Forestry Commission

Preliminary estimates of the changes in canopy cover in British woodlands between 2006 and 2015

National Forest Inventory

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Summary and qualifications to the report

Summary

The National Forest Inventory (NFI) of Great Britain (GB) provides a record of the area and distribution of forests and woodlands in Britain and information on key forest attributes. This report contains new estimates of the amount of clearfell, restocking, woodland loss and windblow observed in Britain's woodlands between 2006 and 2015.[1] The observations were made with satellite imagery, aerial photographs and field survey.

Canopy cover is a subset of woodland area and excludes temporarily unstocked areas, including clearfell and newly replanted areas. Identifying such areas of clearfell and replanting is the key discerning factor of this report compared to previous reports on woodland area. In common with woodland area, gross canopy cover includes small permanent open spaces (of area less than 0.5 hectare). Expanded definitions of these terms can be found in the section on Key definitions. Monitoring canopy change is complex, since many factors drive change in canopy, some of which are related and interdependent such as clearfelling and restocking, while others are largely independent of one another, such as natural colonisation of trees, new planting, woodland restructuring and woodland loss. Canopy change can be temporary and part of either natural processes or woodland management practice, or it can be permanent in nature, which will lead to changes in woodland area. Some of these factors increase canopy cover, while others decrease it. All these factors need to be assessed to build a complete picture of net canopy change over time and how this impacts on woodland area.

Through observing actual change in canopy cover within existing woodland, the report provides the first estimate of the change in the composition of woodland resulting from the new approaches to woodland management practice that arose in the 1980s. It is also the first assessment of the impact of urban and rural development on woodland area. It reports that between 2006 and 2015 there was a net increase in woodland area, alongside evidence of significant levels of canopy cover change in the form of 188 thousand hectares of clearfelling, undertaken primarily for timber harvesting. This level of felling correlates with anticipated increases in timber production resulting from post war planting. The change associated with clearfelling will mostly be temporary in nature as there is a presumption to restock woodlands within the UK Forestry Act. More time will need to pass before further monitoring confirms this and establishes how much of this area of canopy change is temporary and how much is permanent, dependent upon evidence of eventual restocking of this newly clearfelled area.

[1] Areas of change of greater than 0.5 hectare.

In addition to this canopy change of a temporary or indeterminate nature, there were 3,279 hectares identified where evidence of a permanent change in land use has already occurred, primarily of woodland converted to use for mineral extraction and for urban development. In addition to this area, 739 hectares of woodland had changed to ground under development,[2] which may evolve into permanent land-use change.[3]

In terms of permanent woodland loss, the levels in any one year are relatively low when compared to overall woodland area (averaging 0.012% per annum) and are smaller than the area of new woodland that was established (averaging 0.3% per annum), the overall net result being that Britain has gained woodland area between 2006 and 2015.

Qualifications to the report

As the report is based on observations made between 2006 and 2015, it is a partial view of a longer-term process that will continue to evolve. This is because the different factors that affect canopy cover work on different time cycles with, for example, canopy taking decades to establish through natural colonisation, while felling of woodland is almost instantaneous by comparison. Such factors thus require long-term monitoring to fully identify their eventual character and impact. At the same time, their initiation, such as clearfelling events, are relevant to report upon now and are pertinent to establishing a full appreciation of how canopy cover is changing. The NFI, as an observation-based survey, requires measurable evidence to make estimates and can thus only report on what has been seen to date and does not assume what may happen in the future. Thus, as the NFI is only a recently established long-term monitoring operation, it does not as of yet have full evidence for all the eventual outcomes of recent and current change and will only be able to report on these retrospectively in the future.

Observing all these factors and reporting on them across a limited period of time therefore involves careful interpretation, especially in observing and reporting how individual sites will change over longer periods of time. The results published in this report are therefore a preliminary view of long-term canopy change assessed from observations made over a short period of time and thus have their limitations.

Understanding these temporal factors[4] and how the results presented are a partial picture of a long-term process is an important qualification to the report and should be borne in mind when interpreting the results.

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[2] Woodland that has been clearfelled and the ground has undergone civil engineering works.

[3] The estimates do not include more subtle longer-term changes to canopy, such as those that occur gradually through, for example, grazing pressure or competition.

[4] In the NFI, clearfelling and restocking data are collected separately from satellites and ground observations. Satellites identify clearfelling annually, while field surveys take 5 years to assess restocking. This leads to a lag in reporting between the two.

Key findings

The results show that woodland canopy in Britain is undergoing a period of significant change.

Clearfelling

- Woodland area has increased over the period 2006 to 2015. In 2006 there was estimated to be 2,936 thousand hectares of woodland present in Britain of which 3.7% (109 thousand hectares) were clearfelled areas. In 2015 woodland area was estimated at 3,043 thousand hectares.

- There was 109 thousand hectares[5] of clearfelled area observed in 2006, which will have resulted from more than a single year of felling events, as most clearfell sites are left fallow for an average of 2 years (with a typical range of 0–5 years).

- Between 2006 and 2015, an additional 188 thousand hectares of woodland has been clearfelled across Britain, at an average rate of 20.9 thousand hectares per annum. For individual countries, the average rates of clearfell within this period are 3.7 thousand hectares per annum in England, 15.0 thousand hectares per annum in Scotland and 2.2 thousand hectares per annum in Wales.

This clearfelling is likely to be predominantly a temporary change and has largely arisen as a result of the normal economic activity and typical silvicultural practice of felling trees at economic maturity. These areas are likely to subsequently be replanted. Such felling and replanting activity is controlled through a framework of regulatory processes, with a presumption to replant and maintain woodland area. Replanting policy in conifer woodlands involves establishing areas of open ground and broadleaves to take account of environmental considerations. Thus the clearfelled area may also include areas that are part way through approved land-use change and will consequently be lost to canopy cover permanently.

- There is estimated to have been a total of 3,279 hectares of woodland converted permanently to built land uses in Great Britain between 2006 and 2015, which has primarily arisen as a result of mineral extraction and urban development. This area excludes change arising from habitat restoration and other areas for which it is uncertain whether the woodland areas felled will regenerate.
    - Of this area, 123 hectares were on recognised ancient woodland sites (see Table 19).

[5] It should be noted, when comparing clearfell to restock areas, that clearfell areas include previous integral open space and restock areas are 'stocked areas' that exclude integral open space.

- In addition to the above, between 2006 and 2015, 739 hectares of ground under development was observed on previously identified woodland area, which, if confirmed as permanent in future observations, will additionally contribute to woodland loss.
    - Of this area, 12 hectares were on recognised ancient woodland sites (see Table 19).

- Of the 3,279 hectares of woodland loss, 166 hectares were as a result of the establishment of wind farms, although the area of woodland under planning consent[6] for wind farms exceeds this. Such records of wind farm planning applications are incomplete across Britain, but those that are currently available coincide with around 23.1 thousand hectares of land that is currently clearfelled. NFI will observe if any of these areas become permanent land-use change over time (using the principle that land-use change is only confirmed once it is physically observed).

- Of the 288 thousand hectares of apparent woodlands in transition in 2015, it is estimated that 4.1 thousand hectares occurred in areas designated[7] as ancient semi-natural woodland sites and a further 13.3 thousand hectares in plantations similarly designated as being on ancient woodland sites. Breakdowns by country are shown in Table 8.

- Of the 288 thousand hectares of apparent woodlands in transition in 2015, there are around 16.3 thousand hectares adjacent to areas currently classified as ground under development, significant vegetation change or woodland loss. To date these sites show no sign of permanent change and may or may not revert to canopy cover (see Table 11).

- Plant health and its management have contributed to the levels of clearfelling in the period, with, for example, the Forestry Commission and Natural Resources Wales (NRW) reporting that they have issued[8] 15.3 thousand hectares of statutory plant health notices (SPHN) for *Phytophthora ramorum*. Of this area, 3,084 hectares has been identified as clearfelled by NFI. The breakdown of this area by country is shown in Table 9. The total area covered by SPHNs is higher since not all SPHNs involve clearfelling, not all will have been enacted at time of assessment and not all trees within SPHN areas are required to be felled.

[6] Planning consent up to March 2016, either approved/active or installed stage

[7] Mapped by the Nature Conservancy Council in the 1980s and maintained by Natural England, Scottish Natural Heritage and Natural Resources Wales.

[8] Statutory plant health notices issued between March 2010 and March 2015

- Felling with the support of unconditional felling licences, primarily for open habitat restoration, will have contributed to the levels of clearfelling in the period, with, for example, 10.9 thousand hectares subject to unconditional felling licences[9] across Great Britain in the period. Of these areas, 2,983 hectares have been identified by NFI as clearfelled. The breakdown of this area by country is shown in Table 10.

Restocking

- For the clearfell identified at 2006 (109 thousand hectares), a field survey assessment has been made to estimate the amount of tree cover re-established by 2012. There was estimated to be a restocked area of 55 thousand hectares of conifer and 19 thousand hectares of broadleaves (see Table 21). The remaining 34 thousand hectares was composed of clearfell and open space and these areas will be monitored for further canopy establishment until the end of 2016/17, at which point any remaining unstocked area over 0.5 hectare in extent would be classified as confirmed woodland loss.

- For the 29 thousand hectares of clearfell identified between 2006 and 2009, a field survey assessment has been made to estimate the amount of canopy cover re-established by 2012. There was estimated to be a restocked area of 15 thousand hectares of conifer and 3 thousand hectares of broadleaves (see Table 22). The remaining 11 thousand hectares was composed of clearfell and open space and these areas will be monitored for further canopy establishment until 2019, at which point any remaining unstocked area of over 0.5 hectare in extent would be classified as confirmed woodland loss.

- The final extent and nature of replanting of areas felled over the period 2006 to 2015 is not yet known; further partial assessments are due to be made in 2018 and 2020 from analysis of NFI second cycle fieldwork. A full assessment of restocking between 2006 and 2015 will be available in 2025.

Windblow

- There was estimated to be a minimum of 4,113 hectares of new windblow over 0.5 hectare in extent generated in Britain between 2006 and 2015. This is normally a temporary change in canopy cover (see Table 12).

[9] Unconditional felling licences approved between March 2000 and March 2015

Key messages

For the first time Britain has a long-term woodland canopy cover monitoring process based on the use of satellite imagery and fieldwork. Through this the NFI can now identify the temporary changes in canopy cover arising from clearfelling and restocking, alongside permanent changes in canopy cover that lead to woodland loss and gain. Some of the causes of these changes to woodland area can also now be identified. This monitoring capability enables assessment of the levels of habitat restoration and increased broadleaved cover arising from the implementation of the UK Forestry Standard, but further reports will be required to assess the full impact of this. The report highlights the continuing need for further evidence on canopy cover change over time, from which all the evolving benefits and consequences of woodland management can be assessed alongside the impacts of nature. So far the process has identified that:

- Woodland canopy cover in Britain is undergoing a period of significant change,[10] much of which is driven by the higher levels of clearfelling of an increasingly mature conifer resource, which is a sign of growth in economic activity in the sector. The report provides preliminary estimates of what has been replanted on sites clearfelled between 2006 and 2012, but definitive information on the final extent and nature of the replanting will not be available until 2025, when all areas felled between 2006 and 2015 will have had 10 years to re-establish tree cover.

- Of the 188 thousand hectares of area identified as having been clearfelled between 2006 and 2015, and the 109 thousand hectares of clearfelled area in existence at the start of the monitoring period in 2006, preliminary estimates indicate that the majority of the area is replanted within 5 years of clearfelling. Some of the area has been subject to delayed restocking, reductions in conifer composition, increases in broadleaved composition and increases in permanent open habitat, which is in line with current and recent forestry policy. It will take a decade or more to fully establish the final land use of these areas as conifer or broadleaved woodland, development land or open habitat.

- The data presented in this report, combined with further survey work, will be used in revisions of the 25 and 50-year timber availability forecasts, which will more accurately reflect actual restocking practice and policy. This will improve the information available to inform policy, practice and investment in the sector.

[10] Any form of canopy change of under 0.5 hectare in extent within woodland is not included in these estimates. Any such changes will not impact on NFI woodland area and are not covered in this report, but do contribute to the overall profile of woodland composition and will be reported on at a later date.

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Introduction

National forest inventories are carried out by the Forestry Commission to provide accurate, up-to-date information about the size, distribution, composition and condition of forests and woodlands in Great Britain. This information is essential for developing and monitoring policies and guidance which support sustainable forest management.

The current National Forest Inventory (NFI), which began in 2010 (the first cycle completed in 2015), is a multipurpose operation that has involved the production and annual update of a forest and woodland map for Britain and a continuing programme of field surveys of the mapped forest and woodland areas.

Information and data collected by the NFI are being used for a number of purposes, including various estimates and forecasts of key forest metrics, such as of timber and carbon stocks, aspects of habitat condition and the social use of forests and woodlands.

This report sets out preliminary results (as at March 2015) for the amount of temporary and permanent change in woodland canopy arising from clearfell, restocking, woodland loss and windblow. Clearfelling, restocking and a level of open habitat restoration are part of sustainable forest management and are widely practised within Britain. This type of change forms the majority of canopy change and, provided the restocking occurs, the canopy loss arising from clearfelling is temporary in nature and the clearfelled area continues to be classified as woodland. The report also identifies permanent observable change in canopy, where woodland is felled and permanently lost through conversion to other land uses such as built developments and restoration to open habitat.

To set a context around these new results, previously published estimates of other metrics relevant to total canopy cover and woodland area, such as the amounts of new planting and restocking, are also provided. Further information on this and other NFI outputs is available from www.forestry.gov.uk/inventory.

Background, scope and definitions

Background

This is the first time that the Forestry Commission has tracked change in canopy cover and woodland loss over time. The main reason for this is that canopy cover change is a complex process and, as such, is technically difficult to monitor. The current availability of satellite imagery, aerial photography, geographic information systems (GIS) and an established NFI fieldwork programme has enabled this tracking.

Between the 1920s and 1970s there was little change to canopy cover other than its expansion through new planting. From the 1970s onwards the plantations established in the earlier part of the century increasingly came to maturity and began to be harvested and replanted, increasing the rate and type of change to canopy. This occurred at a time when evolving forms of forest management and restructuring were encouraged, with the aim of diversifying the character of plantation woodlands to meet objectives wider than timber production. As these practices were employed they brought about increasing levels and types of change within woodlands, which resulted in increasing diversity within the woodlands, and a more complex picture of how woodland canopy evolved. At the time the capacity did not exist to monitor this process and to provide quantitative measures of its effects on land-use change and canopy cover. This led to the Forestry Commission Executive Board establishing the NFI in 2009 and mandating it to provide a long-term woodland monitoring programme which would report on changes to woodland area and woodland composition over time. More recently, requests were made by the forestry sector to assess permanent change of land use from woodland to other land uses and changes from coniferous to broadleaved species due to drivers such as forest restructuring, wind farm establishment and changes in incentives. This request is being addressed by bringing forward the publication of this report from 2020 to 2016.

Previous estimates of canopy change and woodland loss

There are no previous detailed national estimates of canopy change in Britain and no detailed woodland loss estimates based on direct measurement. This is because there have been no detailed data on change in canopy and woodland loss within Britain prior to the NFI programme. The absence of historical information on canopy and woodland loss prevent the estimates in this report being compared with previous estimates for longer-term comparisons.

However, some limited comparison can be made between the NFI estimates and previous woodland inventories, such as those conducted in 1924, 1947, 1965 and 1979. These comparisons can be used to broadly estimate woodland gain between these periods, but are not particularly helpful in establishing loss. This is because, while all the inventories reported on net woodland area, including breaking woodland area into the amount of high forest and clearfell at a single point in time, they did not report separate

estimates for woodland creation and woodland loss. Some comparisons can be made and inferences drawn between the 1995 survey (NIWT) and the NFI survey. Details of this can be found in Appendix A.

Prior to the NFI, it was not possible to derive quantitative estimates of woodland loss through direct measurement. This necessitated previous estimates to be primarily based on administrative records. The underlying processes that create woodland loss are where trees are felled without replacement, generally for the purposes of habitat restoration and urban development. The administrative records of permissions for such change were kept by the Forestry Commission for woodland to rural land-use changes and by local authorities for woodland to developed land-use changes. There was also an element of illegal felling and conversion to other land uses that was partially accounted for. In such instances, if discovered, restocking notices would have been issued. Collating these records into a complete picture of change was an involved process and relied upon fully representative records. Now, through utilising satellite data and other earth observation techniques, the NFI can quantitatively measure the outcome of all these processes, providing information on the amount of canopy loss and woodland loss over a fixed period of time.

Scope

A core remit of the NFI is to:

- Estimate woodland area
  - Estimate increases to woodland area
  - Estimate decreases to woodland area

- Estimate drivers of change in woodland
  - Estimate permanent and temporary changes to canopy cover
  - Assess causes of increases and decreases to canopy cover

Assessing canopy change is complex as many factors drive change in the canopy, some of which are related and interdependent, such as clearfelling and restocking, while others are largely independent of one another, such as natural colonisation of trees, new planting, restructuring and woodland loss. Some of these factors increase canopy cover, while others decrease it, and all factors need to be assessed to build a complete picture of the underlying causes of net canopy change and net woodland area. A further complication is that each of these factors operates in different time cycles. For example, woodlands may take decades to establish through natural colonisation, while it can take little time (days or months) for woodland to be felled and converted to a new land use. Observing these factors within a limited time period and interpreting their implications for long-term change is challenging, especially in observing and deducting how individual sites have changed over long periods of time.

This report aims to provide estimates of the main factors driving change in canopy cover and woodland area, especially where there is no measured evidence currently available, such as for rates of clearfell, restocking and woodland loss. The report aims to provide a foundation for assessing loss of woodland area over time and to estimate and distinguish, as far as possible, the underlying causes of permanent and temporary changes to canopy cover and woodland area. The NFI has measured these factors from 2009 onwards, and can backcast reliably to 2006.

As a result, this report provides the latest overall estimates for the total area of significant canopy cover change[11] observed and recorded in the NFI between 2006 and 2015, focusing on high forest areas that have been harvested in that period. It also identifies areas that once carried tree canopy and where permanent land-use change has occurred, areas where the woodland has been clearfelled and the ground is under development (potentially to a non-woodland land use) and areas where there is newly established habitat. The report also provides preliminary findings on the restocking of clearfelled areas within the period.

The report excludes making definitive conclusions on how areas of woodland currently clearfelled may evolve over time, as this will require a longer monitoring period to determine. It also excludes a complete assessment of any potential change concerning the type of trees that will constitute the future canopy. While the extent to which conifer tree species are being replaced with broadleaved species is of particular interest to the timber processing sector, NFI will only be able to fully report on species composition change once further cycles of the NFI fieldwork have been completed. However, recognising the interest in species composition change, the report provides information currently available on this matter and aims to make further reports of changes in composition once further cycles of the NFI are complete.

The report also excludes an assessment of natural colonisation of open land by woodland; current evidence to hand suggests that this is not a principal driver of change. However, this will continue to be monitored and will be reported on separately at a future date.

The report does not cover loss of tree canopy in non-woodland situations, such as in lone trees or small groups of trees isolated from woodland. Such canopy is defined as 'small woods and lone trees' by NFI and will be reported on in the forthcoming NFI report on *Small woods and lone trees in Britain*.

[11] Changes of over 0.5 hectare in extent.

This report does not cover minor losses of canopy of less than 0.5 hectare in extent[12] within woodland. Furthermore, it does not cover the more subtle changes of consolidation or degradation of the canopy within its existing area, as a result of drivers such as tree growth, competition between trees, grazing, pests and diseases, or thinning over time. These factors will not significantly impact on canopy cover and woodland area within the 9-year time-frame used in this report, but can impact significantly over longer periods. The quantification of such changes is important and will be addressed in NFI second cycle reports, with reporting beginning in 2020. This delay is necessary since the assessment of these aspects of canopy evolution requires detailed on-the-ground assessments and repeat surveys of woodlands to be made over a span of several years.

This report therefore presents information on gross levels of canopy and woodland area loss and canopy and woodland area gain, in addition to net changes in canopy cover and woodland area at a national level. The causes of observed canopy and woodland area loss are also identified where possible, including an analysis of whether they are temporary or permanent.

Key definitions

To monitor and report upon net change in canopy and woodland area, a standardised set of terminology and rules are used in this report. The following section summarises these and will aid interpretation of the rest of the report. Further detail can be found in the Methodology and Glossary sections.

Woodland area

Woodland area is defined as forest and woodland area that includes:

1. Any area of land covered by trees with an established canopy that is greater than 0.5 hectare in extent (in the NFI the boundary of this area is defined as being to the drip line of the external edge of the canopy).
2. Open spaces of less than 0.5 hectare or less than 20 metres in width within the woodland (e.g. rides, glades, ponds).
3. Areas of clearfelled or windblown woodland for up to 10 years after the clearfell or windblow event, if a change of land use has not been established.
4. Areas covered by young trees of a minimum of 0.5 hectare in extent, or is adjacent to established woodland forming a total area of at least 0.5 hectare, resulting from planting, natural regeneration or colonisation, that have not yet established a continuous canopy.

[12] If areas of less than 0.5 hectare in extent are added to other areas of less than 0.5 hectare in a later period, these will contribute to loss estimates if the sum is greater than 0.5 hectare.

Net and gross canopy cover

Net canopy cover is defined as the area of land under tree canopy. Net canopy cover is measured to the drip line of the individual tree. It does not include small intimate open space between the canopies of individual trees, nor any larger areas within overall woodland area that are not covered by tree canopy.

This report, however, reports on gross canopy cover. This, in addition to the area under net canopy cover, includes intimate space between canopies of individual trees, larger open areas of less than 0.5 hectare that are surrounded by trees (often referred to as intimate open space within woodland in this report), and windblown areas of less than 10 years since the windblow event. Table 1 provides detailed definitions of the various aspects of woodland area and canopy cover.

Throughout this report, references to canopy cover generally refer to gross canopy cover.

Differences between woodland area and gross and net canopy cover

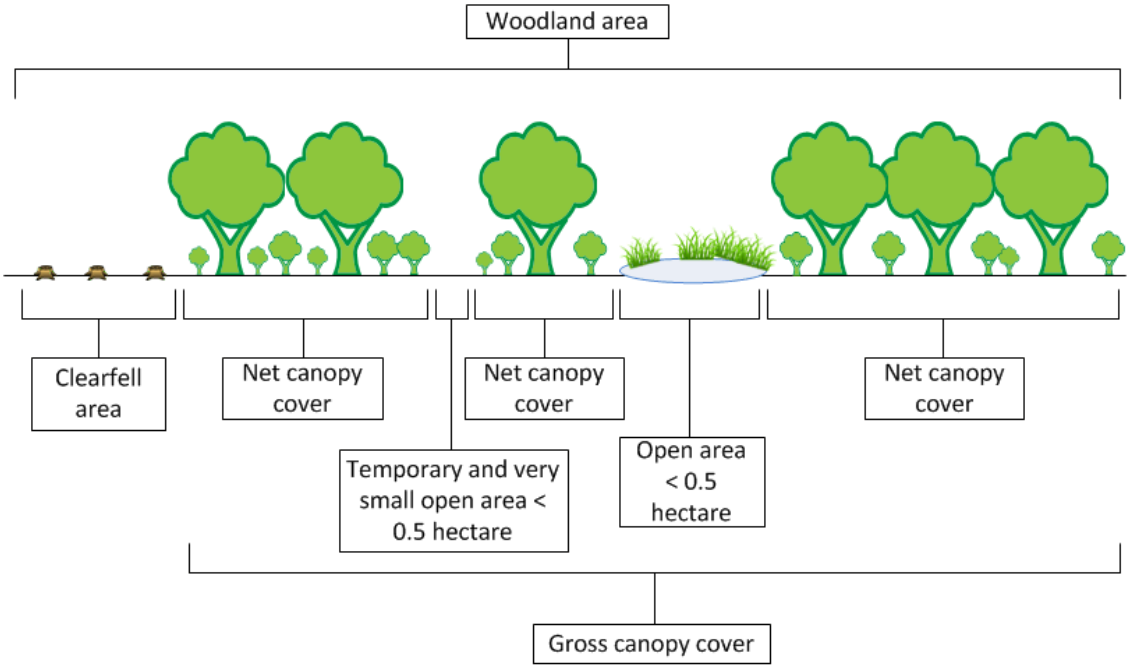
Both gross and net canopy cover are subsets of woodland area and can only be loosely associated with woodland area. The major differences between woodland area and gross and net canopy cover are:

1. Woodland area contains small amounts of permanent open space within the woodland, such as streams, ponds, wetland or rock outcrops. If these open areas are less than 0.5 hectare in extent, they are included in both woodland area and gross canopy cover, but are not included in net canopy cover (see Figure 1). If they are greater than 0.5 hectare in extent, they are excluded from both canopy and woodland area and are accounted for as an open land use in their own right.

2. Areas of woodland that temporarily carry either no or very sparse tree cover are included in woodland area, but are excluded from both gross and net canopy cover. They are included in woodland area since canopy can be temporarily removed or denuded through natural processes such as wind damage, fire, pests and diseases, or through human activity such as harvesting. Usually such areas recover their canopy, either through natural or human processes, such as regeneration or planting (respectively). If this occurs within 10 years, then such areas are classified as woodland throughout the period. However, as they do not carry canopy for a period, they are not part of either gross or net canopy cover during that period and they are classified as ‘temporarily unstocked area’ in woodland area assessments.

3. Young trees have no significant canopy. Areas of young trees that are discrete from the mature and semi-mature trees which can form a canopy, such as areas of new planting and restocking, are thus excluded from both gross and net canopy cover, until such time that the young trees are established and physically possess a canopy. Woodland area is a land use and thus includes areas of established young trees. Young trees that are growing under the canopy of older trees will be included in woodland area and also in gross and net canopy cover by virtue of the canopies of the older trees.

Figure 1 An example of open space within woodland area and its relation to gross and net canopy cover



The temporary and very small open space illustrated in Figure 1 relates to the intimate open space that can be found between individual crowns. These gaps will range from a few centimetres in width to no more than 1 to 2 metres in width. In younger trees, or stands after thinning, these gaps will in time be filled with new growth to complete canopy closure and thus the space is viewed as temporary. In some species and some situations, such very small areas of open space exist permanently between trees.

The woodland and clearfell areas quoted in this report therefore exclude pre-existing permanent open space within woodland that is greater than 0.5 hectare in extent. Areas of clearfell cited in this report refer to areas of gross canopy cover prior to the clearfell event and therefore, in common with woodland area, include areas of pre-existing integral open space of less than 0.5 hectare in extent.

Detailed definitions of woodland and canopy cover

Table 1 identifies what is included and excluded in the NFI definitions used to identify woodland area, canopy area and stocked area.

Table 1 Woodland area and canopy cover area definitions

	Woodland area	Gross canopy cover	Net canopy cover	Stocked area
Tree canopy				
Area under canopy of trees outside of contiguous areas of woodland of a minimum size of 0.5 hectare and minimum width of 20 metres	x	x	x	x
Area under canopy of measurable trees (≥7cm DBH) inside woodland	✓	✓	✓	✓
Open space				
Temporary and very small space between the canopies of individual measurable trees within woodland	✓	✓	x	✓
Permanent open space of area <0.5 hectare within woodland areas	✓	✓	x	x
Permanent contiguous open space of area ≥0.5 hectare surrounded by woodland [1]	x	x	x	x
Clearfelled areas				
<10 year old clearfelled areas of size <0.5 hectare	✓	✓	x	x
<10 year old clearfelled areas of size ≥0.5 hectare	✓	x	x	x
≥10 year old clearfelled areas of size <0.5 hectare within woodland	✓ [2]	✓ [2]	x	x
≥10 year old clearfelled areas of size <0.5 hectare – edge of woodland	x	x	x	x
≥10 year old clearfelled areas of size ≥0.5 hectare	x	x	x	x
Windblow [3]				
<10 year old windblown areas	✓	✓	x	✓
≥10 year old windblown areas of size <0.5 hectare within woodland	✓ [2]	✓ [2]	x	x
≥10 year old windblown areas of size <0.5 hectare – edge of woodland	x	x	x	x
≥10 year old windblown areas of size ≥0.5 hectare	x	x	x	x
Young trees [4]				
Areas of young trees ≥0.5 hectare (or attached to woodland giving a total contiguous size of ≥0.5 hectare)	✓	x	x	✓
Areas of young trees <0.5 hectare non-adjacent to woodland areas	x	x	x	x

Notes for Table 1:

1. Interpreted open areas (IOAs).
2. Becomes internal open space.

3. After windblow is cleared the area becomes an area of clearfell or an area of young trees.
4. If young trees establish on areas of open space, clearfell or windblow, the area converts to an area of young trees.

Definitions of changes in woodland area and canopy cover

This section defines terms or concepts used within the report to describe change in woodland area and canopy cover.

Canopy cover change – In this report canopy cover change is confined to change in canopy area[13] which is greater than 0.5 hectare in extent[14]. It concerns changes to the canopy in terms of the loss, removal or establishment of canopy, through events such as tree harvesting, wind damage or tree planting.

Clearfell **–** Woodland sites that have been clearfelled are classified into two types:

a. New clearfell – Areas of clearfell identified within the previous 12 months.

b. Woodlands in transition – Areas of clearfell that were created by clearfell events more than 12 months previously and no further activity has occurred that would define their long-term land use. These areas will predominantly be land due to be restocked, but may also include areas awaiting land-use change.

Woodland loss – Area previously accounted for under forestry land use that has converted to another land use. This conversion would be caused and maintained by a continued human-induced or natural perturbation action. Woodland loss is only accounted for if greater than 0.5 hectare in extent.

Canopy cover loss – Loss of area covered by a mass of foliage and branches formed collectively by the crowns of trees, and including areas of less than 0.5 hectare that were previously surrounded by trees.

Developed land – This concerns areas where the conversion of canopy to another land use has been confirmed as practically permanent and irretrievable, for example through the presence of a school, residential area or retail area. The areas of confirmed woodland loss will also include open ground associated with the main category; for example, a road category may also include the roadside verge and a railway category

[13] Either the removal of canopy for greater than 80% of an area to signify loss, or the establishment of canopy for over 20% of an area to signify gain.

[14] For canopy cover change at the edge of the woodland, in certain circumstances, loss less than 0.5 hectare is included.

may also have an embankment included. If these associated areas are significant in size they will be recorded separately in their own right. Permanent changes in land use include man-made structures, mineral extraction, agricultural and cropped land.

Ground under development – Where an area of woodland has been clearfelled and the ground has undergone significant modification, typically associated with civil engineering. This would suggest that change from woodland land use into another land use such as development is likely, but it could alternatively involve landscaping back to woodland and thus is designated as a separate category. These areas are considered to have a high potential for land-use change and consequent woodland loss and thus are classified separately.

Clearfell adjacent to woodland loss – Clearfell adjacent to woodland loss, significant vegetation change or ground under development. A sub-class of new clearfell and woodlands in transition has been defined, in which the clearfelled area is adjacent to some form of significant change such as development. This analysis assumes a level of association between such new developments and adjacent clearfell that suggests an elevated potential for woodland loss in these clearfelled areas.

Newly established habitat – Areas that were previously woodland and which have been clearfelled and appear to have developed a new vegetation cover. If this cover persists for more than 10 years these areas will be assigned to a non-woodland land use and be registered as woodland loss.

See the Glossary for definitions of the remaining terms used in the report.

Assessment of net canopy cover change

History of canopy cover change

The total amount of woodland area in Britain has changed throughout history (see Figure 2), with several drivers adding to or subtracting from woodland area and canopy cover over time as part of a series of dynamic and interrelated processes. Many of these processes are benign and are part of the woodland's natural life cycle, while others are not and impact either positively or negatively on woodland area. The largest example of positive change would be how, after the last ice age, most of the land in Britain was composed of grasslands and tundra, but then, as the climate warmed, trees slowly recolonised this post-glacial landscape to leave Britain an almost entirely woodland island. These same establishment processes are currently occurring, where trees are colonising less intensively farmed areas and abandoned industrial land.

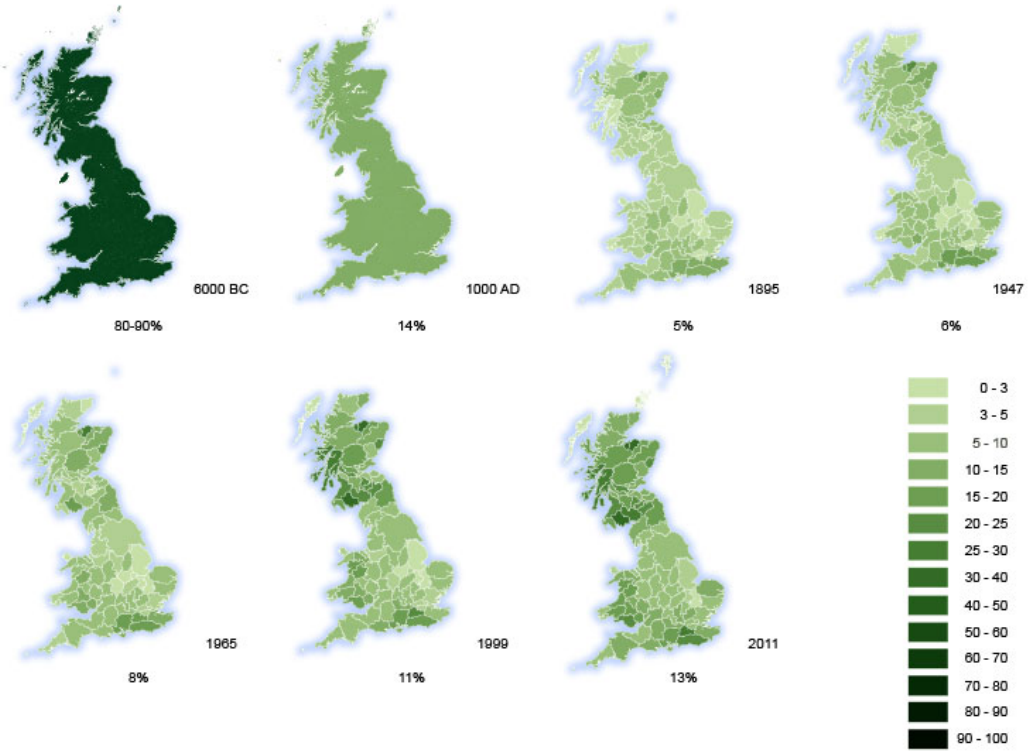
Human activity can also drive changes of both woodland extent and the condition of the woodland. The planting of new woodland is the most obvious example of positive

change, but there are also more subtle influences. For example, in certain types of lowland conifer woods, clearfelling and restocking creates valuable habitat for nightjars. Such activity may be considered to be positive to the condition of woodlands as the change might be similar to natural disturbance events such as storms and fire, which increase the diversity of habitats within the overall woodland area.

Human activities resulting in changes to canopy cover can also be negative for woodlands, when canopy loss is permanent and overall woodland area reduces. Since the advent of human habitation in Britain, the loss of woodland area and/or canopy cover has generally arisen as a result of human activity, in particular from felling and conversion to other land uses. The introduction of livestock to woodland can also be very damaging with grazing preventing the establishment of new trees. A combination of both felling and grazing took Britain from being a predominantly wooded island in the Neolithic era 10,000 years ago to having only around 5% woodland cover by the turn of the 20th century.

Such high levels of canopy change and woodland loss led to a series of negative consequences, including timber shortages. The need to mitigate these consequences led to the establishment of the Forestry Commission in 1919, with a remit to expand woodland area. Since then, through processes of afforestation and enrichment of remnant woodland, woodland area has recovered to its current 13% of total land area (see Figure 2).

Figure 2 Woodland area as a percentage of land use over time in Great Britain

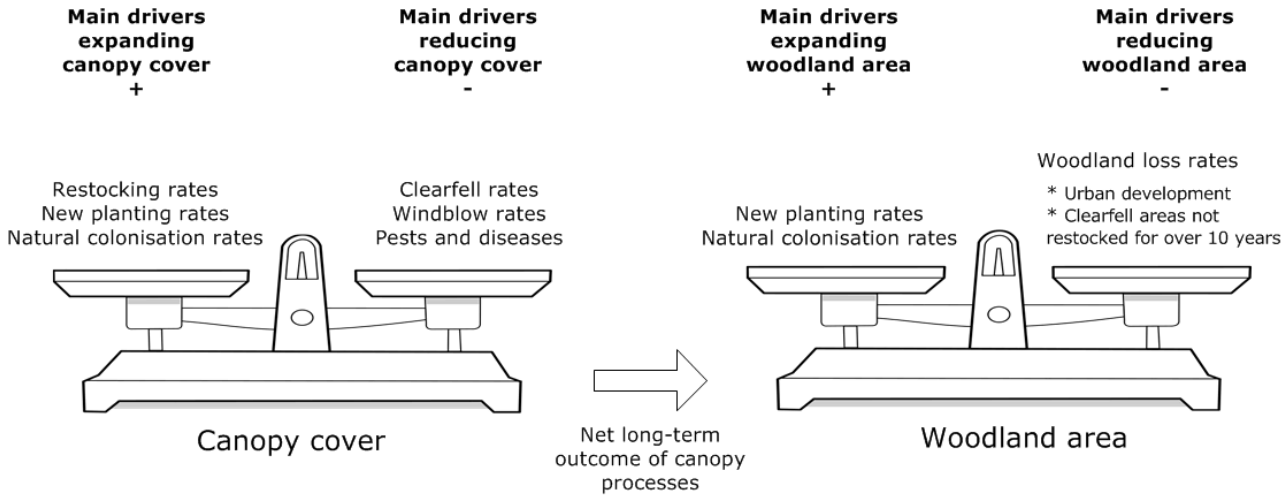


This history of change in canopy cover and woodland area in Britain illustrates that canopy cover change is a dynamic process and that rates of change have accelerated in the modern era of intensive human intervention. Figure 2 shows how rapidly woodland area within Britain has recently changed, increasing from 6% in 1947 to around 13% by 2011. This demonstrates the importance of obtaining relatively up-to-date data for monitoring canopy and woodland area. This rate of change led to the realisation of the need to closely monitor woodlands and the establishment of the annual and 5-yearly reporting cycles of the NFI. Such rates of change, combined with the relative scarcity of woodland in the UK (around 13% compared to the European average of 38%[15]), makes monitoring canopy and woodland area in Britain more complicated[16]. This is because the task to identify and measure woodland area is more difficult for fragmented woodlands that make up a smaller proportion of the landscape.

Main drivers for change in canopy area

Figure 3 summarises the main processes that result in overall canopy cover and woodland area change, most of which are considered and quantified within this report.

Figure 3 Diagram summarising the current main drivers of canopy cover change and woodland area change in Great Britain



The balance between positive and negative drivers of canopy cover and woodland area change determine the magnitude and direction of change within any given period of reference.

[15] This average is for the 28 EU countries

[16] Small, sparsely distributed and fragmented woods such as found in Britain are more costly and technically more difficult to monitor than larger woods.

Accounting for canopy cover change

National picture and site picture

When accounting for canopy cover change it is important to distinguish between overall change at a macro level and change occurring at individual sites. There are several thousand woodland sites where there is either loss or gain in woodland area in any one year and it is the overall sum of these individual positive and negative occurrences that determine the direction and size of overall canopy cover change. However, alongside that overall change, it is equally important to understand the underlying drivers behind the entire process, and to examine what is happening at individual sites, since important trends and patterns can be hidden within the overall picture.

Methodology

National Forest Inventory

The National Forest Inventory (NFI) is composed of two elements: a woodland map based on earth observation techniques and a field survey, details of which are presented below. The map and the data used to update the map form the basis of the clearfell and woodland loss estimates presented within this report. In addition, estimates from the field survey are provided on restocking rates and to illustrate the differences in what can be observed from both space and the air and what is observed on the ground.

How woodland area was established from the woodland map

The NFI woodland map covers all forest and woodland area over 0.5 hectare with a minimum of 20% canopy cover (or the potential to achieve it) and a minimum width of 20 metres, including areas of new planting, clearfell and restocked areas. These criteria conform closely to international definitions of woodland and are referred to here as areas of 'NFI woodland'. Wooded areas and individual trees that do not conform to these criteria are referred to by NFI as 'small woods', which are reported on separately[17].

All forest types are assessed in aerial photography using GIS techniques to establish areas and percentages of tree cover. The woodland is further differentiated into interpreted forest types (IFTs), distinguishing primarily between conifer stands and broadleaved stands, and internal open spaces. All boundaries, woodland and open space are based upon 25-cm-resolution colour aerial photography for England and Scotland and 40-cm-resolution colour aerial photography for Wales. In addition, any open areas of greater than 0.5 hectare that are completely surrounded by NFI woodland are mapped as interpreted open areas (IOAs). For more information regarding the full list of categories in the NFI woodland map see Table 27 in Appendix D.

The first NFI woodland map and accompanying report was published in May 2011 (reference date March 2010). Further details can be found in the *National Forest Inventory woodland area statistics for Great Britain* report at www.forestry.gsi.gov.uk/inventory.

The 2006 map comprised the woodland and forest areas identifiable in the aerial photography available at the time. The majority of the photography used was taken around 2006, but smaller areas were taken at other dates ranging from 1999 to 2009. For more detailed information about the various data sources used, and the date ranges of the imagery used for each country, see Table 25 in Appendix C.

[17] These smaller wooded features are referred to internationally as 'Other Wooded Land' (OWL).

In addition to this main mapping exercise, areas identified under new planting grant aid schemes between 1990 and 2010 were also added to the map, since when trees are small (i.e. newly planted woodland) it is difficult to clearly identify woodland using aerial photography. To account for this, areas that were identified under the new planting grant aid scheme but were not clearly evident as woodland were added to the map and classified as 'assumed woodland' until the trees became visible. The NFI map was also compared to the 2000 National Inventory of Woodland and Trees (NIWT) map and any valid and significant discrepancies identified by the comparison exercise that were greater than 5 hectares in size were added to the 2011 published NFI woodland map. For more information regarding NIWT see www.forestry.gov.uk/forestry/infd-86xc6c.

Prior to the publication of the original NFI map, additional independent cross-checks of woodland present were made by comparing the NFI map to satellite imagery and alternative assessments of land cover such as those arising from the Countryside Survey. After 2011, satellite imagery was used to identify areas of recent canopy change[18]. This included clearfell and windblow areas and areas where a change in land use had occurred since the date of the previous satellite image. Satellite imagery data for 2006, 2009, 2012, 2014 and 2015 were analysed to produce these updates. The 2006 and 2009 datasets were applied retrospectively to the first NFI map. The 2012, 2014 and 2015 imagery sets were used to update the NFI map as part of the annual update process.

Further improvements to the map were made between 2012 and 2015 as the following additional datasets became available:

1. Bluesky's National Tree Map (NTM) product for England and Wales.
2. The Native Woodland Survey of Scotland (NWSS).
3. Further NFI/NIWT comparison work (for areas less than 2 hectares).

In addition, if new photography was available, a new aerial photography assessment was undertaken to confirm canopy cover in areas of the map where the photography used in the first assessment was more than 7 years old.

Field survey work

The NFI field survey work is designed to observe and measure detailed aspects of the composition and nature of forests and woodlands. It is also used to calibrate the satellite and aerial photography map-based estimates of woodland area.

The field survey results in this report were derived from the surveys carried out between 2010 and 2013. This involved ground surveying 1-hectare sample squares that were

[18] The areas of canopy loss identified were restricted to areas of over 0.5 hectare in extent.

partially or entirely covered by forest, including clearfelled areas, according to the NFI woodland map. After completion and processing of the first cycle of NFI fieldwork, the fieldwork data will be combined with the map data to further refine woodland area estimates. Further details of the mapping work and the derivation of forested areas can be found in the 2010 Woodland area reports at www.forestry.gsi.gov.uk/inventory.

In this report the field survey findings are used to estimate the amount or proportion of trees that are too small for earth observation systems to detect, which is a major qualification to the interpretation of the estimates in this report.

Identifying clearfell, windblow and woodland loss from imagery

Estimating new clearfell

The 2006 woodland map (processed during the production of the 2011 NFI map) provides an estimate of the area of clearfelled land in Britain, as of 2006. This established a baseline against which subsequent change could be assessed. It should be noted that the date of the aerial photography used to form this map was taken between 1999 and 2009, with a mean and modal date of 2006 as detailed in the *NFI 2011 woodland map GB* report. This was subsequently updated using 2006 satellite imagery.

The 2006 baseline estimate of area of clearfell in this report will include areas of clearfell that were several years old at the time the image was taken, as well as areas felled in 2006. Reasons for this are:

- Clearfell sites are often left fallow for a number of years (most commonly 0 to 5 years) as a routine management practice before restocking, for purposes such as weevil control.
- When the management practice is to use natural regeneration as a restocking system, it can take several years to establish a new canopy.
- Young trees (planted or naturally regenerated) are typically not visible in earth observation imagery for 5 to 10 years and sometimes longer.

Thus, the initial estimates of total area of clearfelled land will include some areas that were clearfelled over several previous years. It therefore includes both newly clearfelled areas and areas of woodlands in transition. The estimates of area of clearfell from earth observation are of gross canopy area, as defined in Table 1. For an explanation of the satellite imagery techniques employed to detect canopy change see Appendix B.

Identification of windblow

Windblow was not identified as a separate class in the original NFI and NIWT maps, as it had proved too difficult to track in the past. However, with advances in satellite imagery analysis providing the means to identify windblow, identification of areas of windblow has been added as one of the outputs of the NFI. Previously, when areas of windblow

were identified in imagery, they were included in the map as part of an adjacent IFT (e.g. classified as either conifer or broadleaved). The classification protocol has now been changed such that when identified windblow areas are over 0.5 hectare in extent they will be mapped and reported in their own right as windblow. A proportion of windblown sites are cleared rapidly and consequently a proportion of these will be interpreted in the imagery as clearfell rather than as windblow areas.

In 2014, the windblow areas that had been identified in previous monitoring periods (2006–09 and 2009–12) were re-assessed and added into the 2014 NFI woodland map, in locations where the windblow was still visible in the imagery. As with the clearfell estimates, the estimates of windblow reported are annualised rates of windblow based on the four satellite imagery data periods that occurred between 2006 and 2015.

Definitions of temporary and permanent canopy change

This report has set out how temporary changes in canopy cover can be part of either natural or human processes that do not impact negatively on woodland area in the long term. However, if a change in canopy cover is maintained for a protracted period, at some point it needs to be designated as permanent. If canopy gain occurs at an individual site and this canopy perpetuates for a period of more than 10 years then for the purposes of this report afforestation is deemed to have occurred. Conversely, if canopy loss perpetuates for more than 10 years then woodland loss is deemed to have occurred. Gains or losses of canopy of less than 10 years' duration are classified as 'temporary' in nature and do not qualify as woodland gain or loss respectively.

The report sets out to identify and distinguish between temporary and permanent changes in canopy cover in order to accurately determine rates of woodland gain and woodland loss. This is an involved process and it requires individual sites to be monitored for 10 years or longer to determine their status in terms of long-term canopy loss or gain. Monitoring such long-term factors inevitably causes some degree of asymmetry in reporting. This is because, while clearfelling is straightforward to measure on an annual basis through using satellite imagery, in contrast, monitoring a site returning to a tree canopy is more difficult to assess because it is gradual and it can take between 5 and 15 years for the young trees to be evident in imagery.

How canopy loss and woodland loss is identified

The woodland loss estimates in this report are the product of 9 years of canopy cover monitoring. The estimates are primarily based on satellite imagery analysis to identify canopy change, which is then validated with aerial photography analysis. A small proportion is based on aerial photograph assessments only.

New canopy loss areas are initially identified within the satellite imagery using image analysis software (see Appendix B). Each area is then individually validated against the

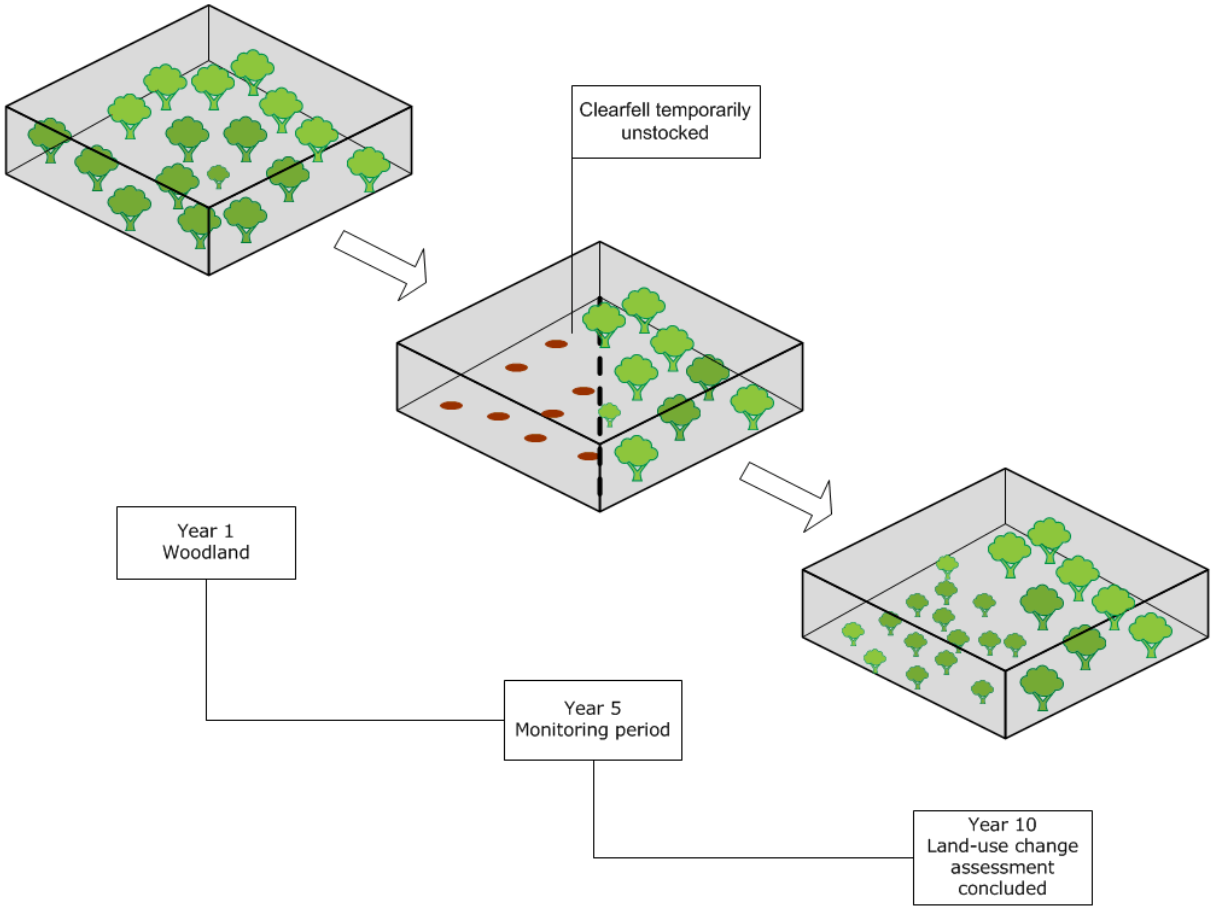
most current data available, using a selection of aerial photography, Ordnance Survey data and external data sources such as Google Maps, Street View etc. (see Figure 5). Once such canopy cover change is validated it is allocated to the appropriate category as either permanent or temporary (see the following section).

Measuring and categorising canopy change and loss

1. Temporary loss

This generally concerns clearfelling which is subsequently followed by the restocking of the site and thus the loss of canopy is temporary (see Figure 4). Similarly, other damage to canopy, such as that arising from storms or pests and diseases, will be temporary if the canopy recovers.

Figure 4 How clearfelled land is treated in canopy cover assessment



Notes for Figure 4:

1. Clearfelled land is treated as temporarily unstocked land and is counted as woodland area until 10 years have passed.
2. If the land is restocked within 10 years it continues to be classified as woodland.

2. Woodland loss

Woodland loss concerns areas where the conversion of canopy to another land use has been confirmed as practically permanent and irretrievable, for example the presence of a school, residential area or retail area (see Figure 5). The areas of confirmed woodland loss will also include open ground associated with the main category; for example, a road category may also include the roadside verge and a railway category may also have an embankment included. If these areas are significant in size they will be recorded separately in their own right. Permanent changes in land use include man-made structures, mineral extraction, cropped land and others (see Table 27 in Appendix D for a full list). Figures 16 to 19 in Appendix F show other examples of woodland loss by permanent change in canopy cover.

Figure 5 An example of canopy cover change with the permanent conversion of a woodland area into a retail area

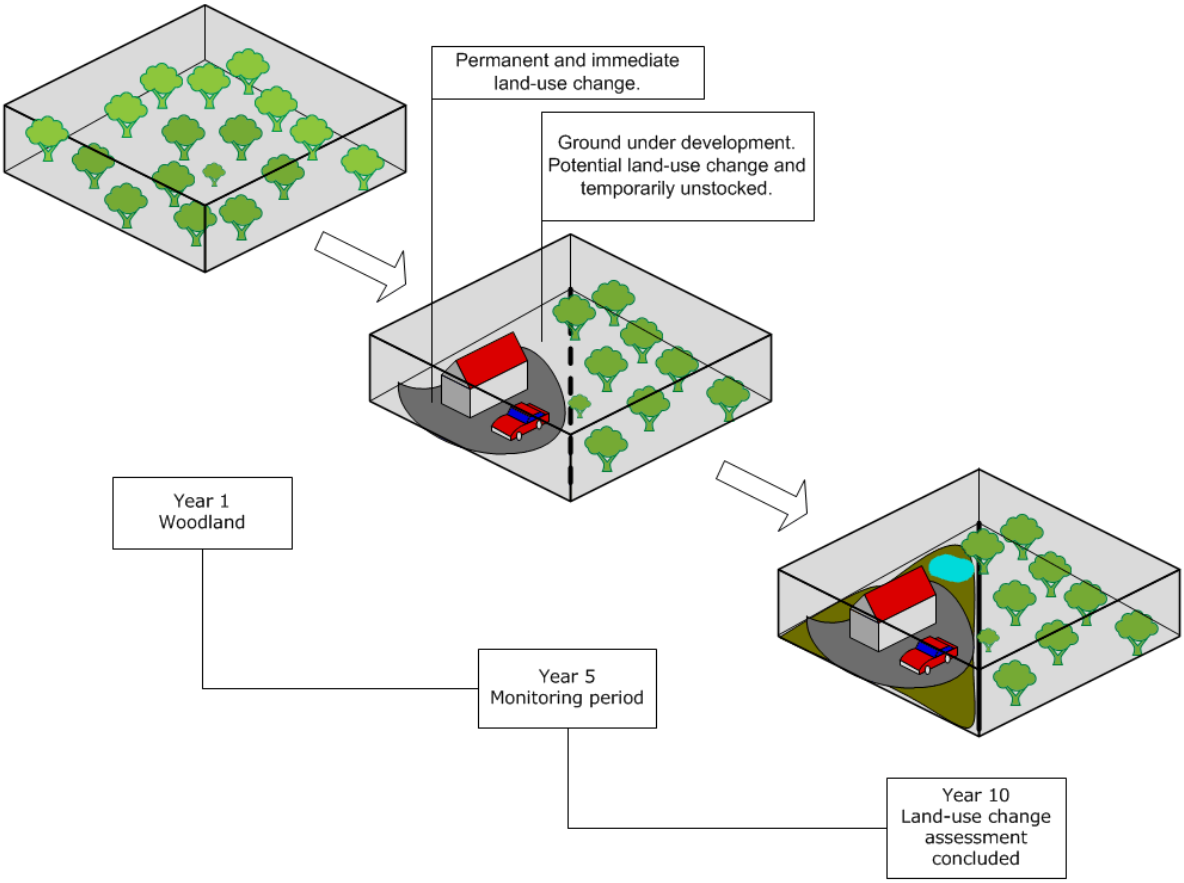
3. Ground under development

Ground under development is defined as areas that are potentially at risk of permanent loss as the area appears to be under development. For example, if an area of woodland has been clearfelled and the ground has additionally undergone civil engineering works involving significant modification of the ground with heavy plant machinery, this would suggest that change is likely to be permanent (see Figure 6), but could possibly involve landscaping back to woodland.

Figure 6 An example of ground under development, carrying the risk of permanent conversion from woodland

The subdivision of canopy loss into developed land, ground under development and clearfell adjacent to woodland loss recognises the windows of time from the event that changes canopy cover, to the detection of canopy cover change by satellite imagery, and to the final development of the land into other land uses (see Figure 7). An NFI assessment at a single point in time will identify only one stage in that transition process.

Figure 7 How built land and partially developed land is accounted for in canopy cover assessment



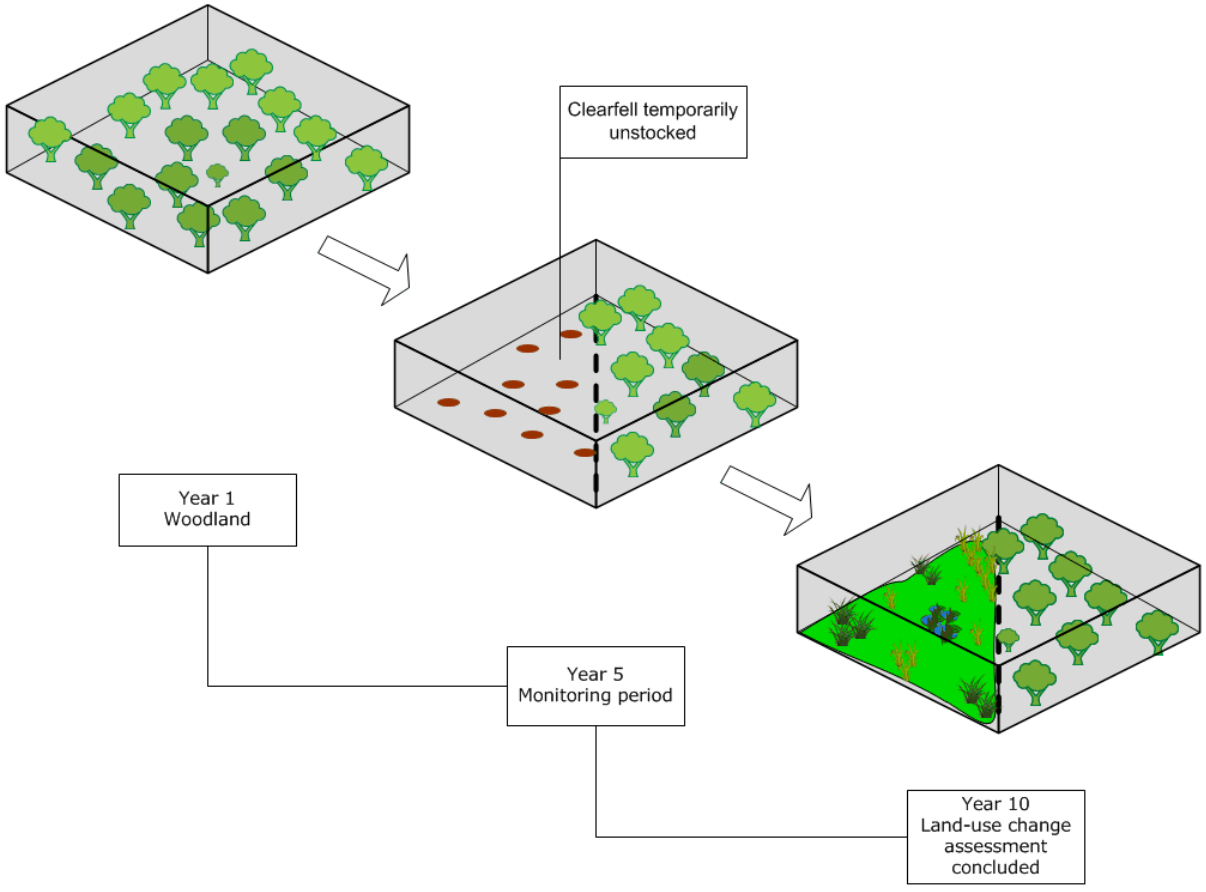
Notes for Figure 7:

1. Built areas with evidence of permanent and irretrievable land-use change are accounted for as land-use change immediately if they are over 0.5 hectare in extent.
2. Land that has been worked with heavy machinery is categorised as ground under development, until such time as it is confirmed as permanent change (either firm evidence of a change in land use or 10 continuous years of canopy loss) or it is returned to woodland canopy.
3. Ground under development is accounted for as woodland area (temporally unstocked).

4. Newly established habitat

Areas classified as newly established habitat are areas that had tree canopy cover at the start of the assessment period, that were subsequently clearfelled, and that have since developed a new non-woodland vegetation cover (see Figure 8). There will be no evidence of normal restocking activity (weed control, cultivation etc.) and there will be evidence of long-term habitat conversion (extensive greening under bracken, heather, grasses etc.) NFI remote sensing classes of newly established habitat include bare area (other than clearfell), grassland and other vegetation. These areas will be monitored for a period of 10 years to ascertain if they are a permanent change in cover or if the area is under a temporary cover before restocking or regeneration. If they do not carry canopy after 10 years, they will be classified as woodland loss. The full list of vegetation types assessed from remote sensing can be found in Table 27 in Appendix D.

Figure 8 How habitat restoration is accounted for in canopy cover assessment



Notes for Figure 8:

1. Areas of potential habitat restoration are categorised as types of temporarily unstocked land (newly established habitat, bare, grassland etc.) for a period of 10 years or until such time as there is evidence that the area will not revert to woodland.
2. Such areas are accounted for within woodland area as temporarily unstocked land until evidence exists to the contrary or 10 years have elapsed.

How woodland loss was categorised

Woodland loss has been categorised into two basic types: loss within the wood and loss at the edge of the wood. This distinction was made because what defines loss differs between the two locations and the actual causes of loss occurring within these two separate types of area fall into two distinct subpopulations: losses within the wood tend to be mainly caused by the outcomes of forest restructuring while losses at the edge of the wood are most commonly caused by development activity (see Figure 9).

Location and causes of woodland loss

Canopy loss inside the wood – internal change – Small areas of canopy loss inside woodlands have different physical and ecological properties compared to loss at the edge of a wood. Open space within woodland is a part of woodland ecology and its creation may result from natural processes or be the result of a management objective. Within a wood, any canopy loss of less than 0.5 hectare in extent is therefore not accounted for as woodland loss.

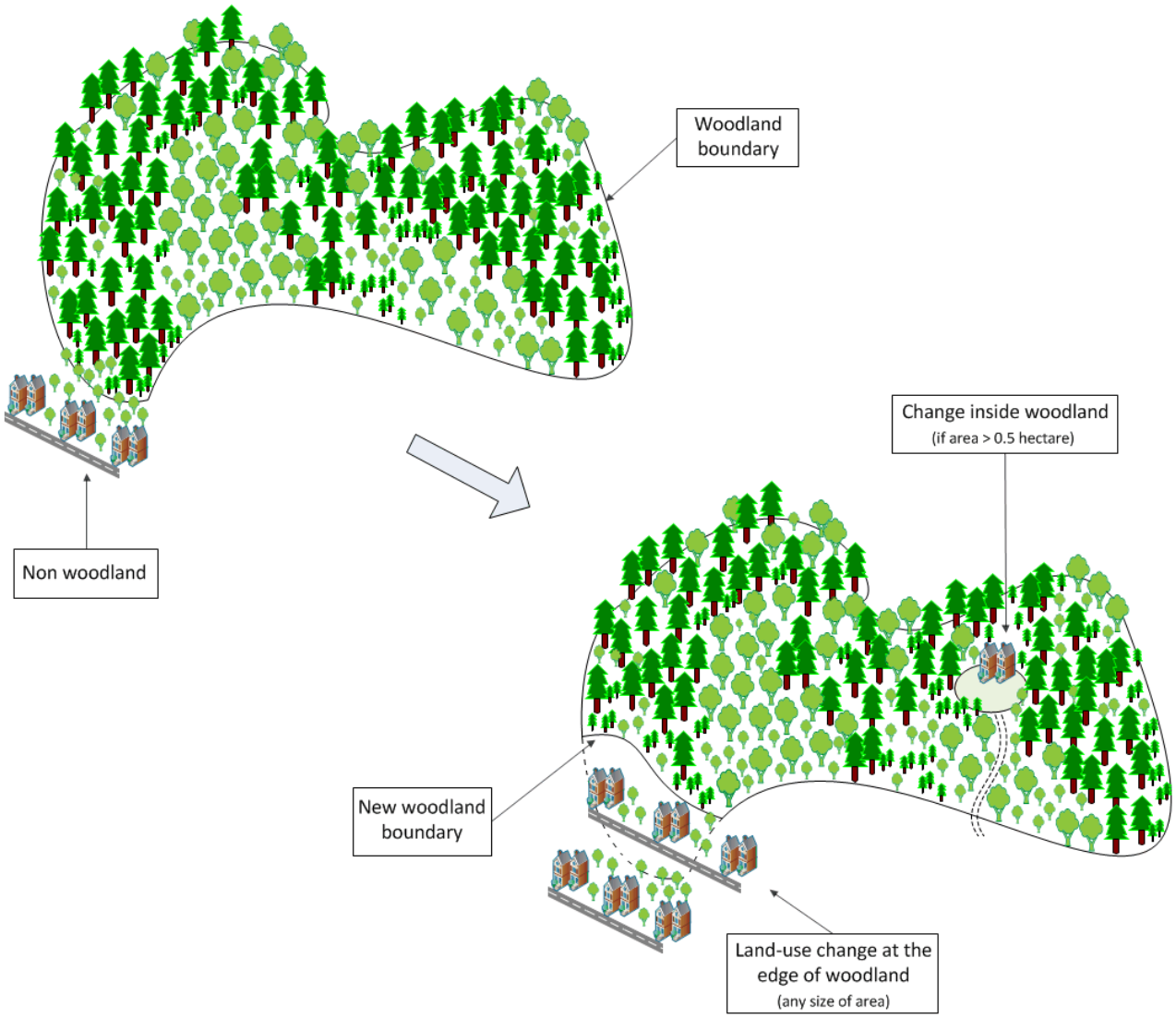
For the purposes of this report, canopy loss areas greater than 0.5 hectare are classified as non-woodland if they become permanent. The policy of creating open space within forests through the forest plan and design process can create such areas for habitat restoration purposes, such as for heathland or wetland restoration.

Canopy loss at the edge of the wood – Areas of canopy loss at the edge of the wood, irrespective of scale, are treated as both canopy and woodland loss. This is because the area is physically an extension of the adjacent non-woodland area; any such change reduces the woodland area and is thus classified as both canopy and woodland loss.

Within each of these two groupings, causes of loss have been identified. These include built, agriculture, construction of roads etc.

Each type of change (inside the wood and at the edge of the wood) follows slightly different observation processes after initial identification and are accordingly attributed slightly differently. For further information regarding the full list of categories of causes of loss, see Table 27 in Appendix D. These two broad types of canopy change (inside the wood and at the edge of the wood) are further subdivided into three groups: woodland loss, ground under development and newly established habitats.

Figure 9 Accounting for canopy loss inside woodland and at the edge of woodland



Permanent reduction in canopy at the edge of the wood always results in woodland loss, irrespective of the size of the loss, whilst within the wood losses have to be greater than 0.5 hectare to qualify as woodland loss.

Summary of change classifications after clearfell and windblow events

Clearfelling and windblow events are currently the two main factors that initiate changes in canopy cover and woodland area in existing woodland. In some instances, these events will only impact temporarily on canopy cover and will have no long-term impact on woodland area. In others, however, they result in eventual woodland loss, or may be characterised as being in an interim state of 'ground under development' or 'newly

established habitat'. Table 2 summarises the conventions used in this report to classify areas that have been clearfelled or windblown into either woodland area, woodland loss or as ground under development.

Table 2 Classification of areas of clearfell and windblow

	Woodland area	Woodland loss	Ground under development	Newly established habitat
Clearfelled areas				
Areas less than 0.5 hectare	✓	-	-	-
Areas greater than 0.5 hectare				
Permanent and irretrievable canopy loss - Built	-	✓	-	-
Restock ≤ 10 years after clearfell	✓	-	-	-
Clearfell ≤ 10 years	✓	-	-	-
Clearfell > 10 years with no restocking	-	✓	-	-
Construction level disturbances ≤ 10 years	-	-	✓	-
Construction level disturbances > 10 years	-	✓	-	-
Restock ≤10 years after contruction disturbance	✓	-	-	-
Newly established non-woodland vegetation ≤ 10 years	-	-	-	✓
Newly established non-woodland vegetation >10 years	-	✓	-	- [1]
Windblow areas				
Areas less than 0.5 hectare	✓	-	-	-
Areas greater than 0.5 hectare				
≤ 10 years	✓	-	-	-
> 10 years with no regeneration	-	✓	-	-
> 10 years with regeneration within 10 years	✓	-	-	-

Notes for Table 2:

1. Where the establishment of a planned non-woodland habitat takes longer than 10 years, the 10-year threshold to confirm permanent woodland loss may be extended

Estimating canopy loss in ancient woodland sites

Ancient woodland is a classification associated with areas of land in Britain that have been under continuous woodland land use for a long period of time. The classification can involve legal protections for woodland and its fauna and flora.

The Ancient Woodland Inventory is Britain's definitive record of ancient woodland and identifies ancient woodland sites greater than 2 hectares in size in England and Scotland and 0.5 hectare in Wales. It includes both ancient semi-natural woodland (ASNW), plantations on ancient woodland sites (PAWS) and open space on ancient woodland sites. In Scotland, the inventory also includes woodlands of ancient interest, which were identified either in the 1860 Ordnance Survey maps or the 'Roy' maps, but not both. To derive estimates of canopy change in ancient woodland, NFI canopy change maps were compared to the most recent maps of ancient woodland sites. There are three main

caveats to this estimate that arise from the definitions used to create the Ancient Woodland Inventory map. The first is that the minimum 2 hectares threshold in the Ancient Woodland Inventory map immediately excludes the NFI from being able to classify any loss detected in ancient woodlands which are less than 2 hectares as specifically loss in ancient woodlands, and these areas will be classified as standard loss. For Wales, a revised ancient woodland inventory was available with a minimum ancient woodland area of 0.5 hectare which was used for this analysis, so this caveat does not apply to Wales. Secondly, the minimum detection rate of 0.5 hectare in the NFI change map automatically excludes loss in ancient woodland of less than 0.5 hectare. This will exclude smaller-scale attritions due to causes such as garden encroachment, or losses that occur over longer periods such as grazing. Thirdly, areas of open space greater than 0.5 hectare which are contained within the Ancient Woodland Inventory map will inflate the total area of 'woodland' reported and may inflate the areas of loss reported.

In addition to these the NFI analysis pointed to there being misclassifications in the Ancient Woodland Inventory map, where the map appeared to misclassify PAWS sites as ASNW sites and this itself forms an important additional caveat to the estimates. These anomalies generally took the form of non-native trees occupying a significant proportion of the mapped ASNW area. This is likely to have arisen as the original map was created without the aid of GIS technology, digital aerial photography, or corroboration of the core desk work with field observation across all areas of the map. This will have led to the misidentification of conifers as broadleaves, especially in younger trees, thus misclassifying some PAWS sites as ASNW sites. This finding was also described in the recent Native Woodland Survey of Scotland report. The Ancient Woodland Inventory map has been used in this work as the source that indicates ancient woodland status because NFI itself does not assess such status. Use of this source is likely therefore to have resulted in higher estimates of rates of clearfelling on ASNW as opposed to PAWS sites than is actually the case.

Similarly, if all the sites included within the Ancient Woodland Inventory maps were to be included in the assessment woodland loss areas would be increased. In particular, the Scottish map includes woodland sites that are of significance, but that do not fully qualify as ancient, such as long-established woodlands of plantation origin (LEPO), types 1b and 2b and 'Other' woodlands on 'Roy' sites, type 3.

In the second cycle of the NFI field survey a direct measure of loss of woodland identified by NFI field surveyors as ancient, based on field measurements alone, will provide field-based estimates of loss of woodland with ancient character.

Estimating change in productive conifer area

Estimating the loss or gain of productive area of conifers is of key interest to the timber growing and processing sector. At present the NFI is able to detect broad changes in

conifer cover over the period through identifying changes to the NFI map interpreted forest types (IFTs) (conifer and broadleaved) from earth observation imagery (see Table 7). This approach enables detection and reporting upon the clearfelling of conifer area and the permanent loss of conifer area, but it does not reveal a full breakdown of the losses by species, felling ages and growth rates, neither can it predict how these sites will be managed in future. In addition to this broad assessment, the NFI has used part of the first cycle of fieldwork (2010 to 2013) to assess the presence and composition of restocking on areas that were identified as existing clearfell sites at 2006 and those clearfelled between 2006 and 2009. However, with no historical data on the composition of these sites before the clearfelling, only a partial picture of change can be drawn.

Results from the NFI field survey were generated from a total of 460 one hectare sample squares covering or partially covering the identified clearfell areas, of which 344 and 116 were covering or partially covering the 2006 and 2006/09 clearfelled areas respectively. At each sample square, the area was stratified into woodland and non-woodland and the woodland area was further stratified into different woodland types or stands, where information on species, age and a range of other parameters, including whether a site was clearfelled or restocked, was collected. Data was also collected from randomly located sample plots within each stand, and information from these, combined with the overall stand assessments, were used to estimate stocked areas of individual species. The results for individual surveyed squares were aggregated and scaled up to the clearfelled areas identified by the woodland map, using standard statistical survey methodology, to produce the estimates in this report (see Tables 21 and 22). When the NFI has two or more cycles of field observations, detailed estimates of the types of changes in species, growth rates, and also age at felling, will also be possible.

How canopy cover change from satellite is confirmed with field survey

As part of an ongoing process, canopy change estimates derived from satellite imagery and the NFI woodland map are quality assured through comparison with findings from the NFI fieldwork. For example, areas of clearfell reported through the NFI field sampling programme and the Forestry Commission's Sub-compartment database (SCDB) were compared on a site-by-site basis to the findings from earth observation to validate their accuracy. In addition, separate estimates of the area of clearfell were made from both fieldwork and earth observation. The two separate estimates were then compared and the findings of this comparison can be found in Tables 5 and 6. Eventually, when the NFI has obtained field samples which are observed 10 years or more after the end of the satellite identification of a clearfell event, full validation of long-term land-use type and change based upon field survey results will be undertaken. Also, once enough field samples are obtained, these can be used to calibrate the findings derived from earth observation.

Results

This section provides new estimates of the area of clearfell, windblow and woodland loss in British woodlands. The estimates are derived from satellite imagery, aerial photography and the NFI woodland map and are broken down to a country level.

The results published in this report provide a limited preliminary assessment of canopy change over a restricted time period. The final outcome of some of the actions which affect woodland area and canopy cover will not become known until after the period of this assessment. Such outcomes require a long monitoring period to detect and evidence is therefore not yet available for all of the outcomes of such change. This partial picture of a complex process is an important qualification to the report and should be borne in mind when interpreting the results, which are preliminary in nature.

To aid interpretation of these results, previously published estimates of woodland area, new planting and restocking in Great Britain, broken down by country, have also been provided. These estimates are reproduced from *Forest Statistics* annual publications (and supporting data), compiled by the Forestry Commission. Further information on these statistics is available at www.forestry.gov.uk/statistics.

In addition, previously published estimates of stocked area and clearfell in Great Britain, derived from the SCDB and from NFI fieldwork, are also supplied. These data are broken down by country and by NFI reporting region with a reporting date of March 2012.

Woodland area, including clearfell, new planting and restocking estimates, are expressed in thousands of hectares (000 ha), while windblow, woodland loss, ground under development and newly established habitat estimates are expressed in hectares (ha). Where change estimates were derived over periods of longer than a year, they are reported as annualised average rates for those periods.

Estimates obtained from the NFI field survey are generated by individual estimation of each value in the table, including the marginal and overall totals, and this may cause the sum of the values in the body of the table to differ from the estimates of the totals. Sampling standard errors (SE) attached to Private sector estimates obtained from the NFI field survey are expressed in relative terms (%) to the right of the relevant estimate. The NFI field survey results were used to generate the estimates shown in **Tables 3** (stocked area only), **6**, **21** and **22.**

The values in some tables may not sum to the totals shown because the individual values and the totals have been individually rounded.

Woodland area estimates

Table 3 shows estimates of both woodland area and stocked area in Great Britain as of 2012. Stocked area is similar to net canopy area but additionally includes intimate space between canopies of individual trees within woodland, windblown areas of less than 10 years since the windblow event and areas of young trees (see Table 1). Woodland area in 2012 was estimated to be close to 3 million hectares and was first published in *Forestry Statistics 2012*.

Table 3 also shows that stocked area amounted to around 2.65 million hectares in 2012. This stocked area was published in 2014 in the *50-year forecast of hardwood timber availability* and the *50-year forecast of softwood timber availability* reports.

Woodland area exceeds stocked area because it includes some areas without standing trees while stocked area does not, most notably integral open space of areas of less than 0.5 hectare, and most areas of clearfelled woodland (see Table 1). The difference between the estimates of total woodland area and total stocked area in Great Britain, after accounting for clearfelled area, indicates that woodland area is composed of around 9% of integral open space.

Table 4 is an estimate of woodland area based on the NFI woodland map, broken down by interpreted forest type (IFT) referenced to 2006. This is the baseline for the subsequent canopy change estimates within this report. This estimates that there were 2.94 million hectares of woodland in Great Britain at 2006. The difference between the woodland area reported in Tables 3 and 4 encompasses real change (new planting minus woodland loss over the period 2006 to 2012) but also contains revisions made due to improved methodology.

Table 3 Woodland area and stocked woodland area of Great Britain referenced to March 2012

	Woodland area estimates			Stocked area estimates				
	FC/NRW (000 ha)	Private sector (000 ha)	Total (000 ha)	FC/NRW (000 ha)	Private sector (000 ha)	*SE%*	Total (000 ha)	% of woodland area
England								
Conifer	150.9	188.6	339.6	127.6	178.9	*2*	306.6	90
Broadleaved	63.5	894.6	958.1	53.7	848.6	*1*	902.3	94
Total	**214.4**	**1,083.3**	**1,297.7**	**181.4**	**1,028.1**	***1***	**1,209.5**	**93**
Scotland								
Conifer	442.5	604.7	1,047.2	366.5	505.5	*1*	872.0	83
Broadleaved	38.7	317.2	355.8	32.1	265.1	*2*	297.2	84
Total	**481.1**	**921.9**	**1,403.0**	**398.6**	**772.4**	***1***	**1,171.0**	**83**
Wales								
Conifer	97.7	52.6	150.3	81.8	47.1	*3*	129.0	86
Broadleaved	19.3	135.0	154.3	16.2	120.9	*2*	137.1	89
Total	**117.0**	**187.6**	**304.6**	**98.0**	**168.4**	***1***	**266.4**	**87**
Great Britain								
Conifer	691.0	846.0	1,537.0	576.0	731.6	*1*	1,307.5	85
Broadleaved	121.5	1,346.7	1,468.3	101.9	1,234.7	*1*	1,336.6	91
Total	**812.5**	**2,192.7**	**3,005.3**	**677.9**	**1,968.9**	***0***	**2,646.8**	**88**

See Table 1 for the definitions of woodland area and stocked area.

Notes for Table 3:

1. Estimates of woodland area are based on *Forestry Statistics 2012*, supporting data and Forestry Commission/NRW SCDB data.
2. Stocked area estimates based on NFI field survey data.
3. Woodland area estimates include clearfell within the woodland, while stocked area excludes clearfell. Clearfell was estimated at 96.5 thousand hectares in 2012 based on NFI fieldwork, see Table 6.
4. The percentage difference in area between woodland area and the sum of stocked area and clearfell is 8.7% and is accounted for by integral open space.

Table 4 Woodland area by interpreted forest type and interpreted open area by type in Great Britain and countries (2006)

	Total area (000 ha)			
	England	Scotland	Wales	Great Britain
Interpreted forest type (IFT)				
Assumed woodland	14.5	79.5	2.5	96.5
Broadleaved	785.1	190.8	115.1	1,090.9
Clearfelled	15.4	58.7	14.3	88.3
Cloud/shadow	0.3	0.4	0.0	0.7
Conifer	319.8	852.3	130.1	1,302.2
Coppice	2.1	0.0	0.0	2.1
Coppice with standards	0.1	0.0	0.0	0.1
Ground prepared for planting	8.8	32.6	3.2	44.6
Mixed mainly broadleaved	21.9	17.3	6.1	45.3
Mixed manily conifer	28.2	14.6	6.1	48.9
Shrub	4.8	3.9	1.0	9.6
Uncertain	3.1	1.3	1.1	5.5
Young trees	69.4	110.2	21.8	201.4
Total	**1,273.3**	**1,361.5**	**301.3**	**2,936.2**
Interpreted open area (IOA)				
Bare area	2.5	9.5	0.8	12.8
Cropped land	2.2	1.0	0.2	3.3
Grassland	16.8	26.2	3.6	46.6
Mineral extraction area	0.2	0.1	0.1	0.4
Other energy production and distribution areas	0.0	0.0	0.0	0.0
Other vegetation	0.8	4.4	0.3	5.5
Track or paths	0.1	1.2	0.1	1.4
Urban/Buildings	0.8	0.2	0.0	1.1
Water feature	1.1	1.9	0.1	3.2
Waterways	0.0	0.1	0.0	0.1
Wind farm	0.0	0.0	0.0	0.0
Total	**24.6**	**44.7**	**5.3**	**74.6**

Notes for Table 4:

1. Estimates are derived from earth observation.
2. IOAs are areas of internal open space within woodland greater than 0.5 hectare in extent.
3. Area of clearfell represents more than a single year of clearfell activity due to the common practice of leaving clearfelled areas fallow for a varying number of years.
4. Table 4 has minor differences from Table 9 of the *NFI 2011 woodland map GB* report due to differences in accounting for open spaces within new assumed woodland areas.
5. An additional 20.7 thousand hectares of clearfell were identified by remote sensing and added to this 2006 published estimate retrospectively to correct the 2006 baseline used in this report.

Estimates of clearfell

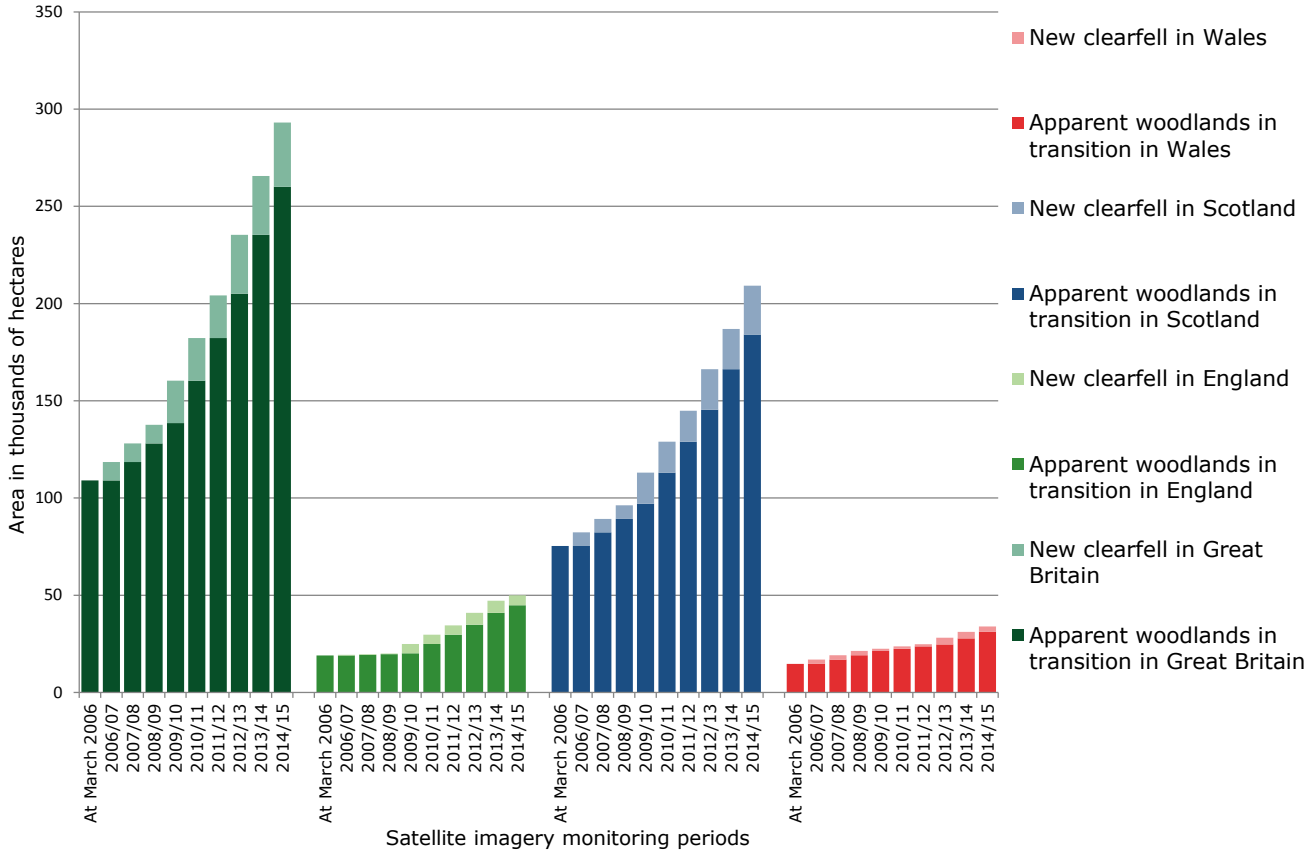
Table 5 provides the areas of new clearfell by country and Great Britain derived from satellite data and aerial photography. Figure 10 shows the Table 5 results in graphical form. Figure 13 in Appendix E shows the area of apparent woodlands in transition and new clearfell at March 2015 in Great Britain in a map. Table 6 provides the estimate of clearfelled area by NFI region, country and Great Britain at March 2012 based on SCDB and NFI fieldwork data published in 2014 in *50-year forecast of softwood timber availability* report.

There is a lag in the detection of young trees and restock on clearfelled areas from imagery. This time lag for detection leads to an overestimation of the area of current woodland in transition in the imagery at any one point in time. This is because it is difficult from imagery, after planting or regeneration has occurred, to identify the young trees associated with restocking for a period of 5 or more years. The availability of aerial photography on a 5-year update cycle adds to this detection lag in those instances where recent aerial photography is not available. Due to these problems of immediate detection of restocked areas, the reported areas of woodland in transition in Table 5 and Figure 10 are described as 'apparent' in recognition that an unknown proportion of this area at any point in time is in fact restocked area and should therefore, in reality, no longer be classified as woodland in transition.

Table 7 provides estimates of areas of conifer and broadleaved clearfelled in Great Britain between 2006 and 2015.

Tables 8 to 11 provide results of analyses of various categories of land within areas of apparent woodlands in transition as at March 2015. Table 8 shows the amount of clearfelling on ancient woodland sites, separated into ancient semi-natural woodland (ASNW) and plantations on ancient woodland sites (PAWS). Table 9 shows the amount of clearfelling on sites that have been subjected to statutory plant health notices issued between March 2010 and March 2015. Table 10 shows areas of clearfelling on areas with unconditional felling licences approved between March 2000 and March 2105. Finally, Table 11 shows the amount of clearfelling that has been adjacent to areas of actual or increased potential woodland loss.

Figure 10 Annualised amounts of clearfell and apparent woodlands in transition in Great Britain 2006–15



Notes for Figure 10:

1. Estimates are derived from earth observation.
2. The increase in area throughout the period reflects the cumulative addition of new clearfell to apparent woodlands in transition. The areas shown in the figure include areas of restocked trees not visible in the imagery. An unquantified proportion of these areas will therefore have been returned to stocked area at the time of observation.

It should be noted that if all restocked areas were able to be immediately accounted for, it is expected that areas of true woodland in transition would still be rising through the period observed. This is because the rate of clearfelling per annum increased between 2006 and 2015 and, if the mean interval between clearfelling and restock remained constant throughout the period, this would result in an increase in woodland in transition over time.

For example, an annual rate of clearfell of 10 thousand hectares per annum, with an average of 2 years' fallow, would lead to 20 thousand hectares per annum of woodlands

in transition. If annual clearfell rose to 20 thousand hectares per annum, a rise in woodlands in transition to 40 thousand hectares per annum would result.

The factors that affect the relationship between annual clearfell rates and apparent areas of woodland in transition include:

- the time lag to identification of newly restocked trees in remote sensing;
- lengths of fallow periods (which may vary according to factors such as pest and disease management);
- lengths of time between canopy removal and eventual planned land-use change;
- failed restocking;
- failure to restock.

If younger trees have been restocked they will become visible in the imagery over time and older areas of apparent woodlands in transition will decline. Net change in apparent woodland in transition is determined by the relative rates of movement of areas of transition into either restocked woodland or non-woodland land use compared to contemporaneous rates of clearfell.

The Forestry Commission production forecast predicts higher rates of timber availability in future and it is forecast that this will lead to higher rates of clearfelling. The actual amount of woodlands in transition will increase accordingly if current lengths of time between clearfell and replanting or conversion to other land use is maintained in the future.

Table 5 New clearfell and apparent woodlands in transition in Great Britain 2006–15

	Area of apparent woodlands in transition			Apparent woodlands in transition as % of woodland area
	Apparent woodlands in transition from earlier periods (000 ha)	Clearfell observed within period (000 ha)	Total area (000 ha)	
England				
Total apparent woodlands in transition observed at March 2006	-	-	19.0	1
2006/07–2008/09 [1]	19.0	1.1	20.1	2
2009/10–2011/12 [1]	20.4	14.4	34.8	3
2012/13–2013/14	32.6	12.3	44.9	3
2014/15	44.8	5.1	49.9	4
Total new clearfell observed		**32.9**	-	-
Scotland				
Total apparent woodlands in transition observed at March 2006	-	-	75.4	6
2006/07–2008/09 [1]	76.2	20.9	97.1	7
2009/10–2011/12 [1]	97.7	47.8	145.5	10
2012/13–2013/14	142.6	41.5	184.1	13
2014/15	179.6	25.1	204.7	14
Total new clearfell observed		**135.3**	-	-
Wales				
Total apparent woodlands in transition observed at March 2006	-	-	14.7	5
2006/07–2008/09 [1]	14.7	6.7	21.4	7
2009/10–2011/12 [1]	21.3	3.5	24.8	8
2012/13–2013/14	24.5	6.7	31.2	10
2014/15	30.6	2.8	33.5	11
Total new clearfell observed		**19.7**	-	-
Great Britain				
Total apparent woodlands in transition observed at March 2006	-	-	109.0	4
2006/07–2008/09 [1]	109.9	28.6	138.5	5
2009/10–2011/12 [1]	139.5	65.6	205.1	7
2012/13–2013/14	199.5	60.6	260.1	9
2014/15	255.0	33.1	288.1	9
Total new clearfell observed		**187.9**	-	-

Notes for Table 5:

1. [(1)]Includes three whole years.
2. Estimates are derived from earth observation.
3. Areas of apparent woodlands in transition will include areas of young trees not identifiable from imagery.
4. Apparent woodlands in transition at each observation point includes pre-existing clearfell observed in 2006 and additional clearfell observed in earlier observation points and therefore includes several past years of clearfell.
5. Areas of young trees observed in imagery in areas of woodlands in transition are subtracted from the area of apparent woodlands in transition annually. There will typically be a minimum 7-year lag before the young trees become visible. This will be extended by another 3 to 5 years if new imagery is not available at the point in time when such trees would become visible in imagery.

6. New clearfell is the amount of clearfell observed within a given observation year that was not observed in previous observation years.
7. At each observation point, any misclassifications found of clearfelled areas identified in earlier periods were used to adjust the current estimate of apparent woodland in transition, but such adjustments were not applied to the estimates of previous clearfelled areas or apparent woodland in transition. Such adjustments were not large, but account for apparent inconsistencies in the table.
8. Total apparent woodland in transition at the end of each period is expressed as a percentage of the contemporaneous estimate of total woodland area at the end of that period.

Table 6 Field estimates of new clearfell and woodlands in transition for Forestry Commission and Private sector land at March 2012

All species	Area (000 ha)			
	FC/NRW	Private sector	*SE%*	Total area
England	**8.5**	**8.8**	***13***	**17.3**
North West England	1.2	1.3	*33*	**2.6**
North East England	2.3	1.4	*38*	**3.7**
Yorkshire and Humber	1.2	1.1	*30*	**2.4**
East Midlands	0.5	0.4	*65*	**0.9**
East England	0.7	0.5	*51*	**1.2**
South East England	0.8	2.5	*26*	**3.3**
South West England	1.0	1.1	*28*	**2.1**
West Midlands	0.7	0.4	*48*	**1.1**
Scotland	**33.2**	**37.0**	***8***	**70.1**
North Scotland	7.3	5.9	*22*	**13.2**
North East Scotland	5.9	4.8	*21*	**10.7**
East Scotland	1.6	3.7	*21*	**5.2**
South Scotland	9.1	12.6	*13*	**21.7**
West Scotland	9.4	10.0	*13*	**19.4**
Wales	**6.2**	**2.9**	***24***	**9.1**
Great Britain	**47.8**	**48.7**	***6***	**96.5**

Notes for Table 6:

1. The estimates in Table 6 are very different to those in Table 5 and Figure 10. This reflects the fact that the fieldwork estimates in Table 6 exclude previous clearfelled areas that have been restocked at the time of the field survey, whereas Table 5 and Figure 10 report the results of earth observation, in which a considerable amount of such restocked area is included in the areas of apparent woodland in transition. This is because earth observation cannot detect the young trees associated with the restocking until they have grown to a detectable size.

Table 7 Area of conifer and broadleaved stands clearfelled in Great Britain in the period 2006–15

	Clearfell area (000 ha)
England	
Conifer	31.7
Broadleaved	1.1
Others	0.2
Total	**32.9**
Scotland	
Conifer	134.4
Broadleaved	0.6
Others	0.3
Total	**135.3**

	Clearfell area (000 ha)
Wales	
Conifer	19.5
Broadleaved	0.2
Others	0.0
Total	**19.7**
Great Britain	
Conifer	185.5
Broadleaved	1.9
Others	0.5
Total	**187.9**

Notes for Table 7:

1. Estimates are derived from earth observation.
2. The 'Others' category of the table represents Uncertain, Ground prep, Low density and Cloud/Shadow

Table 8 Apparent woodlands in transition and new clearfell areas on ancient woodland sites at March 2015

	Clearfelled area in ancient semi-natural woodland sites (000 ha)	Clearfelled area in plantation on ancient woodland sites (000 ha)	Clearfelled area in ancient woodland sites (000 ha)	Total area of all ancient woodland sites (000 ha)	% of area of clearfell	% of ancient woodland sites clearfelled
England	0.5	3.8	4.3	366.0	9	1
Scotland	1.5	8.5	10.0	148.2	5	7
Wales	2.1	0.9	3.0	95.0	9	3
Great Britain	**4.1**	**13.3**	**17.4**	**609.1**	**6**	**3**

Notes for Table 8:

1. Estimates are derived from earth observation.
2. Some of the clearfelling in PAWS areas will result from PAWS restoration activity while other areas may be the result of silvicultural practice and land-use change.
3. The clearfelling in ASNW may reflect:
    - The usual silvicultural practice of felling and replanting of native species.
    - There may be errors in the Ancient Woodland Site map that misclassify PAWS sites as ASNW sites. It is the case that non-native trees occupy a significant proportion of mapped ASNW area, as illustrated in the recent Native Woodland Survey of Scotland report. NFI does not presently confirm species and ancient woodland status at time of clearfell, but will in later cycles.
    - The Ancient Woodland map ASNW sites include small pockets of non-native species.

4. Total area of ancient woodland sites includes areas of open space greater than 0.5 hectare in extent.
5. The ancient woodland estimates for Scotland exclude long-established woodlands of plantation origin (LEPO) (types 1b and 2b) and 'Other' woodlands on Roy sites (type 3). The NFI found 22.2 thousand hectares of clearfell in these areas.

Table 9 Apparent woodlands in transition and new clearfell areas under statutory plant health notices at March 2015

	Clearfelled area in statutory plant health notice sites (ha)	Total area under statutory plant health notices (ha)	% of area of clearfell	% of statutory plant health notices clearfelled
England	654	6,974	1	9
Scotland	460	1,228	0	37
Wales	1,970	7,117	6	28
Great Britain	**3,084**	**15,319**	**1**	**20**

Notes for Table 9:

1. Estimates are derived from earth observation.
2. SPHNs issued between March 2010 to March 2015.
3. The total area covered by SPHNs is higher since not all SPHNs involve clearfelling, not all will have been enacted at time of assessment and not all trees within SPHN areas are required to be felled.

Table 10 Apparent woodlands in transition and new clearfell areas in unconditional felling licence areas at March 2015

	Clearfelled area in unconditional felling licence sites (ha)	Total area under unconditional felling licences (ha)	% of area of clearfell	% of unconditional felling licences clearfelled
England	1,660	7,418	3	22
Scotland	1,147	2,937	1	39
Wales	177	556	1	32
Great Britain	**2,983**	**10,911**	**1**	**27**

Notes for Table 10:

1. Estimates are derived from earth observation.
2. Estimates for unconditional felling licences approved between March 2000 and March 2015.
3. A felling licence permits the woodland owner/manager to fell their woodland between two specified dates; the approval and the expiry dates. If the owner/manager does not fell the woodland within this period, the licence expires. Owners have a number of years to undertake felling and are not obliged to fell.

Table 11 Apparent woodlands in transition and new clearfell areas adjacent to actual or enhanced potential woodland loss areas at March 2015

	Clearfelled area adjacent to woodland loss areas (000 ha)	% of clearfelled area
England	1.4	3
Scotland	13.4	7
Wales	1.6	5
Great Britain	**16.3**	**6**

Notes for Table 11:

1. Estimates are derived from earth observation.
2. These clearfell areas are adjacent to areas of:
    - woodland loss
    - ground under development
    - newly established habitat

New windblow estimates

Table 12 provides the annual area of new windblow in Great Britain identified between 2006 and 2015 in satellite imagery, broken down by country. Refer to Figure 14 in Appendix E for a map of the spatial distribution of all windblow areas across Great Britain between 2006 and 2015.

Table 12 New windblow in Great Britain 2006–15

	Total area (ha)
England	
2006/07–2008/09 [1]	0
2009/10–2011/12 [1]	78
2012/13–2013/14	42
2014/15	66
Total	**186**
Scotland	
2006/07–2008/09 [1]	183
2009/10–2011/12 [1]	1,249
2012/13–2013/14	1,558
2014/15	798
Total	**3,787**

	Total area (ha)
Wales	
2006/07–2008/09 [1]	21
2009/10–2011/12 [1]	17
2012/13–2013/14	39
2014/15	64
Total	**140**
Great Britain	
2006/07–2008/09 [1]	204
2009/10–2011/12 [1]	1,343
2012/13–2013/14	1,639
2014/15	928
Total	**4,113**

Notes for Table 12:

1. [(1)] Includes three whole years
2. These estimates, based on satellite imagery, 2006–15, are likely to be underestimates of areas of new windblow since:
   - They exclude areas of less than 0.5 hectare in extent.
   - They exclude areas where windblow has occurred to only a proportion of the canopy. Typically, levels of windblow of greater than 80% of the canopy will be detected while areas with less than 50% may not be detected. The estimates will exclude areas of windblow cleared rapidly, which will have been classified as clearfell or restock.
3. Estimates are derived from earth observation.
4. The 2006 satellite imagery analysis found an additional 736 hectares of recent windblow in Great Britain, of which 83 hectares occurred in England, 599 hectares in Scotland and 86 hectares in Wales. This will have occurred between 2004/05 and 2005/06 within a partial proportion of all woodland and thus was not included in the above table.

The NFI fieldwork estimates the area of windblow of all ages, sizes and intensities as around 45 thousand hectares across Great Britain in March 2012. This includes smaller areas of windblow at lower intensities, and also contains existing and older windblow that occurred prior to 2006 that had not been cleared at the time of the field survey assessment.

Annual estimates of reported restocking

Table 13 provides the restocking areas reported between 2005 and 2015 as published in the *Forestry Statistics 2015*, broken down by country and Great Britain.

Restocking grant aid for conifers was no longer supported in England for part of the period covered, with the exception of restocking after sanitation felling due to plant health issues. Grant support for the restocking of conifers in Scotland changed in 2008 with the introduction of Rural Development Contracts. As a result, grant aid has not been available for restocking with Sitka spruce in many cases. No estimates have been included for restocking no longer supported by grants. Conifer restocking is therefore under-reported.

Table 13 Annual restocking estimates in Great Britain, based on administrative records

	Conifer area (000 ha)	Broadleaved area (000 ha)	Total area (000 ha)
England			
2006/07	1.8	0.9	2.8
2007/08	2.0	1.5	3.5
2008/09	1.7	1.7	3.5
2009/10	1.5	1.3	2.8
2010/11	2.3	1.7	4.0
2011/12	2.0	1.6	3.6
2012/13	2.2	1.8	4.0
2013/14	2.6	1.9	4.5
2014/15	2.0	4.4	6.4
Total	**18.2**	**16.8**	**35.0**
Scotland			
2006/07	10.6	1.8	12.4
2007/08	10.8	1.8	12.6
2008/09	8.2	1.4	9.6
2009/10	8.0	1.5	9.5
2010/11	5.6	1.3	6.9
2011/12	4.6	1.1	5.7
2012/13	5.1	0.9	6.0
2013/14	6.5	1.4	7.9
2014/15	6.6	1.9	8.5
Total	**66.0**	**13.0**	**79.1**

	Conifer area (000 ha)	Broadleaved area (000 ha)	Total area (000 ha)
Wales			
2006/07	2.1	0.9	3.0
2007/08	1.5	0.8	2.3
2008/09	1.4	0.8	2.2
2009/10	1.3	0.8	2.1
2010/11	1.3	0.8	2.1
2011/12	1.4	0.6	2.0
2012/13	1.4	0.6	2.0
2013/14	1.4	0.8	2.3
2014/15	1.3	0.6	1.9
Total	**13.2**	**6.7**	**19.8**
Great Britain			
2006/07	14.6	3.6	18.1
2007/08	14.3	4.0	18.4
2008/09	11.3	4.0	15.3
2009/10	10.8	3.6	14.4
2010/11	9.3	3.7	13.0
2011/12	8.0	3.3	11.3
2012/13	8.7	3.3	12.0
2013/14	10.6	4.1	14.6
2014/15	9.9	6.9	16.8
Total	**97.4**	**36.5**	**133.9**

Notes for Table 13:

1. The totals are based on summing the unrounded individual estimates.
2. Reproduced from *Forestry Statistics* annual publication.

Areas of woodland loss, ground under development and newly established habitats

Table 14 provides the amounts of woodland loss, ground under development and newly established habitats, broken down by country within observation periods. These estimates are illustrated in the form of annual average rates within periods in Figure 11. Refer to Figure 15 in Appendix E for a map of the spatial distribution of all canopy loss across Great Britain.

Tables 15 and 16 provide a breakdown of the interpreted forest types that have undergone canopy loss resulting in woodland loss, ground under development and newly established habitats in Great Britain between 2006 and 2015. Table 15 reports on such changes at the edge of wood while Table 16 provides the areas of changes inside of the wood. Tables 17 and 18 provide a breakdown of areas of woodland loss into land uses to which woodland has been converted, split into changes inside of the wood (Table 18) and those at the edge of the wood (Table 17). For Tables 15 to 18 a breakdown by each satellite monitoring period is available in the supplementary spreadsheets to this report, available at www.forestry.gov.uk/inventory.

Table 19 provides the total areas of actual, enhanced potential woodland loss and newly established habitat in ancient woodland sites.

Figure 11 New woodland loss, ground under development and newly established habitat in Great Britain 2006–15

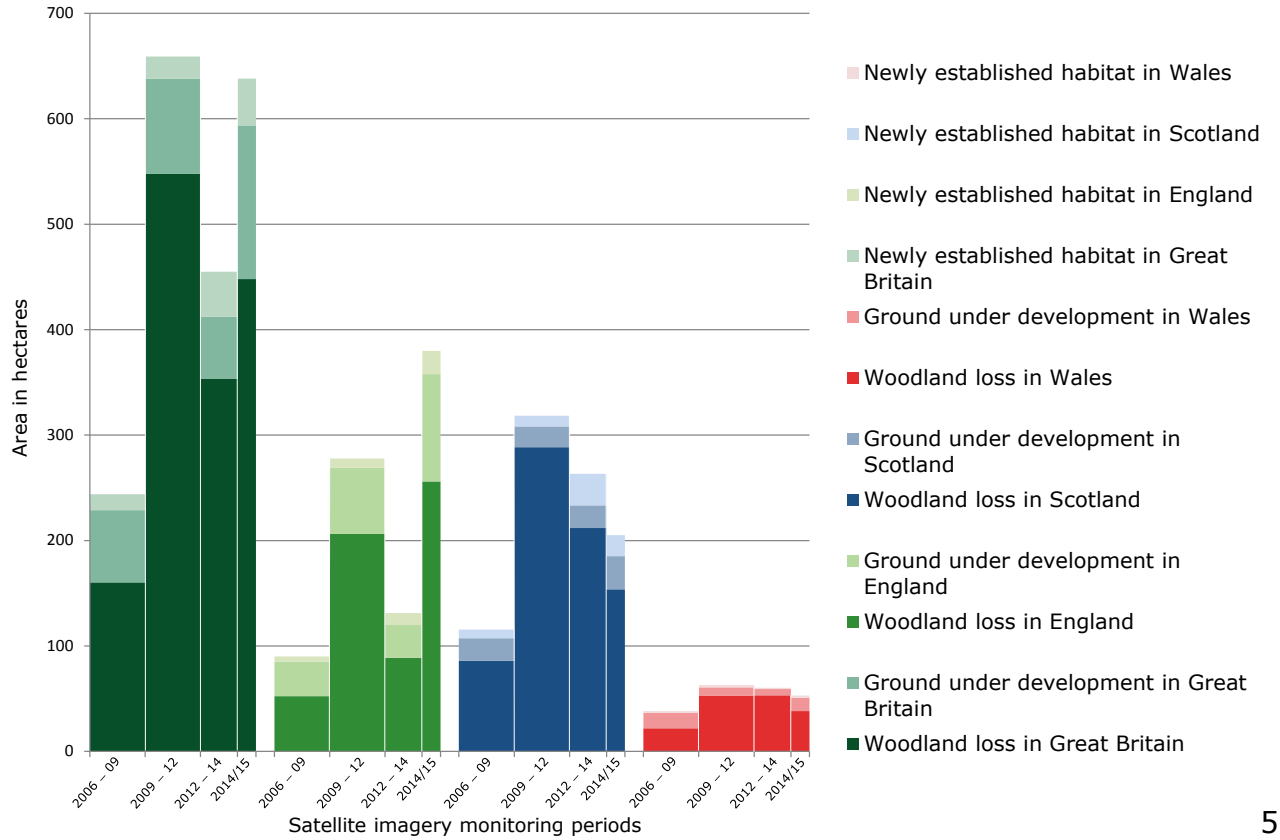


Table 14 Total areas of woodland loss, ground under development and newly established habitats within observation periods 2006–15

	Area of woodland loss (ha)	Area of ground under development (ha)	Area of newly established habitat (ha)	Total area (ha)
England				
2006/07 – 2008/09 [1]	157	98	15	270
2009/10 – 2011/12 [1]	619	188	27	833
2012/13 – 2013/14	178	62	23	263
2014/15	256	102	22	380
Total	**1,209**	**450**	**87**	**1,746**
Scotland				
2006/07 – 2008/09 [1]	258	64	24	346
2009/10 – 2011/12 [1]	865	60	30	955
2012/13 – 2013/14	424	43	60	526
2014/15	154	31	20	205
Total	**1,701**	**198**	**134**	**2,033**
Wales				
2006/07 – 2008/09 [1]	66	44	6	115
2009/10 – 2011/12 [1]	159	23	7	189
2012/13 – 2013/14	106	12	2	121
2014/15	38	12	2	53
Total	**369**	**91**	**17**	**478**
Great Britain				
2006/07 – 2008/09 [1]	481	206	45	732
2009/10 – 2011/12 [1]	1,643	271	63	1,977
2012/13 – 2013/14	707	117	85	910
2014/15	448	146	44	638
Total	**3,279**	**739**	**238**	**4,256**

Notes for Figure 11 and Table 14:

1. [(1)] Includes three whole years
2. Estimates are derived from earth observation.
3. Woodland loss: Areas where definitive evidence for the permanent removal of woodland cover has been established.
4. Ground under development: Areas where there has been significant earth movement of the type associated with development.
5. Newly established habitat: Areas where there has been a significant change in the habitat type through the complete establishment of non-tree vegetation.
6. Some loss occurred between 2004 and 2006 over a partial proportion of woodland and thus have been excluded from the estimates. These account for; Woodland loss - 115 hectares in England, 229 hectares in Scotland, 2 hectares in Wales and 347 hectares in Great Britain, Ground under development - 33 hectares in England, 7 hectares in Scotland and 40 hectares in Great Britain and Newly established habitats - 16 hectares in England, 8 hectares in Scotland and 24 hectares in Great Britain.

Table 15 Types of change at the edge of woodland broken down by IFT in Great Britain and countries 2006–15

Change at the edge of woodland	Total area (ha)
England	
Woodland loss	**1,138**
Broadleaved	815
Conifer	168
Felled	53
Others	102
Ground under development	**449**
Broadleaved	323
Conifer	47
Ground prep	25
Others	55
Newly established habitat	**27**
Broadleaved	21
Conifer	3
Shrub	2
Others	1
Grand Total	**1,614**
Scotland	
Woodland loss	**1,442**
Conifer	716
Broadleaved	326
Felled	228
Others	172
Ground under development	**198**
Broadleaved	77
Conifer	52
Felled	42
Others	27
Newly established habitat	**9**
Conifer	5
Broadleaved	3
Felled	0
Others	0
Grand Total	**1,648**

Change at the edge of woodland	Total area (ha)
Wales	
Woodland loss	**281**
Broadleaved	128
Conifer	96
Felled	22
Others	35
Ground under development	**91**
Broadleaved	42
Young trees	20
Felled	13
Others	16
Newly established habitat	**2**
Mixed mainly conifer	1
Broadleaved	0
Grand Total	**374**
Great Britain	
Woodland loss	**2,861**
Broadleaved	1,270
Conifer	979
Felled	304
Others	308
Ground under development	**738**
Broadleaved	441
Conifer	105
Felled	63
Others	129
Newly established habitat	**37**
Broadleaved	24
Conifer	8
Shrub	2
Others	3
Grand Total	**3,636**

Notes for Table 15:

1. Estimates are derived from earth observation.
2. 'Change at the edge of woodland' = woodland loss at the periphery of the woodland.
3. IFT = interpreted forest type: conifer, broadleaved, shrub, felled etc.
4. IFT classes ordered by prevalence of class at country and categories level.

Table 16 Types of change inside woodland broken down by IFT in Great Britain and countries 2006–15

Change inside woodland	Total area (ha)
England	
Woodland loss	**71**
Conifer	32
Broadleaved	17
Felled	11
Others	11
Newly established habitat	**60**
Young trees	21
Broadleaved	20
Conifer	11
Others	8
Grand Total	**132**
Scotland	
Woodland loss	**259**
Conifer	210
Felled	26
Young trees	16
Others	7
Newly established habitat	**126**
Conifer	70
Felled	31
Cloud/shadow	14
Others	12
Grand Total	**385**

Change inside woodland	Total area (ha)
Wales	
Woodland loss	**89**
Felled	42
Conifer	29
Young trees	16
Others	2
Newly established habitat	**15**
Conifer	7
Broadleaved	6
Young trees	1
Others	1
Grand Total	**104**
Great Britain	
Woodland loss	**419**
Conifer	271
Felled	79
Young trees	40
Others	28
Newly established habitat	**201**
Conifer	87
Felled	34
Young trees	29
Others	52
Grand Total	**620**

Notes for Table 16:

1. Estimates are derived from earth observation.
2. 'Change inside woodland' = woodland loss entirely within woodland.
3. IFT = interpreted forest type: conifer, broadleaved, shrub, felled etc.
4. IFT classes ordered by prevalence of class at country and categories level.
5. There was very little ground under development observed inside woodland and what was observed has been included within areas of woodland loss in this table.

Table 17 The most common causes of change at the edge of woodland in Great Britain and countries 2006–15

Change at the edge of woodland	Total area (ha)
England	
Woodland loss	**1,138**
Mineral extraction area	377
Residential area	239
Road or railways	120
Industrial buildings and grounds	105
Recreational and leisure buildings	53
Others	245
Ground under development	**449**
Ground under development area	449
Newly established habitat	**27**
Grassland	27
Grand Total	**1,614**
Scotland	
Woodland loss	**1,442**
Mineral extraction area	766
Residential area	154
Windfarm	129
Tracks or paths	123
Industrial buildings and grounds	70
Others	200
Ground under development	**198**
Ground under development area	198
Newly established habitat	**9**
Grassland	9
Grand Total	**1,648**

Change at the edge of woodland	Total area (ha)
Wales	
Woodland loss	**281**
Mineral extraction area	124
Residential area	47
Industrial buildings and grounds	31
Road or railways	29
Retail buildings and grounds	11
Others	39
Ground under development	**91**
Ground under development area	91
Newly established habitat	**2**
Grassland	2
Grand Total	**374**
Great Britain	
Woodland loss	**2,861**
Mineral extraction area	1,267
Residential area	439
Road or railways	216
Industrial buildings and grounds	206
Tracks or paths	141
Others	592
Ground under development	**738**
Ground under development area	738
Newly established habitat	**37**
Grassland	37
Grand Total	**3,636**

Notes for Table 17:

1. Estimates are derived from earth observation.
2. Change at the edge of woodland = woodland loss at the periphery of the woodland.
3. Classes ordered by prevalence of class at country and categories level.
4. The five next most common causes of woodland loss categorised as 'Others' are:
    - wind farm - 133.8 hectares
    - recreational and leisure buildings and grounds - 73.9 hectares
    - community service buildings and grounds - 73.2 hectares
    - cropped land - 65.8 hectares
    - other transport infrastructure - 43.1 hectares

    The full list is available in the supplementary spreadsheets at: www.forestry.gov.uk/inventory.
5. The amounts of each category will change over time as new clearfell and transition woodland are monitored over the 10-year period after clearfell. For example there are currently 23.1 thousand hectares of clearfelled land that has planning consent for wind farms at either approved/active or installed stage (up to March 2016). This land may or may not be restocked within 10 years of clearfelling.

Table 18 The most common causes of change inside woodland in Great Britain and countries 2006–15

Change inside woodland	Total area (ha)
England	
Woodland loss	**72**
Mineral extraction area	35
Urban/Buildings	26
Tracks or paths	6
Water feature	4
Newly established habitat	**60**
Grassland	38
Other vegetation	15
Bare area	7
Grand Total	**132**
Scotland	
Woodland loss	**259**
Tracks or paths	142
Mineral extraction area	66
Windfarm	24
Urban/Buildings	22
Water feature	4
Newly established habitat	**126**
Grassland	64
Bare area	34
Other vegetation	28
Grand Total	**385**

Change inside woodland	Total area (ha)
Wales	
Woodland loss	**89**
Mineral extraction area	71
Windfarm	8
Tracks or paths	7
Water feature	1
Urban/Buildings	1
Newly established habitat	**15**
Grassland	9
Bare area	5
Other vegetation	2
Grand Total	**104**
Great Britain	
Woodland loss	**419**
Mineral extraction area	173
Tracks or paths	155
Urban/Buildings	50
Windfarm	32
Water feature	9
Cropped land	0
Newly established habitat	**201**
Grassland	111
Bare area	46
Other vegetation	44
Grand Total	**620**

Notes for Table 18:

1. Estimates are derived from earth observation.
2. 'Change inside woodland' = woodland loss entirely within woodland.
3. Classes ordered by prevalence of class at country and categories level.
4. 'Newly established habitat' represents a change to non-woodland vegetation. This may reflect planned habitat restoration. Further analysis of management plans would be required to confirm this.
5. Ground under development was included within the Urban/Buildings class inside woodlands.

Table 19 Actual and enhanced potential woodland loss on ancient woodland sites in Great Britain and countries 2006–15

	Ancient semi-natural woodlands (ASNW)	Plantation on ancient woodlans sites (PAWS)	Total area of change (ha)	% of area changed
England				
Change at the edge of woodland	**28**	**20**	**48**	**0.01**
Woodland loss	24	19	43	0.01
Ground under development	3	1	4	0.00
Newly established habitat	1		1	0.00
Change inside woodland	**2**	**7**	**9**	**0.00**
Woodland loss	1	4	5	0.00
Newly established habitat	0	4	4	0.00
Grand Total	**30**	**27**	**57**	**0.02**
Scotland				
Change at the edge of woodland	**7**	**16**	**23**	**0.02**
Woodland loss	7	14	21	0.01
Ground under development	0	2	3	0.00
Change inside woodland	**4**	**22**	**25**	**0.02**
Woodland loss	3	6	9	0.01
Newly established habitat	1	15	16	0.01
Grand Total	**11**	**38**	**49**	**0.03**
Wales				
Change at the edge of woodland	**42**	**6**	**49**	**0.05**
Woodland loss	38	6	43	0.05
Ground under development	5	1	5	0.01
Newly established habitat	0		0	0.00
Change inside woodland	**2**	**1**	**3**	**0.00**
Woodland loss	0	1	1	0.00
Newly established habitat	2		2	0.00
Grand Total	**44**	**7**	**52**	**0.05**
Great Britain				
Change at the edge of woodland	**78**	**42**	**120**	**0.02**
Woodland loss	69	39	107	0.02
Ground under development	8	4	12	0.00
Newly established habitat	1		1	0.00
Change inside woodland	**7**	**30**	**37**	**0.01**
Woodland loss	5	11	16	0.00
Newly established habitat	2	19	21	0.00
Grand Total	**85**	**72**	**157**	**0.03**

Notes for Table 19:

1. Estimates are derived from earth observation.
2. The ancient woodland data used in this analysis has a minimum size threshold of 2 hectares in England and Scotland and 0.5 hectare in Wales.
3. ASNW and PAWS are as designated in the Ancient Woodland Inventory of the 1980s published by the Nature Conservancy Council, with revisions by Natural England, Scottish Natural Heritage and Natural Resources Wales.

4. Reasons for change at any particular site may be PAWS restoration, normal silvicultural practice, land-use change or natural decline.
5. The ancient woodland estimates for Scotland exclude long-established woodlands of plantation origin (LEPO) (types 1b and 2b) and 'Other' woodlands on 'Roy' sites (type 3). The NFI found 453 hectares of woodland loss in these areas.

Annual rates of reported new planting

Table 20 provides the areas of new planting reported between 2005 and 2015 as published in the 2015 edition of *Forestry Statistics*.

Table 20 Forestry Commission estimates of annual new planting in Great Britain and countries 2006–15

	Conifer area (000 ha)	Broadleaved area (000 ha)	Total area (000 ha)
England			
2006/07	0.1	3.1	3.2
2007/08	0.1	2.5	2.6
2008/09	0.0	2.5	2.5
2009/10	0.0	2.3	2.3
2010/11	0.0	2.5	2.5
2011/12	0.0	2.7	2.7
2012/13	0.0	2.6	2.6
2013/14	0.0	3.3	3.3
2014/15	0.1	2.3	2.4
Total	**0.2**	**23.9**	**24.1**
Scotland			
2006/07	2.0	4.6	6.6
2007/08	0.7	3.4	4.2
2008/09	1.2	2.3	3.4
2009/10	0.5	2.2	2.7
2010/11	1.8	4.2	6.0
2011/12	3.3	5.7	9.0
2012/13	1.7	5.3	7.0
2013/14	2.0	6.3	8.3
2014/15	2.5	5.1	7.6
Total	**15.7**	**39.2**	**54.9**

	Conifer area (000 ha)	Broadleaved area (000 ha)	Total area (000 ha)
Wales			
2006/07	0.0	0.5	0.6
2007/08	0.0	0.2	0.2
2008/09	0.0	0.2	0.2
2009/10	0.0	0.2	0.2
2010/11	0.0	0.3	0.3
2011/12	0.1	0.6	0.8
2012/13	0.1	0.8	0.9
2013/14	0.1	0.8	0.9
2014/15	0.0	0.1	0.1
Total	**0.5**	**3.7**	**4.2**
Great Britain			
2006/07	2.1	8.2	10.3
2007/08	0.8	6.2	7.0
2008/09	1.2	4.9	6.1
2009/10	0.5	4.7	5.2
2010/11	1.8	7.0	8.8
2011/12	3.4	9.0	12.5
2012/13	1.9	8.7	10.5
2013/14	2.1	10.5	12.6
2014/15	2.6	7.5	10.1
Total	**16.4**	**66.8**	**83.2**

Notes for Table 20:

1. The totals are based on summing the unrounded individual estimates.
2. Reproduced from *Forestry Statistics* annual publication.

Areas of restocking derived from field surveys assessed between January 2010 and August 2013

Table 21 Preliminary field survey estimates of restocking within areas of apparent woodlands in transition and new clearfell identified in 2006 imagery

	Clearfell observed in 2006		
	Area of original clearfell (000 ha)	*SE%*	% of original clearfell area
Restocked area			
All conifers	**55.4**	***4***	**51**
Sitka spruce	42.9	*4*	39
Larches	4.3	*14*	4
Other conifers	8.1	*12*	7
All broadleaves	**19.4**	***8***	**18**
Birches	11.3	*10*	10
Willow	1.4	*16*	1
Other broadleaves	6.7	*13*	6
All species	**75.1**	***3***	**69**
Non-restocked area			
Woodlands in transition	24.6	*8*	23
Open area	9.3		8
Total	**33.9**		**31**
Grand total	**109.0**		**100**

Table 22 Preliminary field survey estimates of restocking within apparent woodlands in transition and new clearfell identified in imagery between 2006 and 2009

	Clearfell observed between 2006 and 2009		
	Area of original clearfell (000 ha)	*SE%*	% of original clearfell area
Restocked area			
All conifers	**15.1**	***5***	**53**
Sitka spruce	13.0	*7*	45
Larches	0.9	*28*	3
Other conifers	1.1	*26*	4
All broadleaves	**2.8**	***18***	**10**
Birches	1.0	*27*	4
Willow	0.5	*52*	2
Other broadleaves	1.3	*16*	4
All species	**17.9**	***4***	**63**
Non-restocked area			
Woodlands in transition	7.8	*10*	27
Open area	2.9		10
Total	**10.7**		**37**
Grand total	**28.6**		**100**

Notes for Table 21 and Table 22:

1. Areas reported are stocked areas.
2. Stocked areas are defined in Table 3 and exclude small areas of integral open space. They will by definition be smaller than the woodland area or clearfell area.
3. The difference between stocked area and woodland area in all woodland types is around 9%. When making comparisons of felled area to stocked area the presence of additional integral open space should be taken into account.
4. A further 2 years of field surveys are required to fully assess the restocking of areas in Table 21 (after which, any areas that have not been restocked are defined as woodland loss) while for the areas in Table 22 a further 5 years of field survey results will be required to fully assess restocking rates for all years of canopy loss shown in the table.
5. The current NFI field sample covering these areas is too small to provide reliable estimates at a country level.
6. Restocked areas will include small amounts of older trees, such as seed trees, lone broadleaves or veteran trees that were retained at clearfell.
7. Open area in the tables above relate to open space that will be permanent in nature, and will have been in existence at clearfell.

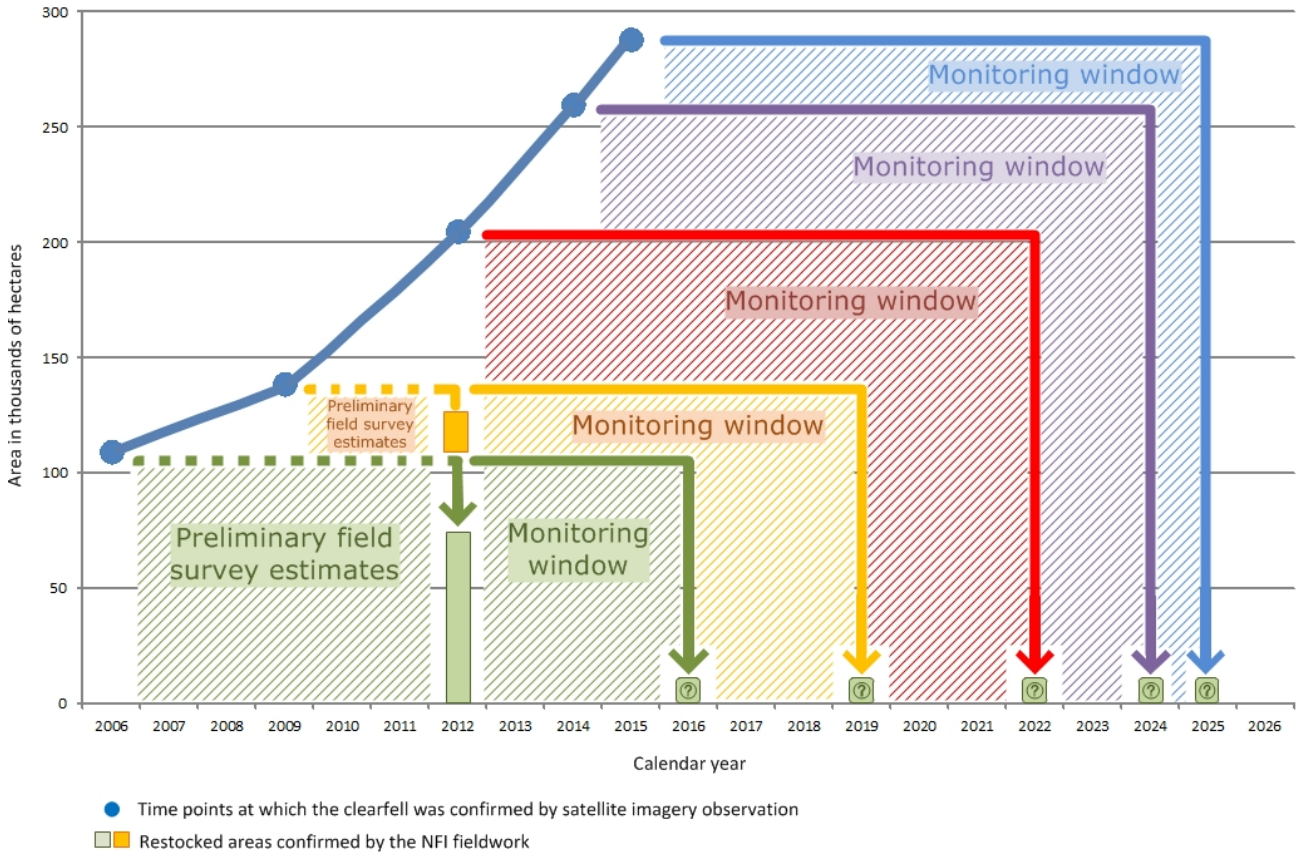
Qualifying the results

The NFI, as an observation-based survey, requires measurable evidence to derive its findings. Making such observations for some canopy change drivers is relatively straightforward as their impacts are immediate and easy to see. For example, urban development, leading to felling and conversion to built facilities, is clearly identifiable as woodland loss in a relatively short period. However, other factors, such as habitat restoration and natural colonisation processes, require many years within which to observe and conclude upon their long-term impacts. This causes any assessment of canopy change that is based on observations over a limited period of time to be incomplete in nature.

The NFI uses two main approaches to assess canopy change: remote earth observation systems and fieldwork. The remote canopy monitoring systems utilise satellite imagery and aerial photography to rapidly identify significant changes in woodland canopy (over 0.5 hectare), providing a contemporary source of information. These systems were first put in place in 2009 and can reliably report on significant canopy change such as clearfelling.

However, even the best satellite data and aerial photography cannot consistently identify very young trees (generally less than 10 years old) or readily identify very minor losses of larger trees (less than 0.5 hectare) as both are too small to consistently observe from space or the air. In such cases remote sensing techniques must be supported and calibrated by fieldwork, with surveyors on the ground to identify minor changes in the canopy and to detect younger, smaller trees. The disadvantage of fieldwork compared to imagery is that, while generating more precise information, it involves relatively more time and resource to obtain. This leads to a typical time lag of 2 to 5 years before events are detected by nationwide field survey compared to a year for satellite imagery. This is why the report has data on clearfelling to 2015 and only to 2012 on restocking. This observational lag adds to an actual lag on the ground between clearfelling and restocking, where clearfell sites are often left fallow for 2 to 5 years before replanting. Where natural regeneration is used to re-establish canopy, this fallow period can stretch to 10 years or more before the achievement of canopy. These two lags need to be taken into account when assessing the results presented. The observation lag for small trees applies equally to the identification of recent natural colonisation of trees and new planting, both of which it is essential to detect to accurately monitor canopy change and woodland area.

Figure 12 Monitoring clearfell and restocking of sites over time



Notes for Figure 12:

1. Each monitoring window starts after the first clearfell is detected and runs for 10 years.
2. The monitoring windows end 10 years after the last of the clearfell was detected.
3. The first field survey results published in this report, those observed from 2010 to 2013/14, have a mean assessment year of 2012 and provide a preliminary assessment of restocking between 3 and 7 years after clearfell. Since 10 years is allowed for canopy to be re-established, in principle a final conclusion can only be drawn on the assessment of sites clearfelled prior to 2006 once fieldwork results to the end of 2016/17 become available for analysis, while for the clearfell that occurred between 2006 and 2009, a final assessment can be made using fieldwork results no earlier than the end of 2019.

Figure 12 illustrates how, at the end of 2016/17, a full assessment will be possible of the amounts of restocking on clearfell sites that existed in 2006, but it will not be until 2025 that a full assessment will be possible of restocking of areas that were clearfelled in 2015. The fieldwork undertaken between 2010 and 2013/14 has been used to estimate restocking to date on sites felled in 2006 or earlier, and between 2006 and 2009. The results published in this report are therefore 'preliminary' in nature. This partial picture of a complex process should be borne in mind when interpreting these results.

Discussion of results

The results show that woodland canopy cover in Britain is undergoing a period of significant change. Assessment of these changes can be grouped into five main areas: levels of clearfell, levels of restocking, levels of woodland loss, levels of windblow, and the net impact of these factors on canopy cover and ultimately woodland area.

Clearfelling

The majority of canopy change in the period 2006 to 2015 has been driven by an increasing level of harvesting in commercial conifer stands, with the amount of clearfell per annum more than trebling over the period from 9.5 thousand hectares per annum to 33.1 thousand hectares per annum. This amounts to a total of 188 thousand hectares of clearfelling detected for the period. British domestic timber production, as reported in the Forestry Commission's *Forestry Statistics*, also shows a rising trend through this period. This has arisen as the conifer stands being clearfelled were planted in the post-war years and have now come to economic and biological maturity. The maturity of these stands has coincided with a period of high market demand and the combination of these two drivers have contributed to a historically high rate of harvesting. This process is a part of normal forest management and it is a requirement of the Forestry Act and the UK Forestry Standard that these stands will, in most instances, be restocked. There are notable exceptions to this, for example in habitat restoration, forest restructuring and building activity associated with economic development. This report sets out evidence for the amounts and types of these changes and describes how they will be monitored in future.

The increased rate of clearfelling occurred in conifer woods, suggesting around 13% of the area of conifer woods[19] at 2006 have been felled over this 9-year period. This area is in addition to the estimated 109 thousand hectares of clearfelled and transition woodland area that was already in existence in 2006. These 109 thousand hectares will have represented clearfelled area created from felling events over several years before 2006, as most clearfell sites are left fallow for a number of years. This increase in clearfelling matches commensurate increases in the amount of domestic softwood timber that was processed within Britain during the same period (see *Forestry Statistics* annual publication at (www.forestry.gov.uk/statistics).

The increased level of clearfelling has consequently increased the total amount of woodland area in transition between clearfell, restocking and complete establishment over the period. Although the area in transition has increased, much of the clearfell has already been restocked and of the area identified as clearfell in 2006, and that

[19] 185.5 thousand hectares of clearfell in conifers (Table 7) divided by 1,452 thousand hectares of conifer IFT, mixed mainly conifer and 50% of young trees (Table 4).

clearfelled between 2006 and 2009 (138 thousand hectares in total), around 93 thousand hectares or 67% of that area had already been restocked by 2012. This restocked area is likely to increase by 2019, when all clearfell sites of that period have had 10 or more years to re-establish canopy and a final assessment of restocking for this period of clearfelling can be made. When examining total clearfell area and total area of transition woodland in relation to the observed amounts of restocking, it is important to recognise that it can take up to 10 years to re-establish canopy cover and that it is difficult to identify the young trees associated with restocking from imagery alone. Information from fieldwork is therefore important for such assessments and its current availability prevents any assessment of restocking rates between 2012 and 2015.

This time lag for detection leads to underestimation of restocked areas in the imagery and, correspondingly, an overestimation of previously clearfelled area known as woodlands in transition that has not been restocked. By comparing the amount of clearfell visible in the imagery to that which was found in the NFI field survey at an equivalent point in time, the broad scale of this overestimation can be assessed. In 2012 the imagery identified 139.5 thousand hectares of apparent woodland in transition and 65.6 thousand hectares of new clearfelled area from clearfell events that occurred in the 2009–12 period, giving a total of 205.1 thousand hectares of clearfelled and apparently un-restocked area. This contrasts with 96.5 thousand hectares of non-restocked clearfell identified by fieldwork referenced to the same year (2012). This implies that 108.6 thousand hectares of the 139.5 thousand hectares of apparent woodland in transition, or 78%, was in fact restocked but undetected in the imagery of 2012. This is reasonably consistent with the 69% and 63% of restocked area specifically found by the fieldwork in the 2006 and 2006–09 clearfelled areas, reported in Tables 21 and 22 respectively.

Such overestimation of total non-restocked clearfelled area does not impact upon the annual estimates of newly identified clearfell, which showed that the annual levels of clearfell from 2006 to 2015 experienced a strong upward trend. Around 7.5% of conifer woods were identified as clearfelled from the air in 2006, rising to 20% in 2015[20]. The rate of clearfelling is consistent with levels of felling that have been predicted based upon the age of the trees. For example, an evenly aged forest resource undergoing a uniform and 'typical' 66-year rotation would experience an average rate of clearfelling of 1.5% per annum of its area. The observed increase over time in total clearfelled area may also indicate that clearfell sites are being left for longer than 2 years before being restocked due to plant health, economic or other reasons. It may also reflect a situation in which some areas are not being restocked at all (see discussion in next section).

[20] Table 5 apparent woodland in transition area at 2006 and 2015 divided by conifer area (sum of conifer, mixed mainly conifer and 50% of young tree IFTs).

Clearfelling at this level most likely reflects the age class structure of plantations in the national forest resource, since age class is the principal determinant of the amount of harvesting activity. The rapid development of a planted forest resource in Britain through large afforestation programmes after the two world wars has led to an uneven age profile of British coniferous woodlands, resulting in the observed increase in clearfelling across Britain, broadly one rotation length after the post-war afforestation programmes.

This trend contrasts with what would occur for a forest resource with a more evenly distributed age structure, where a more stable evolution of clearfelling and standing volume through time would be observed. It should also be noted that the estimates reported are confined to activity within a limited period of time that is a fraction of the full life cycle of the forest. If a considerably longer period were to be assessed, a different overall perspective on canopy and woodland area change might be provided. The uneven age profile in the British forest resource and its impacts on long-term rates of clearfelling and timber availability are addressed in detail in the NFI production forecast reports (for more information see www.forestry.gov.uk/forecast).

The increased level of clearfelling may also have been accentuated by the reported increase in the amount of felling that has been required to manage the series of pests and diseases that have recently affected Britain's woodlands. For example, *Phytophthora ramorum* often necessitates felling and Dothistroma needle blight can bring about shorter rotations, which have led to extensive felling of larch and pine respectively. These diseases have necessitated the issuing of 15.3 thousand hectares of statutory plant health notices by the FC and NRW, between March 2010 and March 2015, within the boundaries of which the NFI has detected 3,084 hectares of clearfell to date.

Rates of restocking

The results in this report demonstrate that the amount of restocking reported through grant aid (an average of around 15 thousand hectares per annum over the period), does not appear to equal the area of clearfelling identified (an average of 21 thousand hectares per annum). The differences may be due to:

1. The usual time lag of 2 to 5 years fallow between felling and restocking.
2. An increase in the average length of fallow time between felling and restocking.
3. The reported restocking figures systematically underestimating the amount of, restocking.
4. The areas being clearfelled not being fully restocked.

Point 3 is a relevant factor because the reported restocking estimates are based solely upon areas of grant aid restocking and Forestry Commission/NRW restocking. In the past, grant aid records covered the majority of conifer restocking, but this is no longer the case. This is because grant aid ceased for restocking of conifers in England and for

Sitka spruce in Scotland. This has had the effect that any resultant non-grant-aided restocking and any wholly privately funded conifer restocking is no longer included in the administrative records. This has removed one of the main ways through which the Forestry Commission monitored restocking rates and has occurred at a time when the need to restock is high, adding uncertainty to estimates of canopy cover and woodland area. Rate of restocking is of interest because if the area being restocked is smaller than that being clearfelled and future growth rates are similar to earlier rotations, then it is likely that future volumes of timber supply from the entirety of the forest resource will decline.

Clearfelled areas may not be restocked for legitimate purposes (point 4). The application of the UK Forestry Standard will introduce open space to woodlands and planned habitat restoration will account for some differences between restock and clearfelling. For example, Scotland has approved 3,693 hectares of peat land restoration[21] up to March 2015 and the Forestry Commission across Britain approved 10.9 thousand hectares of unconditional felling licences in total between March 2000 and March 2015 to enable work such as peat land and heathland restoration (see Table 10). Of this area, the NFI has detected 2,983 hectares of clearfell to date. NRW reports that at April 2016 there was an estimated 210 hectares of woodland lost to three renewable energy developments in the form of wind farms, though this loss is planned to eventually be offset by compensatory planting.

The tree species used at restocking will also influence future productivity. This report has used fieldwork in the NFI field survey undertaken between 2010 and 2013 to analyse the composition of restocking of previously clearfelled sites with respect to species and stocked areas. However, these partial estimates can presently only be made for clearfelling in existence at 2006 and that occurring during the period 2006 to 2009, and no estimates can be made for the period 2009 to 2015 until further time has elapsed and more fieldwork is undertaken. For the areas of clearfell identified in 2006, around 51% was returned to conifer, with Sitka spruce forming the principal species. Broadleaved species form 18% of these areas and 23% is unstocked transition woodland. The remaining 8% of area resembles permanent open space that probably existed before clearfelling. These are preliminary estimates and fieldwork conducted between 2013 and 2016 will be required (at a minimum) to build a complete picture of how the 2006 clearfell sites evolved over the adopted 10 years required for classification.

For the areas of clearfell identified between 2006 and 2009, around 53% of the area has been returned to conifer, with Sitka spruce forming the principal species. Broadleaved species form 10% of these areas and 27% is unstocked transition woodland. The remaining 10% of area resembles permanent open space which apparently did not carry

[21] 3,255 hectares on Forestry Commission Scotland land and 438 hectares on other land.

trees in the previous rotation. When comparing these areas to the areas of clearfell reported it should be noted that those clearfell areas will also have contained elements of pre-existing internal open space of less than 0.5 hectare and the fieldwork restock estimates identify such small areas of pre-existing open space seperately. It should be noted that these are preliminary estimates and fieldwork conducted between 2013 and 2019 will be required (at a minimum) to build a complete picture of how the 2006 to 2009 clearfell sites evolved over the 10 years required for classification.

It will take until 2025 to ascertain the final status of all sites clearfelled between 2006 and 2015. Completion of further cycles of the NFI field survey will provide information on the species composition of the restock compared to the composition of the previous crops.

Woodland loss

The present study has confirmed that a degree of woodland loss occurs in British woodlands. Woodland loss, primarily in the form of mineral extraction and development, was identified at 2,641 individual locations across Britain, between 2006 and 2015. In addition to this, other changes were detected where woodland cover is considered at risk. This occurred at a further 696 locations in the form of ground under development and a further 274 locations through newly established habitats. [22]

The woodland loss element of these changes equated to an average of 364 hectares per year, amounting to 3,279 hectares in total for the 9 years. Of this area, 123 hectares were on sites designated as ancient woodland sites. The annual rate of woodland loss increased over the period between 2006 and 2015, with a peak in 2009/10 to 2011/12.

The principal causes of woodland loss observed were:

- mineral extraction and quarrying
- residential development
- transport development
- industrial development
- wind farm development

Over recent years anecdotal evidence suggested that the area of woodlands lost to wind farm development and habitat restoration would be higher than those reported here. The findings reported here possibly reflect that a proportion of such areas are currently

[22] A number of locations were identified as either woodland loss, ground under development and newly established habitat that occurred between 2004 and 2006. These are not included in the statistics relating to the period 2006 to 2015. These amounted to 163 locations of woodland loss, 27 locations of ground under development and 27 locations of newly established habitats.

classified as woodland in transition. This will arise because areas clearfelled for these purposes will normally not always be immediately or wholly identifiable as confirmed woodland loss in remote imagery and will consequently not be classified as woodland loss until 10 years have passed since clearfell. For example, with wind farms, the footprint of the turbines may be evident in the first year or two after felling, but how any nearby clearfelling is managed (as open, short rotation or high forest) will not become evident for 10 years or more. Such time lags between initial clearfelling and eventual land-use change could also be a reason that more subtle land-use changes, such as habitat restoration, do not currently show as highly as mineral extraction and development, with such sites not becoming evident as permanent canopy loss until the replacement habitat vegetation has established itself over the 10-year monitoring period. Thus, as time passes and the permanence of canopy removal is established beyond doubt, changes of land use other than those such as mineral extraction and development may prove to be a larger driver of loss than is currently indicated.

Indeed there are currently 16.3 thousand hectares of clearfelled land adjacent to confirmed woodland loss, ground under development and newly established habitat sites which may reflect incomplete developments and habitat restoration (see Table 11). Most habitat restoration projects take long periods of time to complete and can run for several decades and such sites will continue to resemble clearfell sites for long periods of time, especially in the uplands with lower rates of vegetation growth. NFI will continue to monitor these sites to check for eventual full conversion to another land use, resulting in woodland loss. In addition, there are 23.1 thousand hectares of land in Scotland that is currently[23] clearfelled that has planning consent for wind farm development at either the approved/active or installed stage. Further monitoring will be required to assess whether these sites revert back to woodland or represent woodland loss in the long term. Similar data is not available for England and Wales.

Similarly there are around 17.4 thousand hectares of land that is clearfelled on ancient woodland sites (see Table 8) which could represent standard clearfell and restock management, PAWS restoration or woodland loss. Further monitoring will be required to assess if these sites revert back to woodland or prove to be woodland loss.

The above findings relate to the period 2006 to 2015. The report also provides estimates in Appendix A of the extent and cause of loss over the period 1996 to 2006. These estimates were derived from a comparison of the NFI and NIWT maps to identify woodland loss (see Table 24). The methodology used is recognised as likely to underestimate woodland loss, but nevertheless provides the best available estimate for the period 1996 to 2006 and should be broadly indicative of what occurred. At 240 hectares per annum, the average amount of woodland loss between 1996 and 2006 is

[23] Based on planning consents issued to March 2016 and clearfelled to March 2015

less than estimated for 2006 to 2015 of 364 hectares per annum. However, the causes of woodland loss are broadly similar to those found in the 2006 to 2015 period and demonstrate a degree of consistency between the two different assessment methods. More information is provided in Appendix A.

New windblow

There were 4,113 hectares of new windblow detected across Britain in the period 2006 to 2015. Of this, 3,787 hectares were in Scotland, 186 hectares in England and 140 hectares in Wales. This period covered the winter storms of 2013/14, including the St Jude's Day storm. The St Jude's Day storm epicentre was across the southeast of England, yet extensive damage was not observed in this area. This finding is confirmed by the results of a field survey undertaken by NFI and Forestry Commission England to assess storm damage at the time. That survey found extensive low-level damage which would be undetectable in imagery. It found that damage occurred to many trees, but these were spread thinly over an extensive area: 36 million trees were damaged or lost in the southeast of England, but this damage was distributed thinly across 605 thousand hectares. Such low levels of damage to the canopy are not detected in satellite imagery, but can still have an impact on canopy cover. For more information see *Survey of the impact of the 2013 St. Jude's storm on woodland in Southern England* report.

The amount and distribution of damage set out in this report demonstrates that it was the later storms in December 2013 and January 2014 that had more impact than the St Jude's Day storm, with the highest levels of damage found over the period in the west of Scotland. The St Jude's Day storm that hit the south and west of England and the storm that caused the tidal surge that hit much of the east coast in 2014 had a much lower impact on woodland.

As these estimates are based on observations of change from satellite imagery taken between 2006 and 2015, they will exclude any woodland area already windblown before 2006 that had not been cleared at that point, or any sites that had established new vegetation cover. The estimates provided will therefore be an underestimate of the total area of woodland that is windblow since the estimates exclude most windblow occurring before 2006. The estimates will also exclude areas of windblow that were cleared rapidly between 2006 and 2015, which will have been identified and accounted for in the report as clearfell or restock. They will also exclude areas of windblow of less than 0.5 hectare in extent and areas where windblow has only occurred to a low proportion of the canopy.

For comparison, NIWT identified a total windblow area of 3,668 hectares in 1998, which is broadly of the same order of magnitude as the amount found over the 9-year period 2006 to 2015. Initial analysis of the NFI fieldwork on the cumulative amount of windblow currently in woodlands (of all ages, types and sizes) indicates an area in excess of both these estimates. Later NFI reports will publish these findings.

The net outcome of canopy change on woodland area over the period

If canopy loss endures for 10 or more years it impacts permanently on woodland area[24]. The report has found strong evidence of 3,279 hectares of woodland loss over the 9 years of the study, an average of 364 hectares per annum. During the same period, reported new woodland creation through new planting has averaged 9.2 thousand hectares per annum, giving a total of 83.2 thousand hectares over 9 years. Thus the area of woodland gain has exceeded the area of confirmed woodland loss so far identified in the period, resulting in a net gain in woodland area (83.2 thousand hectares of new planting less 3.3 thousand hectares of woodland loss). This has led to an increase of around 80 thousand hectares in Great Britain's woodland area through the period. This finding is in agreement with previously published estimates of woodland area (for more information see www.forestry.gov.uk/forecast).

Alongside this reported net growth in woodland area between 2006 and 2015 there has been 188 thousand hectares of additional clearfelling identified in the same period. There is a presumption that this area will be restocked and maintained as woodland area and thus will not impact on woodland area overall. However, open space creation, woodland restructuring and development may, in reality, eventually result in a portion of this area being converted to other land uses. Indicative of this possibility, there are 16.3 thousand hectares of clearfell sites adjacent to existing sites of woodland loss, newly established habitats and ground under development, and 23.1 thousand hectares of clearfell in areas with planning consent for wind farm establishment at either approved/active or installed stage.

To date the NFI fieldwork has established that 69% (75 thousand hectares) of the 109 thousand hectares identified as clearfelled in 2006 has been restocked. This leaves 25 thousand hectares or 23% of the clearfell area not restocked. The remaining 9 thousand hectares or 8% of the original 109 thousand hectares is composed of pre-existing permanent open space.

Similarly 63% or 17.9 thousand hectares of the 28.6 thousand hectares of new clearfell identified between 2006 and 2009 has been restocked. This leaves 7.8 thousand hectares or 27% of the clearfell area not restocked. The remaining 2.9 thousand hectares or 10% of the original 28.6 thousand hectares is composed of pre-existing permanent open space.

These areas are still only part way through the adopted 10 years allowed for canopy establishment after felling, and as time passes the amount of stocked area within these areas is likely to increase. Conversely, some of the remaining unstocked area may

[24] Sometimes longer periods are permissible, for example where natural regeneration is used to re-establish canopy.

eventually become areas of woodland loss, but this cannot be confirmed at present. Confirmation will eventually come from the results of future fieldwork, which will establish the final proportion of permanent open space introduced after clearfell in the monitoring period. Therefore, taking these factors into account, it is too early to draw absolute conclusions on the net long-term impacts on woodland area of the last 9 years of activity in woodlands, as many final outcomes on canopy change and woodland area loss have yet to be determined.

Alongside the present net picture of woodland area gain, consideration should also be given to what type of woodland is being lost and gained. This report provides estimates of the types of woodland lost, including the amount of ancient woodland lost. There were 123 hectares of ancient woodland lost over the period, an average of 14 hectares per annum. These estimates cover ancient woodland of over 2 hectares in extent (the current definition) and for areas of loss greater than 0.5 hectare in extent. If the definition of ancient woodland were revised to cover smaller ancient woodland areas, or if smaller areas of loss were to be included, the overall area of loss would logically be greater. Also, if woodland loss was included from woodland areas identified in either the 1860 Ordnance Survey map for Scotland or the Roy map alone (LEPO, types 1b and 2b) and other types of woodlands on 'Roy' sites (type 3), the total amount would be 453 hectares greater. These estimates will change as sites currently clearfelled develop over time. The area of ancient woodland clearfelled and apparently not yet restocked (according to remote imagery) in 2015 is 17.4 thousand hectares. Over time a proportion of these areas will experience restoration of canopy while others may eventually be identified as woodland loss.

The types of woodland lost are broadly proportionate to their proportion of total woodland area, with no one type of woodland being disproportionally impacted. For example, in England where there are more broadleaved woods than conifer woods, it was mostly broadleaved woodland that was lost. Scotland, with a high proportion of coniferous woodland, experienced greater losses in this class. Equally, other classes, such as ancient woodland, were also lost, with only a small reduction in their proportionate share of loss (proportionately 35% less by area). Further detailed appraisal of the types of woodland lost, with a view to placing different values on different categories of woodland could consider the following categories:

- ancient woodland loss
- losses from plantations
- losses from recently established woodland
- losses from natural colonisation
- losses from woodland areas in urban environments

This report has not reported losses within all these categories, but initial analysis at a national level points to the broad conclusion that rates of loss are proportionate across all such categories.

The majority of woodland loss detected by the NFI occurred within woodlands identified by the 1995 NIWT survey as woodland. Therefore, the majority of woodland losses were in woods at least 20 years old when the loss occurred and most were probably somewhat older. However, a proportion were losses of younger woodland, and these areas represent an amount of short-term woodland colonisation and loss. Such loss of newly established woodland is technically woodland loss, but may not have the same value attached to it as the loss of older or ancient woodland.

In terms of overall woodland loss, the levels in any one year are relatively low compared to total woodland area (about 0.011% per annum) and are smaller than the area of new woodland that was established (around 0.3% per annum), the overall result being that Britain has been slowly gaining woodland area in recent years. However, this provisional conclusion needs to be tempered by the possibility that slower, harder to observe conversion of existing woodland to other land uses and habitats is not yet fully accounted for, and this has the potential to alter the overall conclusion on net change in woodland area.

The results show an interesting difference in the principal causes of canopy loss between canopy loss inside woodlands and that at the edge of woodlands. The evidence to date points to canopy loss inside woodlands being dominated by conversion to open habitats. Conversely canopy loss at the edge of woodlands is quite different and tends to be dominated by conversion to built facilities such as quarries, residential areas and industrial developments. So, while the findings point to habitat restoration changing woods from within, development activity appears to change them at their edges.
There is partial information on what the areas of clearfell that occurred within the reporting period will convert to, in relation to what proportions will be conifer, broadleaved, open, or conversion to other land use. At the start of the assessment period (2006) conifers occupied 49% of the woodland map while broadleaves covered 42%. By the end of the period (2015) identifiable conifer coverage in the NFI map had fallen to 41%, while the broadleaved share remained at 42%. This is not surprising since almost 99% of all clearfelling was in conifers and thus they will be the type of woodland that is most exposed to change. Since earth observation underestimates restocking it is likely that this conifer percentage is an underestimate if we assume that conifer sites are restocked with conifers. The current findings of the NFI fieldwork show that the clearfell identified in 2006 and between 2006 and 2009 has so far had 68% of the area restocked and that this restocked area contains 76% conifer and 24% broadleaves. As the monitoring period progresses, assessment of the currently remaining unstocked area will allow for a full estimate of final stocking to be made.

Woodlands at the start of the monitoring period contained 75 thousand hectares of permanent open space of over 0.5 hectare in extent[25] (see Table 4) and probably about 9% of woodland area, or around 250 thousand hectares, of internal open space of less than 0.5 hectares in extent. Whether the observed increase in clearfelling results in an eventual larger area of permanent open space within woodland cannot yet be determined. Later NFI reports that include the results from future fieldwork will be able to assess any such changes more definitively.

In conclusion, the results reflect a period of significant change in British forests where large areas of conifer woodlands are coming to maturity and are being clearfelled. This has resulted from a large planting programme in the past that has produced a supply of mature stands that are ready for harvesting in the present period. This is producing a current boost in growth to the timber processing sector and the forest industry as a whole. An important consideration relevant to assessing if this growth in the British timber industry can be sustained in the long term, is whether the stands currently being felled are being restocked in a form and to an extent that preserves or enhances their productivity in timber terms. Currently adopted policies for forest restructuring, financial incentives for restocking, levels of new planting, the introduction of genetically improved stock and the creation of open space within woodland are all relevant to answering this question. Measuring how all these factors balance out over time will provide the evidence as to whether the trees felled today are being replaced at a commensurate rate to maintain future timber productivity.

This report confirms the increasing and significant amount of clearfell that is occurring and that the partial evidence on restocking to date supports the supposition that the composition of woods is changing. However, it is too early to conclude on a complete picture of the long-term impact of recent practice in the restocking of clearfelled areas, which will require the sites currently clearfelled to develop further and the results of future fieldwork.

The evidence presented here and that which will arise from future work will inform policy and practice, along with policy and planning tools such as the Forestry Commission production forecasts. The current results allow initial conclusions and inferences to be drawn and future work will more definitively establish whether the woodland resource currently being felled is being replaced with woodland of an equivalent nature and economic value. This work will provide an important part of the evidence required to inform future policy and practice on how best to achieve a sustainable forest resource in the long term.

[25] Such areas of over 0.5 hectare surrounded by woodland are referred to as "Interpreted open area" (IOA) and are not included in woodland area.

Glossary

Aerial photograph	Photographs of the ground taken from an elevated/direct-down position, with a camera that is not supported by a ground-based structure.
Ancient woodland	Ancient woodlands in Britain are woodland areas which have been continuously wooded since AD 1600 in England and Wales and since AD 1750 in Scotland.
Area (forest/woodland)	Forest and woodland area can be defined in net or gross terms. Net area is the land actually covered by trees (in the NFI that is to the drip line of the canopy). Gross area includes both the area covered by trees and the open spaces (<0.5 hectare) within (e.g. rides, glades, ponds).
Broadleaves	Trees and shrubs that belong to the angiosperm division of the plant kingdom (as distinct from the gymnosperm division that includes conifers). Most in the UK have laminar leaves and are deciduous. Sometimes referred to as 'hardwoods'.
Canopy cover	Area covered by a mass of foliage and branches formed collectively by the crowns of trees.
Clearfell area	Area where all trees have been felled at once. In non-clearfell areas, only some of the trees are felled at any one time.
Clearfelling	Cutting down of an area of woodland (if it is within a larger area of woodland it is typically a felling greater than 0.25 hectare). Sometimes a scatter or small clumps of trees may be left standing within the felled area.
Conifers	Trees and shrubs that belong to the gymnosperm division of the plant kingdom (as distinct from the angiosperm division that includes broadleaves). Conifers mostly have needles or scale-like leaves and are usually evergreen. Sometimes referred to as 'softwoods'.
Definiens eCognition software	eCognition is object-oriented image analysis software which allows images to be segmented in a process that converts individual pixels into homogeneous objects.
Diameter at breast height (DBH)	The diameter of a tree (overbark) at breast height, which is usually defined as 1.3 metres along the axis of the stem from the ground.
Forest	Land predominately covered in trees (defined as land under stands of trees with a canopy cover of at least 20%, or the ability to achieve this, and with a minimum area of 0.5 hectare and minimum width of 20 metres), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts).
Forestry Commission (FC)	The government department responsible for the regulation of forestry, implementing forestry policy and management of state forests in England, Scotland and (until 31 March 2013) Wales. Forestry policy is devolved, with the exception of common issues, addressed on a GB or UK basis, such as international forestry, plant health and forestry standards.
Grant Schemes	Government funding programme that provides financial support to private owners to plant and maintain new areas of woodland.
Great Britain (GB)	England, Scotland and Wales.

Interpreted forest type (IFT)	Interpreted forest type is a classification of woodland into woodland types as identified from aerial photography and satellite imagery.
Interpreted open area (IOA)	Interpreted open area is a classification of open spaces within woodlands as identified from aerial photography and satellite imagery.
National Forest Inventory (NFI)	An inventory run by the Forestry Commission, set up in 2009, to provide a record of key information about GB forests and woodlands.
National Inventory of Trees and Woodlands (NIWT)	An inventory run by the Forestry Commission, set up in 1995 and completed in 2002, to provide a record of key information about GB forests and woodlands.
Natural regeneration	Area predominantly composed of trees established through development of tree seeds.
Natural Resources Wales (NRW)	The body responsible for advising the Welsh Government on the environment, created on 1 April 2013. NRW is responsible for the functions previously undertaken by the Environment Agency in Wales, the Countryside Council for Wales and Forestry Commission Wales. The woodland referred to in this report as 'NRW' relates to the woodland previously managed by Forestry Commission Wales.
New clearfell	Areas of clearfell identified within the NFI woodland map in the current annual update.
New planting	Area in which trees have been directly seeding or has been planted with young tree stock.
Normalized Difference Vegetation Index (NDVI)	An index of plant greenness or photosynthetic activity. NDVI is calculated by NDVI = RNIR-RRed / RNIR+RRed, where RNIR and RRed are spectral bi-directional reflectance factors at near-infrared and red wavelengths respectively.
Phytophthora ramorum	Fungus-like pathogens that can cause extensive damage and mortality to trees and other plants.
Private sector estate	Forests and woodlands in GB not owned or managed by the Forestry Commission or Natural Resources Wales. In the context of the Forestry Commission publications, 'Private sector' is used for convenience although it includes land owned or managed by bodies such as local authorities and charities.
Restocking	Planting trees on areas that have had a tree crop that has been recently harvested.
Satellite imagery	Imagery of the Earth taken from space from a satellite.
Standard error (SE)	The measure of the margin of error associated with an estimate as a result of sampling from a population with statistical variability. Larger standard errors indicate less precision in the estimate. Standard errors in this report are quoted in relative terms (i.e. as percentages of the value of the estimate).
Stocked area	The area stocked with living trees. The stocked areas in this report are quoted in gross terms for the FC/NRW estate and in net terms for the Private sector estate (see definitions of Area above).
Sub-compartment database (SCDB)	A database owned and maintained by the Forestry Commission that holds an inventory of all stands of trees managed by the Forestry Commission (including that formerly managed by Forestry Commission Wales, that is now managed by Natural Resources Wales)

Windblow	Uprooting of trees by the wind. Windblow can be endemic – i.e. that caused by frequently recurring peak winds – or catastrophic – an infrequent occurrence associated with exceptionally strong winds where large areas/numbers of trees are blown down.
Woodland loss	Area previously accounted under forestry land use that has been converted to another land use. Such conversion can be caused and maintained by either a continued human-induced or natural perturbation action.

Appendixes

Appendix A: NFI (2006) and NIWT (around 1996) comparison

National Inventory of Woodland and Trees

The National Inventory of Woodland and Trees (NIWT) woodland map covers all forest and woodland over 2 hectares with a minimum of 20% canopy cover (or the potential to achieve it) in England and Wales and a minimum of 50% canopy cover (or the potential to achieve it) in Scotland, including new planting, clearfelled sites and restocked areas, and a minimum width of 50 metres. Intervening land classes such as active railways or roads surfaced with tarmac or a similar material are included if less than 50 metres in extent.

In Scotland, the woodland map was a product of the Land Cover of Scotland (LCS) 1988 project, which used 1:24,000-scale aerial photography to create a land-use cover map. The woodland components of this dataset were extracted to provide the basis for the woodland boundaries and then differentiated into interpreted forest types (IFTs) of 1 hectare and over. In England and Wales, the woodland map was derived from 1:25,000-scale stereo colour aerial photography flown between 1991 and 1999. Both maps were then updated to 1995, in Scotland, and 1998, in England and Wales, incorporating new planting based on Woodland Grant Schemes information and Forestry Commission first rotation new planting information from its Sub-compartment database.

The NIWT map was subsequently updated three times, referenced to 31 March 2000, 2001 and 2002, using updated information on Forestry Commission new planting and Grant Scheme boundaries.

How NIWT was compared to NFI to determine woodland loss estimates

To better understand the reasons behind the area differences between the two woodland maps, a comparison was carried out. This work identified and classified areas that were present in the NIWT woodland map and were not present in the NFI woodland map. Areas were validated and put into the categories listed in Table 23.

Table 23 NFI and NIWT comparison categories

Category	Description
Methodology difference	Areas under this category are due to differences between NIWT and NFI woodland maps with regard to the mapping rules, mapping techniques and the technology available to each operation.
Land-use change	Areas under this category are due to verified and permanent change of land use from forestry to non-forestry observed by comparison of the photography used for the NIWT and NFI maps.
NFI missed woodland	Areas under this category were correctly mapped by NIWT as woodland area (including grant scheme and low density woodland), and incorrectly identified as non-woodland in the NFI map. This information was used to correct subsequent versions of the NFI map.
NIWT error	Areas under this category represent misinterpretation of the imagery available to NIWT, which erroneously identified these areas as part of woodland area, whereas NFI correctly identified them as non-woodland.
Not determinable	Areas under this category were mapped by NIWT as woodland but show no evidence of woodland in the latest (NFI) imagery and insufficient evidence of woodland in the earlier (NIWT) imagery.

All areas in size classes greater than 1 hectare were validated and categorised based on the most recent aerial photography available, archive aerial photography (where available) and other external sources (e.g. Google Earth). For the size classes of less than 1 hectare, a sample of polygons was assessed and the results from these samples were scaled up on the basis of the ratio of the area of the sampled polygons to the area of all polygons in the size class within each country. Most of these samples were randomly selected, but also included assessments for some polygons in these size classes when they occurred in proximity to larger polygons that were being assessed.

Across Great Britain as a whole, the sampling fraction on the area basis described was 23.4% for polygons in the 0.5–1.0-hectare size class, and 8.2% for polygons of less than 0.5 hectare. The scaling up from the sample results to the full population was performed using individual sampling fractions for each of these two size classes and for each of England, Scotland and Wales.

Results

Table 24 provides estimates of areas validated and categorised as land-use change that occurred between the provenances of the two woodland maps.

Table 24 Woodland land-use changes broken down by country identified between the NIWT and NFI inventories

	Enumerated			Scaled-up estimates		Total area ☐
	Areas ≥ 20 ha (ha)	Areas > 5 & ≤ 20 ha (ha)	Areas > 1 & ≤ 5 ha (ha)	Areas > 0.5 & ≤ 1 ha (ha)	Areas ≤ 0.5 ha (ha)	(ha)
England						
Residential area	54	67	151	12	11	**295**
Mineral extraction area	13	44	108		8	**173**
Other		3	135	3		**141**
Golf course buildings and grounds	39	11	39			**89**
Water feature	1	15	59	2	3	**80**
Industrial buildings and grounds	4	11	54	0		**69**
Recreational buildings and grounds		20	15		6	**41**
Cropped land			35			**35**
Restoration			15		7	**22**
Car park		3	12		2	**17**
Agricultural buildings			7			**7**
Retail buildings and grounds			1			**1**
Total	**112**	**174**	**631**	**17**	**36**	**970**
Scotland						
Wind farm	354	2	2			**358**
Residential area	43	94	169	4	1	**310**
Mineral extraction area	58	47	52			**157**
Industrial buildings and grounds		54	50	1	3	**107**
Other	33	13	57			**103**
Cropped land		11	54		3	**68**
Golf course buildings and grounds		21	21			**42**
Recreational buildings and grounds		19	21		0	**40**
Water feature		1	17	0		**18**
Agricultural buildings	1	1	7			**8**
Car park	1		5			**6**
Restoration			2	3		**5**
Total	**490**	**261**	**456**	**8**	**7**	**1,221**
Wales						
Mineral extraction area	31	20	8	6	5	**69**
Residential area		31	16	4		**50**
Golf course buildings and grounds	33					**33**
Recreational buildings and grounds			12			**12**
Industrial buildings and grounds			7		4	**11**
Other			10			**10**
Wind farm		6				**6**
Agricultural buildings			6			**6**
Cropped land			4			**4**
Car park			4			**4**
Water feature			1	2		**3**
Restoration			2			**2**
Total	**63**	**57**	**70**	**11**	**8**	**209**
Great Britain						
Residential area	97	191	336	20	12	**655**
Mineral extraction area	102	110	169	6	12	**399**
Wind farm	354	8	2			**364**
Other	33	16	202	3		**254**
Industrial buildings and grounds	4	64	112	1	6	**188**
Golf course buildings and grounds	72	32	60			**164**
Cropped land		11	93		3	**107**
Water feature	1	15	77	4	3	**100**
Recreational buildings and grounds		40	47		6	**93**
Restoration			19	3	7	**29**
Car park	1	3	21		2	**27**
Agricultural buildings	1	1	19			**20**
Retail buildings and grounds			1			**1**
Total	**665**	**491**	**1,157**	**36**	**52**	**2,401**

Appendix B: Satellite imagery techniques employed to detect canopy change

The process to identify canopy change from satellite imagery is semi-automated and utilises sophisticated GIS-based computer analysis. Definiens eCognition software is used to segment and classify the satellite images into homogeneous groups of objects and to calculate for each object the Normalized Difference Vegetation Index (NDVI). As NDVI is sensitive to the amount of foliar biomass, this routine was effective in the identification of clearfelled areas, wind damage, infestations and low stocking. The classification analysis was focused on areas initially classified as high forest areas in the woodland map.

An NDVI threshold value was set to identify areas of high forest subject to canopy change and these were classified as 'change' areas. Change areas were subject to further analysis to confirm the nature and extent of the canopy loss, with the woodland map updated accordingly.

Four further updates to the satellite imagery produced in 2009, 2012, 2014 and 2015, were used to monitor canopy cover changes. Areas identified as clearfell in 2006 and that have subsequently been identified as containing tree cover were also updated. For more detailed information about the range of dates for the satellite imagery used across Britain, see Table 26 in Appendix C.

In Table 5, where a 'running tally' of clearfell arising in the monitoring period is presented, the areas of new clearfell identified in the satellite imagery are designated as new clearfell. In subsequent years this clearfelled area is added to the apparent woodlands in transition category.

Areas classified as apparent woodlands in transition remain in this category until they show evidence of restocking in the imagery, or are classified as woodland loss if 10 years elapses with no evidence of restocking having taken place. At this point they will be removed from the apparent woodlands in transition category. In some circumstances, a site can be apparently devoid of canopy for longer than 10 years without being classified as undergoing land-use change; an example would be in a natural regeneration site that is given more time to establish.

During the annual update of the NFI map, a proportion of the existing apparent woodlands in transition are re-assessed to determine if these areas have been replanted or regenerated. This process will continue until all apparent woodlands in transition have been validated using fieldwork, satellite imagery or aerial photography. This validation is first undertaken once 7 years have elapsed. This lag between the identification of a clearfell area and validation is to allow for the time between felling and planting or

regeneration to occur (usually between 2 and 7 years), and to allow for the trees to grow large enough to be observable in imagery as either having achieved 5 metres in height or have been established. Once the trees have established it can take between 7 and 14 years for them to be large enough to be identifiable using photography. This longer time-frame is particularly relevant in deciduous stands, where the trees have lighter crowns, slower growth rates and, through their deciduous nature, lose leaves in winter.

The different growth rates of each individual tree species, combined with the 3 to 5-year update cycle of aerial photographs, results in a natural lag in the re-assessment of existing woodland in transition. This time lag for detection leads to an overestimation of woodland in transition in the satellite imagery at any one point in time and the results from this process are accordingly referred to as 'apparent' woodland in transition in this report. It requires the NFI fieldwork to identify the trees too small to identify in imagery. The information gathered during fieldwork is used to calibrate and/or interpret the imagery-based map data. The clearfell estimates in Table 5 contain both 'new clearfell' and 'apparent woodland in transition' and demonstrate the difference between the two techniques for assessment, when compared to Table 6. They also provide a broad proxy for an indicative conversion of satellite-identified clearfell and woodland in transition area to an actual confirmed area of clearfell 'on the ground'. The rates of new clearfell in this report are estimates based upon the satellite imagery data only.

In this report, the period between the two sets of satellite imagery used to derive the estimates was longer than one year for some periods; thus for some assessments the amount of new clearfell identified arose over several years. To allow for annual change trends to be derived an average amount of within-period change per annum was calculated. The time-lapses between successive imagery range from 1 to 3 years and the new clearfelled areas identified within a period could have occurred at any point within that period. The length of time between successive imagery can sometimes result in underestimating the amount of clearfell. For example, areas that were clearfelled early in the period may not be identified as new clearfell in the imagery as they could already have experienced further change, such as having already been restocked or otherwise lost to another land use. In more fertile areas these longer gaps between the imagery may have led to some clearfell sites having enough time for non-woody vegetation to colonise to the extent that the sites are missed by the detection routines. This will lead to a degree of underestimation of clearfelled areas, but should be restricted to where time-lapses in imagery exceed 2 years, which is increasingly rare.

Appendix C: Aerial photographs and satellite imagery metadata

Table 25 sets out the age of aerial photographs used to build the 2006 base NFI map by country and Table 26 sets out the age of satellite imagery used to update the NFI map.

Table 25 Aerial photography dates by country used for the 2006 baseline woodland map

Year flown	% of coverage		
	England	Scotland	Wales
1999	2		
2000	1		
2001	2		
2002	4	2	
2003	9	4	
2004	7	19	
2005	27	36	
2006	31	16	100
2007	13	8	
2008	4	7	
2009		8	

Notes for Table 25:

1. The full 2006 aerial photograph coverage of Wales was provided to the Forestry Commission by the Welsh Assembly.

Table 26 Satellite imagery dates by country used for woodland map updates

	Year flown range	
	Oldest imagery	Newest imagery
2006 satellite imagery	March 2005	April 2007
2009 satellite imagery	April 2008	September 2010
2012 satellite imagery	April 2011	September 2012
2014 satellite imagery	February 2014	April 2014
2015 satellite imagery	May 2015	July 2015

Appendix D: Woodland mapping categories

Table 27 NFI woodland map categories

Interpreted forest type (IFT)	
Assumed woodland	Ground prepared for planting
Broadleaved	Low density
Cloud/shadow	Mixed mainly broadleaved
Conifer	Mixed mainly conifer
Coppice	Shrub
Coppice with standards	Uncertain
Failed	Windblow
Felled	Young trees
Permament woodland loss	
Cemetery and crematoria area	Other utilities and infrastructures
Communal residential area	Public car park
Community service buildings and grounds	Recreational and leisure buildings and grounds
Cropped land	Residential area
Cropped land with woody perennial crops	Retail buildings and grounds
Golf course buildings and grounds	Road or railways
Ground under development	Tracks or paths
Industrial buildings and grounds	Urban/Buildings
Landfill	Water feature
Mineral extraction area	Water storage and treatment area
Other energy production and distribution areas	Waterways
Other transport infrastructures	Wind farm
Other established habitats	
Bare area	Grassland
Other vegetation	

Appendix E: Woodland maps

Figure 13 Woodlands in transition and new clearfell identified within the NFI woodland map as at March 2015

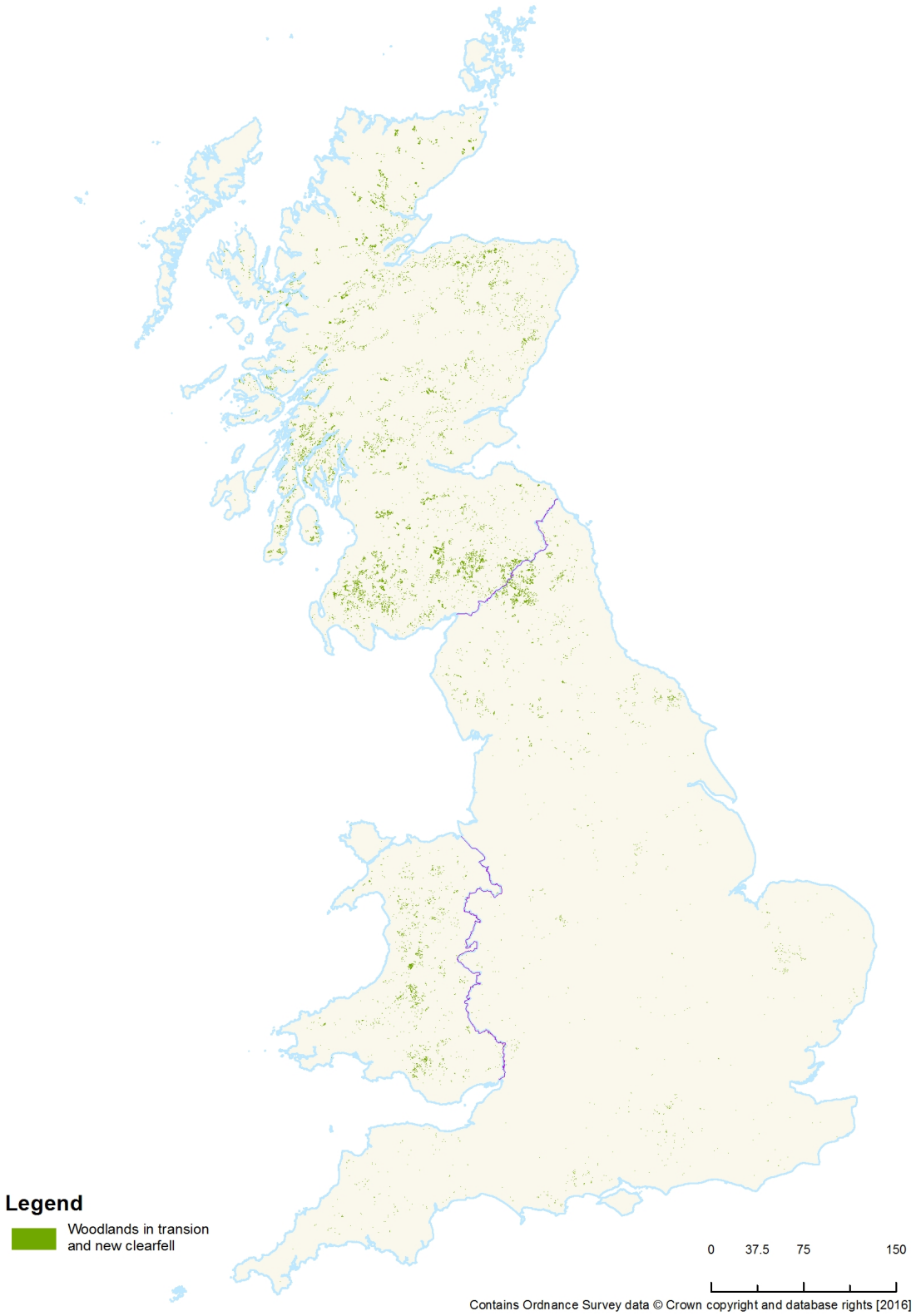


Figure 14 Windblow identified within satellite imagery 2006–15

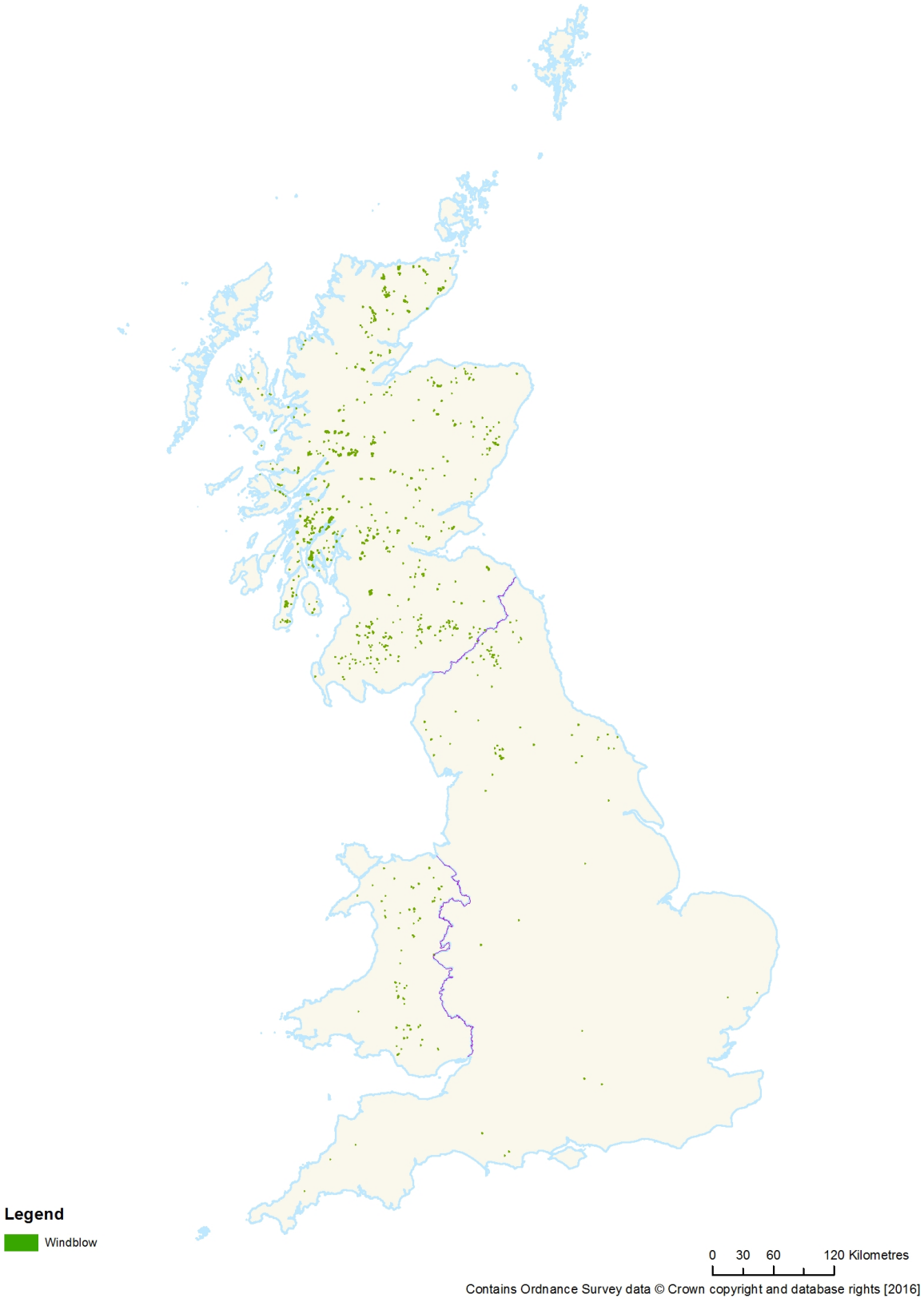
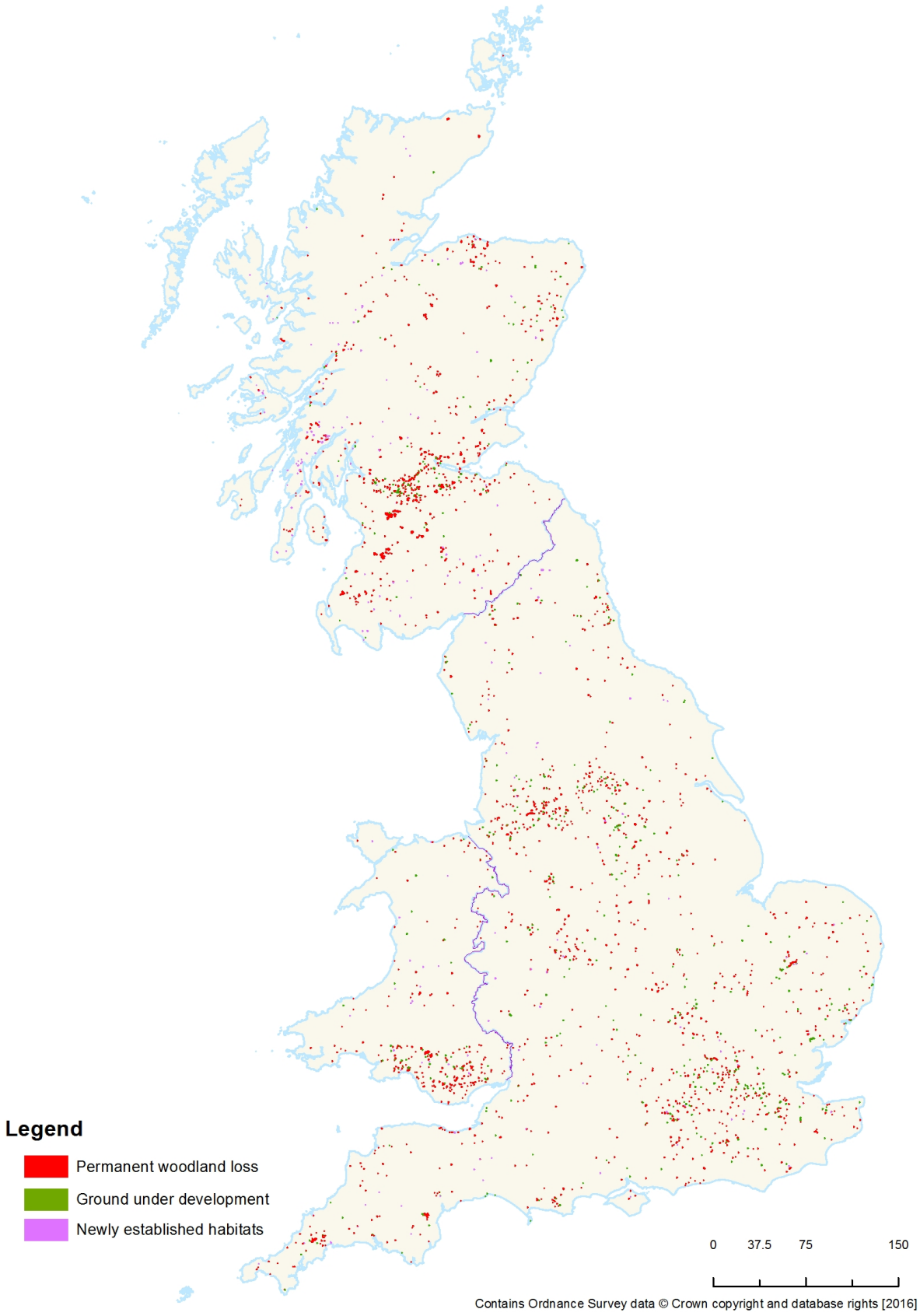


Figure 15 Canopy loss in Great Britain identified within the NFI woodland map 2006–15



Appendix F: Woodland loss examples

Figure 16 An example of permanent change in canopy cover with the conversion of a woodland area into a mineral extraction area

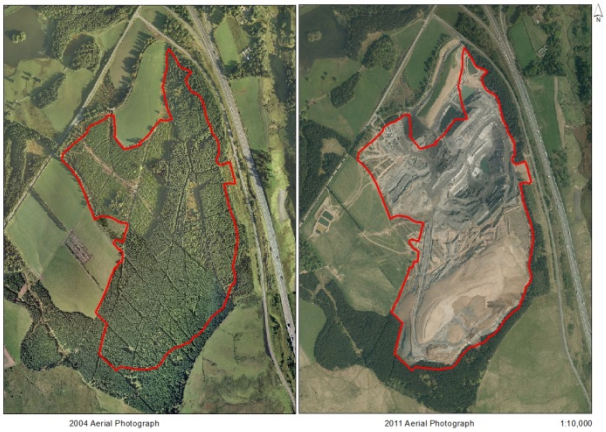
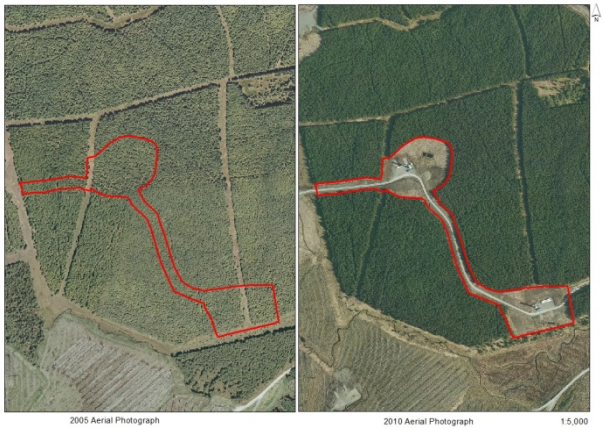


Figure 17 An example of permanent change in canopy cover with the conversion of a woodland area into an energy production and distribution area

Figure 18 An example of permanent change in canopy cover with the conversion of a woodland area into a wind farm area



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NFI national reports and papers

This report concerns aspects of the changing size, structure and composition of British forests. NFI reports that contain information relating to these areas are:

- NFI Woodland Area Statistics, Great Britain, England, Scotland, Wales (2011)
- 25-year forecast of softwood timber availability (2012)
- 50-year forecast of softwood timber availability (2014)
- 50-year forecast of hardwood timber availability (2014)
- 25-year forecast of softwood timber availability (2016)

Each theme has a series of associated reports, papers and data, tailored for different audiences and uses.

All these documents and data can be found on the NFI website www.forestry.gov.uk/inventory.

Official Statistics

This is an Official Statistics publication. More information about Official Statistics and the UK Statistics Authority is available at www.statisticsauthority.gov.uk

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Reviewed by

For a list of the 33 people who assisted in the quality assurance of these statistics please see Pre-release Access to Official Statics for Quality Assurance document available on the Forestry Commission website www.forestry.gov.uk/forestry/infd-83mfrz.