Growing Network Protects UK Tree Genetic Diversity

Tom Sim, **Joan Cottrell** and **Stephen Cavers** introduce Genetic Conservation Units (GCUs) and explain their importance in conserving genetic diversity.

Back in 2019, the first GCU in the UK was registered for Scots pine (*Pinus sylvestris*) at Beinn Eighe National Nature Reserve (NNR), managed by NatureScot (Figure 1). This population is an iconic remnant fragment of the ancient Caledonian pinewoods and is located at the northwestern edge of the species' range. Over generations, the population here has adapted to the mild and wet local conditions, and this distinctiveness makes up a key component of the species' genetic diversity at a European level.

As of early 2026, the UK has registered a total of 40 GCUs across 12 native species (Figure 2). This is a significant step forward in conserving genetic diversity in our native tree species and is testament to the positive engagement of stakeholders across the forestry and conservation sectors.

However, much more work is needed to capture distinctive genetic diversity in other parts of our islands. This article will discuss why GCUs are important and outline how stakeholders are now collaborating to expand the UK network.

Figure 1. Scots pine in a gully woodland at Allt a Chuirn, Beinn Eighe NNR, Kinlochewe, Scotland, May 2022. (Photo: ©Laurie Campbell/NatureScot)

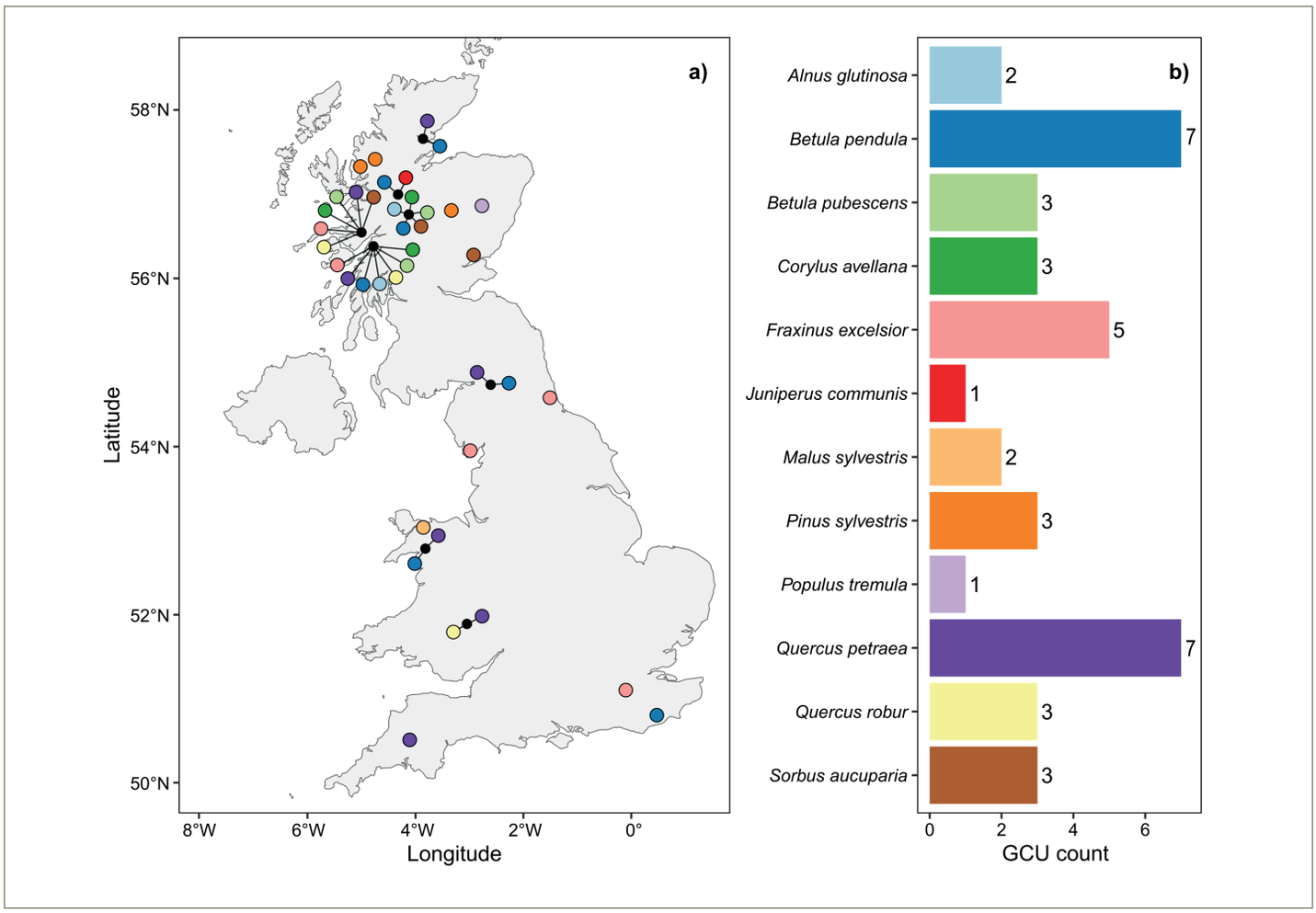

Figure 2. UK Genetic Conservation Units (GCUs) by species: a) locations of current GCUs and b) counts of current GCUs by species. Where multiple target species are present at the same location, each is counted as a separate GCU. Note the location of a Malus sylvestris GCU is private and has been omitted from the map.

What is a GCU?

GCUs for trees were conceived as part of a Europe-wide conservation effort coordinated by the European Forest Genetic Resources Programme (EUFORGEN) – a network formed in 1994 at the behest of the Ministerial Conference on the Protection of Forests in Europe (now Forest Europe) and that the UK has been a member of since 2000. EUFORGEN (2008) defined a GCU as:

"…a forest area that is formally designated to the protection of forest genetic resources (FGR) of one or more forest tree species. It is established to allow the full cycle of natural processes to occur with the conservation objective of dynamically conserving the evolutionary potential of the population."

> "This is a significant step forward in conserving genetic diversity in our native tree species."

In other words, a GCU is a stand of trees of one species that acts as a living repository of genetic diversity. Crucially, a GCU is managed to ensure it continues to evolve and adapt to local environmental conditions, termed 'dynamic conservation' by EUFORGEN (Koskela et al., 2013; Lefèvre et al., 2013). The ideal method of achieving this is through the promotion of natural regeneration. The majority of GCUs are '*in situ*' at a site where the tree population is autochthonous (naturally occurring or indigenous). Typically, this would mean the best and most pristine of our ancient woodlands, usually managed with conservation as a priority (Figure 3). Less common are '*ex situ*' GCUs, human-modified or planted populations away from the natural site, that are nevertheless recognised as

Figure 3. Veteran oak tree covered in lichens, mosses and ferns, Ariundle NNR, Ardnamurchan. (Photo: ©Lorne Gill/NatureScot)

Figure 4. A veteran wild apple at a GCU on private land in Scotland. (Photo: Tom Sim)

genetically distinctive. The focus on *in situ* conservation allows for evolutionary processes to be maintained alongside local ecological interactions. Furthermore, this approach sees any adaptive changes in the population as a positive force and the best way to secure the resilience of genetic diversity in the long term.

There is a defined set of minimum requirements relating to size and management that must be met for a site to be recognised as a GCU (EUFORGEN, 2008; Hubert and Cottrell, 2014). The minimum number of reproductive trees required is 500 for typical stand-forming species (e.g. Scots pine), 50 trees for naturally scattered species (e.g. wild apple; Figure 4) and 15 for rare or endangered species (e.g. black poplar, although there are currently no UK GCUs for this species). Multiple target species can be registered in the same woodland area. Furthermore, provided dynamic conservation is implemented for the target species, sites can still be managed for multiple purposes, including timber production. The GCU registration is intentionally non-restrictive, ensuring that management obligations are not burdensome. GCUs are recorded on the European Information System on Forest Genetic Resources (EUFGIS) by the National Focal Point (NFP) of each EUFORGEN member country – the NFP for the UK is Tom Sim (see author details). Monitoring of the site is recommended every five to ten years to ensure the minimum requirements are still met and is coordinated by the NFP. The EUFGIS database provides site-specific information for each GCU, including current and future climate and soil moisture data, as well as being the central repository of information on GCUs; this is a useful resource for GCU managers, national forestry agencies, researchers and the wider conservation community.

Why are GCUs important?

Genetic diversity is a key element of species resilience (Smith et al., 2025), which has been fully recognised by international convention (Target 4, Kunming-Montreal Global Biodiversity Framework, KMBGF). As a party to the convention, the UK is committed to conserving genetic diversity in its species and has developed guidance to support achieving this for tree species (UK Forestry Standard, Forest Research, 2023). The EUFORGEN (2024) framework provides a way to do this quantifiably, consistently and robustly. Importantly, given the growing threats from climate change, pests, and diseases, conservation strategies have to be adaptable to be resilient. A network of *in situ* GCUs across the full range of a tree species, managed according to dynamic conservation principles, can protect genetic diversity while realising the adaptive potential of populations to adapt to changing environmental conditions (Figure 5).

Genetic diversity increases the odds that suitable genotypes exist within a population that can thrive in future climates or resist novel pests or pathogens (Salgotra and Chauhan, 2023). Tree populations maintain high genetic diversity, promoted by mechanisms such as cross-pollination, prolific flowering and fruiting, and long-distance pollen and/or seed dispersal (Cottrell, 2020). Natural selection, continually acting on this diversity, will tend to favour genotypes that are well-suited to their local environments and will, over time, produce populations that are locally adapted (Figure 6). Among-provenance differences (e.g. height, phenology or resistance to water stress) suggestive of local adaptation have now been widely documented at large to fine spatial scales for many of our tree species, e.g. Scots pine (Donnelly et al., 2016; Oleksyn et al., 1998; Salmela et al., 2013), silver birch (Lee et al., 2015) and ash (Rosique-Esplugas et al., 2022).

The key to maintaining the process of adaptation in tree populations is ensuring ongoing natural regeneration (Cavers and Cottrell, 2015), which in the UK

Figure 5. Regenerating aspen woodland at Muir of Dinnet NNR, Grampian area. Multiple aspen clones (both male and female) are present at the site. (Photo: ©Lorne Gill/NatureScot)

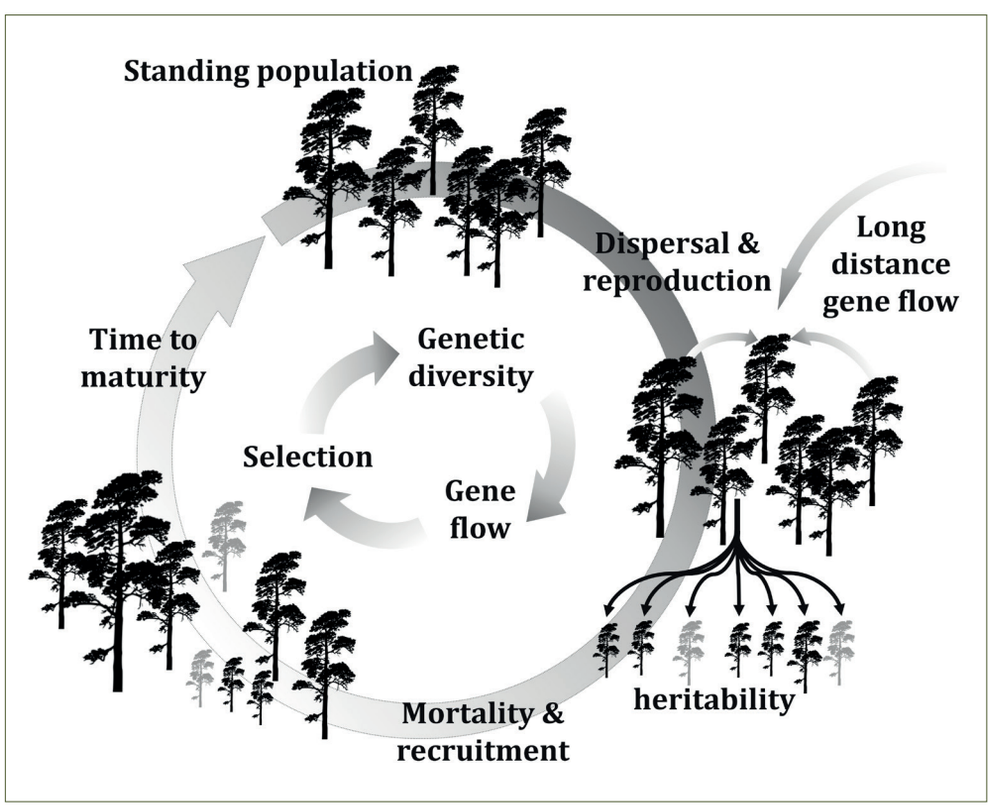

Figure 6. Processes conferring species resilience for forest trees. The capability to adapt to new pressures depends on genetic diversity, gene flow and the rate at which new genotypes can be recruited into the population.

Figure 7. Natural regeneration of Scots pine at Glen Derry on Mar Lodge Estate, managed by the National Trust for Scotland. (Photo: Shaila Rao)

often requires appropriate management of deer or other herbivores to avoid selective browsing of young trees. This is, of course, not without its challenges. A well-publicised success story of effective deer management is in Glen Derry, a Caledonian pinewood and GCU on Mar Lodge Estate (Figure 7). When regeneration is achieved, ongoing natural selection effectively allows continual resampling, recombination and selection of the standing genetic diversity. In principle, this can allow a population to track changing environmental conditions, albeit with a lag defined by the time it takes for populations to recruit new individuals and the time they take to reach reproductive maturity. The dynamic conservation approach taken for GCUs maintains these evolutionary processes, giving populations the best possible chance to adapt to changing conditions, securing their genetic diversity for the future.

Figure 8. Native birch natural regeneration, Choill a Choire, Creag Meagaidh NNR. (Photo: ©Lorne Gill/NatureScot)

The current network

Following extensive collaboration and stakeholder engagement *A Strategy for UK Forest Genetic Resources* was published in 2019 (Trivedi et al., 2019). Among other things, this aimed to kick-start the establishment of a network of *in situ* GCUs for the UK, based on EUFORGEN principles. Since then, 40 GCUs across 20 sites and 12 species have been identified and registered (Figure 2), thanks to the enthusiastic participation of a diverse range of stakeholders. The majority have been established on Woodland Trust and NatureScot sites (e.g. Figures 8 and 9), with others on sites owned or managed by Natural Resources Wales (NRW), Bangor University, National Trust for

Scotland (NTS), Trees for Life and private landowners.

To optimise the sampling of genetic diversity in the absence of comprehensive empirical data, EUFORGEN uses an environmental stratification of Europe (Metzger, 2018), which splits the UK into two primary ecozones, covering our distinctive northern oceanic climates. The principle is that trees are likely to be adapted to their local environments, so by registering GCUs across different ecozones we can capture a wider range of genetic diversity. EUFORGEN recommends at least one GCU for each ecozone that a species occurs in; so in the UK the minimum number of GCUs would be two per native species. However, as many studies have shown local adaptation at finer spatial scales within the UK (e.g. Donnelly et al., 2016; Lee et al., 2015; Rosique-Esplugas et al., 2022; Salmela et al., 2013), and to provide protective redundancy, the aim in the UK is to have ten GCUs per species, well distributed across ecozones.

National progress towards achieving these goals can be tracked within the new EUFGIS database (www.eufgis.org), where each country can be regularly evaluated by a set of indicators (Table 1), which measure achievements against the overall goal of protecting diversity in all of the country's target species. The UK still has some way to go in terms of securing its overall species diversity but, of the GCUs registered, a good ecozone coverage is being achieved (Figure 10; Table 1). The most well-represented species in the UK are silver birch (*Betula pendula*) and sessile oak (*Quercus petraea*) with seven GCUs each, followed by ash (*Fraxinus excelsior*) with five, and then downy birch (*Betula pubescens*), hazel (*Corylus avellana*), English oak (*Quercus robur*), rowan (*Sorbus aucuparia*) and Scots pine (*Pinus sylvestris*) all with three GCUs (Figure 2). Notable native species that are yet to have a GCU registered include yew (*Taxus baccata*), native willows (e.g. *Salix caprea* and *Salix alba*) as well as small-leaved lime (*Tilia cordata*) and large-leaved lime (*Tilia platyphyllos*).

"The most well-represented species in the UK are silver birch and sessile oak."

Figure 9. Rowan berries near Loch Laggan, Creag Meagaidh NNR. (Photo: ©Lorne Gill/NatureScot)

Table 1. Description of indicators used in EUFGIS to evaluate GCU coverage in each country.

Indicator	Description
Species diversity index	Diversity of the species conserved, namely how many of the conserved species are represented by at least one GCU. Calculated as: number of species listed as target species in genetic conservation units / number of priority species occurring within the country.
Insurance index	Insurance of conservation, namely the presence of more than one GCU of the same species in the same ecozone. Calculated as: number of ecozones represented in the conservation network with a minimum number of two units / number of ecozones occurring within the country (summed over conserved species only).
Ecozone diversity	Representativeness of the different ecozones in conservation efforts. Calculated as: number of ecozones represented in the national conservation network / total number of ecozones occurring within the country (summed over conserved species only).

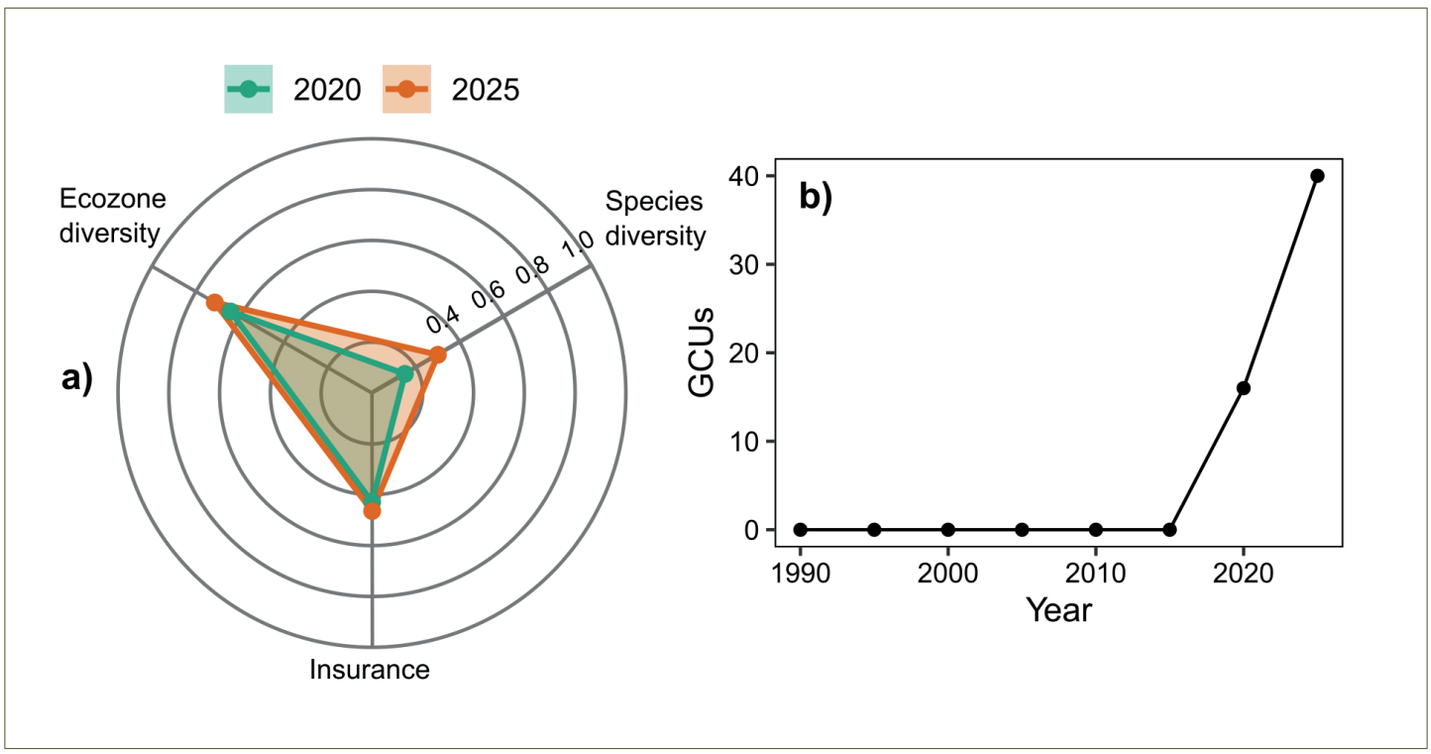

Figure 10. EUFGIS summaries for the UK showing: a) status of three indicators (species diversity, ecozone diversity and insurance) in 2020 and 2025, scaled 0-1: see Table 1 for full descriptions of indicators; and b) numbers of in situ GCUs registered over time, 5-year intervals. All data available at EUFGIS.org.

What does the future look like?

Within the next year, the aim is to register a minimum of 25 more GCUs in collaboration with Forestry and Land Scotland (FLS), Forestry England, Natural England, the National Trust, NRW, NTS, among others, and any landowners who may wish to participate in extending the network. If you would like to join the network or know of someone that would, please contact the authors. Under-represented species and ecozones will be targeted, to address gaps in the conservation network, with a focus on expanding representation in England and Wales. Working towards a target of 10 GCUs per species for the whole UK, sites will be identified across the distributions of our native species, stratified to capture the UK's full environmental and geographic diversity. Here, the existing Regions of Provenance (ROP; Herbert et al., 1999) can be a guide on mainland Great Britain (GB). For example, for beech (*Fagus sylvatica*), the native distribution is confined to the south, so potential GCUs in ROP 3 and ROP 4 will be targeted, which capture environmental variation across this area.

> "Within the next year, the aim is to register a minimum of 25 more GCUs."

In the next few years, there will also be work to include more *ex situ* GCUs – for example, seed stands of non-local material that perform well in their adopted environment and where natural regeneration is encouraged – and to collate information on important genetic resources of non-native species and native species outside natural stands.

The progress made to date demonstrates what can be achieved through coordinated effort across the forestry and conservation sectors. Expanding and strengthening the UK GCU network will help to future-proof our native woodlands by conserving the genetic diversity and evolutionary processes that underpin the capacity of our tree species to adapt to an uncertain future.

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