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Marginal/peripheral populations of forest tree species and their conservation status: report for Atlantic region

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Abstract - This report is a synthesis of information from the national reports, prepared as part of the COST Action FP1202 *Strengthening conservation: a key issue for adaptation of marginal/peripheral populations of forest trees to climate change in Europe (MaP-FGR)*. The individual national reports can be found as part of the supplemental data to the COST action. The data compiled in this report indicate that the Atlantic area has sufficient resources in terms of knowledge and capacity to assess the potential impact of climate change on marginal and peripheral (MaP) sites within the area. Maps of vegetation, soil, climate and climatic predictions are publicly available for most countries and often are of high quality and resolution. These can be utilized to help identify MaP sites and populations in the Atlantic area. In addition, some species have been characterized genetically and the genetic data can also be utilized to identify and characterize sites. However, genetic data is not universally available and in particular may be absent for peripheral sites. There are many data sources for phenotypic traits, such as data from provenance trials but these have not been assessed for MaP populations. There may not be sufficient legislative capacity for the conservation of MaP populations in comparison to, for example, annex habitats of the EU Habitats Directive. Although some of the MaP sites lie within Natura 2000 boundaries, many are not in protected areas. If MaP populations are not characterized and conserved there is a risk of losing traits that may be of potential in adaptation to climate change. A detailed spatial analysis incorporating all of the data is needed to give a comprehensive assessment of the potential threats to MaP populations in this area.

Keywords - Forest genetic resources; forest tree marginal populations; MaPs; marginality; Cost Action FP 1202 MaP FGR.

Geographical characteristics of the Region

Extension and borders

For the purposes of this report the Atlantic Area of Europe covers countries that are most influenced by the Atlantic Ocean. It is the western seaboard of Europe from Spain in the south to Norway in the north. It includes parts of Germany in the east to Ireland in the west. The area corresponds to the Atlantic floristic region for Europe. The Atlantic area is discussed in a broad and general sense in this report and is supplemented by details from the national reports. The countries covered include; Portugal, Spain, France, The United Kingdom, Ireland, Belgium, The Netherlands, Germany, Denmark and Norway. However, the report is not an exclusive account of the Atlantic area as it includes data from all parts of the countries included, not just the Atlantic areas.

Orography

A shallow shelf extends along much of the western European coast. The highest mountains present in this area are located at national borders, for example, the Pyrenees between Spain and France. Mountainous areas are a dominant part of the landscape in the North of Spain, to a certain extent along the west of Ireland and Scotland and along the western fringe of Norway.

Human presence

The area is a mix of the most heavily populated regions in Europe, such as France, the UK and Germany and some of the least populated regions such as in Ireland and Norway. There is a long history of human impact, including deforestation, and the coasts along the Atlantic region were routes of Viking colonization. The area is often referred to as the Celtic fringe in a biogeographical context. Some of the least forested regions of Europe occur in the Atlantic area, including Ireland and coastal parts of France, the UK and the Netherlands.

Geographic barriers to gene flow

The main geographic barrier to gene flow in this area and the most dominant climatic factor is the Atlantic Ocean. The warmth and northerly direction of currents in the Atlantic have had a major influence on post-glacial colonization of trees (Bennett et al. 1991). The currents in the Atlantic result in a prevail-

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ing south-westerly wind direction, thus potentially impacting wind-borne seed and pollen to flow in a northerly direction. At the most northern extent of this area arctic winds will have significant impacts in limiting gene flow. The rise in sea level during the most recent glacial retreat resulted in the isolation of islands and land masses, in particular for the UK and Ireland (e.g. Devoy 1995). A large scale study of oaks across Europe has shown that oaks in the Atlantic fringe form a genetic lineage, thus indicating the potential for rapid but restricted post-glacial movement along the western seaboard (Petit et al. 2002, Kelleher et al. 2004 for Ireland).

Other barriers

The varied topography from mountainous regions to lowlands will influence gene flow. This is particularly relevant in northern regions of Spain and western regions of Ireland, Scotland and Norway, where there are more mountains.

Ecological aspects

Climatic characteristics of the region and availability of databases and maps at a regional level

The main climatic influence on the Atlantic Area is the Atlantic Ocean. However, there are large differences in temperature and precipitation across the area. For example, the average annual temperature in the most southern part of the Atlantic Area in Portugal is 16°C, while that in Norway is 1 to 2°C. The extremes of temperature are even more dramatic than these averages. The average rainfall tends to be quite high, generally above 800 mm per annum and in high elevation coastal regions it can be above 1,600 mm (EEA 2012). According to the climatic stratification of Metzger et al. (2005) the Atlantic area considered in this report is composed of four main climatic strata; the Lusitanian, Atlantic Central, Atlantic North and Alpine North. This is an indication of the heterogeneity of the area. Most of the countries within the Atlantic area have undertaken research on mapping of climatic characteristics and databases and maps are available online or in selected publications (see individual country reports for details).

Soil characteristics and availability of databases and maps at a regional level

Similar to the climatic mapping, the coverage of soil maps across the Atlantic area is also good. Most countries have online soil maps at various scales (see individual country reports for details).

Possible future modifications due to climatic change

Climate change models predict significant changes across this area, which will bring challenges and opportunities to the Atlantic area, as with other regions. In particular the southern areas will be most affected by increases in temperature (e.g. IPCC 2007). The prediction is for a decrease in rainfall for the southern parts of Europe and increases in the northern parts. Another potential vulnerability in the Atlantic area is species on coastal mountains. These species are likely to be impacted by increased temperatures and thus increased competition with other species. One major influence that is difficult to predict is the increase in extreme events such as storms, which have shown an increase since the 1970s in the North Atlantic (IPCC 2013) and are predicted to increase in frequency into the future (Haarsma et al. 2013). Although there is a large degree of uncertainty involved in predicting storms, increased flooding is predicted with a high degree of confidence (IPCC 2013).

Parts of the Atlantic area of Europe, in particular western oceanic regions such as Ireland, are likely to benefit from climate change in some aspects due to an increase in the length of the growing season arising from increases in temperatures (Menzel and Fabian 1999). For example, phenological records in Ireland over the last 30 years show an increase in the length of growing season by 5 days due to earlier spring and later autumn (Donnelly et al. 2006).

Vegetational aspects

Diffusion of forests

Following the last glacial maximum, tree migration in the Atlantic region was quite rapid (Hewitt 1999). Pollen records indicate a rate of migration for many tree species between 50 – 500 m per year and this slows as the trees moved northwards (Bennett et al. 1986). The resultant spatial genetic pattern for oaks in this area indicates a combination of long distance travel through vectors such as birds followed by localized dispersal of these pioneer individuals (Lowe et al. 2005). However, in comparison to today there was a lack of competition during the initial phases of post-glacial migration. The post-glacial landscape was a *tabula rasa* for species colonization. Today the landscape is occupied by more stable vegetation, is managed for agricultural or is urbanized. Migration under current conditions will be heavily influenced by competing species and competing land uses. Due to increased habitat fragmentation the diffusion of forests is also likely to be impeded. Hedgerows in an agricultural

landscape can act as a corridor for gene migration while more intensive agricultural landscapes offer few migration routes.

Kinds of forest prevalent

In the southern part of the Atlantic area, in Portugal, dry forests, such as Cork oak (*Quercus suber*) forests are the dominant forest habitat. Pines, such as *Pinus pinaster* are also prevalent in the southern drier regions. Further north, mixed deciduous forest, including oak forests dominated by *Quercus petraea* and *Q. robur* are more frequent. In lowland regions with basic soils *Q. robur* forests tend to be more dominant, while in upland regions with acidic soils *Q. petraea* tends to be more dominant. Beech (*Fagus sylvatica*) forest reaches its geographical limit in the Atlantic area and is not considered native in Ireland.

For forestry plantation some non-native species are also used in the Atlantic area. In Britain and Ireland and parts of France and Denmark Sitka spruce (*Picea sitchensis*) is the dominant species for commercial forestry. *Pinus contorta* is planted frequently in Ireland, Britain and Denmark. In Spain there are *Pinus radiata* plantations in the north along the coast. In Portugal exotic eucalyptus species (*Eucalyptus globulus*) are important elements of the forest coverage, forming 26% of the forest cover.

Species more common and/or representative

Broadleaf species are most common in the Atlantic area, with oak species probably being the dominant taxa, *Quercus suber* in more southern parts and *Q. robur* and *Q. petraea* in more northern parts. Other broadleaves such as F*raxinus excelsior*, *Betula* spp. and *Prunus avium* are also common.

Major threats to forests

Habitat fragmentation is one of the biggest threats to forest areas and forest continuity. The dominance of agricultural landscapes along the Atlantic area has led to increased fragmentation of forests with limited migration corridors for gene flow. Land use, such as urbanization, is also a significant threat to forest habitat.

Forest fires are also an increasing threat, particularly in southern areas, such as Portugal and Spain.

In terms of biotic threats, a major threat for *Fraxinus excelsior* in recent years is Ash dieback caused by *Hymenoscyphus fraxineus*. This disease has had a major impact on commercial forestry of *F. excelsior*. Other biotic threats that are of increasing concern are *Phytophthora alni* on alder, *P. ramorum* on oak and *P. kernoviae* on beech.

Range expansion of introduced exotic species and invasive species is also a concern, although little data exists for tree species in this area.

Expected modifications due to climatic change

Changes in forest ranges and forest types are expected as a result of climate change, however there is a large degree of uncertainty regarding the specific outcomes. Potential changes include species range shifts, changes in species composition, biotic factors such as competition and disease, adaptation capacity and changes in performance (Kelleher et al. 2015). Species range shifts are predicted based on current species envelopes and models of climate change, a northward expansion and a contraction in the south is expected for Europe (Kremer et al. 2012). Northward migration in the Atlantic area is likely due particularly to increases in temperatures. There is also potential for increased competition with species migrating from central Europe to coastal areas. Changes in species composition are likely not only from migration but also from hybridization and introgression. A study in Ireland showed increased risk of genetic assimilation and hybridization of two taxa due to potential changes in species climatic envelopes (Beatty et al. 2014). Hybridization is common for example in oaks (e.g. Bacilieri et al. 1993; Valbuena-Carabaña et al. 2005) and so increased overlap of species ranges will lead to increased potential for hybridization.

The extended growing season that is predicted to occur and which has been shown for recent years will result in increased growth. This is the case for more Northern region as these will potentially benefit from an increase in temperatures. Although increases in temperatures generally increases growth, there are potential issues with species that need extended chilling to break dormancy (Myking and Heide 1995) and this could have important implications for local adaptation (Pletsers et al. 2015).

In the southern parts of this region there will be changes to the fire regime, such as extensions of the fire risk season and increased intensity and frequency of fires. There will also be increased risk of drought, especially in areas of poor soil water retention.

Forest species at the edge of their distribution range

Species

The Atlantic Ocean marks the western limit of most species in this area as few can migrate across the Atlantic. However, a few species reach their terrestrial range limit or have disjunct distributions within the Atlantic area. *Fagus sylvatica* reaches its

northern limit in Norway and the natural range does not extend far into the UK. *Fraxinus excelsior* also reaches its northern limit in Norway. One notable species with a disjunct distribution is the Strawberry tree (*Arbutus unedo*), which is found in an isolated population in south-western Ireland. As part of the COST Action FP1202 a list of marginal populations was compiled from the countries involved. This list was based on expert opinion rather than a statistical assessment. The list includes 22 species in 117 populations (Table 1).

Table 1 - A list of species and numbers of marginal and peripheral populations identified as part of the COST FP1202 (no data was available for Belgium, Denmark and Norway). Note it should be taken into account that the data for each country includes the whole country and not only the Atlantic region.

Species	Country							
	France	Germany	Ireland	Netherlands	Portugal	Spain	The UK	Totals
Abies alba	4	1				3		**8**
Acer monspessulanum					1			**1**
Arbutus unedo			2					**2**
Castanea sativa					2	2		**4**
Fagus sylvatica	15	1		1		4	2	**23**
Fraxinus excelsior							2	**2**
Juniperus turbinata					1			**1**
Picea abies	3							**3**
Pinus halepensis	2							**2**
Pinus nigra	4					4		**8**
Pinus pinaster					1	7		**8**
Pinus pinea					1	5		**6**
Pinus sylvestris	7		2		1	5	3	**18**
Populus nigra		1		1			1	**3**
Populus tremula							2	**2**
Quercus petraea	4		1	1		5	2	**13**
Quercus pyrenaica					2			**2**
Quercus robur					1	3	1	**5**
Quercus robur / petraea							1	**1**
Quercus suber					1			**1**
Salix phylicifolia			1					**1**
Sorbus torminalis							2	**2**
Ulmus laevis				1				**1**
Totals	**39**	**3**	**6**	**4**	**11**	**38**	**16**	**117**

Kind of marginality occurring in the area

The marginality occurring in this area is a mix of geographical, ecological and disjunct marginality. With regard to geographical marginality, the populations are generally at the leading edge of the range of the species, for example in *Fagus sylvatica*. The leading edge will be in the northern regions, while a limited number of species will also have populations at the trailing edge of the species. Migration of populations from the leading edge can lead to populations that are disjunct from the core. An example of ecological marginality in the Atlantic area is the occurrence of rear edge populations of *Quercus suber* in Portugal. Low elevation *Picea abies* populations represent an ecological marginality in the Atlantic area.

Genetic information available on marginality

Very little information exists specifically on marginal populations, instead the genetic information tends to be for a species range or a national range. A considerable number of species have been assessed at a European scale, for example 22 widespread species were tested across Europe in Petit et al. (2003) and many more have been analyzed on a more local scale.

There is also a significant amount of information on provenance trials across this area. However, these tend to be focused on general performance rather than specifically investigating performance of marginal populations or marginal sites.

Most countries have contributed to a general assessment of forest genetic resources in the FAO *State of the World's Forest Genetic Resources* (FAO 2014). In this report the importance of marginal populations potentially containing specific adaptations for climate change was emphasized.

Most important marginal populations

One of the tasks of the FP1202 COST action working groups was to develop methodology to define and identify marginal and peripheral populations. Although the methodologies were developed the implementation of these still needs to occur in order to identify potential populations. As part of this task a list of marginal and peripheral populations for each country were suggested by different members of the COST action (Table 1). For the Atlantic area there are important marginal populations at the leading edge and the rear edge of range distributions.

Forest ecosystems and protected areas

Measures of environmental protection

A total of 11,385 Natura 2000 sites are located in the European Union countries of this area (https://www.eea.europa.eu/data-and-maps/data/natura) – i.e. Norway is excluded (Table 2).

The Natura 2000 sites in Table 2 include all areas of the countries and habitats of all types, not exclusively forest habitats in the Atlantic area. However, the numbers give an indication of the level of habitat protection in this area. According to Statistics Norway (https://www.ssb.no/en/arealvern), there are 2,885 protected sites with a total of 39,875 km2 on mainland Norway. This number is also not limited to forest habitats in the Atlantic area and includes all protected sites.

Table 2 - Overview of Natura 2000 sites their respective areas within the Atlantic Area (Norway is excluded) (https://www.eea.europa.eu/data-and-maps/data/natura-8/). Note it should be taken into account that the data for each country includes the whole country and not only the Atlantic region.

Country	Natura 2000 sites	Area (km²)
Belgium	310	5,589
Denmark	350	31,270
France	1,766	155,755
Germany	5,211	113,118
Ireland	595	22,841
The Netherlands	195	25,326
Portugal	165	56,676
Spain	1,863	283,651
The United Kingdom	930	177,663
Totals	11,385	871,893

There is no Natura 2000 site devoted primarily to conserving Forest Genetic Resources (FGR). Conservation of FGR is generally a by-product of species and habitat conservation. However, the EUFGIS portal contains populations that are conserved for FGR. The EUFGIS portal gives an indication of the coverage in this area (Table 3). The countries in the Atlantic area have a total of 423 *in situ* Genetic Conservation Units (GCUs) within the EUFGIS portal (as of 20/6/2017). This is an over-estimate of the number of GCUs in the Atlantic region as much of Germany is not within the Atlantic region and similarly for Spain, France and Norway. In total 47 different tree taxa are maintained in GCUs in this area.

Table 3 - Overview of in situ genetic conservation units in the countries within the Atlantic Area and the number of species registered in EUFGIS for each country. Note it should be taken into account that the data for each country includes the whole country and not only the Atlantic region.

Country	Number GCU (*in situ*)	Number of tree species in EUFGIS
Belgium	25	6
Denmark	73	23
France	93	8
Germany	127	22
Ireland	17	9
The Netherlands	13	13
Norway	23	10
Portugal	9	8
Spain	43	5
The United Kingdom	No information	No information
Total	**423**	

Measures for protection/exploitation/valorisation of MaPs already existing

The populations identified in Table 1 often have no protection. A limited number are Natura 2000 sites and some are also listed in EUFGIS as GCUs. From the 117 sites in total only 24 are confirmed as Natura 2000 sites, while 11 are confirmed as not being Natura 2000. Most of the sites are of unknown conservation status. Similarly for sites designated as GCUs, only 21 are confirmed as being entered into EUFGIS.

In summary, significant data sources are available in the Atlantic area to assess the status and potential impact of climate change on MaP populations. However, a thorough spatial analysis would be needed to get a comprehensive understanding of the status of MaPs in the Atlantic area.

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