

Indicator name			Version
NF5 Planted forest tree species diversity index			25/03/16
Indicator type:	Risk/opportunity	Impact	Action
			X
SCCAP Theme	SCCAP Objective	CCRA risk/opportunity	
Natural Environment	N2: Support a healthy and diverse natural environment with the capacity to adapt N3: Sustain and enhance the benefits, goods and services that the natural environment provides	Cross cutting BD4 Risks of diseases to biodiversity	

At a glance

- Diversity of tree species within a forest ecosystem can enhance resilience to environmental change
- There is currently a lack of diversity in Scotland's forests, with Sitka spruce occupying 43% of all forest area
- Enhanced diversity can reduce vulnerability to climate related threats such as changes to species suitability for future climatic conditions and damage due to pest and disease
- Changes to legislative and policy drivers such as woodland grants appear to have influenced species diversity in the past
- The Shannon Index is an ecological indicator of diversity that accounts for the number of tree species and their proportionate distribution in Scotland's forests

Latest Figure	Trend
The Shannon Index of Diversity is currently 2.10, which can be considered moderately diverse.	Forest Tree Species Diversity has increased slightly over the last 18 years, with an increase in broadleaf forest area.

Why is this indicator important?

Reliance on only a few tree species increases the vulnerability of a forest ecosystem to disturbance, whereas increasing diversity can spread the risk and reduce potential impacts (Thompson *et al.* 2009). Scotland's forests consist of relatively few species in significant proportions, and a single species (Sitka spruce) occupies 43% of all forest area. Increasing the diversity of forest tree species grown in Scotland can build resilience to climate related threats, including changes to species suitability in an

uncertain future climate, and damage from an outbreak of insect pest or plant pathogens. Increased tree species diversity can also increase wider biodiversity and support forest ecosystems to adapt. This indicator considers the forest tree species composition of standing forest in Scotland, and measures the diversity using the Shannon Index, an ecological indicator of diversity which accounts for both the number of species and their proportionate distribution.

Related indicators:

NF4 Diversity of tree species ordered for planting in Scotland

What is happening now?

The Shannon Index (SI) of diversity accounts for both the number and the proportion of each forest tree species, and can be used to measure diversity. Higher SI values equate to higher diversity. The current SI value for forests in Scotland is 2.10, which equates to moderate diversity based on a total of 81 species categories which were identified in the National Forest Inventory (NFI) (Forestry Commission, 2014). A hypothetical maximum Shannon Index score for Scotland would be 4.4, where all 81 species categories were present equally¹.

A minimum of 73 species were found in the 2001 NFI survey, with an additional seven categories for 'other' species (either rare specimen trees or unidentified). However the majority of these species only occupy a small area. Approximately 35 species occupy 1000 hectares or more, 14 species occupy 10,000 hectares or more, and 3 species occupy 100,000 hectares or more.

Scotland's forests contain a higher proportion of conifer forest (75%) than broadleaf (25%) (Forestry Commission, 2014). Forest area was measured as 1,419,000 hectares in 2014. Across all of Scotland's forests, Sitka spruce is the dominant conifer species accounting for 59% of all conifer forest (Figure 1a), and 43% of total forest area. Scots pine accounts for 18% of conifer area, and 13% total forest area (Forestry Commission, 2014). Birches are the predominant broadleaf species, comprising 43% of all broadleaf forest and 11% of total forest area, followed by oak species at 9% of all broadleaf forest and 2% of total forest area (Figure 1b) (Forestry Commission, 2014).

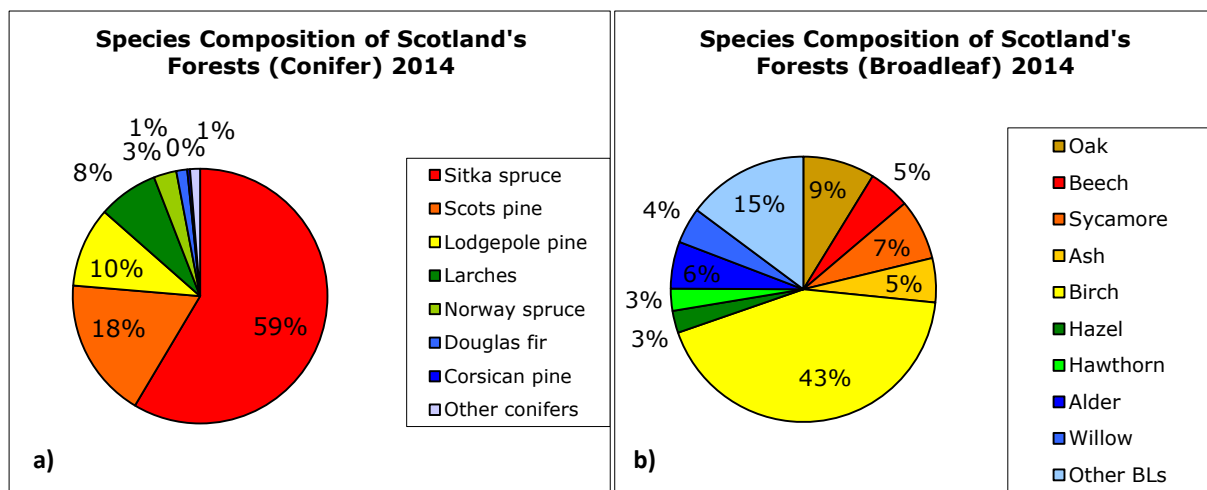


Figure 1. Species composition of Scotland's forests, including both privately owned and National Forest Estate a) Conifer species and b) broadleaf (Forestry Commission, 2014). Data from March 2012.

¹ If five species each occupied 10%, another five species 5% each, and the remaining 25% was divided between the remaining 71 species the Shannon Index would be 3.3.

What has happened in the past?

A previous national inventory was taken in Scotland in 1995, (the National Inventory of Woodland and Trees (Forestry Commission, 2001)), allowing a comparison of forest tree species composition over almost 20 years. Detailed species composition is not available and therefore a Shannon Index value cannot be calculated.

Forest area was measured as 1,281,000 ha in the 1995 survey, and has therefore increased by 138,000 hectares, or 11% by 2014 (Forestry Commission, 2014). The overall proportion of conifer forest has decreased, from 81.6% in 1995 to 74.6% in 2014, and broadleaf forest has increased, from 18.4% in 1995 to 25.4% in 2014. The area of conifer forest has decreased by almost 44,500 hectares, and the area of broadleaf forest has increased by over 90,000 hectares (figures exclude open space, coppice and felled areas) (Forestry Commission, 2014).

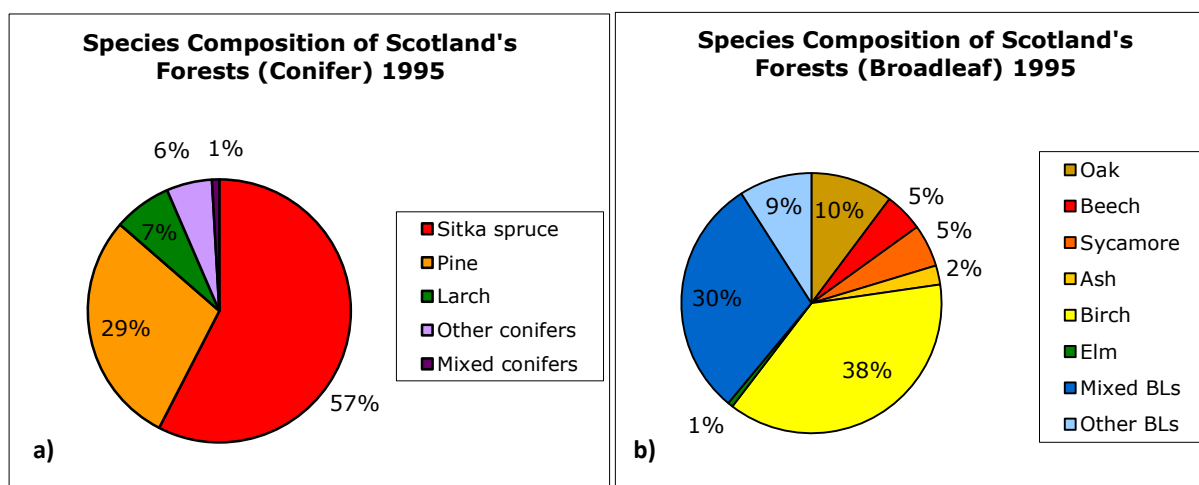


Figure 2. Species composition of Scotland's forests (privately owned and National Forest Estate) as surveyed in 1995 (Forestry Commission 2001), a) Conifer species and b) broadleaf species

Figure 2 shows the species composition as recorded in 1995. The proportion of Sitka spruce and larch are similar across both surveys, and the overall proportion of pines is similar at 29% and 28% in 1995 and 2014 respectively, although the grouping of pine species in 1995 prevents further comparison.

The composition of broadleaf species shows a greater change with time. Birch is the dominant species in all surveys, and the area increased from 38% to 43% from 1995 to 2014. The proportions of oak and beech remain similar, and the proportions of ash and sycamore have increased. The category groupings prevent further comparison of minor species.

Recent pathogen outbreaks affecting larch and ash species have reduced the area of these species, through increased felling and decreased planting. This is not evident between the 1995 and 2014 data sets, as the area of ash increased with the increase in broadleaf planting over the wide time frame. The 2014 data were collected in March 2012, which is prior to the peak of the outbreaks.

What is projected to happen in the future?

As a result of changes to legislation and guidelines, species diversity might be expected to increase in future. The UK Forestry Standards include criteria for species diversity, requiring a maximum of 75% of a single species in a management unit (Forestry Commission, 2011). In the UK Woodland Assurance Scheme the maximum is also 75%, reducing to a maximum of 65% where at least two species are suitable for the site and match the management objectives (UKWAS, 2012). Forestry Commission Scotland's Climate Change programme supports the 'planning and managing of well-structured and diverse forests' to build resilience to climate change. (Forestry Commission Scotland, 2013).

Additional business and policy objectives support an increase in species diversification for benefits to

amenity and recreation, visual impact on the landscape, and improved water quality (Forestry Commission Scotland, 2006).

If increasing tree species diversity is adopted by the sector as a means of building resilience, the rate of change is still likely to be slow. The rate of change is limited by the area of forest which can be felled and replanted each year, currently around 1-2%. Initial change will also be restricted by the forest supply chain, including: timber markets, nursery stock, seed availability, and forest management knowledge and experience.

The effects of pests and pathogens may have detrimental effects on forest diversity in the short term, as the range of species available decreases. The impact on diversity could be beneficial in the longer term if a wide range of novel species are planted, subject to the restrictions described above.

Patterns of change



Figure 3. The 5 regions of Scotland as used in the National Forest Inventory 2011, insert Shetland Islands. (Forestry Commission 2012)

The National Forest Inventory divides Scotland in to 5 regions (Figure 3). Species composition varies between regions (Figure 4b and 4c), as does the Shannon Index (Figure 4a).

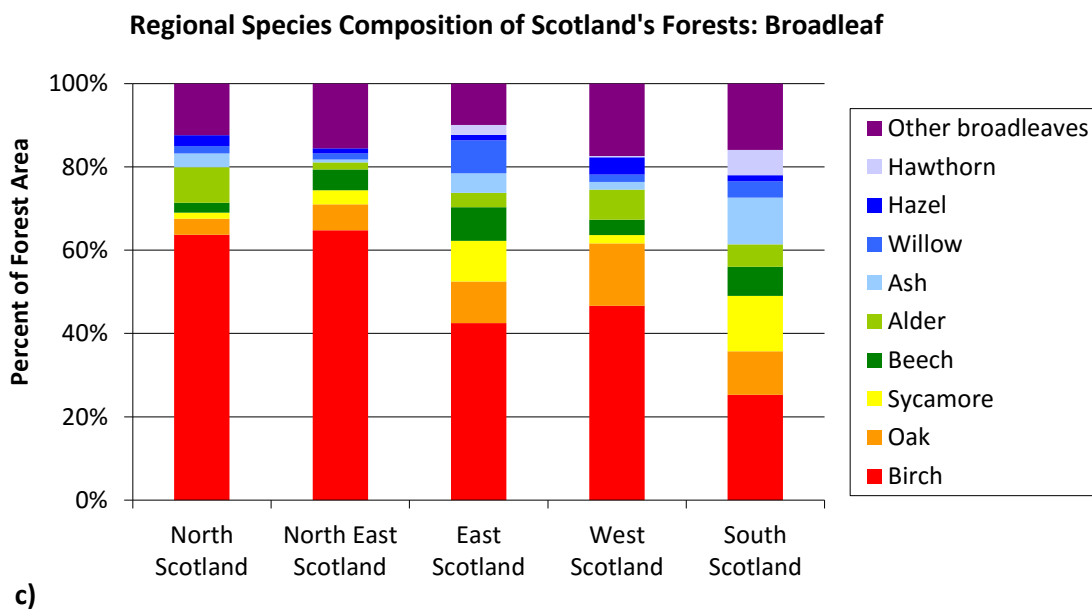
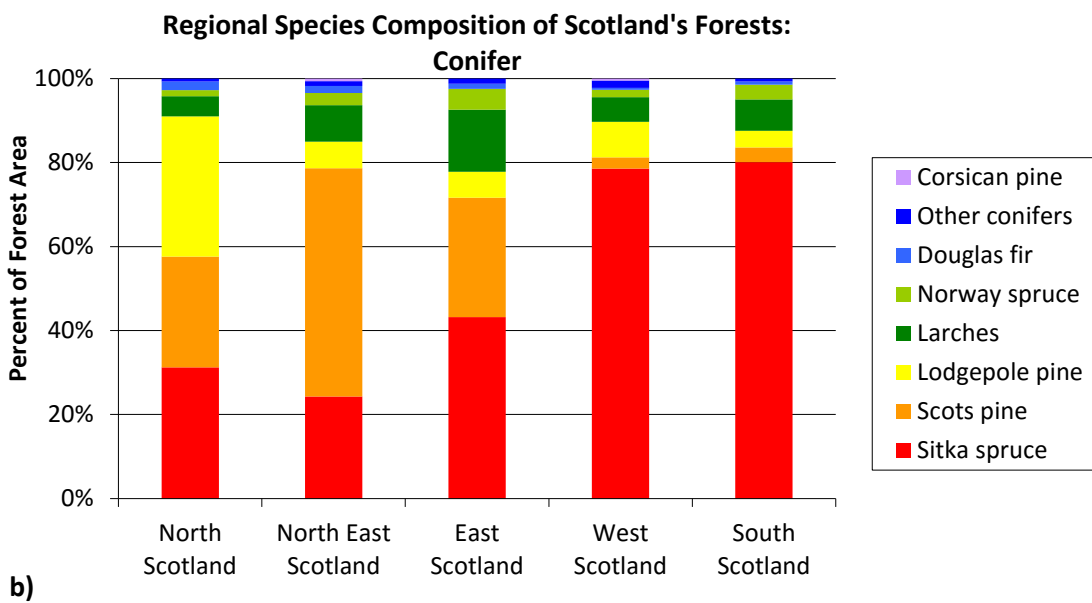
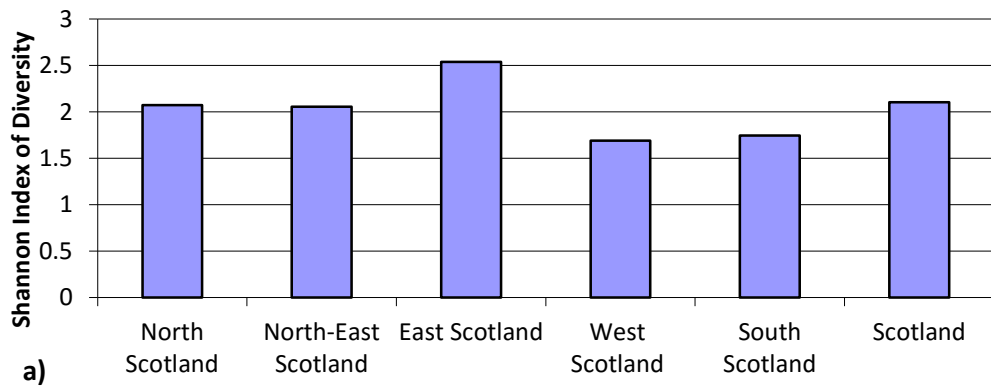


Figure 4. Regional variation in a) Shannon Index, b) conifer species composition c) broadleaf species composition. National Forest Inventory data (Forestry Commission 2012)

Sitka spruce accounts for almost 80% of conifer area in South and West Scotland. North East Scotland contains a higher proportion of Scots pine, and North Scotland has almost equal proportions of Sitka spruce, Scots pine and lodgepole pine. Regional variations in soil type and climate account for much of the variation in species composition. In eastern parts of Scotland conditions are frequently too dry for growing Sitka spruce and are more suitable for Scots pine. In northern Scotland it is common management practice to grow Sitka spruce in self-thinning mixtures with lodgepole pine or Scots pine, as the high wind risk in these areas makes conventional thinning unviable. Instead, natural thinning takes place, as the slower growing species will be outgrown by Sitka spruce. The diversity in North Scotland will therefore be lower than it appears, as the final crop will often be a single species.

Broadleaf species composition also varies by region, with North and North East Scotland dominated by birch species. South Scotland has the highest diversity of broadleaf species and West Scotland has the highest area of Oak. Again, regional differences in climate and soil conditions can account for these differences, as birch is well suited to the upland sites found in northern Scotland, and Oak is well suited to western Scotland, and the milder conditions in southern Scotland suit a wider range of broadleaf species.

These differences are reflected in the Shannon Index (Figure 4a), with East Scotland having a higher Shannon Index (2.54) and West and South Scotland the lowest scores (1.7).

Interpretation of indicator trends

Overall, forest tree species diversity has increased between 1995 and 2014 due to the increase in planted broadleaf forest. Species composition of the major commercial species does not appear to have changed greatly since 1995, with Sitka spruce occupying the same overall proportion of forest area. It is not possible to calculate Shannon Index values from the national inventory datasets for Scotland, as records do not include a detailed breakdown for more novel species. Future analysis will identify subsequent trends in species diversity.

There are regional variations in species composition, with North East and East Scotland showing the highest overall diversity. It is important to consider that regional diversity may be constrained by climatic conditions and available soil types.

The concept of increasing forest diversity for resilience to climate change is fairly recent, and the small changes seen in this dataset are likely due to other drivers. Woodland grants in the last 20 years have promoted native woodland planting, and this is evident in the rate of increase in broadleaf forest area. Changes in legislation affecting the areas where conifers can be planted, such as riparian areas, peatland and ancient woodland sites (Scots pine excluded), may account for the reduction in conifer forest area (Forestry Commission, 2011).

Changes to species composition are likely to occur slowly, as the rotation length in Scottish forestry is around 50 years for conifer species, and the rate of felling and replanting is currently around 1-2% of forest area annually. The management objective of large areas of Scotland's forest is to produce timber, which limits the range of species choice. Any changes to the supply chain, including market demand, are likely to occur slowly. It is important that any changes in species composition are considered in light of the business needs of the sector, and any efforts in diversification are matched by research and investment into alternative timber species and wood products to support Scotland's timber industry.

Limitations

Species composition and Shannon Index figures in this Indicator are calculated at national and large regional scales, but does not account for diversity at smaller scales.

References

Forestry Commission (2001) *National Inventory of Woodlands and Trees – Scotland*. Available at: www.forestry.gov.uk/inventory

Forestry Commission (2011) *UK Forestry Standards*. Forestry Commission, Edinburgh 108 pp. Available at: www.forestry.gov.uk/theukforestrystandard

Forestry Commission (2014) *Forestry Statistics 2014, National Statistics*. Available at: www.forestry.gov.uk/statistics

Forestry Commission Scotland (2006) *Scottish Forestry Strategy*. Available at: [www.forestry.gov.uk/pdf/SFS2006fcdc101.pdf/\\$FILE/SFS2006fcdc101.pdf](http://www.forestry.gov.uk/pdf/SFS2006fcdc101.pdf/$FILE/SFS2006fcdc101.pdf)

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Thompson, I., Mackey, B., McNulty, S., Mosseler, A. (2009). Forest Resilience, Biodiversity, and Climate Change. *A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems*. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67 pages. Available at: <https://www.cbd.int/doc/publications/cbd-ts-43-en.pdf>

UKWAS (2012) *UK Woodland Assurance Standard Third Edition (version 3.1)*. Available at: <http://ukwas.org.uk/>

Further information

Acknowledgements

This indicator was written by Kate Beauchamp, Forest Research

Forestry Commission Scotland; National Forest Inventory, Forestry Commission

Appendix One: Indicator metadata and methodology

Table 1: Indicator metadata

	Metadata
Title of the indicator	Planted forest tree species diversity index
Indicator contact: Organisation or individual/s responsible for the indicator	Ruth Monfries, RBGE
Indicator data source	Forestry Commission National Forest Inventory and Forestry Commission National Inventory of Woodland and Trees
Data link: URL for retrieving the indicator primary indicator data.	www.forestry.gov.uk/inventory www.forestry.gov.uk/statistics www.forestry.gov.uk/datadownload

Table 2: Indicator data

	Indicator data
Temporal coverage: Start and end dates, identifying any significant data gaps.	National data for species composition are available for 1995 and 2014, and regional data are available for 2014. National and regional Shannon Index values are available for 2011.
Frequency of updates: Planned or potential updates	The next National Forest Inventory survey is expected to be carried out in 2016, with preliminary results available from 2017.
Spatial coverage: Maximum area for which data is available	Scotland
Uncertainties: Uncertainty issues arising from e.g. data collection, aggregation of data, data gaps	Shannon Index values are calculated from NFI sample data which have not been stratified according to identified forest types or FC/private management.
Spatial resolution: Scale/unit for which data is collected	Scotland and 5 sub-regions within Scotland
Categorical resolution: Potential for disaggregation of data into categories	Data can be separated into conifer and broadleaf species, National Forest Estate and private ownership.
Data accessibility: Restrictions on usage, relevant terms & conditions	

Table 3 Contributing data sources

Contributing data sources

Data sets used to create the indicator data, the organisation responsible for them and any URLs which provide access to the data.

Forestry Commission (2001) National Inventory of Woodlands and Trees - Scotland

Available at: www.forestry.gov.uk/inventory

Forestry Commission (2014) Forestry Statistics 2014, *National Statistics*.

Available at: www.forestry.gov.uk/statistics

National Inventory, Forestry Commission, provided details of the area of all species found in the 2011 survey for Scotland and the 5 regions for calculating Shannon Index Values.

Table 4 Indicator methodology

Indicator methodology

The methodology used to create the indicator data

The Shannon – Wiener Index (from here referred to as the Shannon Index or SI) is a widely used measure of diversity, which incorporates both the number of species (richness) and the proportion (percent cover) of each species in a defined region. The SI is calculated by first calculating the proportion of forest area occupied by each species (p_i). The natural log of the proportion is taken, and multiplied by the proportion. The product values are summed and multiplied by -1 to give the Shannon Index:

$$SI = - \sum_{i=1}^n p_i \cdot \ln p_i$$

The data used to calculate the Shannon Index are unpublished data provided by the National Forest Inventory, Forestry Commission (2014). Sample area data for each species were provided for each of the 5 regions. The sample data were adjusted for forest area in each region but not stratified by forest type or FC/private ownership. Full details of the NFI sampling methodology can be found at: www.forestry.gov.uk/forestry/inf-d-89q9r3