The Second National Forest Inventory

Republic of Ireland

Main Findings

Department of
Agriculture,
Food and the Marine
An Roinn
Talmhaíochta,
Bia agus Mara

The Second National Forest Inventory – Republic of Ireland – Main Findings

Covering the National Forest Inventory, 2009 to 2012

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List of Abbreviations

BFC	British Forestry Commission
CI	Confidence Interval
Dbh	Diameter at breast height
FAWS	Forest Available for Wood Supply
FWPM	Fresh Water Pearl Mussel
IFER	Institute of Forest Ecosystem Research
NFI	National Forest Inventory
NHA	National Heritage Area
OLL	Other Long-Lived Species
OSL	Other Short-lived species
SAC	Special Area of Conservation
SFM	Sustainable Forest Management
SPA	Special Protection Area

1 INTRODUCTION

The purpose of the National Forest Inventory (NFI) is to record and assess the extent and nature of Ireland's forests, both public and private, in a timely, accurate and reproducible manner to enable the sustainable development of our forest resource. Reliable, current and consistent information is required to inform domestic forest policy, to support forest research and fulfil national and international reporting commitments.

Between 2004 and 2006 the Forest Service carried out the first NFI of Ireland's forests, with results published in 2007. The 2006 NFI was the first purely statistical approach to forest inventory undertaken in Ireland to provide an assessment of growing stock in both the public and private national forest estates.

In order to assess changes in the state of Ireland's forests over time, Ireland's NFI was designed using permanent sample plots which facilitated a repeat measurement programme. This robust reporting strategy was adopted to provide credible information to address strategic objectives and reporting commitments (Figure 1). The fieldwork for the second cycle of the NFI began in 2009 and was completed in 2012.

Figure 1. NFI International reporting obligations.

The NFI provides information to monitor Sustainable Forest Management (SFM) and data to support forest policy, specifically in relation to:

- Growing stock;
- Harvesting;
- Increment;
- Carbon;
- Forest area;
- Species composition;
- Forest biodiversity; and
- Forest health and vitality.

This document presents a compact and comprehensive overview of the results of the 2012 NFI along with a comparison of results with the 2006 NFI. Two other NFI publications are available, namely:

- NFI Field Procedures and Methodology;
- NFI Results.

Both documents are available at: http://www.agriculture.gov.ie/nfi/.

2 SURVEY METHODS

The NFI involved a detailed survey of permanent forest sample plots based on a randomised systematic grid sample design. A grid density of 2km x 2km provided sufficient forest plots to achieve a national estimate of volume with a precision of ± 5%, at the 95% confidence level. This grid density equated to 17,423 points nationally, each representing approximately 400 hectares (ha). Each circular NFI sample plot measures 25.24 metres (m) in diameter, comprising 500 m², and is permanent in nature to allow future re-sampling as required.

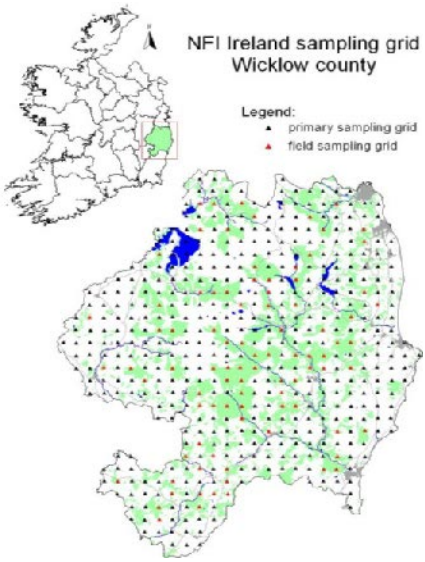


Figure 2. NFI grid design.

An initial desk study was carried out to identify land-use type, including forest areas, at each of the sample points using aerial photos and existing digital maps of forests. As the grid is permanent, it allows for the re-assessment of these primary sample points at future dates, to monitor forest land-use change e.g. afforestation.

Figure 3. Aerial photo interpretation.

In the field survey at each sample plot a variety of primary attributes were assessed, from the tree top to the soil underneath. For example, information was collected on: tree growth and development, the diversity of plant species and soil type.

The underlying technology used in the NFI, Field-Map consisted of an integrated system of hardware and software developed by the Institute of Forest Ecosystem Research Ltd (IFER). It allowed for the preparation of a NFI database, background maps, and plot generation. This in turn allowed for the creation of projects for field teams, which facilitated the field data collection process.

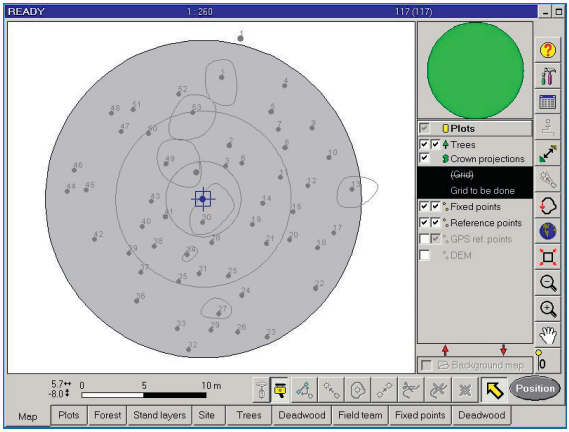


Figure 4. NFI field data collection software.

To carry out the data collection work, the Forest Service recruited professional foresters, with six foresters working in the field at any one time. In total, 1,742 forest plots were assessed throughout the country in the 2006 NFI. Due to the expansion of the forest estate, additional plots were assessed in the 2012 NFI; bringing the total number of NFI plots to 1,827. Training, field team support, validation and other quality control procedures were undertaken by two staff to ensure data quality and the smooth running of field operations.

Figure 5. Field data collection.

Following the completion of field data collection work, primary data pre-processing and data analysis were completed. During data pre-processing the validity of the data was checked and data values were amended where necessary. Secondary variables, such as volume increment, were also calculated. Forest attributes (e.g. ownership) are used to classify evaluated variables (e.g. area) through the calculation of statistics (e.g. totals and/or means).

3 DATA PROCESSING

The analysis and results generation for the 2012 NFI were undertaken in 2013 by the Forest Service, in close collaboration with the IFER. During this second NFI, all forest sample plots were re-assessed which not only provided current estimates for forest attributes but also allowed direct comparison with the previous NFI 2006 results.

3.1 PRESENTATION OF RESULTS

The analysis software (Field-Map Inventory Analyst) produces standardised tables and charts for reporting purposes. As errors are associated with all forms of sampling, most tables detail the calculated statistics with associated confidence intervals (α=0.05). The confidence interval quantifies the uncertainty in measurement by specifying the range of values within which the true value for the whole population lies. As a 95% confidence interval is used for the NFI analysis, there is a 95% probability that the true value for the population lies within the range of values. Only sampling error is included in the confidence interval, modelling errors (e.g. volume estimation) and measurement errors (e.g. Dbh data) are not incorporated in the confidence intervals. Sub-totals are provided where a variable is classified by more than one attribute. The proportion of the variable in each classifier class is also included. Interpretation of the results is aided by the use of charts and graphs.

3.2 STEM VOLUME MODELS

The British Forestry Commission (BFC) single tree volume equations were used in the first NFI cycle to estimate the standing volume of conifer and broadleaf species. The stem volume was measured from the ground to 70 mm top diameter overbark for conifers and from the ground to timber height overbark for broadleaves. Since the first cycle, conifer and broadleaf single tree stem profile models have been developed for Ireland and were used to generate the latest NFI volume estimates. Funded by the National Council for Forest Research and Development, the TREEMODEL project[1] developed models for six conifer species namely Sitka spruce, Norway spruce, Scot's pine, Douglas-fir, Japanese larch and Lodgepole pine. In addition single tree stem profile models have been developed by the Forest Service and IFER for four broadleaf species, namely Birch, Beech, Ash and Oak. These new broadleaf models give a more complete estimate of stem volume for all parts of the above ground stem. Both sets of models use the explanatory variables of diameter at breast height (Dbh) and height to generate volume. The coefficient of determination (R^2), which measures how well a model explains and predicts future outcomes, was very good for both new conifer and broadleaf models, at 0.99 and 0.97 respectively.

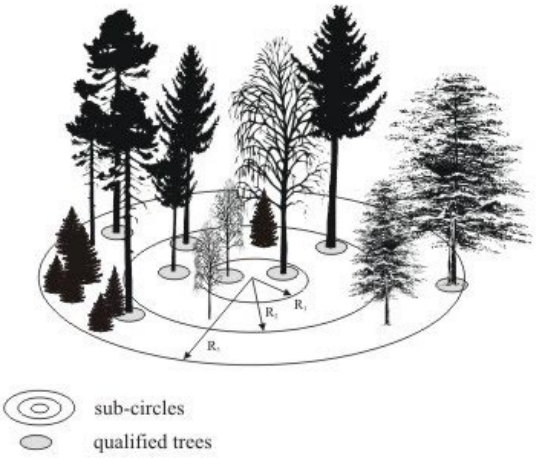
[1] http://www.coford.ie/researchprogramme/thematicareaestablishingandgrowingforests/forestplanningandmanagement/treemodel/

4 INTERPRETATION OF RESULTS

4.1 SPECIES COMPOSITION

Careful consideration is needed in the interpretation of stocked areas of individual species presented, since many forests contain an intimate mixture of species. The total stocked area of a given species therefore does not represent distinct areas of land covered by pure stands of the species, but represent the sum of shares of areas of mixed forest apportioned to it.

Since the NFI used concentric circles not all trees present on the plot were assessed (Figure 6). Tree data on the inner sub-circles is expanded over the entire plot by weighting individual tree data by the respective concentric circle size. This expansion assumes that what is observed in the inner sub-circles for smaller Dbh trees can be replicated over the whole plot.



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12.62
Sub-circle area (m^2)	28.3	153.9	500
Threshold Dbh (mm)	70	120	200

Figure 6. Plot design.

In order to enable area related calculations, such as the determination of species composition, a procedure for the calculation of the so-called representative area of a tree is used. The area of each inventory plot was distributed among the trees proportionate to their size. Larger trees were allocated larger areas. The sum of all the individual tree representative areas within the plot is equal to the total plot area of 0.05ha. These tree representative areas are used to scale up from plot to national species composition estimates.

4.2 Accuracy of Results

The confidence interval quantifies the uncertainty in measurement by specifying the range of values within which the true value for the whole population lies.

The frequency of which certain attributes occur in the forest varies. Attributes that occur less frequently tend to have poorer levels of accuracy. The problem can be exacerbated through classification. Classification by small geographic areas, results in higher error margins for those small counties. For example the mean annual volume increment per ha for Co. Dublin is 15.9 m^3 ± 8.9 m^3, while the figure for Co. Cork is 13.4 m^3 ± 1.8 m^3. As Co. Dublin has a much smaller area of forest than Co. Cork, far fewer sample plots contribute to the result for Co. Dublin. In turn fewer plots result in a larger error margin.

Assessment of the NFI results should always be done in conjunction with the evaluation of the confidence interval presented with the statistic, which indicates the reliability of the results

4.3 Forest Area

Forest area statistics are presented in three different ways in the results. As it is not possible to collect the same level of information on every plot (e.g. species) the total forest area is not always presented. For example, forest open area plots will have no trees present, resulting in no species composition data for this plot. As a result there are three main types of forest area presented in the NFI (Figure 7):

1. Total Forest Area, 731,652 ha.
   Encompasses all forest land. Data collected at a plot level, such as altitude, can be presented.

2. Forest area, 653,980 ha
   Excludes forest open area. Data collected at a plot level, such as forest type, can be presented.

3. Stocked forest area, 637,133 ha.
   Excludes forest open area and temporarily unstocked areas. Data that has been collected at tree level, such as species, can only be specified according to the stocked forest area

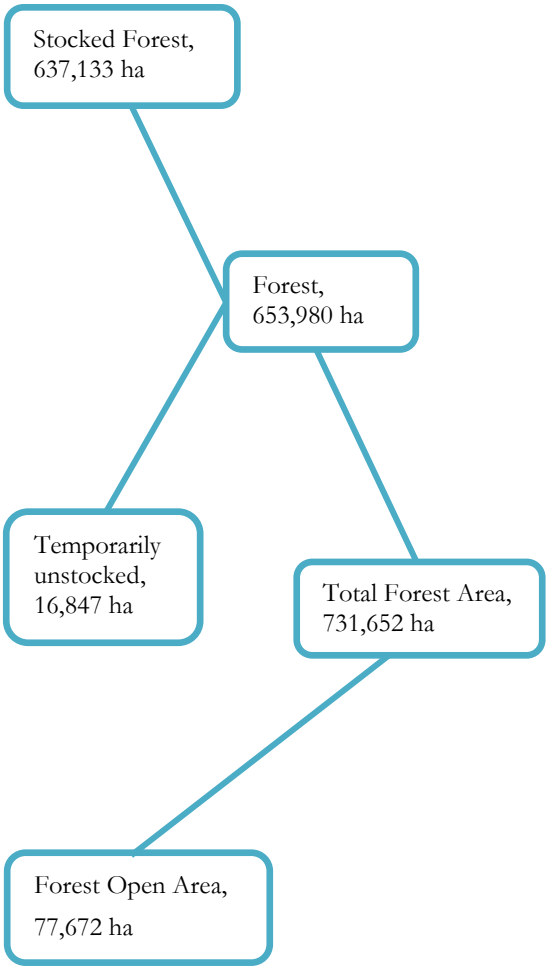


Figure 7. Forest area (ha) types reported in the NFI.

5 RESULTS SUMMARY

5.1 LAND-USE TYPE CHANGE, 2006 TO 2012

Aerial photo interpretation of all 17,423 grid points was carried out in 2006 and again in 2012, with the primary aim of identifying forest plots. Other land-use types were also recorded allowing for trend analysis in land usage between these two points in time. In terms of tree cover; Other Woodland has decreased from 50,878 ha to 47,681 ha and the area of hedgerows has also decreased from 276,460 ha to 271,912 ha. The area of scrub (e.g. gorse and shrub) has decreased from 89,030 ha in 2006 to 82,606 ha in 2012. The total forest area has increased from 697,842 ha to 731,652 ha (Table 1).

Table 1. Land use and land use change 2006-2012

	2006		2012		
Land-use type	Area (ha)	%	Area (ha)	95% C.I.	%
Forest	697,842	10.0	731,652	(700,053-763,251)	10.5
Other Woodland	50,878	0.7	47,681	(39,147-56,216)	0.7
Hedgerow	276,460	4.0	271,912	(251,878-291,946)	3.9
Scrub	89,030	1.3	82,606	(71,402-93,809)	1.2
Bare Rock	76,124	1.1	73,684	(63,188-84,181)	1.1
Bog and Heath	923,037	13.2	916,415	(883,894-948,935)	13.1
Built Land (Rural)	113,704	1.6	128,854	(114,923-142,785)	1.8
Built Land (Urban)	63,303	0.9	70,599	(60,566-80,631)	1.0
Cropland	379,748	5.4	352,262	(330,508-374,017)	5.0
Cutaway Peat (Domestic)	101,767	1.5	101,760	(89,407-114,113)	1.5
Cutaway Peat (Industrial)	69,322	1.0	67,715	(57,821-77,609)	1.0
Grassland	3,776,999	54.2	3,725,092	(3,674,824-3,775,360)	53.4
Green Space (Rural)	57,348	0.8	84,562	(73,231-95,893)	1.2
Green Space (Urban)	24,827	0.4	28,026	(21,518-34,535)	0.4
Quarry	8,417	0.1	12,019	(7,723-16,315)	0.2
Road (Paved)	84,911	1.2	92,103	(80,283-103,923)	1.3
Track (Unpaved Road)	19,607	0.3	22,812	(16,900-28,723)	0.3
Water Body	141,616	2.0	144,376	(129,745-159,007)	2.1
Sea & Coastal Complex	21,182	0.3	21,980	(16,192-27,768)	0.3
Total	6,976,112	100	6,976,112		100

5.2 Forest Area

Forest is defined as land with a minimum area of 0.1 ha, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20% within the forest boundary, or trees able to reach these thresholds *in situ*.

The area of forest in Ireland in 2012 was 731,650 ha or 10.5% of the land area excluding inland water bodies (Table 2). Since 2006, forest area has increased by 33,810 ha as a result of afforestation. Co. Cork has the highest share of national forest area at 83,619 ha or 11.6% of the total forest estate (Figure 7). A map of forest cover in Ireland is presented in Figure 8.

Table 2. Total forest area

	2006		2012		
	Area (ha)	%	Area (ha)	95% C.I.	%
Forest	697,842	10.0	731,652	(700,053-763,251)	10.5
Non-forest	6,278,270	90.0	6,244,460	(6,212,861-6,276,059)	89.5
Total	6,976,112	100	6,976,112		100

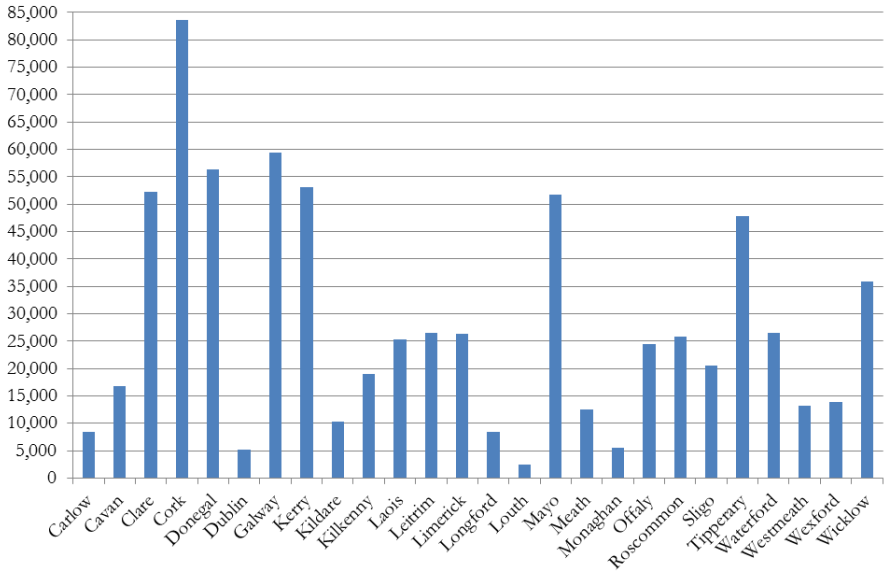


Figure 7. Total forest area (ha) by county.

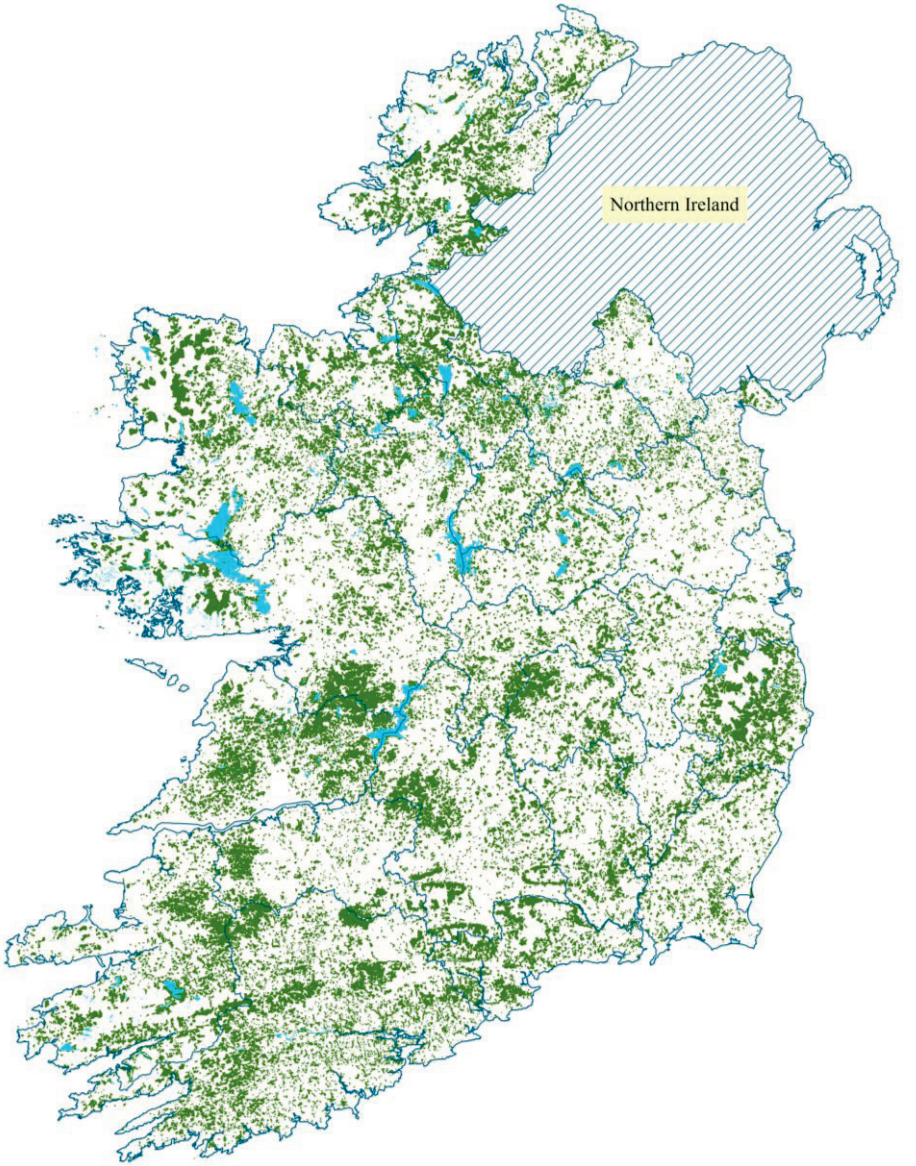


Figure 8. Forest cover map of Ireland

In terms of forest cover as a proportion of the total county land area, Co. Wicklow has the highest forest cover at 17.7% (Figure 9). Counties with the highest proportion of national forest area are primarily distributed along the western and south-western seaboards (Figure 10).

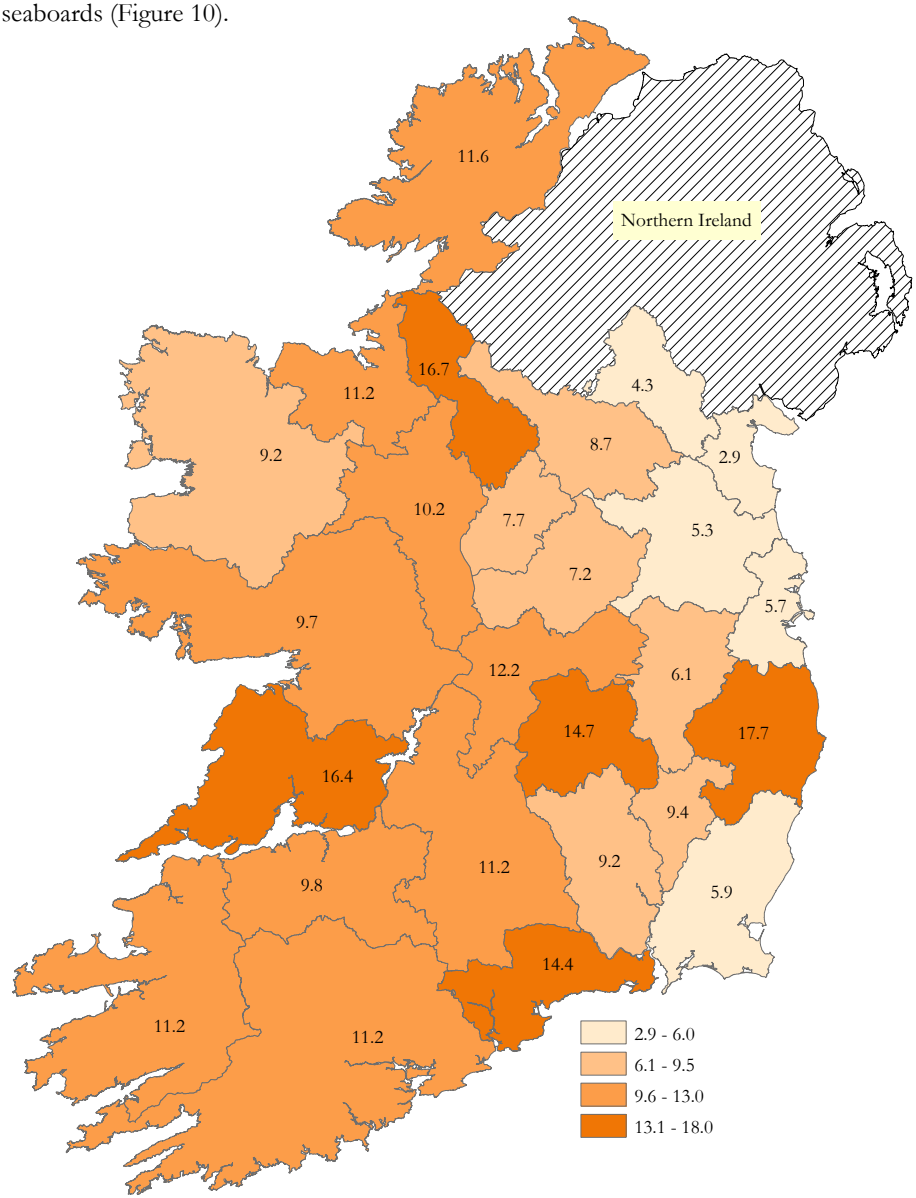


Figure 9. Proportion of forest cover in each county.

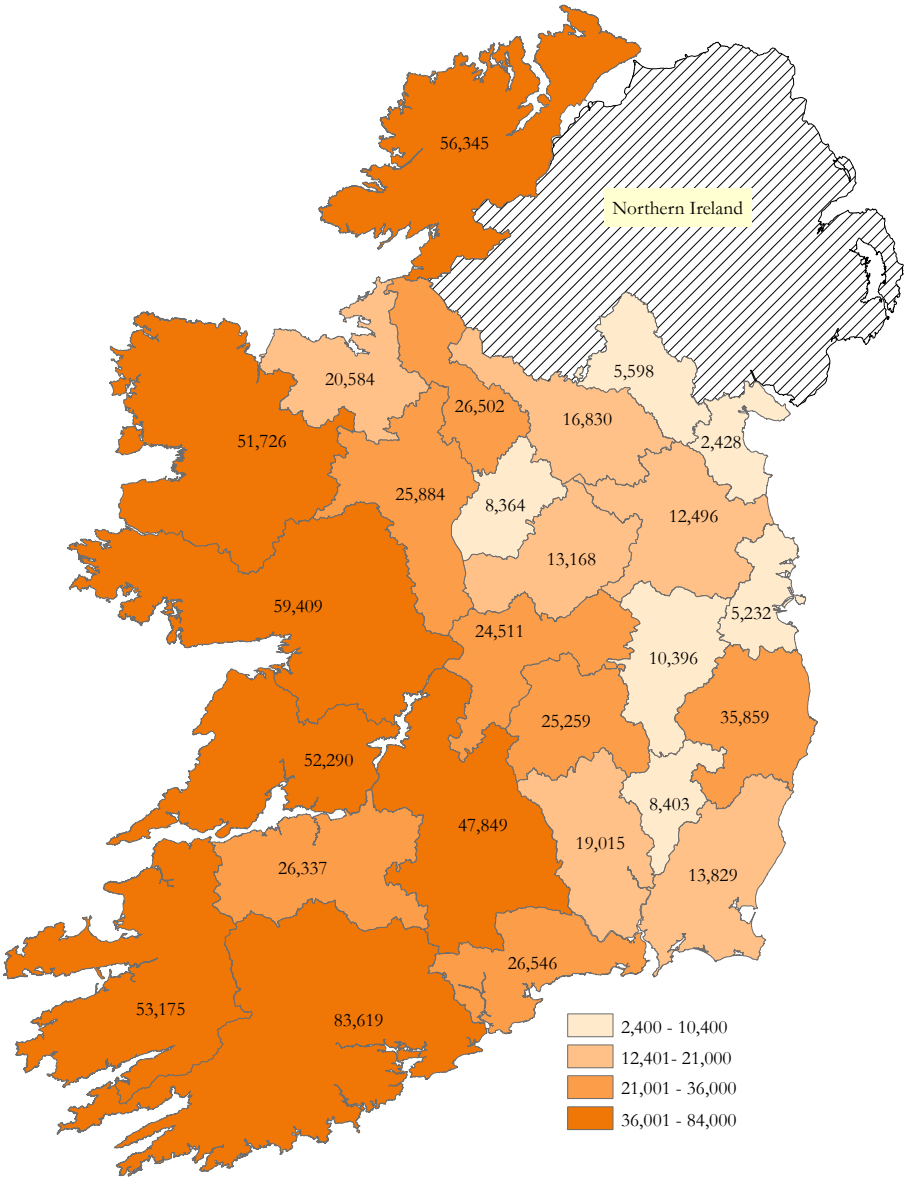


Figure 10. Forest area (ha) per county.

5.2.1 Forest Ownership

Forest ownership specifies land ownership. Over half (53.2%) of forests are in public ownership and 342,296 ha (46.8%) are in private ownership (Table 3 and Figure 11). The private forest estate is in effect comprised of two distinct forest types; the older non grant aided forests, referred to as Private (other), and the younger grant aided forests categorised as Private (grant aided), planted post 1980. The share of private forests in the national forest estate has increased by nearly 4% since 2006.

Table 3. Total forest area by ownership

	2006		2012		
Ownership	Area (ha)	%	Area (ha)	95% C.I.	%
Public	397,463	57.0	389,356	(365,679-413,038)	53.2
Private (grant aided)	212,202	30.4	248,554	(229,394-267,714)	34.0
Private (other)	88,177	12.6	93,742	(81,825-105,658)	12.8
Total	697,842	100	731,652		100

5.2.2 Forest Open Area

Forest open areas (e.g. firebreaks) are integral to the forest and constitute 10.6% of the total forest area (Figure 11). The Private (grant aided) estate has 13.5% forest open area, compared to 8.7% in the Public forest. As the majority of the private estate has yet to be roaded, the forest open area differential between the two ownership types will increase over time.

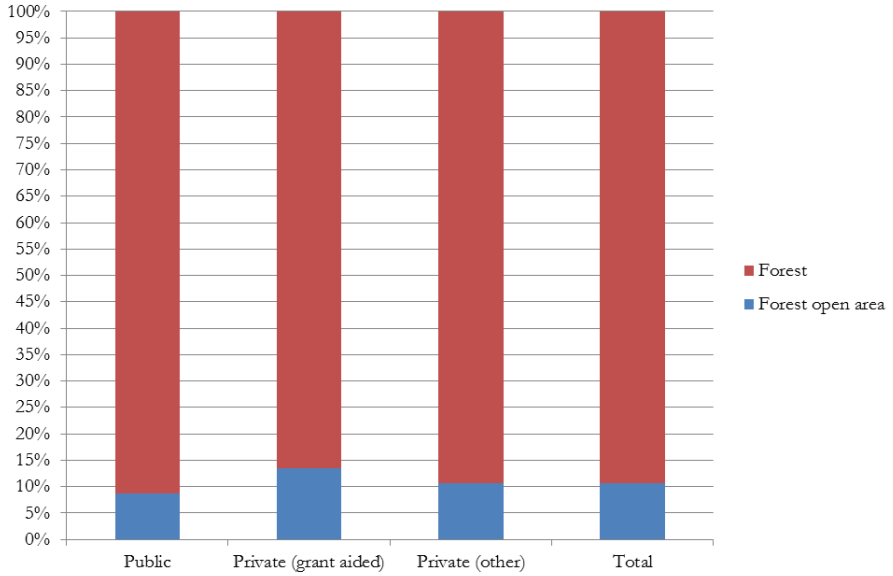


Figure 11. Proportion of forest open area in the total forest area by ownership.

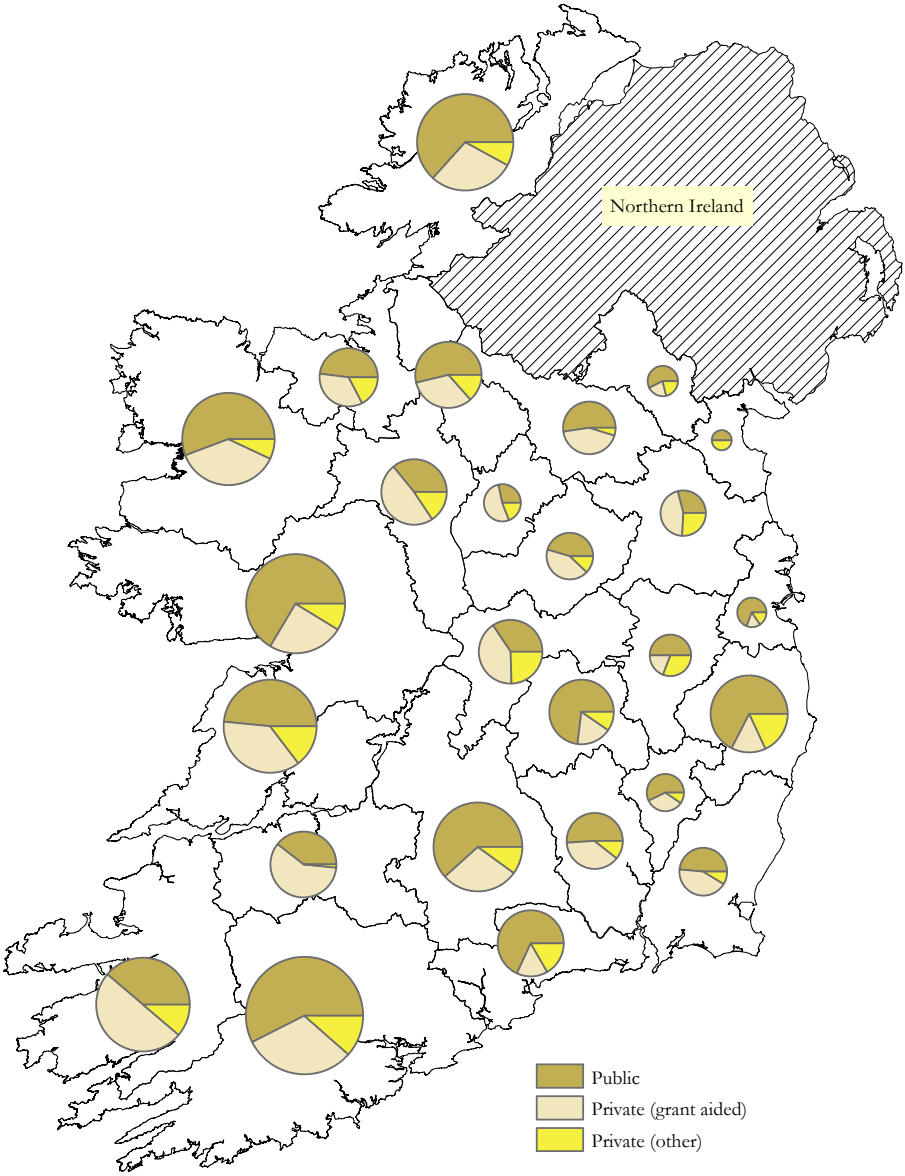


Figure 12. Proportion of national forest cover by county and ownership.

5.2.3 Forest Available for Wood Supply

The classification of Forest Available for Wood Supply (FAWS) describes the relative importance of the estate in terms of timber supply. The majority (83.7%) of forests in Ireland have no restrictions on timber supply (Figure 13). A small portion (0.6%) of the estate is considered not available due to the National Parks and Nature Reserves designations.

A significant portion (15.7%) of the estate is considered unlikely to contribute to wood supply, primarily due to the site constraints, physical productivity or wood quality limitations. Nearly two-thirds (64%) of the Private (other) estate is classified as unlikely to contribute to wood supply, primarily due to the presence of poorly performing broadleaf forests.

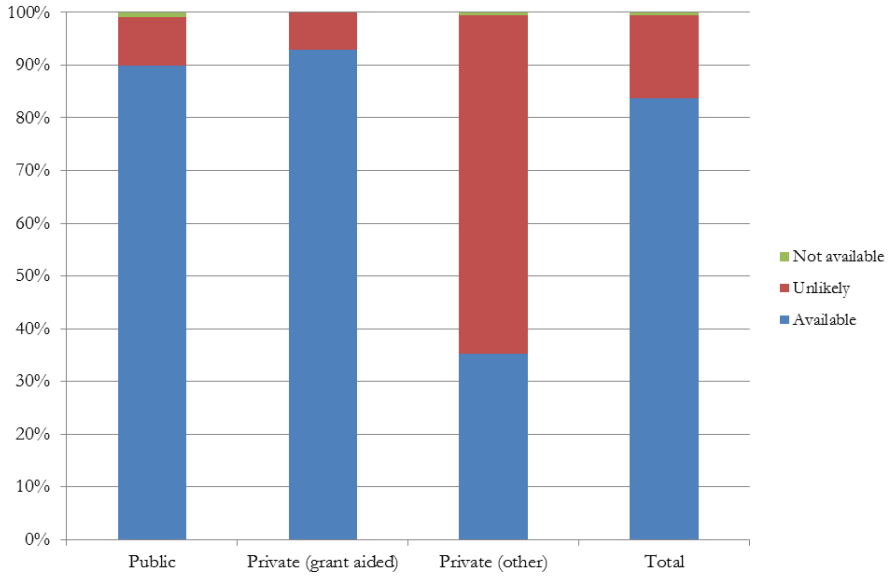


Figure 13. Proportion of the stocked forest area by ownership and Forest Available for Wood Supply.

5.3 Species Composition

The portion of the forest estate that has tree cover or is available for planting is 653,980 ha. At any one time a portion of this will be temporarily un-stocked due to events such as felling or fire. The removal of these temporarily unstocked areas leaves 637,133 ha with tree cover present.

Conifer forest is the dominant forest type representing 74.2% of all forests (Figure 14 & 15). Broadleaved forests represent 25.8%. The share of broadleaf forest in the national forest estate has increased by 1% between 2006 and 2012.

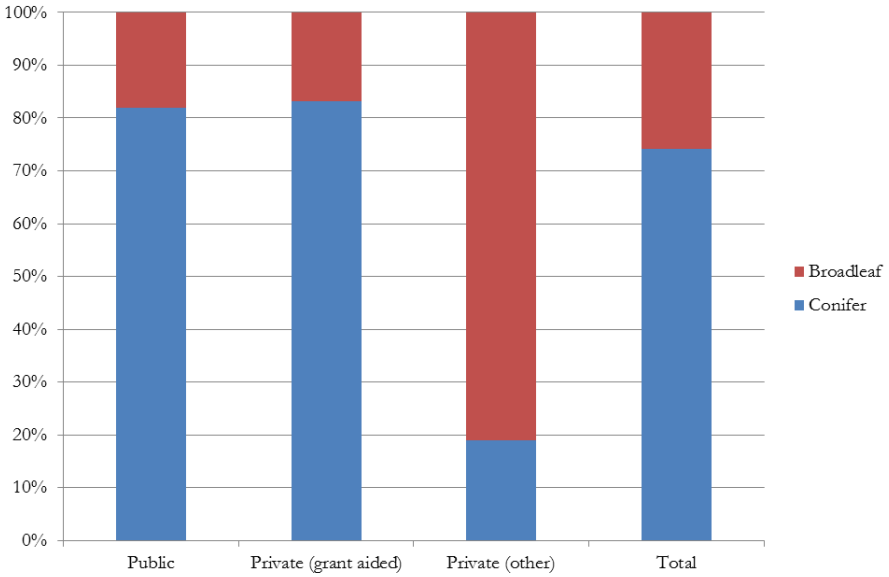


Figure 14. Proportion of the stocked forest area by ownership and species group.

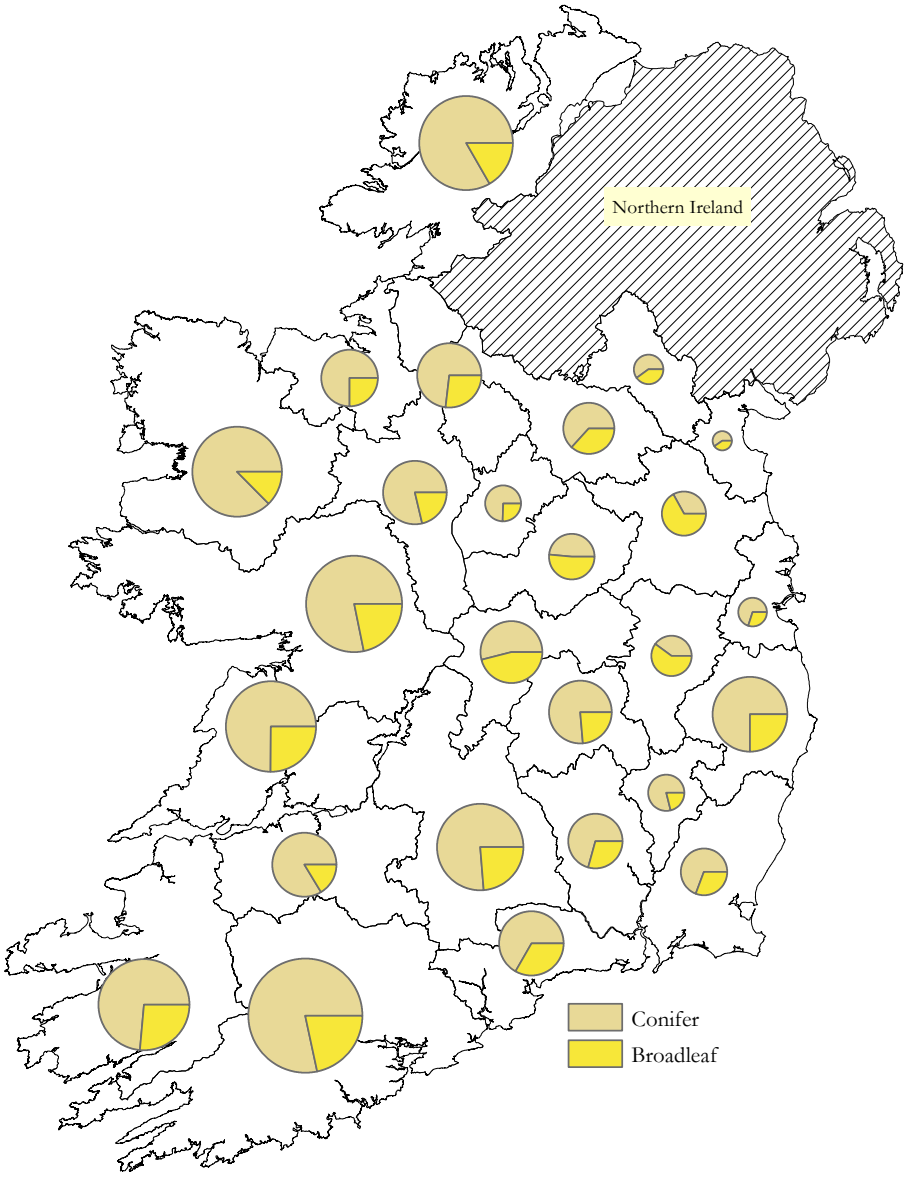


Figure 15. Proportion of the stocked forest area by county and species group.

The main tree species is Sitka spruce occupying 334,560 ha or 52.5% of all species (Figure 16). Other pines, composed primarily of lodgepole pine, accounted for 9.7%. The most common broadleaf species present in the estate include Other short living broadleaves (OSL), such as willow and hazel, representing 7.3% of the forest estate. Birch is the next most common broadleaf species occupying 5.9% of the forest estate.

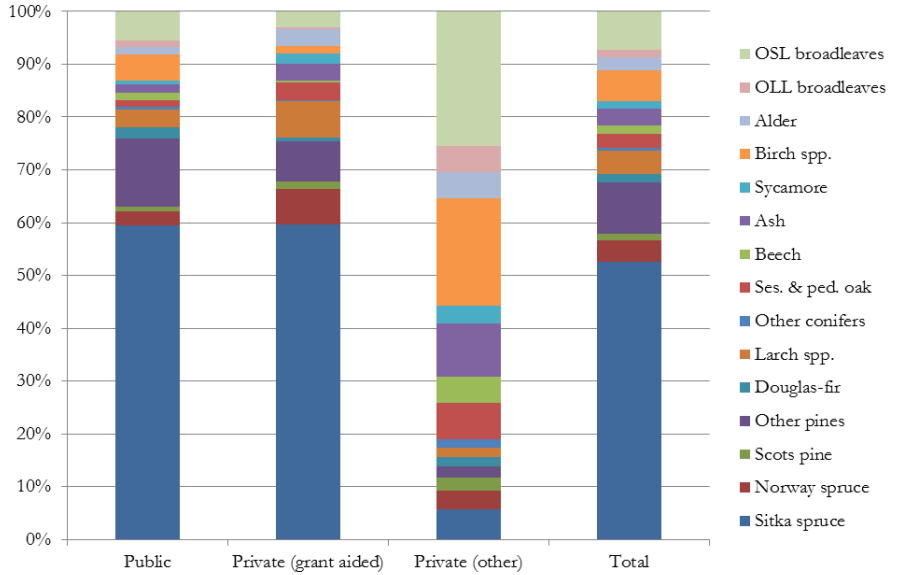


Figure 16. Proportion of the stocked forest area by ownership and species group.[2]

5.3.1 Age class

The age of a forest is described as the number of growing seasons since initial planting or natural regeneration. Over half (56%) of the stocked forest estate is less than 20 years of age (Figure 17). The private forest estate has a younger age profile compared to the public estate, with 67% aged 20 years or less in the former. The Private (grant aided) forests are predominantly less than 30 years old. Private (other) forests are evenly distributed across the range of age classes with a slight dominance in the 51 years plus category, reflecting their partial composition of the older private estates.

In general, there is a higher proportion of broadleaves in young forests due to higher levels of broadleaf afforestation and natural regeneration (Figure 18).

[2] OLL Broadleaves are Other Long Living broadleaves e.g. Sweet chestnut, Holly, and Lime. OSL are Other Short Living broadleaves e.g. Willow & Hazel.

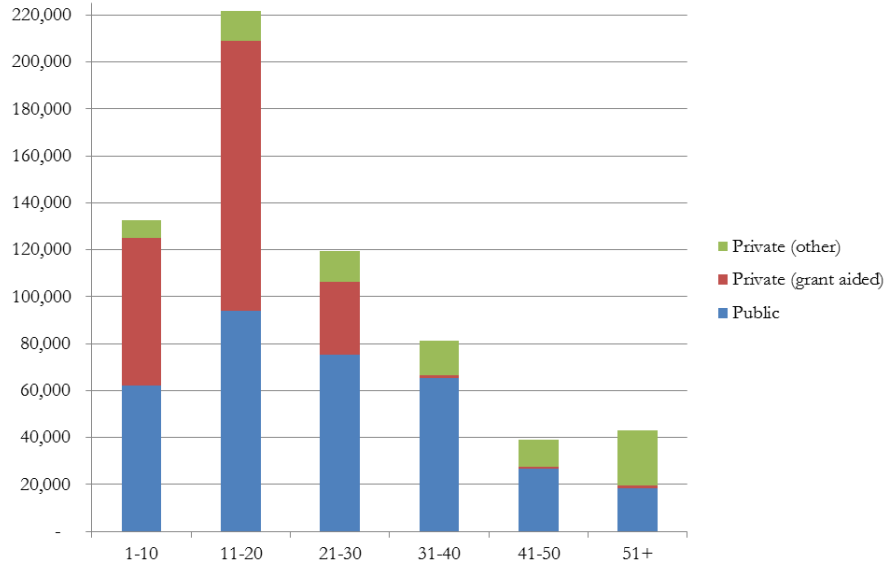


Figure 17. The stocked forest area by age class and ownership.

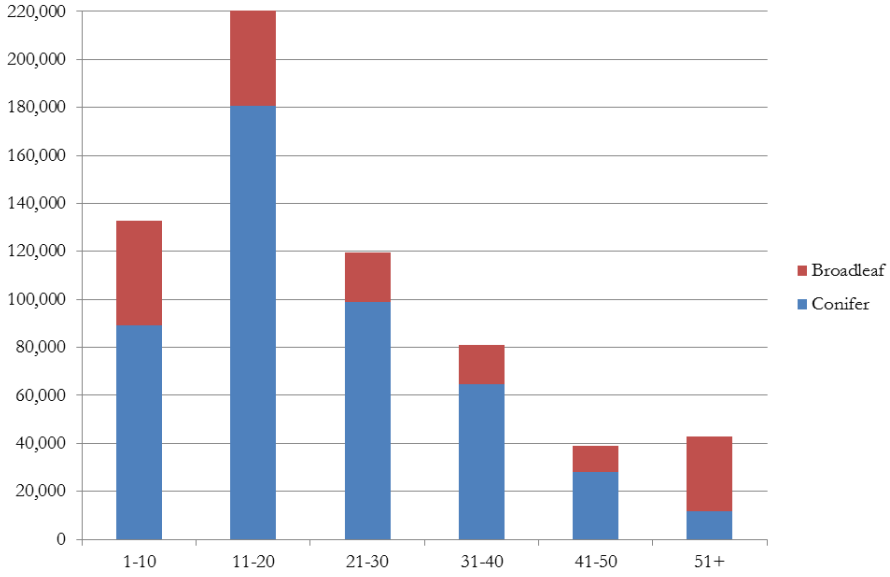


Figure 18. Total stocked forest area by age class and species group

5.4 Forest Classification

The following sub-sections describe the structure of the forest estate.

5.4.1 European Forest Type

European forest type applies a broad species class at forest level, as opposed to the broadleaf/conifer classification presented in the previous section which is derived from tree species class. Over two-thirds (69%) of the stocked forest area is composed of forests with conifer species predominating (Figure 19). The Private (other) forests are composed of forests with broadleaf species predominating.

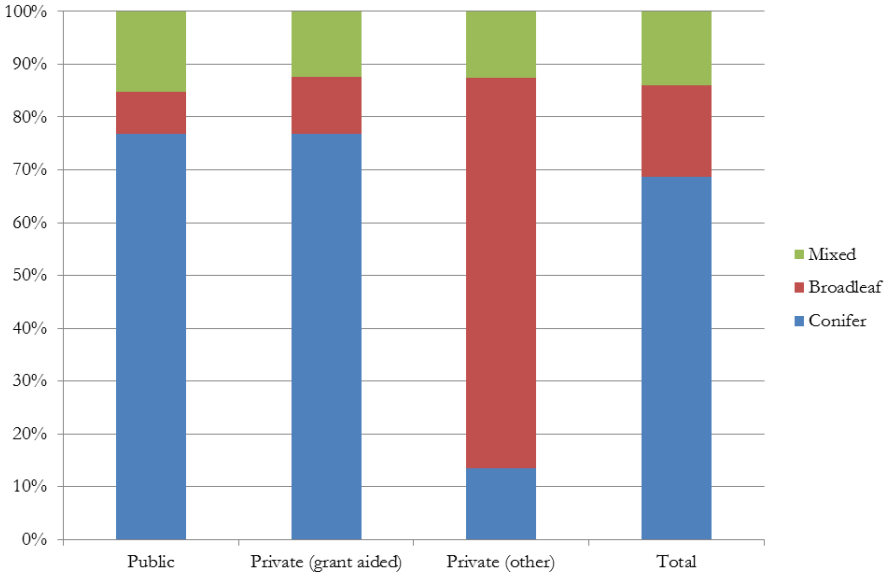


Figure 19. Proportion of the stocked forest area by European forest type and ownership.

5.4.2 Nativeness

A number of different native forest types are found across Ireland, each influenced by soil type, climate and other physical factors. Native tree species are trees that have arrived and inhabited an area naturally, without deliberate assistance by man. For NFI purposes the species list of natives trees recorded is primarily based on the list of species eligible for inclusion in Ireland's Native Woodland Scheme[3].

Native and mixed forests comprise 28.7% of Ireland's forests (Figure 20). Native tree species predominate in Private (other) forests while non-native tree species predominate in both Private (grant aided) and public forests.

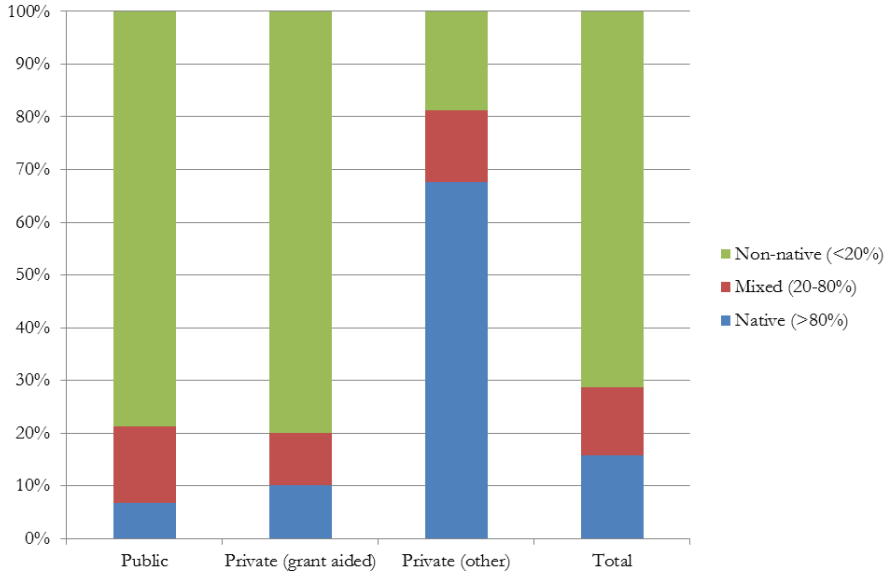


Figure 20. Proportion of total stocked forest by nativeness by ownership.

[3]Anon., 2008. Native Woodland Scheme Manual. Forest Service, Department of Agriculture, Food and the Marine, Johnstown Castle Estate, Co. Wexford, Ireland.

5.4.3 Establishment type

Afforestation is the man-made establishment of new forests on treeless lands which did not carry forest in contemporary history. Afforestation dominates as the main method by which forests have become regenerated with 64.2% of forests established in this way (Figure 21). Reforestation, the man-made establishment of trees on lands that have been cleared of forest within the relatively recent past, comprises 24.7% of forests.

Semi-natural forest, which are forests established by natural regeneration, occupy 11.1% of forests. Private (grant aided) forests are almost entirely established as afforestation reflecting their contemporary nature since 1980. A large proportion (65%) of semi-natural forests occupy the Private (other) forests while Public forests have the largest share (42.5%) of reforestation.

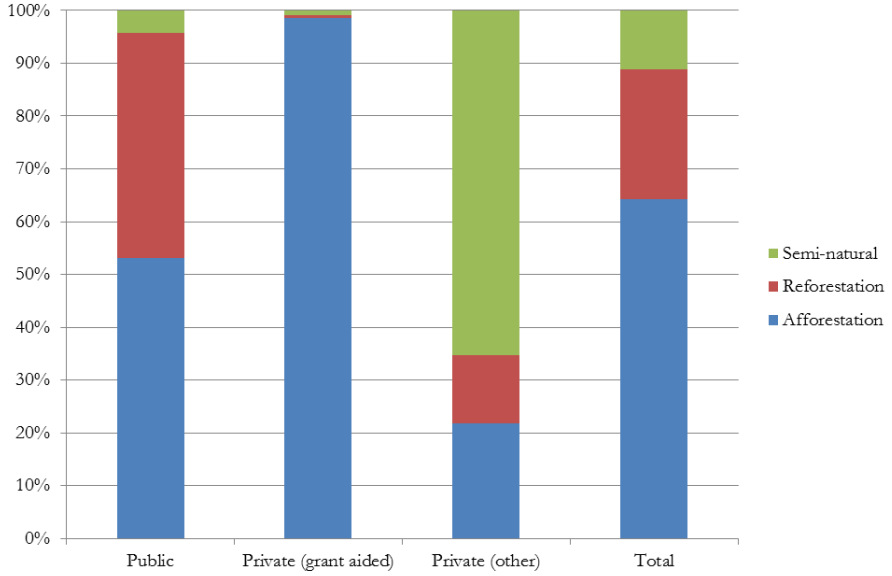


Figure 21. Proportion of total stocked forest by establishment type and ownership.

5.4.4 Development stage

Development stage categorises the maturity classes of the forest estate. The stages range from young post establishment forests to overmature forests along with multistoried forests.

In the ownership class Private (grant aided) a high proportion of small-pole and pole stage forests occur, indicating their readiness for thinning (Figure 22). Multistoried forests comprise the largest element of Private (other) forests while the Public forests display a relatively high proportion of high forest areas.

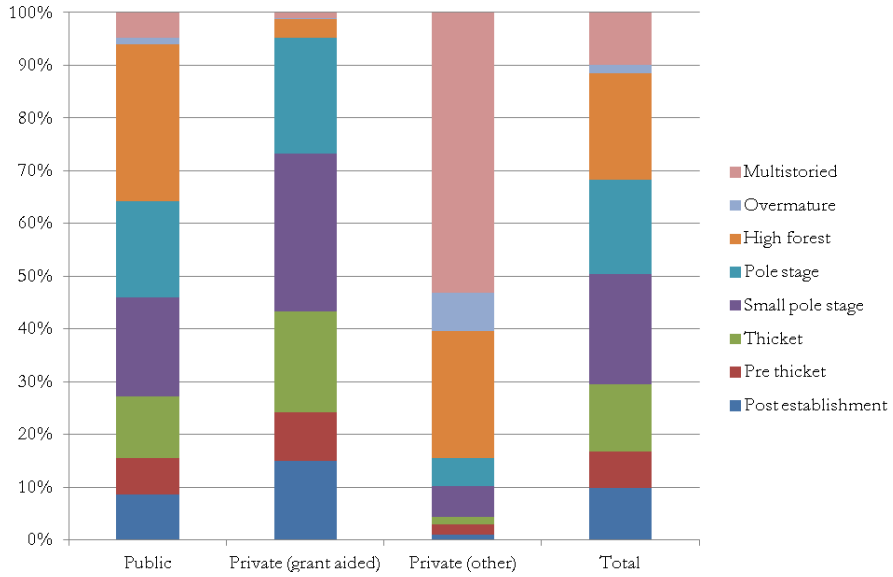


Figure 22. Proportion of the stocked forest by development stage by ownership.

5.4.5 Thin Status

Thin status describes the progression of thinning operations or absence of thinning operations in the national forest estate.

In terms of the extent of thinnings, 15.2% of forests have been thinned or re-spaced at least once. Nearly two-thirds (61.7%) of forests are juvenile (i.e. at a maturity stage where they could not be thinned) and 23.1% of forests are categorised as "no thin" (Figure 23). For the latter category the forest is theoretically at a maturity stage where it could be thinned but has not been thinned due to a variety of factors such as high windthrow risk, economic factors/considerations or thinning may be imminent.

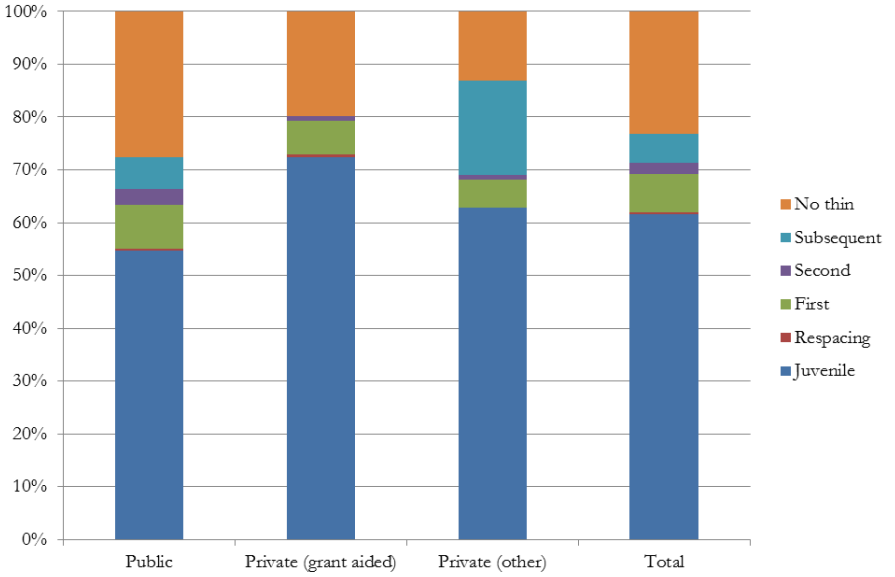


Figure 23. Proportion of the stocked forest by thin status and ownership.

5.5 SITE CONDITIONS

Site conditions in the forest estate are described in this section.

5.5.1 Soil Type

Over half (56%) of forests occur on mineral soils, with the remaining 44% on peats (Figure 24). One-quarter of all forests are growing on highly productive gley soils while 33% of Private (grant aided) forests occur on these soils, reflecting forestry's move onto more productive soils since the mid to late 1980's.

Over the last 40 years, fewer forests are being afforested on peat (Figure 25). The proportion of basin peats being afforested has increased in the last ten years, largely as a result of the afforestation of land that was reclaimed for agriculture. Afforestation of blanket peat is declining, reflecting a shift away from the unenclosed land type.

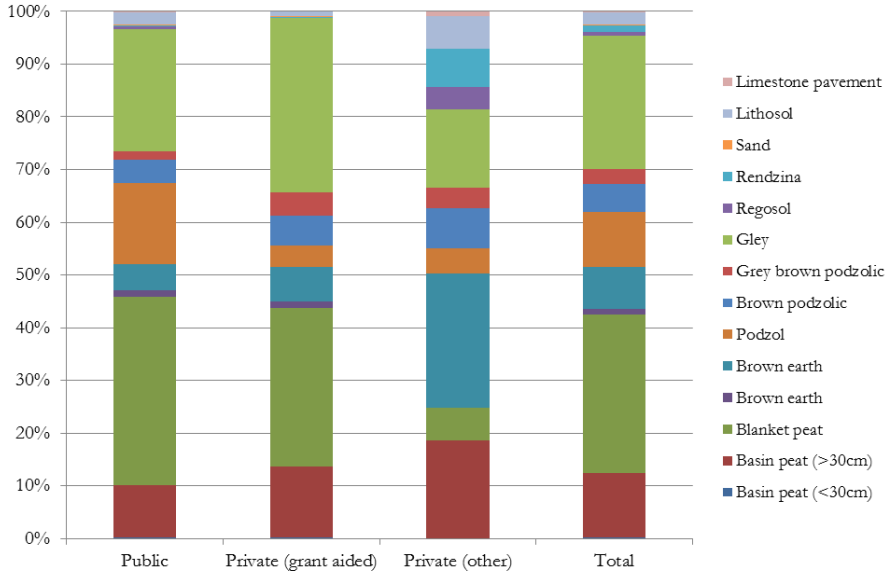


Figure 24. Proportion of the stocked forest by soil group by ownership.

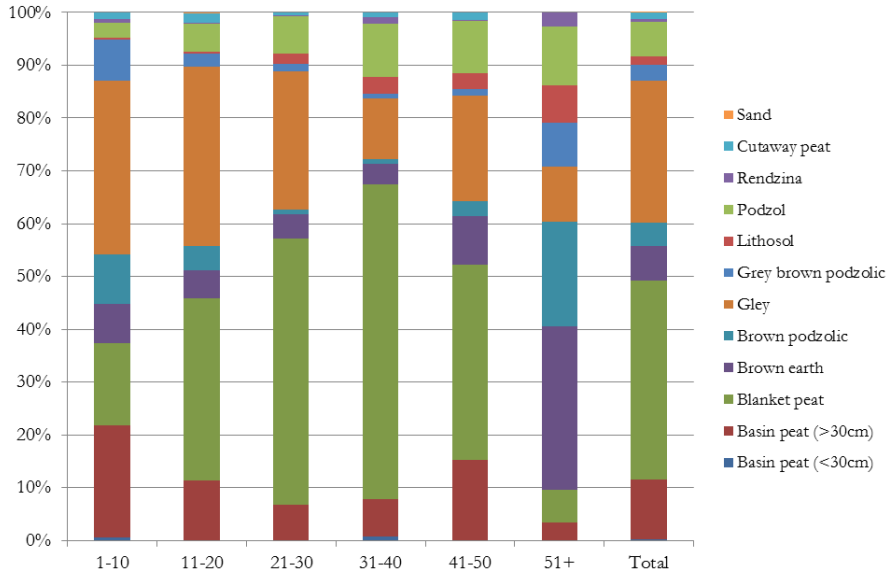


Figure 25. Proportion of total afforested area by age class (10 year) and soil group

5.5.2 Environmental Designations

There are a number of environmental designations[4] that affect forest management but do not necessarily restrict timber harvesting. Over half (51%) of the forest area had one or more environmental designation (Figure 26), compared to 43% in the 2006 NFI results.

Eight environmental designations are included with some having greater affects than others in terms of restricting forest management operations (Figure 27). The increase in hen harrier SPA designations has resulted in 77,000 ha being designated since 2006. In addition 24,000 ha have been designated for the protection of the Fresh Water Pearl Mussel.

[4] Designations include: Special Area of Conservation (SAC); Special Protection Area (SPA); National Heritage Area (NHA); Fresh Water Pearl Mussel (FWPM); Nature Reserve; National Park; Fisheries Sensitive and Acid Sensitive.

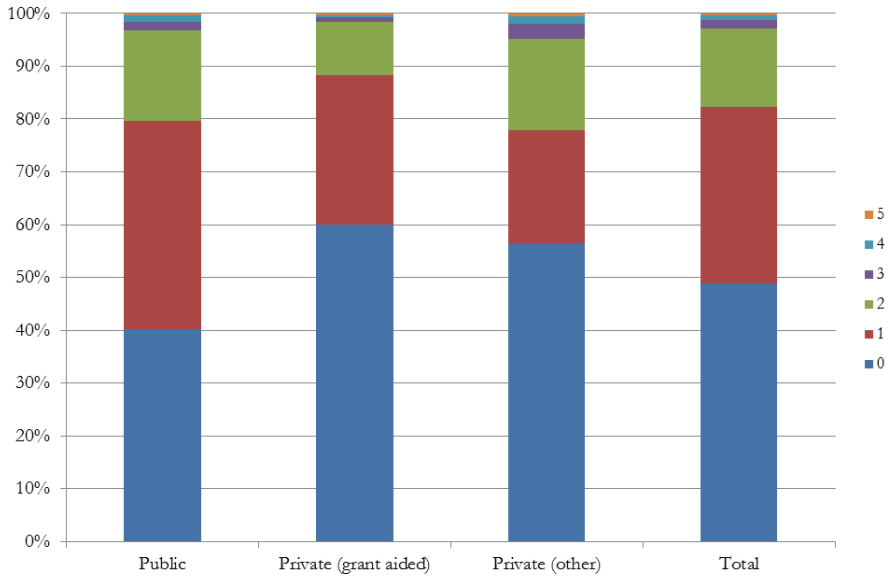


Figure 26. Proportion of total forest area by ownership and number of environmental designations.

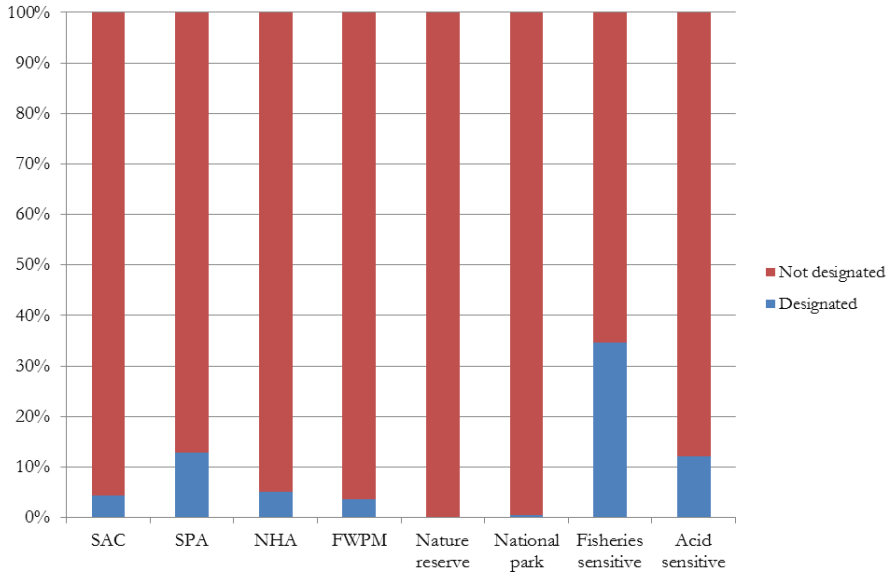


Figure 27. Total forest area by environmental designations.

5.6 GROWING STOCK AND BASAL AREA

Information on growing stock and basal area provide essential information about the actual production of the forest estate.

5.6.1 Growing Stock

In the first NFI cycle, the British Forestry Commission single tree volume equations were used to estimate the standing volume for each tree on the plot with a minimum Dbh of 7 cm. The stem volume was measured from the ground to 70 mm top diameter overbark for conifers and from the ground to timber height overbark for broadleaves. Timber height concerns the merchantable material only, frequently the spring of the crown is the timber point; however it may extend into the crown if merchantable lengths are present. In the second cycle stem volume was assessed from stump to 7cm for all species using newly developed Irish single tree volume equations. The 2006 NFI growing stock estimates were recalculated for comparative purposes.

The total standing growing stock of Irish forests is estimated to be over 97 million m³, an increase of over 25 million m³ on the 2006 standing volume; while growing stock volume has nearly tripled in the Private (grant aided) forests over this same time period. Public forests contain nearly twice the growing stock volume of private forests (Table 4).

Table 4. Standing volume in Irish forests (2006 and 2012) by ownership.

	2006		2012		
	1000's m³	%	1000's m³	95% C.I.	%
Public	51,713	72.0	61,233	(56,794-64,016)	62.8
Private (grant aided)	7,490	10.4	21,664	(20,079-23,570)	22.2
Private (other)	12,658	17.6	14,579	(13,322-17,172)	15.0
Total	71,860	100	97,476	(92,906-102,046)	100

In terms of broad species groups, 81.8% of growing stock volume refers to conifer species, while 18.2% is contained in broadleaf species. Sitka spruce contains 59% of the growing stock, followed by other pines at 10% (Figure 28).

Counties in the west of Ireland have the highest proportion of growing stock, with Co. Cork having the highest volume at 12.5 million m³ (Figure 29 and 30).

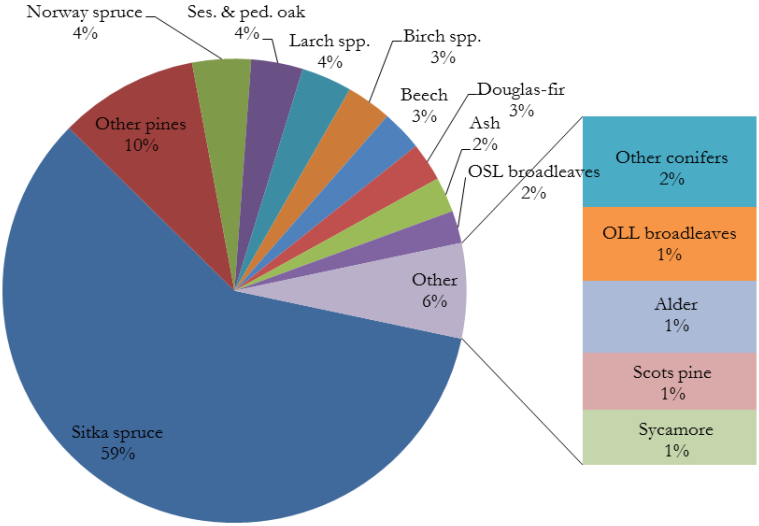


Figure 28. Proportion of growing stock (m^3) by species group.

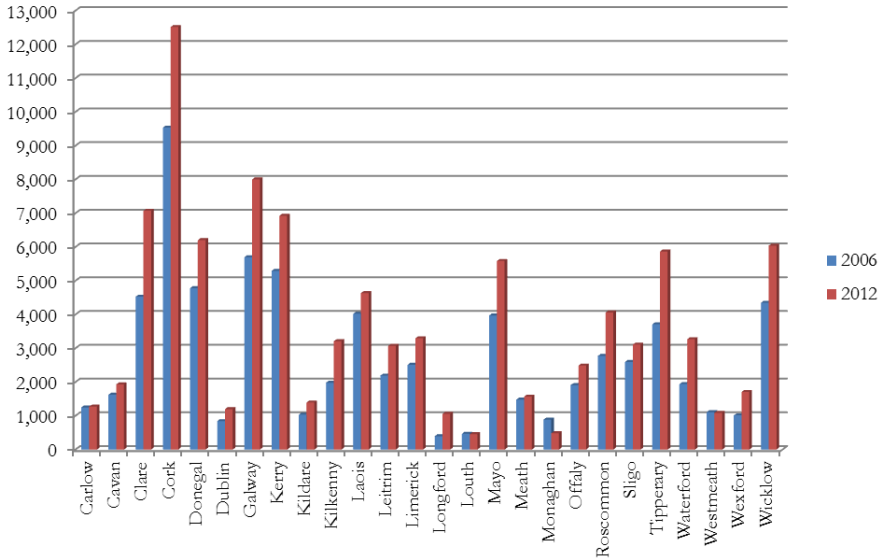


Figure 29. Total growing stock (m^3) by county.

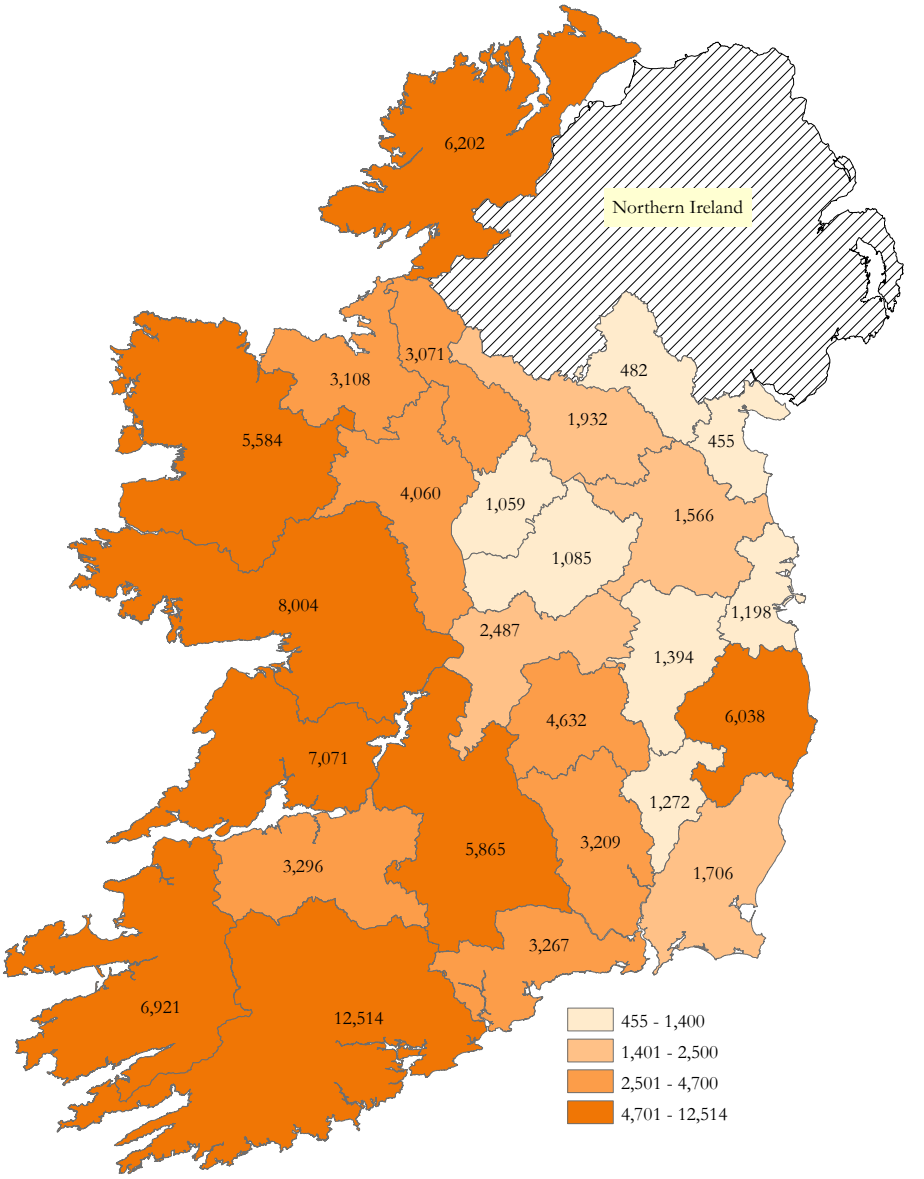


Figure 30. Distribution of growing stock (m^3) by county.

5.6.2 Basal Area

Basal area is the term used in forest management that defines the area of a given section of land that is occupied by the cross-section of tree stems at height of 1.3 m from the tree base. The average basal area for all Irish forests is 25 m^2 per ha. The Private (grant aided) estate basal area increased from 11 m^2 per ha to 21 m^2 per ha between 2006 and 2012, due to the rapid growth phase of these forests and the low levels of removals (harvesting) (Table 5).

Table 5. Basal area comparison in Irish forests between 2006 and 2012 by ownership.

	2006	2012	
Ownership	Ba (m^2/ha)	Ba (m^2/ha)	95% C.I.
Public	24.1	27.0	(25.6-28.3)
Private (grant aided)	10.7	21.2	(19.6-22.7)
Private (other)	26.3	29.6	(27.2-32.0)
Total	20.2	25.3	(24.4-26.3)

5.7 Increment and Fellings

The balance between increment and fellings is an important indicator of SFM in a country as it describes the sustainability of wood production over time, the current availability of wood and the potential for the future. Completing both the 2006 and 2012 NFI's allows, for the first time, a field-based assessment of forest increment in Ireland for the entire forest estate.

5.7.1 Increment

Gross annual volume increment between 2006 and 2012 was 7.685 million m³. Nearly two-thirds of the increment occurred in the Public forest estate (Table 6).

Table 6. Gross annual volume increment by ownership.

Ownership	Annual Volume Increment	
	1000's m³	% Total
Public	4,702	61.2
Private(grant aided)	2,392	31.1
Private(other)	591	7.7
Total	7,685	100

Sitka spruce dominates the volume increment in terms of species groups comprising 70% of the annual volume increment followed by other pines at 9 % (Figure 31). The counties with most significant growing stock increment are distributed on the western and south western seaboards (Figure 32).

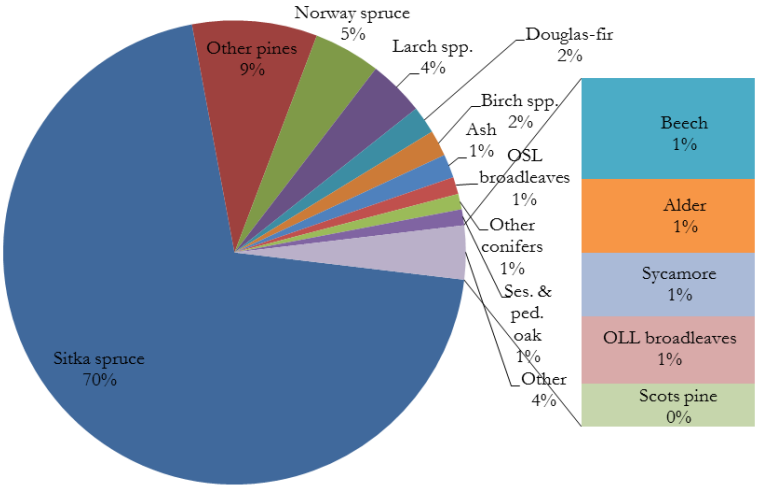


Figure 31. Gross volume annual increment by species group.

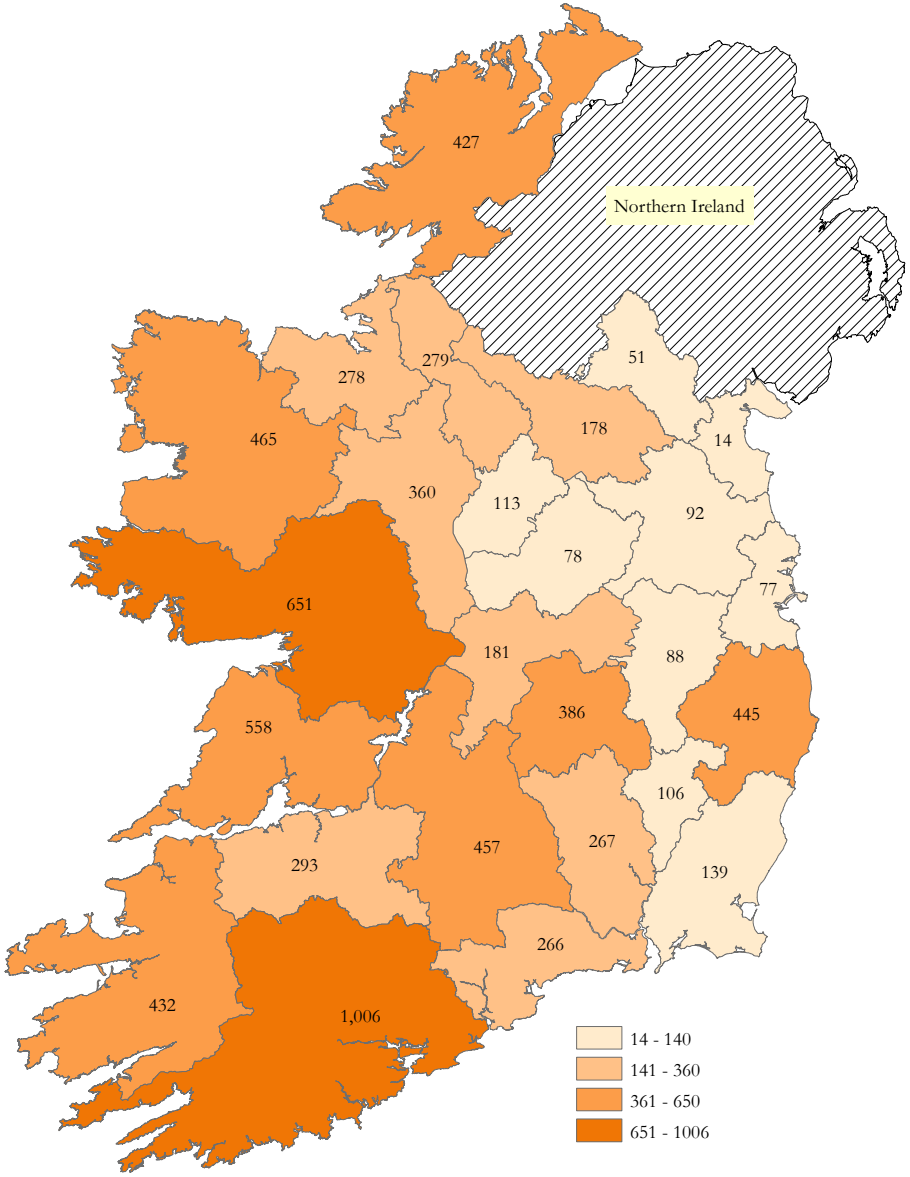


Figure 32. Distribution of volume annual increment (m^3) by county.

The mean annual increment per hectare is 11.5 m³/ha/year in the whole forest estate. Public forests average 13 m³/ha/year and Private (grant aided) 11 m³/ha/year, with Private (other) significantly lower at 7 m³/ha/year (Figure 33). The differences are due to a combination of age, species composition and soil type.

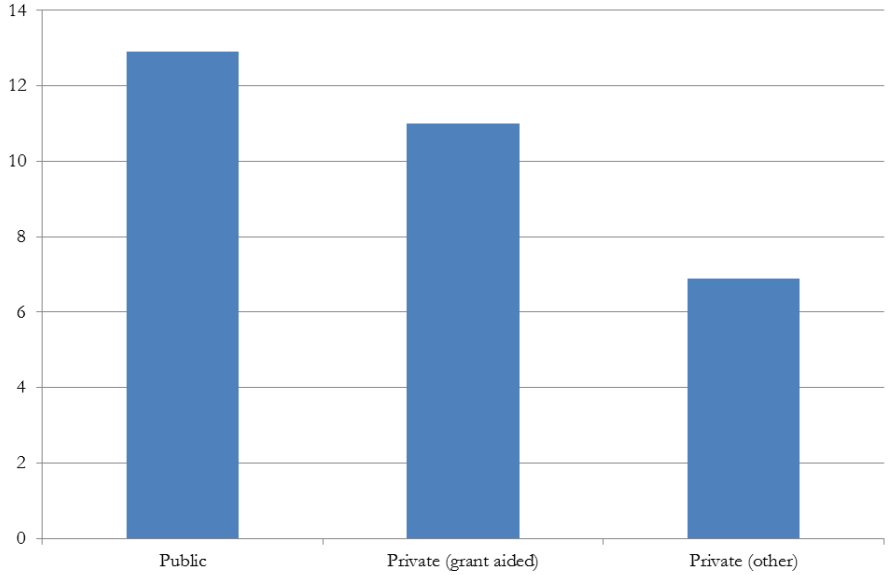


Figure 33. Mean volume increment (m³/ha/year) by ownership.

The county with the highest mean annual volume increment is Laois at 16.3 m³/ha/year (Figure 34). Low increment results from one or more of the following; high proportion of broadleaves, very young forest and low productivity sites.

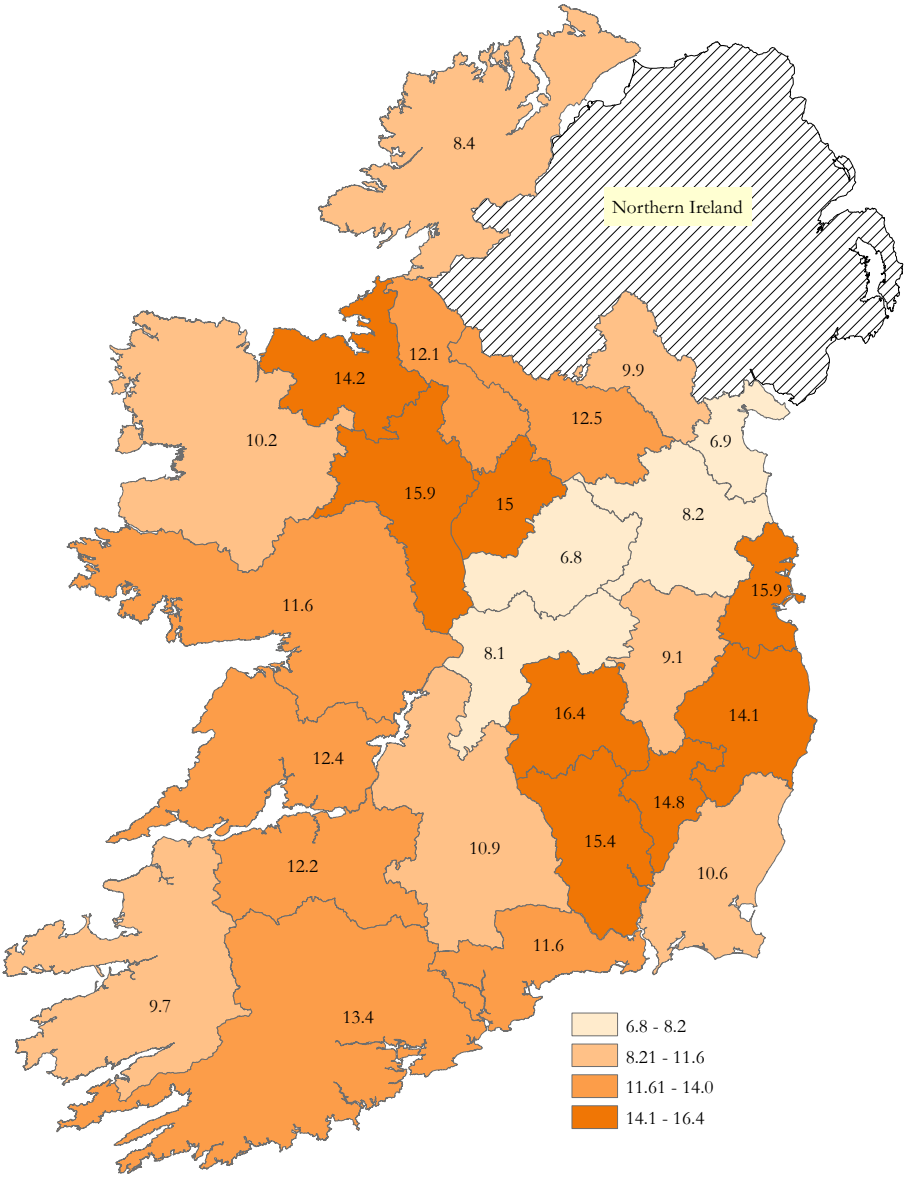


Figure 34. Mean Annual Volume increment (m³) per hectare per county.

5.7.2 Fellings

The mean annual standing volume harvested between 2006 and 2012 is 3.6 million m^3 (Table 7). Nearly half (47%) of the gross annual increment was harvested showing sustainable harvesting in Ireland's forests.

Table 7. Harvest volumes per ownership category.

Ownership	1000's m^3	95% C.I.	%
Public	3,152	(2,522 - 3,783)	87.1
Private (grant aided)	208	(103 - 313)	5.8
Private (other)	256	(109 - 402)	7.1
Total	3,637	(2,960 - 4,271)	100

Harvest volumes are concentrated in Public forests which accounted for 87% of mean annual harvest volumes between 2006 and 2012. In terms of broad species categories 97.8% of the annual harvest volume comes from coniferous species (Figure 35). Sitka spruce accounted for 78.6% of the share of the mean annual harvest volume, followed by others pines at 11.7% and Norway spruce comprising 3.5%.

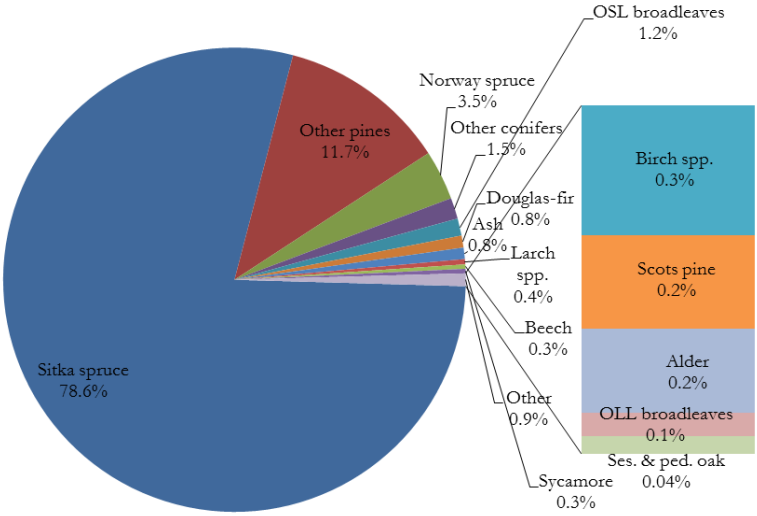


Figure 35. Proportion of total harvest volume by species group.

Clearfelling, the felling of a continuous block of trees, is the dominant harvest type, accounting for 76.6% of the timber felled (Figure 36). First thinning is the dominant harvest type in Private (grant aided) forests compared to clearfelling in the Public forest, reflecting their very different age structure.

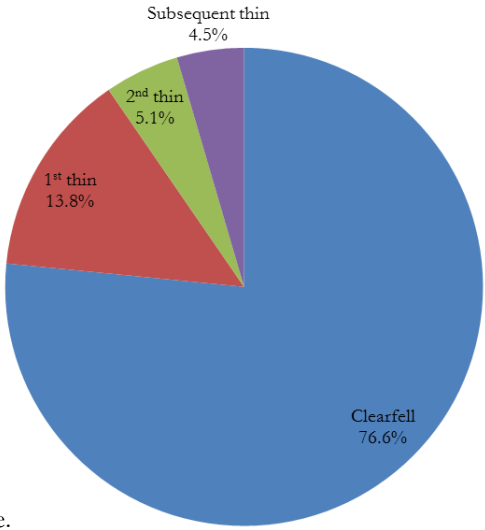


Figure 36. Harvest volume by felling type.

5.7.3 Mean Tree Volume Harvested

The mean tree volume harvested in Irish forests is 0.36 m³. The mean tree harvested according to harvest type ranges from 0.20 m³ in first thinning operations to 0.54 m³ in final clearfell harvests (Table 8).

The mean tree harvest volume associated with 1st thinning operations is higher than expected due to the incidence of 1st thinnings in older crops (30+ years of age).

Table 8. Mean tree volume harvested by harvest type.

	Harvest Type				
	1st thin	2nd thin	Subsequent thin	clearfell	All
Tree Volume (m³)	0.20	0.32	0.53	0.54	0.36

In terms of tree sizes per harvest type, nearly 60% of the harvest volume of clearfell trees comes from trees ranging in size from 0.25 m³ to 0.99 m³. In terms of the 1st thin volumes 64% of trees are under 0.24 m³ on average (Figure 37).

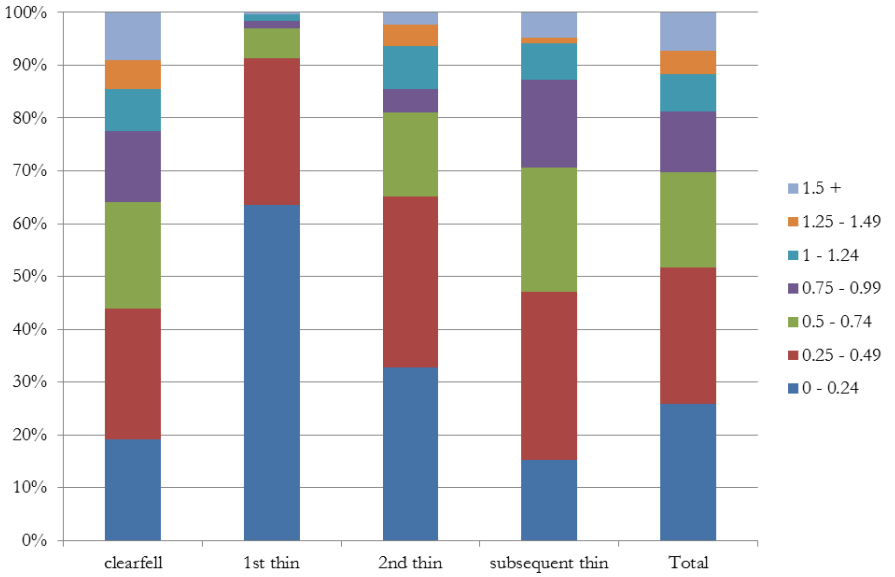


Figure 37. Mean annual standing volume (m^3) harvested by harvest type and mean tree volume (m^3) class.

5.8 FOREST CARBON

In this chapter, the analysis of the carbon pools in the forest estate is presented. Forests play an important role in mitigating climate change by sequestering and storing atmospheric carbon dioxide (CO_2). Sequestration is the net removal of CO_2 from the atmosphere, and storage in plant biomass, deadwood and harvested wood product pools. Trees absorb CO_2 through photosynthesis and release it through respiration; the difference is new biomass. Some of this biomass is transferred to the forest floor as litter (foliage, deadwood, etc.), which in due course decays and is either released back to the atmosphere or becomes part of soil carbon. The remainder accumulates as increment in the forest, mostly as stemwood, branches or roots. A proportion of this accumulated biomass is harvested, for wood products or fuel wood; this is either directly emitted back to the atmosphere or stored as long term harvested wood products and harvest residues on the forest floor; while the rest is a net increase in the living forest biomass.

In 1997, Ireland committed to reduce the national emissions of greenhouse gases by 13% above the 1990 level, in an effort to combat climate change under the Kyoto protocol. Over the five years of the first commitment period of the Kyoto Period (i.e. 2008 to 2012), Ireland will meet its Kyoto obligations when the impact of approved *Forest Sinks* associated with afforestation, reforestation and deforestation *activities since 1990,* under article 3.3 are taken into account[5]. The NFI has been instrumental in estimating the carbon stock in Irish forests and their contribution to national climate change mitigation. NFI data is a crucial component of the national forest reporting system (CARBWARE), which is used to estimate annual greenhouse gas emissions and removals as submitted to the United Nation Framework Convention on Climate Change (UNFCCC) and the Kyoto protocol[6]. Article 3.3 forests represented a net removal of over 16 Mt of CO_2 eq. from the atmosphere between 2008 and 2012, offsetting ca. 5 % of all national emissions.

The total forest area has been estimated to sequester 23 Mt CO_2 between 2006 and 2012. This includes emissions associated with drainage of forest soils, forest fires and deforestation. Ireland has elected to report and account for all forest lands, including forests planted before 1990, in the second commitment period (2013-2020). The use of these offsetting provisions would not be possible without data provided by the NFI on an ongoing basis.

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[5] Anon. 2013. Ireland's Greenhouse Gas Emissions in 2012 - Key Highlights. Environmental Protection Agency, Johnstown Castle Estate, Co. Wexford, Ireland 2013.

[6] Duffy, B. Hyde, E. Hanley, O'Brien, P., Ponzi, J. and Black, K. 2013. National inventory report greenhouse gas emissions 1990 – 2010 Reported to the United Nations Framework Convention On Climate Change, EPA, Dublin.

5.8.1 NFI Carbon Stocks

The 2012 results confirm that the national forest estate is an important carbon reservoir, amounting to 381 million tonnes (Table 9). These direct estimates show that carbon in biomass, deadwood and litter pools has increased between 2006 and 2012.

Table 9. Forest Carbon stock 2006 and 2012.

	2006		2012	
Carbon Stock	Million t	% Total	Million t	% Total
Above-ground biomass*	30.619	8.9	39.705	10.4
Below-ground biomass**	6.695	1.9	8.846	2.3
Deadwood***	1.249	0.4	2.475	0.6
Litter	2.480	0.7	6.269	1.6
Soil	304.860	88.1	323.738	85.1
Total	348,394	100.0	381.033	100.0

* Above-ground biomass includes all living stems, branches and needles/leaves based on a stump height at 1% of total tree height.
** Below-ground biomass includes all roots to a minimum diameter of 5 mm
*** Deadwood includes all logs, stumps and branches with a minimum diameter of 7cm

The carbon stock in forest soils is the dominant component, accounting for 85.1% of the carbon stock in the forest estate in 2012. Total living tree biomass amounts to 12.7% of the total carbon stock, while deadwood, including logs, stumps and standing dead trees along with litter constitutes the remaining 2.2%.

The carbon stock in the living tree biomass was 48.5 million tonnes in 2012, with Sitka spruce and 'other pine' species the predominant contributors (62.8%) (Figure 38). From an ownership perspective, the Public, Private (grant aided) and Private (other) forest estates account for 53.6%, 33.1% and 13.3% respectively of the carbon stock in the living tree biomass (Figure 39).

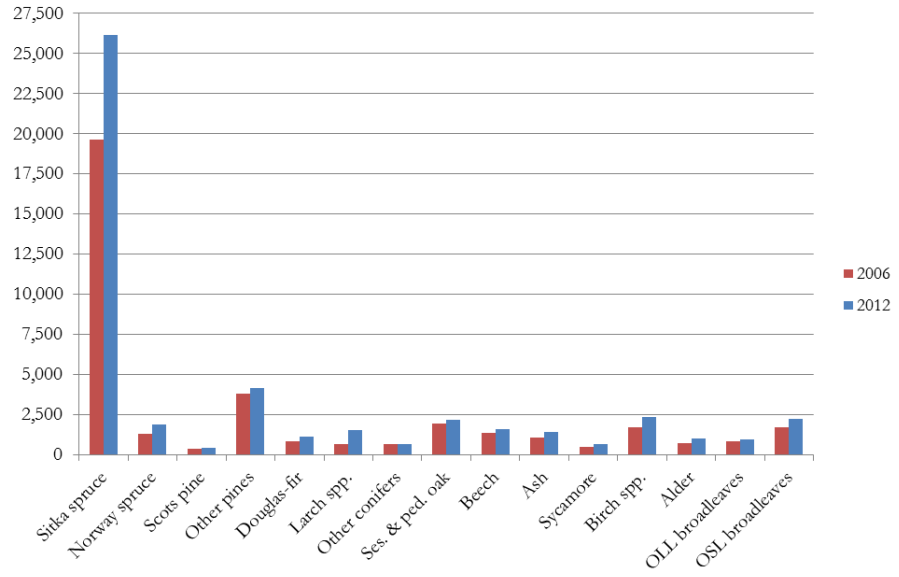

Figure 38. Total living tree carbon stock by species group 2006 & 2012.

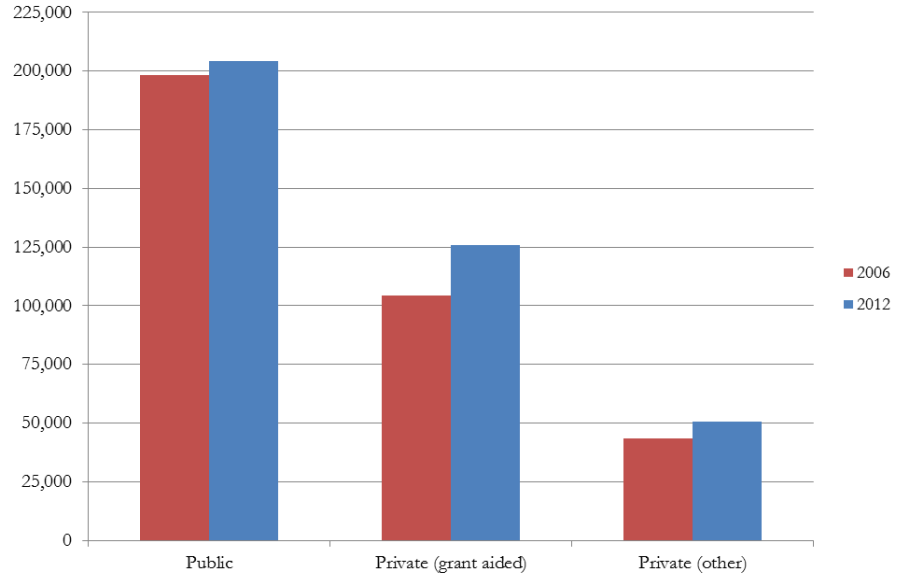

Figure 39. Total carbon stock by ownership type 2006 & 2012.

Notes

1. Due to improved estimation techniques, in which biomass equations from other countries were replaced with nationally generated biomass equations, the original 2006 carbon estimates have been revised. This also allows for valid comparisons between 1st and 2nd cycle carbon estimates.
2. The forest carbon stock estimates were calculated using the CARBWARE model which used NFI data.
3. Direct estimation of stock changes, based on presented biomass, litter and deadwood carbon stocks (Table 9) are higher than those estimated derived based on the gain and loss approach used in the CARBWARE reporting system. This is because standard inventory approaches do not capture key processes such as emissions associated with drainage of soils, forest fires and residual affects following deforestation. Other factors include CARBWARE single tree growth model bias, where biomass increment is under estimated, particularly for less common broadleaf common species.
4. It is important to note that the increase in soil carbon stock is a direct result of the increase in forest area since 2006, so the calculated stock change does not reflect a 'real' removal of CO_2 from the atmosphere. Drained organic forest soils emit ca. 0.1 Mt CO_2 per year, but this is offset by a much larger removal of CO_2 due to accumulation of biomass, litter and deadwood.
5. The accumulation of carbon in the litter and deadwood pools is due to an increase in forest area and accumulation of harvest residues on the forest floor. These carbon pools decompose relatively slowly due to the presence of highly recalcitrant compounds, such as lignin, in these pools.

5.9 Health and Vitality

The NFI is the only systematic national assessment of forest damage in Irish forests. Information is collected on forest damage at the individual tree level**.** Abiotic (e.g. wind), biotic (e.g. deer) and human induced (e.g. mechanical harvesting) factors affect forest health and vitality. It can increase forest susceptibility to disturbances or changes in the environment. Defoliation is a key variable used in monitoring forest health. The types of forest damage recorded are those which are most common or cause most damage to Ireland's forests. Over 15 different types of forest damage are recorded including windblow, frost, human induced, nutrient deficiency, browsing, peeling, squirrel, defoliators, decay or canker fungi.

5.9.1 Factors Affecting Forest Estate

Over three quarters (77%) of stocked forest areas have no negative factors impacting on tree growth and development (Table 10). Nutrient deficiency was recorded as an issue with 78,571 ha or 12% of the stocked forest area.

Table 10. Total stocked forest area by negative factors

	Area (Ha)	95% C.I.
No neg. factors	492,879	(480,073-505,685)
Vegetation competition	4,005	(1,531-6,479)
Current grazing	1,998	(247-3,749)
Browsing	20,074	(14,638-25,509)
Exposure	22,011	(16,352-27,669)
Waterlogged soil	18,816	(13,529-24,102)
Frost	5,194	(2,386-8,002)
Nutrition deficiency	78,571	(68,600-88,542)
Insect	2,801	(734-4,869)
Other factors	5,219	(2,440-7,998)
Squirrel damage	2,811	(733-4,889)

Height growth on forests was assessed as an indication of the performance of forests. The majority of forests (88%) have satisfactory height growth. A minority (4.3%) were described as having stagnating height growth, which is predominately due to nutrient deficiency and/or water-logging (Figure 40).

In terms of windblow, just over 8,000ha or 1.2% of the stocked forest estate was recorded as windblown. Some 62% of the windblown area was composed of the species groups Sitka spruce and Other pines. In terms of growing stock just over 1.7 million m^3, or 1.8% of total growing stock, was windblown.

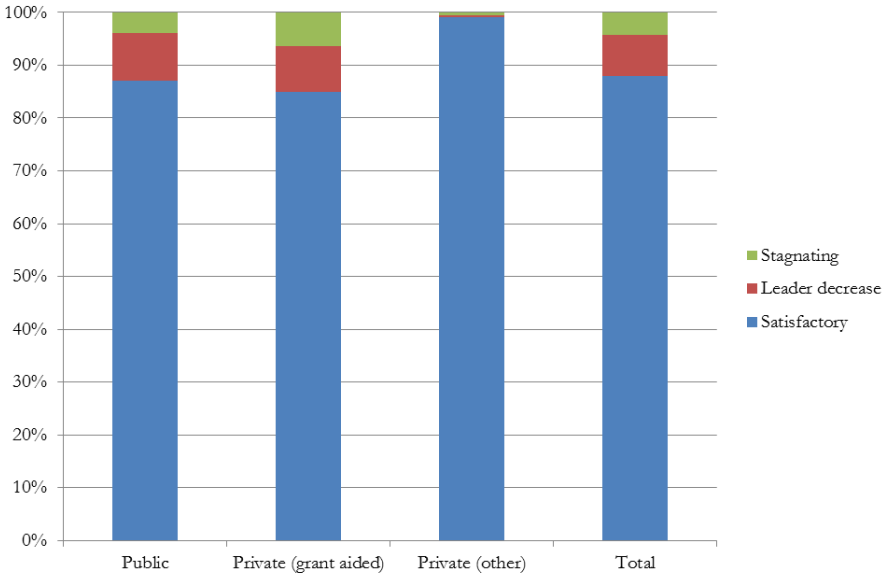

Figure 40. Proportion of the stocked forest area by ownership and height growth status.

5.9.2 Tree Vitality

Tree vitality describes the capacity of a tree to survive and grow. Trees showing normal growth and vitality, with no serious defoliation or damage in the crown were the main category observed comprising 86% of trees recorded. Very biotic trees with very little defoliation or damage in the crown comprised 1.8% of tress recorded; while weak trees, poorly performing trees with serious defoliation and/or crown damage, comprised 12.2% of trees sampled for health and vitality (Figure 41). Broadleaf and coniferous species were comparable in terms of vitality.

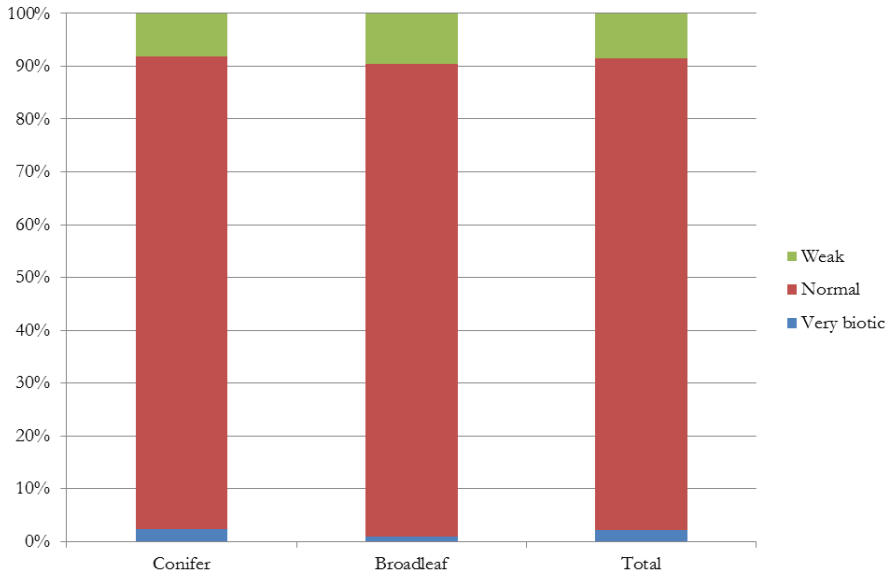

Figure 41. Proportion of trees (Dbh ≥7cm) by species group and tree vitality.

5.9.3 Discolouration and Defoliation

Discolouration is a deviation from the usual colour of the living foliage for a given species; dead or dying needles are excluded from the assessment. Tree defoliation is the abnormal loss of tree foliage. In general the main coniferous tree species are very healthy, displaying low levels of defoliation with an overall average of 16.8% defoliation (Figure 42). The coniferous species showing least defoliation was Norway spruce, while our main commercial tree species Sitka spruce showed no defoliation in 82.6% of trees and Scots pine had the highest levels of defoliation (27.9%).

In terms of discolouration the spruces showed little discolouration at less than 10% overall (Figure 43). However the Other pines comprised mainly of Lodgepole pine showed significant discolouration with 27.1% of trees assessed displaying yellowing or browning of needles.

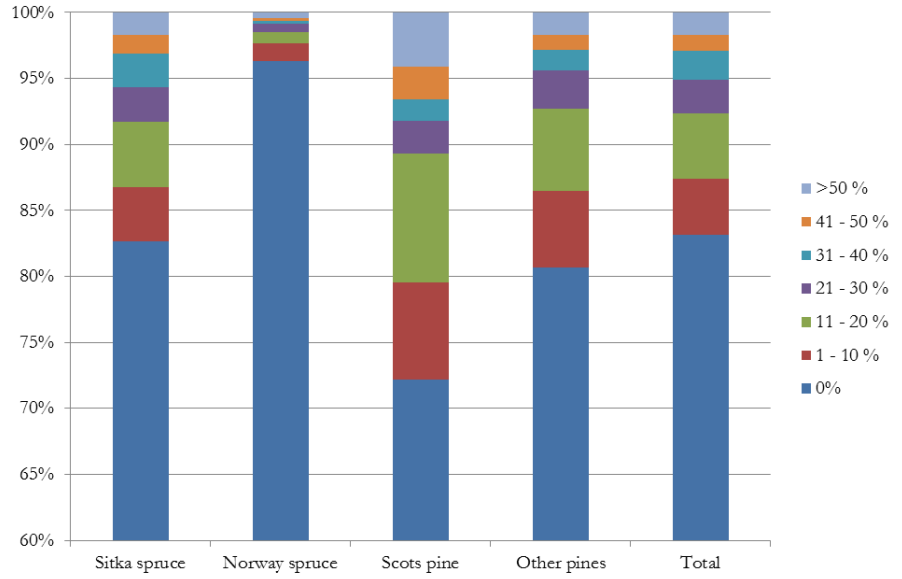

Figure 42. Proportion of main conifer species trees by defoliation.

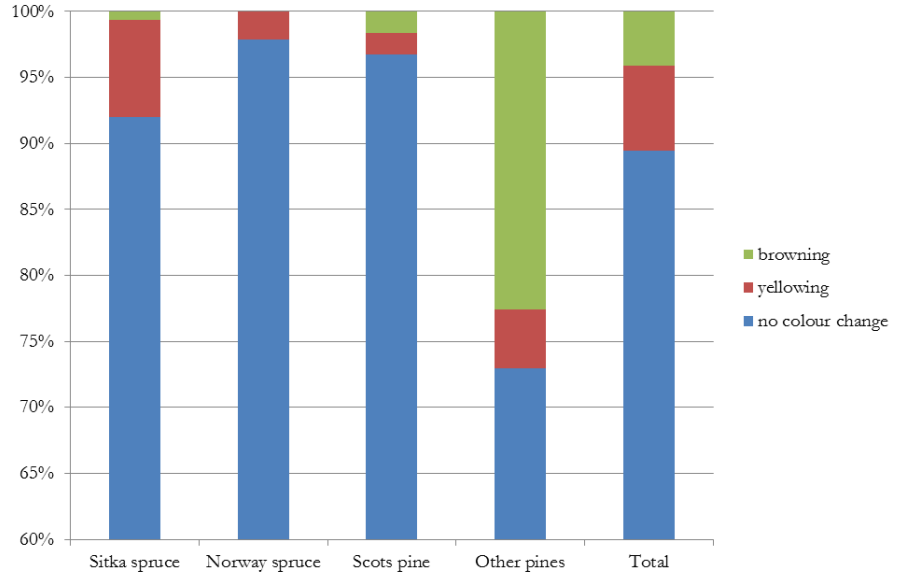

Figure 43. Proportion of main conifer trees by discolouration.

5.9.4 Stem and Peeling Damage

Deer are the main causative agent for tree peeling damage while mechanical harvesting also has a significant impact in tree stem damage.

Broadleaf trees display a higher proportion of stem damage than coniferous trees. Approximately 6% of broadleaf trees examined displayed stem damage affecting at least up to ⅛ of the perimeter bark with the comparable figure for coniferous trees less than 3% (Figure 44).

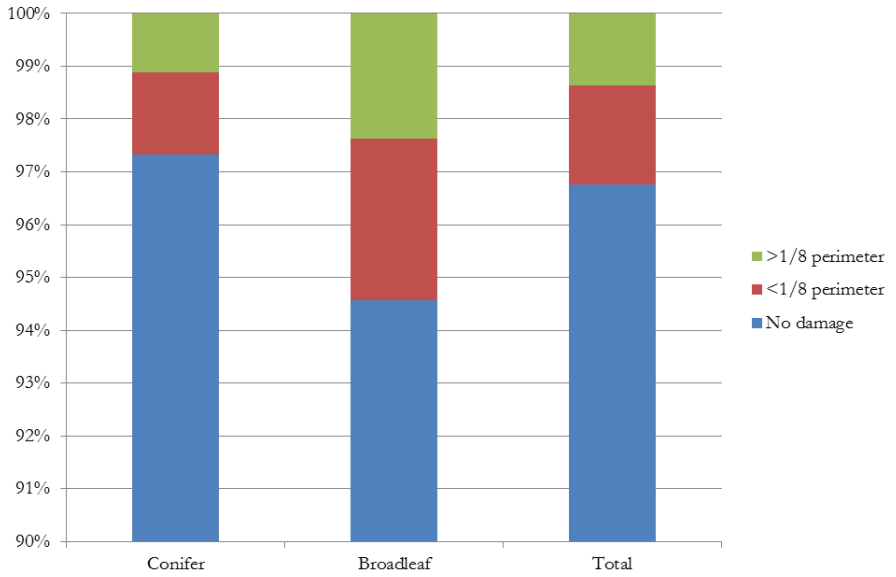

Figure 44. Proportion of trees (Dbh ≥7cm) by stem damage.

In terms of peeling damage, again, the broadleaf species display greater damage than coniferous species due to their preference by biotic factors such as deer and squirrels (Figure 45).

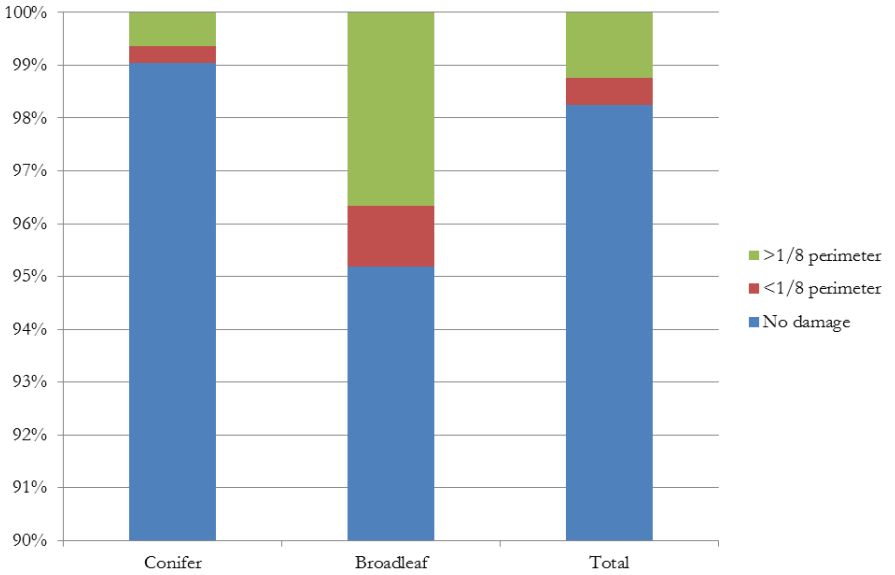

Figure 45. Proportion of trees (Dbh ≥7cm) by peeling damage.

5.10 Diversity and Deadwood

Ireland positioned at mid-latitudes is warmed by the Gulf Stream and experiences a very favourable climate for plant growth and diversity.

5.10.1 Tree Diversity

Tree species diversity in our forests enhances the appearance of the landscape, creates wildlife habitats, protects forest health and provides a variety of timbers that can be used in a wide range of end uses.

Less than 30% of Ireland's forests are single species forests (Figure 46). In terms of tree diversity the most diverse cohort of Ireland's forests are the Private (other) category, comprising of at least 4 or more tree species in nearly 60% of the area.

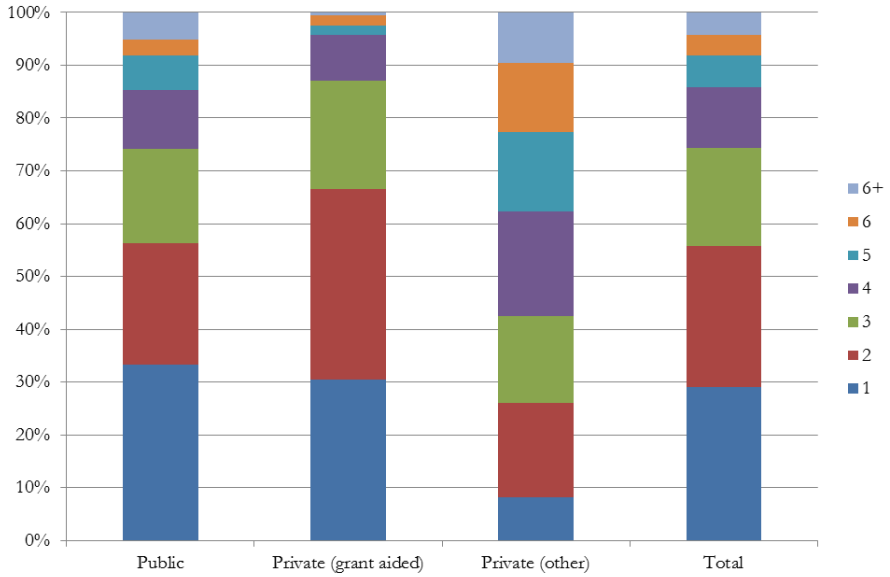

Figure 46. Proportion of the forest area by ownership and number of tree species.

5.10.2 Plant Diversity

The assessment of plant diversity is an important indicator which can be used in the monitoring of SFM. The structure/range of the vegetation present will also be indicative of the insect diversity. Both the Public and Private (grant aided) forests show similar levels of circa 60% abundant vegetation cover on the forest floor while the Private (other) cohort contains nearly 80% abundant vegetation (Figure 47).

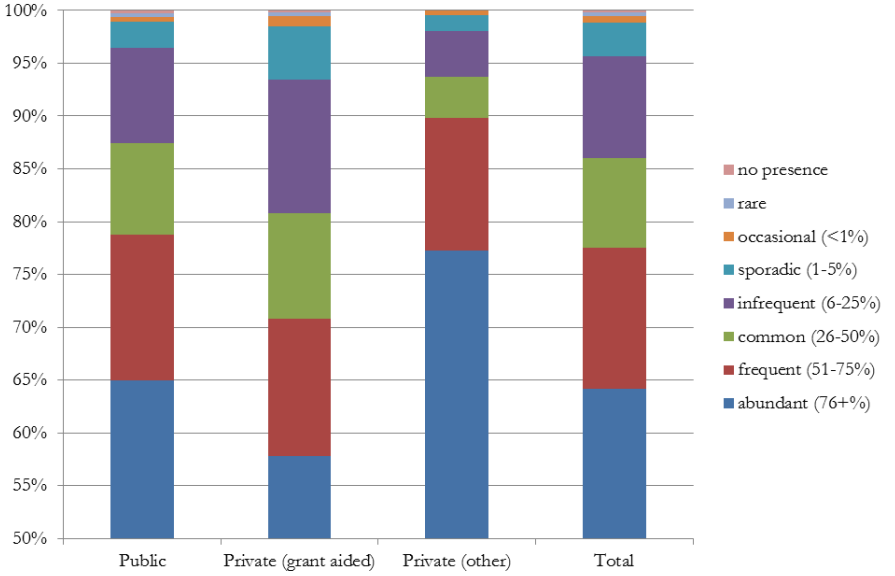

Figure 47. Proportion of the forest area by ownership and vegetation cover.

In terms of the occurrence frequency of plant species in Irish forests, all forests have at least 1-5 different plant species present and over 80% have between 6 and 21+ plants species present (Figure 48).

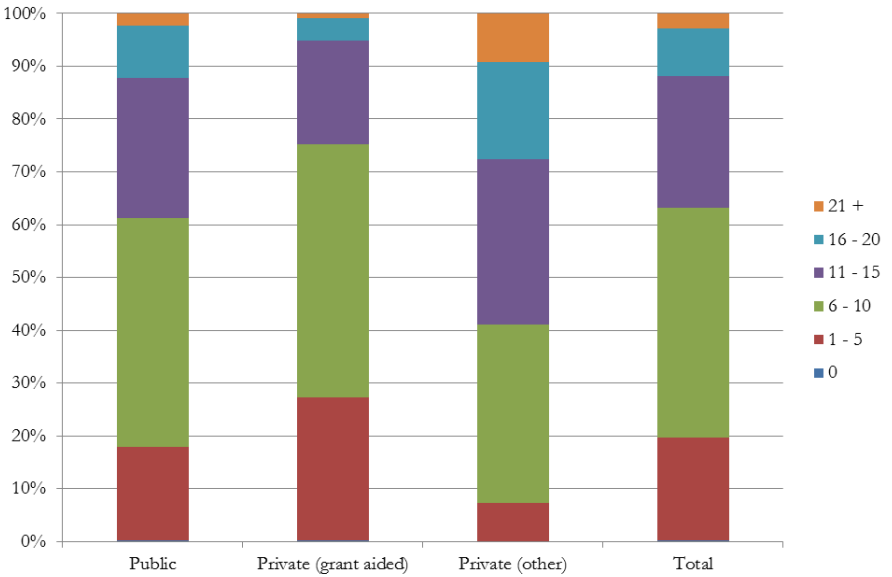

Figure 48. Proportion of forest area by ownership and number of plant species.

5.10.3 Deadwood

Large woody material contains very significant stores of carbon and energy and is the foundation of an important forest food web. This large material usually decays more slowly and therefore provides a more steady input of energy and longer-lasting structures. Deadwood also provides habitat for plants, animals and insects and a source of nutrients for soil development.

There are 5.56 million m^3 of deadwood in the forest estate. Nearly half (46%) of all deadwood is lying on the forest floor.

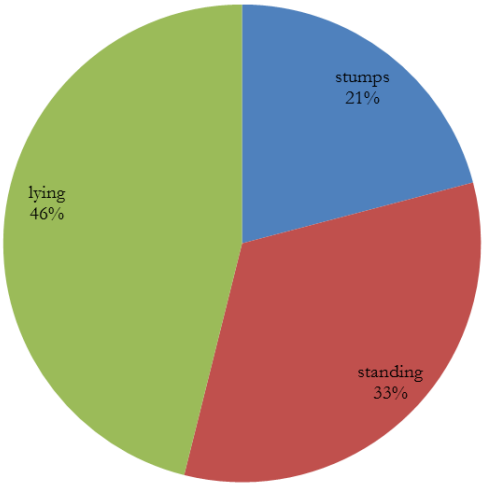

Figure 49. Proportion of deadwood volume by deadwood type.

The Public forest estate has the majority (82.5%) of the deadwood, due primarily to the relatively high level of harvesting occuring in these forests (Figure 50). As the Private (grant aided) estate is only entering the production phase, deadwood amounts are low.

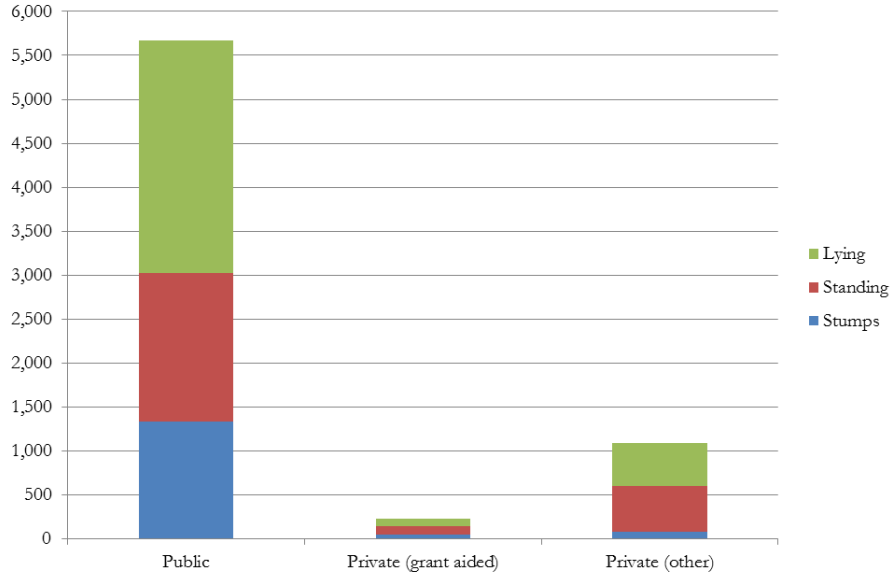

Figure 50. Total deadwood volume by ownership.

Glossary

Age	The number of growing seasons since initial planting or natural regeneration.
Afforestation	Afforestation is the man-made establishment of new forests on treeless lands which did not carry forest in contemporary history.
Basal Area	The cross-sectional area of a tree measured at 1.3m from the ground, or the sum of the basal areas of trees in a specified area, expressed in m^2.
Broadleaves	Trees with broad, flat leaves, e.g. oak, ash, beech and sycamore. Growth is not in whorls but almost always diffusely branched. Usually deciduous.
Carbon pool	A system with the capacity to accumulate or release carbon, expressed in mass units (tonnes C).
Clearfell	A continuous block of trees that have been felled.
Conifers	Trees that have needle-like leaves and bear cones. They are usually, but not always, evergreen.
Confidence Interval	The confidence interval quantifies the uncertainty in measurement by specifying the range of values within which the true value for the whole population lies. As a 95% confidence interval is used for the NFI analyses, there is a 95% probability that the true value for the population lies within the range of values.
Diameter at breast height (Dbh)	The Dbh of a tree is the stem diameter at 1.3 m from ground level.
Forest	Forest is defined as land with a minimum area of 0.1 ha, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20% within the forest boundary, or trees able to reach these thresholds *in situ*.
Gross Annual Volume Increment	Mean annual volume of tree increment over the period 2006-2012 of trees ≥7cm Dbh. Includes the increment of trees which have been felled or have died during the reference period.
Growing stock	The overbark volume of living trees (Dbh≥7 cm) from stump to 7cm top diameter.
High forest	A forest that has a high proportion of sawlog approaching or at normal rotation length.
Multistoried forest	Forest with trees present at various stages of development, i.e. height.
Native species	Species that have arrived and inhabited an area naturally, without deliberate assistance by man. For trees in Ireland usually taken to mean those present after post-glacial

	recolonisation and before historic times. For NFI purposes the species list of natives trees recorded is based on the list of species eligible for inclusion in Ireland's Native Woodland Scheme.
Ownership	**S**pecifies land ownership.
Overmature forest	A forest retained beyond its normal rotation length, resulting in the presence of large trees.
Pole stage	A forest at a stage where it could be thinned or in the early stages of thinning.
Post establishment stage	A recently established forest that is not at free growing stage.
Pre-thicket stage	The forest is established, but the green branches are not yet touching.
Private (grant aided)	Private afforested land which was or is in receipt of grant and/or premium over the period 1980 to present.
Private (other)	Private forest land which was not established with grant aid since 1980. This category includes estate planting and natural succession land.
Public	Forest land owned by the Irish State e.g. Coillte, National Parks and Wildlife Service, Bord na Mona.
Scrub	Refers to vegetation types where the dominant woody elements are shrubs i.e. woody perennial plants, reaching a height of more than 0.5 m and less than 5 m in height at maturity and without a definite stem and crown.
Semi-natural woodland	Forests established by natural regeneration, i.e. greater than 80% of the tree species regenerated naturally
Sustainable Forest Management (SFM)	Sustainable Forest Management as a central principle of Irish forest policy, whereby forests are managed to provide economic, social and environmental benefits on a sustainable basis for both current and future generations.
Small pole stage	Forest where the canopy has fully closed and the lower branches are dead.
Thicket stage	Forest where the canopy has closed but the lower branches are mainly green.
Thinning	Periodic removal of trees in a stand which are competing with those better trees which are expected to form the final crop. The object is to benefit the final crop trees, and to get income from the thinnings before they die.

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