferris & Humphrey, 1999).

The RWBA includes previously developed biodiversity indicators, but also introduces some new proposed indicators (e.g. invasive species abundance, browsing pressure, levels of topographical variation) that are applicable at the FMU scale to help assess woodland biodiversity potential. The scores against each indicator serve to guide the direction of management practice. The application of the RWBA in two case study woodlands demonstrated the time requirement of only a few hours for the full assessment where all proposed indicators are considered. Some time is also required subsequently to process and interpret the information obtained, but this is also limited to less than a days work. The RWBA requires further testing for repeatability by independent parties who in future might be auditors delivering forest certification/ woodland grant awards

Further development of the RWBA is likely to consider proposing a minimum number of biodiversity indicators that should be assessed, including those that cannot be left out for the most basic assessment of woodland biodiversity potential. Additional biodiversity indicators can be envisaged for those woodland owners who are interested to obtain more detailed (and therefore higher resolution) feedback on the biodiversity potential of their woodland. For example, deadwood decay classes and proximity of ancient woodland could be included to give a better idea of the level of continuity of these important habitats for wildlife.

If the RWBA is considered to be a useful tool following further consultation and testing, it could be extended to include rapid evaluations of other ecosystem services such as recreational potential and woodland aesthetic appeal. Recreation is another ecosystem service with high valuation (Table 2) that could easily be included in the RWBA methodology. Many of the indicators assessed for biodiversity are also relevant indicators of woodland recreational use and woodland appreciation. These include (as listed by Edwards *et al*., 2012) the size of trees, variation in tree sizes, variation in tree spacing, the extent of tree cover, density of ground vegetation, number of tree species, size and number of open spaces, volume of deadwood and 'naturalness' of the forest edge.

Using the RWBA to inform management choices for other woodland ecosystem services i.e. carbon, woodfuel

The largest overall predicted difference in carbon stocks in standing trees and woody debris between the original and RWBA informed management scenarios for both case study woodlands, was just over 10% and many of the differences were much smaller. Assuming that carbon stocks are not the only, or main, consideration when managing woodlands, this relatively small loss may be entirely justifiable, given the likely improvements in woodland biodiversity potential resulting from the recommendations of the RWBA.

The effect of the RWBA recommendations on the production of harvested products from the two case study forests, such as sawlogs, appears to depend on the extent of the resulting changes in management. For example, the RWBA informed management prescriptions for Hartley Mauditt, although involving changes relative to the original management plan, were not very different compared with the original management proposals. The main change was from coppice to coppice with standards and the difference in overall production of harvested products was estimated to be less than 7%, although this was based on a modified version of the model to account for coppice. The difference in production for Land of Nod was rather larger than that for Hartley Mauditt. This is likely to stem from the significant change in management prescription for many of the sub-compartments of the woodland between the original and RWBA informed scenarios. The original management plan was largely characterised by 'traditional' high forest with clear-fell as the management system. The RWBA recommendations involved modelling to represent more continuous-cover management of the trees where around 1/5 of the trees in a sub-compartment would be felled at the normal rotation/felling age with another 1/5 felled 5 years later and so on, to represent progressive removal of the over-storey. This more gradual management is reflected in a predicted reduction in overall oven dry tonnes of harvested products, over the 100 years of the forecast, of just over 20% relative to the original management plan.

Consideration of management for carbon and woodfuel following the RWBA, brought to light the importance of considering RWBA results not only at the FMU scale (Figure 5), but also at the compartment and sub-compartment scales where management decisions occur. This suggests that RWBA sample plot assessments should be carried out in each compartment and even sub-compartment, rather than at only a few stopping points to provide more accurate information for carbon stock and woodfuel evaluations. The author propose to trial the Woolhope Dome methodology in a follow-up study in order to do an inventory/ assessment in tandem with the RWBA; this would allow for the calculation of allowable cut of the standing timber to further safeguard the sustainability of ecosystem services and woodland resilience.

Given that the carbon and harvested wood products estimation methodology developed in this study seems to produce viable outputs that help to quantify some of the effects of recommendations for changing management for improved biodiversity from the RWBA on provisioning ecosystem services, it would be worthwhile to develop the methodology to make it more readily and easily applicable to other woodland types as a decision-support tool for woodland managers.

8 References

Bailey, S. (2007) Increasing connectivity in fragmented landscapes: an investigation of evidence for biodiversity gain in woodlands. *Forest Ecology and Management* **238** (1-3): 7-23.

Blakesley, D. and Buckley, G.P. (2010) Managing your woodland for wildlife. Pisces Publications, Newbury.

Boutin, S., Haughland, D.L., Schieck, J., Herbers, J. and Bayne, E. (2009) A new approach to forest biodiversity monitoring in Canada. *For. Ecol. Manag*. **258**, 168-175.

Buckley, P. and Howell, R. (2004) The ecological impact of sweet chestnut coppice silviculture on former ancient, broadleaved woodland sites in south-east England. English Nature Research Reports Number 627.

Burnett, M.R., August, P.V., Brown, J.H. and Killingbeck, K.T. (1998) The influence of geomorphological heterogeneity on biodiversity: I. A patch-scale perspective. *Conservation Biology* **12**(2): 363-370.

Bütler, R., Angelstam, P. and Schlaepfer, R. (2004) Quantitative snag targets for the three-toed woodpecker *Picoides tridactylus*. *Ecological Bulletins* **51**: 219–232.

Chirici, G., McRoberts, R. E., Winter, S., Bertini, R., Brändli, U.-B. Asensio, I.A , Barsoum, N., Bastrup-Birk, A., Rondeux, J., and Marchetti, M. (2012). National Forest Inventory contributions to forest biodiversity monitoring. *Forest Science* **58**(3):257-268.

Convention on Biological Diversity (1992) Convention on Biological Diversity, United Nations Environment Programme.

Convention on Biological Diversity (2010) Global biodiversity outlook 3, Secretariat of the Convention on Biological Diversity, Montreal QC, Canada.

Davies, Z.G. and Pullin, A.S. (2007) Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. *Landscape Ecology* **22**(3): 333-351.

Edwards, D., Jay, M., Jensen, F.S., Lucas, B., Marzano, M., Montagné, C., Peace, A. and Weiss, G. (2012) Public preferences for structural attributes of forests: Towards a pan-European perspective. *Forest Policy and Economics* **19**: 12–19

Emberger, C. (2013) L'indice de biodiversité potentielle en 2013 : quelles perceptions

et utilisations en forêt privée ? CNPF-IDF, 2013, 36 p.

Ferris, R. and Humphrey, J.W. (1999) A review of potential biodiversity indicators for application in British forests. *Forestry* **72**, 313-328.

FORESTRY COMMISSION - England (2005). Managing woodland open space for wildlife. Operations Note 011. 21 pp.

FORESTRY COMMISSION - England (2008).Deadwood. Operations Note 015. 4 pp.

FORESTRY COMMISSION (2011). The UK Forestry Standard. Forestry Commission, Edinburgh. i–iv + 1–108 pp.

Forêt Privée Française (2014) IBP - Indice de biodiversité potentielle http://www.foretpriveefrancaise.com/ibp/ (accessed November 2014)

Hodgson, J., Thomas, C., Wintle, B. and Moilanen, A. (2009) Climate change, connectivity and conservation decision making: back to basics. *Journal of Applied Ecology* **46**: 964-969.

Hodgson, J.A., Moilanen, A., Wintle, B.A. and Thomas, C.D. (2011) Habitat area, quality and connectivity: striking the balance for efficient conservation. *Journal of Applied Ecology* **48**: 148–152.

Humphrey, J. and Bailey, S. (2012) Managing deadwood in forests and woodlands. Forestry Commission Practice Guide. Forestry Commission, Edinburgh. I-iv + 1-24 pp.

Humphrey, J, Stevenson, A, Whitfield, P and Swailes, J. 2002. Life in the deadwood: a guide to managing deadwood in Forestry Commission forests. Forestry Commission, Edinburgh.

Jenkins, T. A. R., Mackie, E. D., Matthews, R.W., Miller, G, Randle, T.J. and White, M. E. (2011) FC Woodland Carbon Code: Carbon Assessment Protocol. Forestry Commission: Edinburgh.

Lamb, E.G., Bayne, E., Holloway, G., Schieck, J., Boutin, S., Herbers, J. and Haughland, D.L. (2009) Indices for monitoring biodiversity change: Are some more effective than others? *Ecol. Indic*. **9**, 432-444.

Larrieu, L. and Gonin, P. (2008) L'indice de biodiversité potentielle (IBP) : une méthode simple et rapide pour évaluer la biodiversité potentielle des peuplements forestiers. *Rev. For. Fr.* **60**, 727-748.

Larrieu, L. and Gonin, P. (2011) L'Indice de Biodiversité Potentielle (IBP) « Foire aux questions ». http://www.foretpriveefrancaise.com/data/info/274430-IBP_FAQ_110330.pdf. CRPF Midi-Pyrénées, IDF, INRA Dynafor, Toulouse.

Larrieu, L., Gonin, P., 2011b. Presentation de l'Indice de Biodiversité Potentielle (IBP) v2.6.3 http://www.foretpriveefrancaise.com/data/info/316339-2011_dec_IBP_presentation_v2.pdf. CRPF Midi-Pyrénées, IDF, INRA Dynafor, Toulouse.

Lawton, J.H., Bignell, D.E., Bolton, B., Bioemers, G.F., Eggleton, P., Hammond, P.M., Hodda, M., Holt, R.D., Larsen, T.B., Mawdsley, N.A., Stork, N.E., Srivastava, D.S. and Watt, A.D. (1998) Biodiversity inventories, indicator taxa and effects of habitat modification in a tropical forest. *Nature* **391**, 72-76.

Lawton, J.H., Brotherton, P.N.M., Brown, V.K., Elphick, C., Fitter, A.H., Forshaw, J., Haddow, R.W., Hilborne, S., Leafe, R.N., Mace, G.M., Southgate, M.P., Sutherland, W.J., Tew, T.E., Varley, J. and Wynne, G.R.D. (2010) Making space for nature: a review of England's wildlife sites and ecological network. Defra. London. http://archive.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf (accessed November 2014)

Lush, M. J., Hewins, E.J., Lush, C.E., Peterken, G.F. (2012) Woodland Conservation Condition Survey Handbook: A method for assessing the nature conservation condition on non-statutory woodlands. Version 1.0. exeGesIS SDM Ltd. 65pp.

Matthews, G.A.R. (1993) The Carbon Content of Trees. Forestry Commission Technical Paper 4. Forestry Commission: Edinburgh.

Matthews, R.W. and Mackie, E.D. (2006) Forest Mensuration: a handbook for practitioners. Forestry Commission, Edinburgh.

McElhinney, C., Gibbons, P. and Brack, C. (2006) An objective and quantitative methodology for constructing an index of stand structural complexity. *Forest Ecology and Management* **235**, 54-71.

National Forest Inventory of Great Britain Survey Manual (2014) (accessed Jan 2015)

http://www.forestry.gov.uk/pdf/NFI-survey-manual.pdf/$FILE/NFI-survey-manual.pdf

Newton, A.C., Kapos, V., 2002. Biodiversity indicators in national forest inventories. Background paper 6.4. Kotka IV: Expert Consultation on Global Forest Resources Assessments – Linking National and International efforts, Kotka, Finland.

Puumalainen, J., Kennedy, P. and Folving, S. (2003) Monitoring forest biodiversity: a European perspective with reference to temperate and boreal forest zone. *J. Environ. Manag*. **67**, 5-14.

Quine, C., Cahalan, C., Hester, A., Humphrey, J., Kirby, K. Moffat, A. and Valatin, G. (2011) Introduction to the UK National Ecosystem Assessment. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. & Snowdon, P.R. (eds) (2009) Combating climate change—a role for UK forests. The Stationery Office, Edinburgh.

Stevens R. D. and Tello J. S. (2011) Diversity begets diversity: relative roles of structural and resource heterogeneity in determining patterns of community structure. *Journal of Mammalogy* **92**: 387-395.

Tews, J., Brose, U., Grimm, V., Tielborger, K., Wichmann, M.C., Schwager, M., Jeltsch, F. (2004) Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *J. Biogeogr*. **31**, 79–92.

United Nations, 1992. Report of the United Nations Conference on Environment and Development: Annex 3 - Non-legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests. A/CONF.151/26 (Vol. III), United Nations, Rio de Janeiro.

United Nations, 1993. Agenda 21: Earth Summit - The United Nations Programme of Action from Rio., United Nations, Department of Public Information, New York.

UPM Tilhill (2010a) Wick and Coombe Wood Biomass Harvesting Implementation Plan. Tilhill Forestry Ltd

UPM Tilhill (2010b) Land of Nod Woods Biomass Harvesting Implementation Plan. Tilhill Forestry Ltd

Van Den Meersschaut, D. and Vandenkerkhove, K. (1998) Development of a Stand-scale Forest Biodiversity Index Based on the State Forest Inventory, Intergrated Tools Proceedings, Boise, Idaho, USA.

Willoughby, I., Evans, H., Brown, A., Denman, S., Hendry, S., Jones, B., Mayle, B., Moore, R., Nisbet, T., Straw, N., Trout, R. Tubby, K. and Webber, J. (2012) Weed, Pest and Disease Management in Forestry: Minimising Pesticide Use in the Forest. Final Draft. Forest Research Practice Guidance for the Forestry Commission.

Appendix 1

FR questionnaire circulated at the *UK Forestry Society and Woodland Management Workshop* (February 27, 2014) organised by the Institute of Chartered Surveyors and Forestry Commission England

Forest Research QUESTIONNAIRE

Forest Research, the research agency of the Forestry Commission, is currently working on a project to assist woodland owners to identify the multifunctional potential of their woods. If you are a woodland owner we would be very grateful if you could complete the following survey to help us understand how you make decisions on woodland management. Please return your completed questionnaire to an event organiser.

1. **Do you understand the term 'ecosystem services'** ☐ Yes ☐ No ☐ Not sure

2. **In looking after your woods do (or will) any of your management decisions specifically aim to do the following** (*please specify what priority level you give to each aim)*

	High Priority	Medium Priority	Low Priority	Not an aim or consideration
• Increase or protect biodiversity/wildlife	☐	☐	☐	☐
• Increase carbon sequestration potential	☐	☐	☐	☐
• Increase public access	☐	☐	☐	☐
• Reduce flooding or improve water quality	☐	☐	☐	☐
• Improve soil quality	☐	☐	☐	☐
• Increase income from recreation/sport	☐	☐	☐	☐
• Increase income from non wood products	☐	☐	☐	☐
• Increase income from wood products	☐	☐	☐	☐
• Take into account the history of the wood	☐	☐	☐	☐
• Take into account the surrounding landscape	☐	☐	☐	☐

3. **Do you feel you are well informed about how managing your woodland can affect biodiversity/wildlife?** ☐ Yes ☐ No ☐ Not sure

4. **Do you feel well informed about how managing your woodland can affect the carbon sequestration potential of your wood?** ☐ Yes ☐ No ☐ Not sure

5. **Do you feel well informed about the benefits of managing your woodland for wood fuel production?** ☐ Yes ☐ No ☐ Not sure

6. **How long would you be prepared to spend assessing the biodiversity (wildlife) potential of your woodland**

☐ No time ☐ Less than 2 hours ☐ 2-4 hours ☐ 4-10 hours ☐ 2-3 days ☐ More than 3 days

Thank you for completing this questionnaire.
If you have any additional comments please write them on the back of this page.
Please hand the completed questionnaire to an event organiser or post to address below:

Laura Henderson, Forest Research, Alice Holt Lodge,
Farnham, GU10 4LH

February 2014

Forestry Commission

Appendix 2

List of native British tree species (≥5m tall at maturity)

Common name	Latin name
Field Maple	*Acer campestre*
Sycamore	*Acer pseudoplatanus*
Horse chestnut	*Aesculus hippocastanum*
Common Alder	*Alnus gultinosa*
Birch (silver/downy)	*Betula spp*
Silver Birch	*Betula pendula*
Downy Birch	*Betula pubescens*
Box	*Buxus sempervirens*
Hornbeam	*Carpinus betulus*
Sweet chestnut	*Castanea sativa*
Hazel	*Corylus avellana*
Midland hawthorn	*Crataegus laevigata*
Hawthorn	*Crataegus monogyna*
Beech	*Fagus sylvatica*
Ash	*Fraxinus excelsior*
Holly	*Ilex aquifolium*
Crab Apple	*Malus sylvestris*
Scots Pine	*Pinus sylvestris*
Grey poplar	*populus canescens*
Black poplar	*Populus nigra*
Aspen	*Populus tremula*
Wild cherry/gean	*Prunus avium*
Dwarf cherry	*Prunus cerasus*
Wild plum	*Prunus domestica*
Bird Cherry	*Prunus padus*
Blackthorn	*Prunus spinosa*
Pear	*Pyrus communis*
Wild pear	*Pyrus pyraster*
Sessile Oak	*Quercus petraea*
Pedunculate/common oak	*Quercus robur*
White willow	*Salix alba*
Goat Willow	*Salix caprea*
Grey willow	*Salix cinerea*
Crack willow	*Salix fragilis*
Bay willow	*Salix pentandra*
Almond willow	*Salix triandra*
Osier	*Salix viminalis*
Elder	*Sambucus nigra*
Whitebeam	*Sorbus aria*
Rowan	*Sorbus aucuparia*
Wild service tree	*Sorbus torminalis*
Yew	*Taxus baccata*
Small-leaved lime	*Tilia cordata*
Common lime	*Tilia europaea*
Large-leaved lime	*Tilia platyphyllos*
Smooth-leaved elm	*Ulmus carpinifolia*
Wych elm	*Ulmus glabra*
Smooth-leaved elm / Small-leaved	*Ulmus minor*
English elm	*Ulmus procera*

Appendix 3

List of tree species that are not native to Britain (≥5m tall at maturity)

Common name	Latin name
Fir sp	
European silver fir	*Abies alba*
Red (pacific silver) fir	*Abies amabilis*
Bornmullers fir	*Abies bornmuelleriana*
Grecian fir	*Abies cephalonica*
Grand Fir	*Abies grandis*
Nordmann fir	*Abies nordmanniana*
Noble Fir	*Abies procera*
Big leaf maple	*Acer macrophyllum*
Norway Maple	*Acer platanoides*
Silver maple	*Acer saccharinum*
Italian alder	*Alnus cordata*
Grey Alder	*Alnus incana*
Red alder	*Alnus rubra*
Green alder	*Alnus viridis*
Paper-bark birch	*Betula papyrifera*
Shagbark hickory	*Carya ovata*
Atlas cedar	*Cedrus atlantica*
Cedar of Lebanon	*Cedrus libani*
Lawsons cypress	*Chamaecyparis lawsoniana*
Japanese cedar	*Cryptomeria japonica*
Leyland cypress	*Cupressocyparis leylandii*
English Elm	*Ulmus spp*
Cider gum	*Eucalyptus gunnii*
Shining gum	*Eucalyptus nitens*
Oriental beech	*Fagus orientalis*
White ash	*Fraxinus americana*
Narrow-leafed ash	*Fraxinus angustifolia*
Red ash	*Fraxinus pennsylvanica*
Black walnut	*Juglans nigra*
Common walnut	*Juglans regia*
European larch	*Larix decidua*
Japanese Larch	*Larix kaempferi*
Hybrid Larch	*Larix x eurolepis*
Tulip tree	*Liriodendron tulipifera*
Raoul/rauli	*Nothofagus nervosa*
Roble	*Nothofagus obliqua*
Lenga	*Nothofagus pumilio*
Norway Spruce	*Picea abies*
Serbian spruce	*Picea omorika*

Appendix 3 (continued)

Common name	Latin name
Oriental spruce	*Picea orientalis*
Sitka spruce	*Picea sitchensis*
Armand's pine	*Pinus armandii*
Mexican white pine	*Pinus ayacahuite*
Calabrian pine	*Pinus brutia*
Lodgepole Pine	*Pinus contorta*
Slash pine	*Pinus ellottii*
Korean pine	*Pinus koreana*
Western white pine	*Pinus monticola*
Bishop Pine	*Pinus muricata*
Corsican Pine	*Pinus nigra var maritima*
Austrian Pine	*Pinus nigra var nigra*
Macedonian pine	*Pinus peuce*
Maritime pine	*Pinus pinaster*
Ponderosa pine	*Pinus ponderosa*
Monterey pine	*Pinus radiata*
Weymouth pine	*Pinus strobus*
Loblolly pine	*Pinus taeda*
Mountain pine	*Pinus uncinata*
Bhutan pine	*Pinus wallichiana*
Yunnan pine	*Pinus yunnanensis*
Plane spp	*Platanus spp*
London plane	*Platanus x acerifolia*
White poplar	*Populus alba*
Grey poplar	*Populus canescens*
Hybrid poplar	*Populus serotina/trichocarpa*
Douglas Fir	*Pseudotsuga menziesii*
White oak	*Quercus alba*
Red Oak	*Quercus borealis*
Hungarian oak Quercus frainetto	*Quercus frainetto*
Hungarian oak Quercus frainetto	*Quercus frainetto*
Holm oak	*Quercus ilex*
Downy oak	*Quercus pubescens*
Pyrenean oak	*Quercus pyrenaica*
Coast redwood	*Sequoia sempervirens*
Wellingtonia/ Giant Redwood	*Sequoiadendron giganteum*
Western Red Cedar	*Thuja plicata*
Lime all	*Tilia spp*
Western Hemlock	*Tsuga heterophylla*
Turkey oak	*Turkey oak Quercus cerris*

Appendix 4

List of native British shrub species (up to 6m tall at maturity)

Common name	**Latin name**
Dogwood	*Cornus sanguinea*
Broom	*Cytisus scoparius*
Spurge laurel	*Daphne laureola*
spindle	*Euonymus euopaeus*
Alder buckthorn	*Frangula alnus*
Juniper	*Juniper communis ssp. communis*
Dwarf Juniper	*Juniperus communis ssp. nana*
Wild privet	*Ligustrum vulgare*
Purging buckthorn	*Rhamnus catharticus*
Field rose	*Rosa arvensis*
Dog Rose	*Rosa canina*
Bramble	*Rubus fruticosus*
Butcher's broom	*Ruscus aculeatus*
Eared Willow	*Salix aurita*
Purple willow	*Salix purpurea*
Dwarf Birch	*Betula nana*
Guelder rose	*Viburnum opulus*
Gorse	*Ulex europaeus*
Montane Willows (all)	
Wayfaring tree	*Viburnum lantana*

Appendix 5

List of invasive vegetation species of relevance to forestry (Willoughby *et al.*, 2012).

Common name	Latin name	Problem
Spear thistle	*Cirsium vulgare*	Competitive weed
Creeping thistle	*Cirsium arvense*	Competitive weed
Curled dock	*Rumex crispus*	Competitive weed
Broadleaved dock	*Rumex obtusifolius*	Competitive weed
Common ragwort	*Senecio jacobea*	Competitive weed; poisonous to livestock
Cotoneaster	*Cotoneaster horizontalis;*	Competes with native flora.
	C. integrifolius;	Competes with native flora.
	C. simonsii;	Competes with native flora.
	C. bullatus;	Competes with native flora.
	C. microphyllus.	Competes with native flora.
Salal	*Gaultheria shallon*	Suppresses native flora, potentially competitive with trees
Himalayan balsam	*Impatiens glandulifera*	Highly competitive, swamps young trees and native flora.
Giant hogweed	*Heracleum mantegazzianum*	Highly competitive, swamps trees and native flora, stems contain chemicals that cause skin damage in humans.
Japanese knotweed	*Fallopia japonica*	Highly competitive, swamps trees and native flora
False acacia	*Robinia pseudoacacia*	Might pose a competitive threat to native species in some circumstances
Yellow azalea	*Rhododendron luteum*	Swamps trees and native flora, harbours *Phytophthora ramorum* .
Rhododendron	*Rhododendron ponticum*	Highly competitive. Swamps trees and native flora, harbours *Phytophthora ramorum* .
Wood small reed	*Calamagrostis epigejos*	Highly competitive with trees in open light conditions, restricts other native flora
Bracken	*Pteridum aquilinum*	Can be highly competitive in open light conditions, swamps trees and native flora, can be carcinogenic.
Sitka spruce	*Picea sitchensis*	Natural regeneration can prove invasive in some woodlands
Sycamore	*Acer pseudoplatanus*	Natural regeneration can prove invasive in some woodlands
Western hemlock	*Tsuga heterophylla*	Natural regeneration can prove invasive in some woodlands

Appendix 6

Example RWBA survey forms for whole woodland and survey plot scale assessments

Whole Site Details

Survey date	Start and finishing time	Site name

Section 1 – Woodland Landscape

What area of woodland is temporary open space?
Provide either area in hectares or % of the woodland ☐ ha or ☐ % of

Are there any of the following water features present on the site?
Tick those that apply

☐ Pool or pond ☐ Lake ☐ River ☐ Stream ☐ Wet Ditch ☐ Dry Ditch

☐ Natural Spring/flush ☐ Bog/Marsh or Swamp

Are there any of the following rocky features present on the site?
Tick those that apply

☐ Rocky ridge or rock face ☐ Scree Blocks/slabs/☐s of stones

☐ Stone wall or ruin

Section 2 – Woodland protected species/habitat

Is there any evidence or sightings of European Protected or Priority Species i.e dormouse, bats, smooth snakes, great crested newts, red squirrels? Is there the potential for these species to be present (e.g. appropriate habitat available and existing populations in neighbouring woods)? If so mark on map and detail species below.

Are there any veteran trees on site – if so how many?
(including any those seen in survey plots)
Mark locations on a map and put total number in whole woodland in box ☐

Section 3 – Opportunities and Notes

The following box can be used to make notes on the woodland and any threats or opportunities you might see. This might include species conversion, heritage features, surrounding land use, vandalism or fly tipping, access, recreation, timber harvest etc

Appendix 6 continued

10 m Radius Plot page 1/2

Survey date	Site name	Plot number (x) of total (y) i.e 1/10

Section 1 – Woodland Stand Structure

Record the tree size Structure present *Tick all that apply*

Trees with trunk girth greater than 22 cm	Trees with trunk girth less than 22 cm:
• Mature trees > 225 cm circumference or >1.5 hugs ☐ • Mature trees 150-225 cm circumference or 1-1.5 hugs ☐ • Mature 75 – 150 cm circumference or 0.5-1 hugs ☐ • Pole trees 22 – 75 cm circumference ☐	Saplings >100 cm tall ☐ Seedlings 10 – 100 cm tall ☐ Seedlings < 10 cm tall ☐ Suckers (shoots growing from the base or roots of a tree) ☐ Coppice Stool with regrowth >100 cm tall ☐ Coppice stool with regrowth < 100 cm tall ☐

What is the % of canopy occupied by native tree species ☐ % of canopy

Which of the following canopy layers are there in the plot?

Herbaceous and semi woody shrub layer ☐
Low woody species (< 7 m high) ☐
Intermediate woody (7-20 m high) ☐
High woody (>20m high) ☐

How many quarters of the plot contain the following?:

Standing or aerial deadwood ☐ Lying deadwood ☐ Tree Stumps ☐

What percentage of ground cover is covered by the following (total should = 100%)?:

Ground flora vegetation	☐	% of plot	Deadwood	☐	% of plot
Moss	☐	% of plot	Bare Ground	☐	% of plot
Leaf Litter	☐	% of plot	Other	☐	% of plot

Section 2 – Woodland Composition

How many different native tree and shrub species are there in the plot ? ☐

Are there any invasive non-native species present?
If so note species and mark location on a map ☐ Yes ☐ No

Grazing and Browsing

Do the following apply?

There is a clear and visible browse line ☐
Bark below 2 m has been stripped from more than about 20% of the trees and shrubs ☐
Are more than 20% of shoots damaged or browsed (absent shoot tips) ☐

Plot notes

The following box can be used to make notes about the plot – any species of interest, opportunities etc

Equipment

No specialist equipment is needed but the following items would be useful:

- Pens
- Survey forms and clipboard
- Map with planned route
- Compass
- Tape measure
- First aid kit/sun screen/insect repellent
- Mobile phone
- Camera (optional)
- Field guides (optional)

Health & Safety and Biosecurity

Surveyors should be aware of risks associated with the survey. Particular attention should be paid to steep slopes, ponds/wet boggy areas, cliff faces or quarries, ticks and other insects. Weather conditions should also be considered and surveying in extreme heat, strong winds,or lightning storms should be avoided. Alterations should be made to the survey route if it reduces the risk of accidents.

Be aware of good practice in respect of biosecurity. Tree diseases can be spread between woodlands on tyres, machinery and boots/clothes. Ensure all clothing, boots and tools are washed, especially if the woodland is known to have tree diseases. The Forestry Commission has published guidance on biosecurity which is applicable to all woodland

Appendix 7

Management prescriptions for M1 growth and yield model for both the Management Plan and RWBA informed scenarios

Hartley Mauditt

Cpt	Sub Comp	Species	Management Plan	Increased Biodiversity (RWBA) options
1	A1	POK	Split into 8 components fell new component Every 5 years From age 110. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
1	A2	SB	Fell at age 50; Repeat rotation	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
1	B	SP	Fell at age 68; Repeat rotation	Split into 4 components. 10 year intervals from age 68. Replace with OK, Restocked SP, SAB, continue last as original SP, not felled
1	C	MB	Split into 8 components fell new component Every 5 years From age 8. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
1	D	JL	Fell at age 53; Repeat rotation	Split into 4 components. 10 year intervals from age 53. Replace with OK, SP, SAB, continue last as original JL, not felled
1	E	MB	Split into 8 components fell new component Every 5 years From age 40. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
1	F	JL	Fell at age 50; Repeat rotation	Split into 8 components. Coppice with standards: Replace first component with BE (109 yr cycle); 2,4,5,6,8 with SCC coppice 20 year cycle. Third and 7th with SAB (YC6)
1	G1	OK	Split into 8 components fell new component Every 5 years From age 120. Replace with MB coppice/SRF no thin on 40 year cycle	Continue OK rotation
1	G2	JL	Fell at age 53; Repeat rotation	Split into 4 components. 10 year intervals from age 53. Replace with OK, SP, SAB, continue last as original JL, not

				felled
2	A	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle

Cpt	Sub Comp	Species	Management Plan	Increased Biodiversity (RWBA) options
3	A	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
4	A	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
5	A	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
6	A	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
7	A1	MB	Split into 8 components fell new component Every 5 years From age 90. Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
7	A2	OK	Split into 8 components fell new component Every 5 years immediately (From age 27). Replace with MB coppice/SRF no thin on 40 year cycle	Split into 8 components. Coppice with standards: Replace first and 5th component with SAB (YC6) Standard 50 year cycle. Others with SCC coppice 20 year cycle
7	B	OK	Split into 8 components fell new component Every 5 years immediately (From age 27). Replace with MB coppice/SRF no thin on 40 year cycle	Continue OK rotation (70 year cycle)

Where increased deadwood is required, leave 10% of thinning/harvesting. First 2 thins; fell to waste.

Land of Nod

Cpt	Sub Comp	Species	Management Plan	Increased Biodiversity (RWBA) options
1	A1	BE	Standard MT, Fell age 109; Repeat rotation	Split into 10 components fell new component Every 5 years From age 80. Replace with BE, on MT cycle
1	A2	JL	Standard MT, Fell age 56; Repeat rotation	Split into 5 components. Fell new component every 5 years from age 50. Replace with SAB (YC6) on MT cycle
1	B	EL	Standard MT, Fell age 47; Repeat rotation	Split into 5 components. Fell new component every 5 years from age 47. Replace with SAB (YC6) on MT cycle
1	C	SCC	No thin, 20 Fell age 20; repeat rotation	Unchanged from initial prescription
1	D1	MB	Standard MT. Fell age 120 Repeat rotation	Unchanged from initial prescription
1	D2	MB	Heavy thin age 24 (28.4m3); 29 (28.4m3); 34 (26.2m3), then nothing until fell age 120 Repeat rotation	Unchanged from initial prescription
1	E	MC	Standard MT, Fell age 56. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 56. Replace with SAB (YC6) on MT cycle
1	F	EL	Standard MT, Fell age 50. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 50. Replace with SAB (YC6) on MT cycle
1	G1	SCC	No thin, Fell aged 20; Repeat Rotation	Unchanged from initial prescription (20 yr Rotation)
1	G2	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 65. Replace with SCC coppice/SRF NT; 20 yr Cycle
1	H1	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 65. Replace with SCC coppice/SRF NT; 20 yr Cycle
1	H2	WH	Standard MT, Fell age 56. Repeat rotation	Unchanged from initial prescription
1	I	MB	Standard MT, Fell age 120. Repeat rotation	Unchanged from initial prescription
1	J1	WH	Standard MT, Fell age 65. Repeat rotation	Unchanged from initial prescription
1	J2	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 65. Restock with SP MT, 65 yr Cycle
1	K	SP	Standard MT, Fell age 65. Repeat rotation	Split into 2 components: Fell at 65. 10% OK standard MT, fell age Fell age 90. 90% Restocked SP. 65 yr Cycle
1	L	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 65. Restock with SP MT, 65 yr Cycle
1	M	CP	Fell aged 54, Repeat Rotation	Fell aged 54, Replace with SAB (YC6) on MT cycle
1	N1	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years

				from age 65. Restock with SP MT, 65 yr Cycle

Cpt	**Sub Comp**	**Species**	**Management Plan**	**Increased Biodiversity (RWBA) options**
1	N2	NS	Standard Management, Fell aged 67; Repeat rotation	Unchanged from initial prescription
1	N3	RC	Standard Management, Fell aged 94; Repeat rotation	Unchanged from initial prescription
1	P	CP	Standard Management, Fell aged 53; Repeat rotation	Fell Aged 53, Replace with SAB (YC6) on MT cycle
2	A	CP	Standard Management, Fell aged 54; Repeat rotation	Split into 5 components. Fell new component every 5 years from age 60. Replace with SAB (YC6) on MT cycle
2	B1	SP	Standard MT, Fell age 65. Repeat rotation	Fell age 65. Restock with 10% OK (90 year cycle), 90% SP (on MT cycle)
2	B2	SP	Standard MT, Fell age 65. Repeat rotation	Fell age 65. Restock with 10% OK (90 year cycle), 90% SP (on MT cycle)
2	C	SP	Standard MT, Fell age 65. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 65. Restock with SP MT, 65 yr Cycle
2	D	MB	Standard MT; Heavy thin age 101 (20.7m3); 106 (20.7m3); 111 (34m3). Fell age 120. Repeat rotation	Unchanged from initial prescription
2	E1	EL	Standard MT;, Fell age 50; Repeat rotation	Split into 5 components. Fell new component every 5 years from age 47. Replace with SAB (YC6) on MT cycle
2	E2	SCC	No thin, Fell aged 20; Repeat rotation	Unchanged from initial prescription (20 yr Rotation)
3	A	SP	Standard MT, Fell age 65. Repeat rotation	Split into 2 Fell age 65. Restock with 40% OK (90 year cycle), 60% SP90 on MT cycle
4	B	CP	Standard MT, Fell age 54. Repeat rotation	Split into 5 components. Fell new component every 5 years from age 64. Replace with SAB (YC6) on MT cycle

Where increased deadwood is required, leave 5-10% of thinning/harvest

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