EG041: "Encomienda de Gestión para actividades relacionadas con las conservación y promoción de recursos genéticos forestales contempladas en el programa nacional de desarrollo rural"

Línea Ae.f.3. Plan de obtención y utilización de recursos genéticos mejor adaptados.

Linea A7a. Reuniones y actividades de divulgación y formación.

Publicación de divulgación sobre Utilización de materiales mejorados

Seed sourcing in reforestation and ecological restoration programs

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Abstract

Adaptation of future plantations is one main concern when planning an afforestation or restoration program, but usually it is not the only objective of such a program. Are we looking for the performance in the value of some important traits (e.g., production, tolerance to pests, tolerance to special soil conditions, or survival)? Which level of genetic diversity do we need? Are there some special limitations for the conservation of genetic resources? In order to try to answer these questions, firstly, we have to distinguish among the procurement zones of the reproductive material, and the deployment zone of such material. To assist in the decision, we have developed a database with different criteria. We discuss the use of this database in afforestation and restoration programms.

Introduction

Adaptation of future plantations is one main concern when planning an afforestation or ecological restoration program, but usually it is not the only objective of such a program (Ruiz-Jaen, Aide, 2005). Increase production or tolerance to some biotic or abiotic factors, maintain the ecosystem services, or favour the conservation of genetic resources are important targets in planning afforestation or restoration programs. Also, in face of climate change, there are new information we will need to take into consideration for increasing the resilience of our future forests (Konnert et al. 2015b).

Usually, in afforestation and ecological restoration programs we need to transfer forest reproductive material (seeds, fruits, plants, part of plants) from a procurement zone (van Buijtenen, 1992) (area from which the material is obtained) to a deployment zone (i.e. the area where we the material is used). The strict use of local populations is widespread in revegetation programs (Breed et al. 2013) and in many afforestation and ecological restoration programs and is based on the expectation that populations are locally adapted (Kawecki and Ebert 2004; Alberto et al. 2013). However, not always local is the best, due to lack of native forest species in the same area, lack of adaptation or low performance of the local material (Namkoong 1969; Savolainen et al. 2007; Leimu and Fischer 2008), a reduced size (Robledo-Arnuncio and Gil 2005) not having enough evolutionary potential or a reduced fruits or seed production in the area.

For many species, the marketing of forest reproductive material is regulated (*eg*., UE and OCDE schemes (Anonymous 2000; Nanson 2001), or national schemes), both in types of basic materials (*eg*. seed sources, stands, seed orchards, parent of families, clones, clones mixtures) and categories (*eg*. source-identified, selected, qualified, and tested). Therefore, to select the forest reproductive material to use in a given locality it is necessary to choose among a list of materials available from different providers that are in accordance with the existing marketing regulation.

The different categories and type of basic material provide different information to favour the election of forest reproductive related to the location, phenotypic and genetic characteristics of the basic material and also the performance in genetic tests.

Source-identified and selected materials are obtained from seed sources or stands from a given region of provenance (equivalent to seed zones in the OCDE scheme). The region of provenance should be considered as the procurement zone as according to the regulation the seedlots from a given region of provenance can be mixed. The region of provenance “is the area or group of areas subject to sufficiently uniform ecological conditions in which stands or seed sources showing similar phenotypic or genetic characters are found, taking into account altitudinal boundaries.” (Anonymous 2000). Many studies have demonstrated a high level of differentiation among populations for traits under selection, such as bud set, growth initiation and cessation, frost tolerance, and drought tolerance (Van Andel, 1998). The origin determines many important characteristics related to the future performance of the plants (e.g., traits related to adaptation to climate, to biotic or non biotic factors, growth, and survival) as a result of the evolutionary factors that shape the genetic structure of the populations in the forest species. These properties can influence the deployment zones in which the material can perform according to the objectives for establishing the plantation.

At the level of the region of provenance there is ecological information, and some information on the performance of a limited number of provenances in a limited number of sites. Only for important commercial species, information is available in many sites to obtain a detailed function of the performance of the material. Deployment zones are usually not been formalized and some lists of recommended material can be available (CEMAGREF, 2003; García-del-Barrio *et al.*, 2000; García del Barrio *et al.*, 2004; Nanson, 1992). However, for some important commercial species there are models relating the origin of the material and the deployment zone where it can be used under present or future climatic conditions (Parker 1992; Hamann et al. 2000; Lindgren and Ying 2000; O’Neill and Aitken 2004; Rehfeldt et al. 2004; Farjat et al. 2017). Despite the absence of this information, some procedures, specially derived of niche modelling can predict the suitability of a species (or even a genetic group) in a given location (Serra-Varela et al. 2015; Serra-Varela et al. 2017c; Serra-Varela et al. 2017b).

For qualified material the origin is not so important, as the material is the result of selection programmes. For qualified material the basic material must have been individually selected, and testing need not necessarily have been undertaken or completed. Adaptation to the ecological conditions prevailing in the Region of Provenance must be evident, according to the admission criteria. Therefore transfer guidelines should be based in the region of provenance of the material, in absence of testing, or as in the case of clones and clonal mixture, in the area where the experimentation had taken place.

For tested material the superiority of the reproductive material must have been confirmed by comparative testing or an estimate of the superiority of the reproductive material calculated from the genetic evaluation of the components of the basic material. A statement of the suggested region of probable adaptation within the country in which the test was carried out and characteristics which might limit its usefulness must also be given.

Some additional principles, mainly related to the conservation of forest genetic resources, have to be considered in order to avoid endangering valuable local resources by introducing exotic material. Even when the regulation on forest reproductive material is not aimed at conservation purposes, this aspect should be considered as a general principle in all restoration programmes. In this context, some question arise, specially concerning the plantation in areas close to those valuable populations related to the future gene flow, with a result of introgression with non-native material (form the same o other close taxa) (Unger et al. 2014; Ramírez-Valiente and Robledo-Arnuncio 2015), and a reduction of the adaption of the local population (due to outcrossing depression or resulting in an admixture of populations). Also, some problems could be related to the reduced population size that could determine an inbreeding material or recommend avoiding the over seed-harvesting due to the effect on the persistence of the population. We are lacking detailed information concerning these effects, but we must take into consideration these aspects when deciding the best material to use in a concrete site.

Also, there are other information concerning historical records or even knowledge of local experts that can be used to decide the better material. This information have a different reliability and can be easily updated. Therefore, we can include this information in a support-decision tool.

The number of species under regulation (or of interest in afforestation or restoration programs) is quite high, and includes many no commercially important species. For instance, the EU system for forest species is applied to 47 species (or genera) in all the European countries when used for forestry purposes (but the countries can regulate additional species in their territory, e.g. Spain has added 20 Mediterranean species). Therefore, we have to establish some general principles to the use of the material for all those species, even when the level of information is quite different for each of them.

In this paper we define 17 indicators for seed sourcing of the identified and selected categories. These indicators are related to: *Species pool* **(**Species pool, Importance for the species; Actual and future climatic suitability); *Region of provenance (*Local provenances, Provenances recommended by climate suitability, Genetic tests, regional guidelines); *Genetic resource conservation (*Endangered local populations, Protection figures, other aspects); *Basic and reproductive material.* We also defined 8 indicators for seed sourcing of qualified and tested material, related to *Basic and reproductive material* and *Genetic resource conservation.*

This method has been implemented in a database for 58 species under regulation for the marketing of forest reproductive material and the deployment zones in Spain to assist as a decision-support tool for afforestation and/or restoration activities. For 48 species, we implement the guidelines for identified and selected material, at the deployment region scale. For 19 species we establish guidelines for qualified and tested material (10 of the species or genera were not included in the identified and selected guidelines). This system is flexible, and can be update when the information is available. The available information is not the same for all the species, and still there are missing information for some of the indicators.

Material and methods

Transfer Guidelines: sourcing of forest reproductive material

The restoration activities have three different goals: initial establishment of plants, long-term population persistence and restoration of a functioning ecosystem (Kettenring et al. 2014). Also for forestry purposes afforestation could have also the goal of increasing the production of timber and/or non-timber products.

These objectives also have implications in the propagule-sourcing approaches (cultivar, local adaptation and genetic diversity) that can be used (Kettenring et al. 2014), both at the species and intraspecific level. Usually with qualified and tested material, we are mostly orienting the selection of the material according to the performance for different important traits for the end-user (cultivar approach in the previous description), as we have information concerning the performance of the FRM as result of the inclusion in the national register of basic material. Therefore, we can divide these transfer guidelines in two parts. One for identified and selected material, and the second one for qualified and tested materials.

For source identified and selected material we define seed sourcing guidelines at the deployment region scale, but some information is provided at a larger scale. There are different approaches to address point-specific recommendations (e.g. focal point seed zones, (Parker 1992), or recommendations for specific locations (Tranque, 2016),) but usually they can be implemented for some well-known species.

To select the best provenance, there are different approaches (Figure 1). We used two approaches based in the *local provenances*, or the predicted adapted/productive provenance (*predictive provenance*) (Breed et al. 2013). In case of qualified and tested material, we will use the *cultivar approach*, that can be considered a modification of the previous method, in which the prediction of the performance is based in phenotypic evaluation or genetic testing to provide the specific characters for selection and “a statement of the suggested region of probable adaptation within the country in which the test was carried out and characteristics which might limit its usefulness must also be given” (Directive).

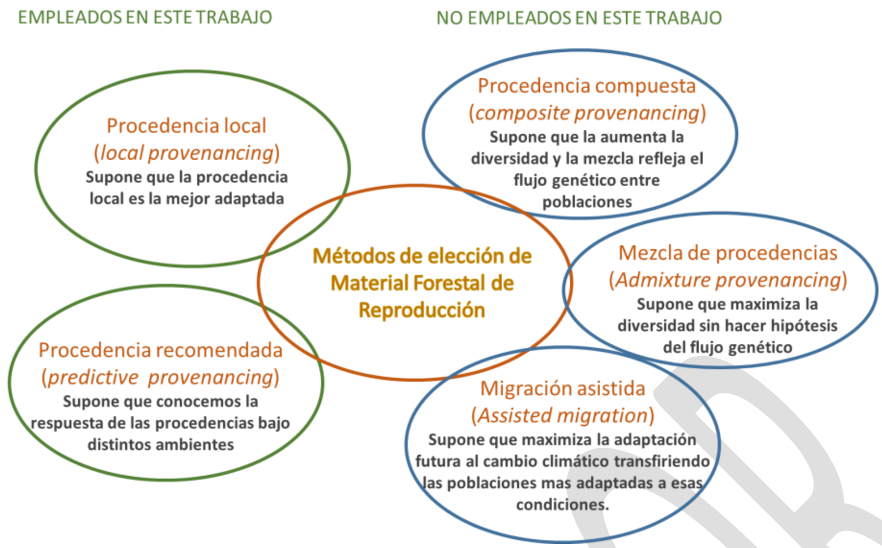

Figure 1. Methods for selecting the best provenance in a revegetation, ecological restoration or reforestation program.

However, we do not take into consideration other strategies based in the combination of seed from different populations. *Composite provenancing*, based in collecting a mixture of seed from populations of increasing distance that attempts to mimic natural gene flow patterns (Broadhurst et al. 2008), and *Admixture provenancing* (Breed et al. 2013), similar to the previous approach but collected from large populations to have a wide selection of genotypes from various environments with no spatial bias towards the deployment site, and without considering the gene-flow dynamics. These approaches are a way to reduce the impact of seed harvesting and increase the genetic diversity of the future populations, as this option will increase the risk for the genetic resources at a long term perspective, and should be restricted to special cases. Also, we do not take into consideration the *assisted migration* (or assisted colonization), due to some controversies on the application (McLachlan et al. 2007; Seddon 2010; Thomas 2011; Pedlar et al. 2012; Schwartz et al. 2012).

There are also some decision trees for selecting the best provenance, based in the different approaches (Figure 2).

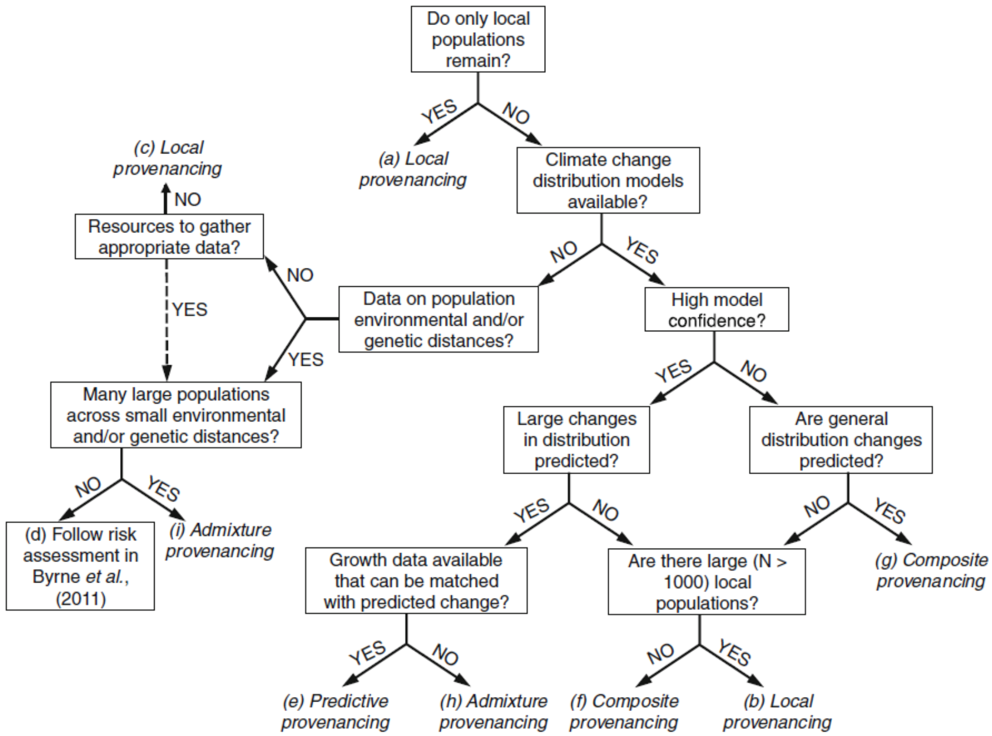

Figure 2. Provenance strategy decision tree in revegetation programs. Decision are based in the knowledge of climatic change response, and the genetic/environmental differentiation of populations (from (Breed et al. 2013).

Species

We implemented the method to 49 species (Table 1), as the rest have limitations based on a restricted (or no autochthonous) distribution, or being riparian species.

From the taxon regulated by the EU directive, 22 of them have not been included in the analysis as they do not present native populations in Spain, except *Carpinus betulus* (which has a very restricted distribution, and *Populus* (with identification problems for some of the populations). From the species regulated by the RD289/2003 in Spain, 9 species have not been considered as they do not have any base material approved or they have a very restricted distribution. (See Annex 1 for details on the importance of the species and the election for this study).

For qualified and tested material we applied the system to 17 species or artificial hybrids with transfer guidelines (which represent 92% for the seed and

98% for plants and part of plants), from which 10 do not have transfer guidelines for identified and selected material.

Table 1. Species considered in the study.

Species	Code	Regulation[1]	A[2]	I/S[3]	Q/T[4]	Species	Code	Regulation	A	I/S	Q/C
Abies alba Mill.	31	FRM; GRC	Y	Y	N	*Pinus pinaster* Aiton.	26	FRM; GRC	Y	Y	Y
Abies pinsapo Boiss.	32	FRM; GRC	Y	Y	N	*Pinus pinea* L.	23	FRM; GRC	Y	Y	Y
Acer platanoides L.	676	FRM; GRC	Y	Y	N	*Pinus radiata* D. Don.	28	FRM	N	N	Y
Acer pseudoplatanus L.	576	FRM; GRC	Y	Y	Y	*Pinus sylvestris* L.	21	FRM; GRC	Y	Y	Y
Alnus glutinosa (L.) Gaertn.	54	FRM; GRC	Y	NC	N	*Pinus uncinata Ram.* ex DC.	22	FRM2; GRC	Y	Y	Y
Arbutus unedo L.	68	FRM2; GRC	Y	Y	N	*Pistacia atlancia* Desf.	293	FRM2; GRC	Y	Y	Y
Arbutus canariensis Veill.	268	FRM2; GRC	Y	Y	N	*Populus alba* L.	51	FRM; GRC	Y	N	D
Betula pendula Roth	373	FRM; GRC	Y	NC	D	*Populus nigra* L.	58	FRM; GRC	Y	N	D
Betula pubescens Ehrh.	273	FRM; GRC	Y	Y	D	*Populus tremula* L.	52	FRM; GRC	Y	N	D
Carpinus betulus L.	98	FRM; GRC	Y	Y	N	*Populus spp.* Hybrids		FRM	Y	N	Y
Castanea sativa Mill.	72	FRM; GRC	Y	Y	D	*Prunus avium* L.	95	FRM; GRC	Y	Y	Y
Castanea sativa spp. Hybrids		FRM2	N	N	Y	*Pseudotsuga menziesii* Franco.	34	FRM	N	N	Y
Fagus sylvatica L.	71	FRM; GRC	Y	Y	N	*Quercus canariensis* Willd.	47	FRM2; GRC	Y	Y	N
Fraxinus angustifolia Vahl.	455	FRM; GRC	Y	NC	N	*Quercus coccifera* L.	49	FRM2; GRC	Y	Y	N
Fraxinus excelsior L.	255	FRM; GRC	Y	Y	D	*Quercus faginea* Lam.	44	FRM2; GRC	Y	Y	N
Ilex aquifolium L.	65	FRM2; GRC	Y	Y	D	*Quercus ilex* L.	45	FRM; GRC	Y	Y	N
Juglans nigra		FRM2	N	N	Y	*Quercus petraea* (Matt.) Liebl.	42	FRM; GRC	Y	Y	N
Juglans regia L.	75	FRM2; GRC	Y	Y	Y	*Quercus pubescens* Willd.	243	FRM; GRC	Y	Y	N
Juglans spp. Hybrids		FRM2	N	N	Y	*Quercus pyrenaica* Willd.	43	FRM2; GRC	Y	Y	N
Juniperus communis L.	37	FRM2; GRC	Y	Y	N	*Quercus robur* L.	41	FRM; GRC	Y	Y	N
Juniperus oxycedrus L.	237	FRM2; GRC	Y	Y	N	*Quercus suber* L.	46	FRM; GRC	Y	Y	N
Juniperus phoenicea L.	39	FRM2; GRC	Y	Y	D	*Sorbus aria* (L.) Crantz	278	FRM2; GRC	Y	Y	N
Juniperus thurifera L.	38	FRM2; GRC	Y	Y	N	*Sorbus aucuparia* L.	378	FRM2; GRC	Y	Y	N
Olea europea Brot.	66	FRM2; GRC	Y	Y	N	*Tamarix gallica* L.	53	FRM2	Y	Y	N
Phoenix canariensis Hort.	69	FRM; GRC	Y	Y	N	*Taxus baccata* L.	14	FRM2; GRC	Y	Y	N
Pinus canariensis	27	FRM; GRC	Y	Y	Y?	*Tilia cordata* Mill.	277	FRM; GRC	Y	Y	N

Pinus halepensis Mill.	24	FRM; GRC	Y	Y	Y	*Tilia platyphyllos* Scop.	377	FRM; GRC	Y	Y	N
Pinus nigra subsp. n*igra*		FRM	N	N	Y	*Ulmus glabra* Huds.	256	FRM2; GRC	Y	Y	N
Pinus nigra subsp. *salzmannii*	25	FRM; GRC	Y	Y	Y	*Ulmus minor* Mill. *s.l.*	56	FRM2; GRC	Y	Y	Y

[1]-Regulation: FRM: Directive 199/105; FRM: Rd289/2003 [2]-A: Authochtous (Y/N)

[3]-I/S: Guidelines for Identified and selected FRM (Y/N/NC: No Climatic niche model adjustment) [4]-Q/T: Guidelines for qualified and tested FRM (Y/N). D: to check

Data Sources

Species distribution

Species' distribution data are available for the species. Maps indicating the presence/absence of the species are based on the 4th Spanish National Inventory and the Spanish Forest Map. We have considered only the natural populations, excluding the plantations, according to the regions of provenance of the species (Alia et al. 2009).

Deployment zones

Fifty-seven deployment regions (DR) were established for Spain (del Barrio et al. 2001; García del Barrio et al. 2005; Alia et al. 2009) based on an ecological classification (Elena 1997) and geographically implemented using administrative limits.

Procurement zones

For identified and selected basic material, the unit for marketing of reproductive material is, according to the EU Council Directive the Region of provenance, and therefore was chosen as the procurement zones in our study for identified and selected forest reproductive material. They are defined for all the species considered in this study (Alía *et al.*, 2009).

National Register of Basic Material

Availability of basic material (FBM) was obtained from the National Register held by the Spanish Ministry of Environment (Supp. Information Annex1). This register include the existing basic material (all the four categories) that could provide forest reproductive material for afforestation or restoration activities. But also, for tested and qualified basic material, the register include some useful information for the end-user: the traits for which the material was selected for, their breeding value and also the deployment recommended area.

Conservation of genetic resources

The classification of endangered populations is based on the studies from different species and follows the National Strategy of Forest Genetic Resource Conservation (Jiménez et al. 2009). We used the information for marginal populations of the species.

The data concerning the protected area was provided by the National Databank of the Biodiversity.

Seed sourcing for identified and selected forest reproductive material

We established eleven indicators for the election of FRM, and complementary information (availability of Basic material, historical records of use of FRM). In all the cases, the guidelines establish the relationship among the deployment area (area were the material is going to be used) and the procurement zone (in this case the region of provenance).

1. Species pools

Defining the species pool according to the objectives is the first step in the afforestation and restoration project. We have included four indicators that provides the species pool for restoration in the deployment region (García del Barrio et al. 2013), considering the actual (based in the distribution of the species in the area), and the potential species pool (dark diversity, (Partel et al. 2011)) of the deployment area.

There are different studies about the ecological limits for some of the species (e.g. Gandullo et al 1994 for Iberian pines). We include the references to the most important for each of the species (if available). However, at this stage, we do not take into consideration the intraspecific genetic difference among the FRM of the species.

1.1 Species pool

Following the approach by (García del Barrio et al. 2013) we provide the species pool (actual and potential) in a 10x10 km^2 grid.

1.2 Presence of the species.

Once we select one of the species, the actual presence of the species is computed in a given deployment region as the ratio of grids (1x1 km^2) with presence of the species to the total number of grids of the Deployment Region.

1.3 Importance of the species.

For each Deployment Region is the ratio among the actual presence of the species (number of grids) to the total species distribution (as the number of grids) was computed. This value measures the importance of the species in the deployment region respect the total area of distribution of the species. A species could be very rare in a Deployment Region, but could represent an important part of the distribution for the species.

1.4. Presence of Non-autochtonous populations

The ratio of non-autochtonous populations of the species respect the total area in the Deployment area are included as a measure of past afforestation and restoration activities.

1.5*. Importance of Non-autochtonus populations of the species in the DR*

The ration of non autochtonous populations of the species in the Deployment region respect the total of non-autochtonous populstions of the species.

1.6 *Actual Climatic suitability*

The ratio of the deployment area suitable (after a niche model approach, seed annex 2) to the species, to the total area of the Deployment region. Measures the climatic suitability of the Deployment Region for a given species under actual climatic conditions. If this value is low, the species should be used with caution, as we can expect adaptation to specific area in the deployment region.

1.7 *Future Climatic suitability*

Measures the climatic suitability of the Deployment Region for a given reproductive material under under future climatic conditions of the Deployment Region. The projection of the suitable area under different climatic scenarios were obtained, and GIS information is provided for a limited number of species and genetic groups (Benito-Garzón et al. 2011; Serra-Varela et al. 2017a). Other approaches can be implemented when enough genetic tests are available (Farjat et al. 2017) based on the response functions of the different populations.

This value indicate the risk associated to the use of the species considering some likely climatic conditions in the future for the species. If there is a reduction of the area respect the actual climatic suitability, we should look for alternatives to increase the resilience of the future forest.

EUFORGEN have included some recommendations for transfer guidelines of forest reproduction material in face of climate change (Konnert et al. 2015a):

- Transfer of FRM is a valuable option to adapt forests to climate change, although there may be limits to the transfer of FRM.
- Local provenances may not always be the best source of FRM.
- Before considering changing tree species, forest managers should consider deploying other, well-tested provenances of the existing tree species. At the European level, recommendations on FRM transfer must be revised and harmonised and at the same time, all stages of production and marketing should be more stringently controlled.
- Tree breeding also offers opportunities to assist forests and forest management to adapt to climate change.
- Improved documentation is crucial to ensuring that today’s use of FRM can inform tomorrow’s choices, just as past efforts have helped to guide today’s recommendations.
- Basic research on adaptation of forest tree populations, along with provenance research, should continue and be strengthened, and the results disseminated in forms that forest owners and managers and policy makers can use.

2. Region of provenance

The best material should be selected based on the performance in genetic tests that allow the estimation of response functions of the different provenances. However, this it is not possible usually. In absence of information we should considered as a proxy the actual conditions as the most likely for the performance of the populations. In absence of information on genetic testing, we consider that local populations (geographically or climatically) are better adapted to the ecological conditions of the area than other material.

In general, we will prefer those populations that are well adapted and performance under genetic tests. If not, among the local basic material, and if this it is not available, with the material that is climatically closer to the considtions of the deployment area.

2.1 *Local provenances*

Include the lists of local regions of provenances, *i.e*. those with native populations in the Deployment Region, and the area occupied by each of them with respect to the total of the species (in percent).

2.2 *Provenances with climatic suitability*

For each Deployment Region, we computed the climatic distance (Mahalanobis distance) based in the same set of climatic variables that were used in the niche modelling estimation, among the points with presence of the Region of Provenance and the points of each of the Deployment Zone. According to the distance, the recommendation is classified in 3 categories:

- High adequacy;
- Adequate;
- Possible use.

For each of these categories we include the list of regions of provenance within each category. We need to take into consideration that the similary have been established among all the points in the deployment area, and the points of the distribution range of each of the regions of provenance. Therefore, the result is a "general" pattern for all the deployment region, and depending on the location, some less similar regions of provenance can be more suitable than other with higher similarity.

2.3 *Genetic testing*

Summarize the data on the performance in comparative traits. This indicator is based on genetic studies (comparative tests). We provide the value respect the average of the test for different traits under evaluation in trials located in the deployment region.

This information is based in the existing information in the genfored network (www.genfored.es).

2.4 *Regional guidelines*

The different regional governments can establish transfer guidelines for some of the species. This information is recorded in a GIS database, as the material to be used in different geographical areas.

3. Conservation of genetic resources

This part offer additional information about some aspects related to Biodiversity and Genetic resource conservation when deploying forest reproductive material in a given area. In forest tree species, usually is the population what is endangered, not the species. Therefore, all the restoration and afforestation activities should consider this aspect to avoid any risk to the local genetic resources.

We need to check for the existence of endangered populations in the vicinity of the deployment area. Also, for the existence of marginal populations, and genetic conservation units that can result in restrictions to the use of forest reproductive material. In some of these situation, it is not possible to use non-local material or commercial seedlots not obtained with the objective of conservation of genetic resources. Also, there are restrictions in the protected area for the use of forest reproductive material.

We have considered three different aspects:

3.1 *Endangered local populations.*

We provide information about the necessity to establish special measures to protect the genetic resources of the species, or the existence of other related taxons that can affect the conservation status of the populations when deploying forest reproductive material in the area. To provide this information we followed rules related to the presence of local populations, the size of these populations, and the endangered status (marginal population) according to the National Conservation Program.

The information is coded as follows:

0: No special requisites for this species;

No local material of the species in the deployment region. In this case it is necessary to check the introgression or hybridization with intercrossing species in the area.

1: Not endangered local provenances.

It is necessary to check if they are close to natural stands, and the new material can introgress or hybridize with intercrossing species in the area.

2: Moderately endangered local provenances.

Necessary to check introgression (hybridization) with foreign material if transfer from other areas. Special measures to protect the local provenances.

3: Endangered/marginal local provenances.

Special measures to establish to protect the local provenances. Very limiting to the use of exotic (or even local) material.

Apart from this information, we provide the GIS database corresponding to the genetic conservation units established (or the proposal) for the network of conservation units in Spain, as a guideline to check the influence on these units of the establishment of material.

3.2 *Protected areas*

We provide the information about the protected areas in the region, with different categories, in order to check for limitations of use or for establishing special measures when introducing FRM in the area. This information is included in a GIS database.

3.3 *Other aspects*

We indicate if there are some other special aspects to consider in the selection of the material. It can be related to the hybridization with other species, the use of material for other purposes not considered in the EU regulation for forest reproductive marketing, etc.

4. Basic and reproductive material

One main concern when elaborating the afforestation or restoration project is the availability of FRM in the market. In many occasions, after electing the best seed source, when establishing the new plantation, there are no available FRM and the technician should change the source. By checking at this stage the availability of Basic Material and FRM we can decide about the best strategy for having the best material at the right moment. Therefore, we provide the information concerning the availability of basic material for the different production areas selected in the previous stages. Availability of FRM should be check with the providers, in case the can produce the material for the right moment after approval of the project. We need to take into consideration the time necessary for producing the FRM (collection of fruits/seeds, nursery) in case there are no material available.

4.1 Basic Material approved for production of Identified Forest reproductive material

For each of the procurement zones, we include the number and size of Basic material included in the national register of Forest reproductive material. This information is useful to check the possible availability of FRM.

4.2 Basic Material approved for production of Selected Forest reproductive material

For each of the procurement zones, we include the number and size of Basic material included in the national register of Forest reproductive material. This information is useful to check the possible availability of FRM.

4.3. *Genetic diversity*

For each of the procurement zones the genetic group according to the analysis available (if any) and the diversity values respect the average of the species. It is also included the inbreeding coefficient, and the population size of the population.

Seed sourcing for qualified and tested Forest Reproductive material

In this case, we will focus in selecting among the existing Basic material the most suitable for our objectives (*cultivar approach* and/or *local material* if applicable). We have a limited set of material for selection, included in the *Community List of Approved Basic Material for the Production of Forest Reproductive Material*. We should take into consideration the main characteristics of this material to select among them. We have included information from the Spanish national list.

1. Basic and reproductive material

1.1 Pool of FRM available

This is the information included in the Register of Basic Material (national or EU list). This is the only material available at the EU level for species under regulation.

For each of the basic material, we include the information from the National Register of basic material.

1.2 Traits selected for and improved value

Se summarize the traits under selection and the improved value respect the control for each of them.

1.3 Deployment area

Based on the genetic tests. The deployment recommendations were adapted to the deployment regions include in our study according to the information provided by the National register, after consulting with the original obtentors.

Also, some additional information concerning the special ecological requirements are included (e.g. frost, altitude, site preparation, tending..) according to the obtentor.

1.4 Limitations

If some limitations exists according to the National register (e.g number of copies, number of years)

2. Conservation of genetic resources

We followed the same describe for identified and selected material.

Results

Identified and selected material

There are large differences among species in the different criteria. The summary for all the species are found in Table 2. There are a large species pool for selecting in a given deployment region. But usually the species are suitable for a restricted set of environments.

There are species with a reduced area, and also, limited value for afforestation or restoration from a general perspective. However, there are many deployment regions where the species can be applied. Usually in very local areas. For the species with regions of provenance established by the agglomerative method the number or local provenances usually is quite high. Therefore, we can have different sources of basic material. Also, there are more than one additional region of provenance in case we cannot select the local material.

We should consider carefully the criteria on the conservation of forest genetic resources. As a mean, in 70% of the cases we will need to check the possible interactions with some local populations, and the conditions of use of the material.

Concerning the availability of Basic material and Forest reproductive material, for many of the species there are limitations in the basic material approved in the National Register. But usually the main problem is the availability of Forest reproductive material from the desired area, due to some problems related to the masting, or even the commercial interest of the species.

Also, it is interesting to notice that all the species differ greatly in terms of availability of basic material and production of FRM of identified and selected categories (Table 3).

For 10 species out of the 48 species, the production of seed or fruits is less than 50 kg/year. It is also interesting to notice that there are enough basic material for production of FRM. However, due to the number of regions of provenance for the different species and the aspects related to masting and conservation of seeds or frutis, most of the FRM suppliers have a limited number of entries.

One main question is the reduced information on the use of a given FRM in an afforestation or restaruation action. Usually this information is included in the project, but there are no information in a gis system allowing the evaluation of the material used except in some areas (e.g. CyL). At present, the afforestation during the period 2006-2015 for the different species can be summarized in table 4.

Table 2. Description of different indicators for all the species considered in the study.

		DR Importance		DR		Regions of provenance with climatic suitability / DR			Genetic Resource Conservation		
Species	DR	≥25.0%	<5.0%	suitable climate	Local RP by DR	High	Adequate	Possible	CRG=1	CRG=2	CRG=3
	#	#	%	#	#	#	#	#	%	%	%
Abies alba Mill.	3	33.33	33.3	9	3.3	3.3	0.7	2.0	66.67	33.33	33.33
Abies pinsapo Boiss.	2	50.00	50.0	8	2.0	3.0	1.0	0.5	0.00	100.00	50.00
Acer platanoides L.	6	16.67	50.0	20	1.2	1.2	0.0	1.8	16.67	100.00	0.00
Acer pseudoplatanus L.	19	5.26	78.9	16	1.0	1.0	0.1	1.8	36.84	36.84	26.32
Alnus glutinosa Gaertn.	34	0.00	73.5	na	1.0	1.0	0.2	1.6	35.29	64.71	0.00
Arbutus canariensis Veill.	3	33.33	66.7	7	1.0	1.0	0.0	0.3	66.67	33.33	0.00
Arbutus unedo L.	47	0.00	85.1	8	1.0	1.0	0.2	1.5	31.91	68.09	0.00
Betula pendula Roth.	20	5.00	90.0	na	1.0	1.0	0.2	1.7	10.00	90.00	0.00
Betula pubescens Ehrh.	23	4.35	78.3	16	1.0	1.0	0.1	1.7	30.43	52.17	17.39
Carpinus betulus L.	1	100.00	0.0	2	1.0	1.0	0.0	0.0	0.00	100.00	0.00
Castanea sativa Mill.	42	0.00	88.1	39	1.0	1.0	0.2	1.5	26.19	73.81	0.00
Fagus sylvatica L.	16	0.00	56.3	17	3.1	1.2	1.2	0.8	0.00	100.00	0.00
Fraxinus angustifolia Vahl.	46	0.00	87.0	na	1.0	1.0	0.2	1.5	36.96	63.04	0.00
Fraxinus excelsior L.	17	0.00	70.6	17	1.0	1.0	0.0	1.8	58.82	41.18	0.00
Ilex aquifolium L.	30	0.00	90.0	20	1.0	1.0	0.2	1.7	40.00	60.00	0.00
Juglans regia L.	42	0.00	97.6	51	1.0	1.0	0.2	1.6	28.57	71.43	0.00
Juniperus communis L.	31	0.00	90.3	31	1.0	1.0	0.1	1.6	35.48	64.52	0.00
Juniperus oxycedrus L.	45	0.00	97.8	49	1.0	1.0	0.2	1.4	40.00	60.00	0.00
Juniperus phoenicea L.	41	0.00	97.6	52	1.0	1.0	0.2	1.2	31.71	68.29	0.00
Juniperus thurifera L.	28	3.57	89.3	33	1.0	1.0	0.1	1.8	35.71	64.29	0.00
Olea europea Brot.	50	0.00	96.0	52	1.0	1.0	0.2	1.2	30.00	70.00	0.00
Phoenix canariensis Hort.	5	20.00	20.0	7	1.0	1.0	0.0	0.6	100.00	0.00	0.00
Pinus canariensis C. Smith.	5	40.00	40.0	5	1.2	1.0	0.4	0.6	60.00	0.00	40.00
Pinus halepensis Mill.	31	0.00	90.3	48	2.5	1.4	0.8	1.5	6.45	93.55	0.00
Pinus nigra Arn.	24	0.00	75.0	38	1.6	1.6	0.5	1.1	16.67	83.33	0.00
Pinus pinaster Ait.	34	0.00	88.2	46	1.8	1.3	0.5	1.2	17.65	55.88	26.47
Pinus pinea L.	24	0.00	87.5	49	1.3	1.6	0.3	0.2	29.17	37.50	33.33

		DR Importance		DR		Regions of provenance with climatic suitability / DR			Genetic Resource Conservation		
Species	DR	≥25.0%	<5.0%	suitable climate	Local RP by DR	High	Adequate	Possible	CRG=1	CRG=2	CRG=3
	#	#	%	#	#	#	#	#	%	%	%
Pinus sylvestris L.	21	4.76	81.0	22	2.1	1.2	0.9	0.7	9.52	90.48	0.00
Pinus uncinata Mill.	5	20.00	80.0	2	1.6	1.0	1.2	0.2	0.00	20.00	80.00
Pistacia atlantica Desf.	4	50.00	50.0	na	1.0	1.0	0.0	0.5	75.00	25.00	0.00
Prunus avium L.	34	0.00	94.1	39	1.0	1.0	0.1	1.7	35.29	64.71	0.00
Quercus canariensis Willd.	9	11.11	77.8	13	1.0	1.6	0.0	0.3	22.22	22.22	55.56
Quercus coccifera L.	33	0.00	93.9	49	1.0	1.0	0.2	1.6	54.55	45.45	0.00
Quercus faginea Lam.	43	0.00	95.3	44	2.3	1.0	0.8	1.2	2.33	65.12	32.56
Quercus ilex L.	48	0.00	100.0	51	2.7	1.1	0.8	1.5	12.50	52.08	35.42
Quercus petraea Liebl.	17	5.88	76.5	17	2.4	0.8	0.8	1.6	5.88	58.82	35.29
Quercus pubescens Willd.	8	25.00	37.5	14	2.3	1.5	0.5	1.5	12.50	25.00	62.50
Quercus pyrenaica Willd.	36	0.00	94.4	42	2.3	0.9	0.6	1.3	2.78	55.56	41.67
Quercus robur L.	15	6.67	66.7	10	2.5	0.9	0.7	1.3	6.67	66.67	26.67
Quercus suber L.	36	0.00	91.7	43	1.7	1.1	0.4	1.4	5.56	38.89	55.56
Sorbus aria Crantz.	32	3.13	84.4	25	1.0	1.0	0.2	1.6	25.00	75.00	0.00
Sorbus aucuparia L.	22	0.00	81.8	26	1.0	1.0	0.1	1.5	50.00	50.00	0.00
Tamarix gallica L.	28	0.00	89.3	51	1.0	1.0	0.3	1.3	35.71	64.29	0.00
Taxus baccata L.	26	0.00	73.10	17	1.0	1.0	0.2	0.8	73.08	26.92	0.00
Tilia cordata Mill.	14	7.14	78.6	35	1.0	1.0	0.0	1.6	35.71	64.29	0.00
Tilia platyphyllos Scop.	18	5.56	83.3	19	1.0	1.0	0.2	1.9	22.22	77.78	0.00
Ulmus glabra Huds	19	5.26	94.7	21	1.1	1.1	0.0	2.2	31.58	78.95	0.00
Ulmus minor Mill.	47	0.00	97.9	55	1.0	1.0	0.2	1.5	36.17	63.83	0.00
	24.7	9.31	77.1	28.1	1.40	1.16	0.33	1.29	29.90	59.05	13.31

DR: Deployment Regio, RP: Region of Provenance, CRG: code for Conservation of genetic resources. (Explanation in Material and Methods)

Table 3. Availability of Basic material and consumption of forest reproductive material in Spain for 48 species.

		Source-identified material						Selected material			
		Basic material				FRM		Basic material		MFR	
		Seed sources		Stands		Seeds	Plants	Stands		Seeds	Plants
Species	**Regulation**	**Nb**	**ha**	**Nb**	**ha***	**kg**	**(x1000)**	**Nb**	**ha**	**Kg**	**(x1000)**
Abies alba Mill.	Directive EU	18	30,097.7	-	-	3.43	2.75	2	94.0	6.25	2.77
Abies pinsapo Boiss.	Directive EU	5	2,146.0	-	-	54.53	19.77	-	-	-	-
Acer platanoides L.	Directive EU	2	536.2	-	-	0.96	8.91	-	-	-	-
Acer pseudoplatanus L.	Directive EU	44	5,981.5	-	-	106.02	82.53	-	-	-	-
Alnus glutinosa Gaertn.	Directive EU	263	37,715.5	-	-	19.46	57.55	-	-	-	-
Arbutus canariensis Veill.	RD289/03	5	65.3	-	-	2.34	7.50	-	-	-	-
Arbutus unedo L.	RD289/03	157	83,026.7	1	8.8	332.18	150.19	-	-	-	-
Betula pendula Roth.	Directive EU	6	11,606.1	-	-	2.38	23.02	-	-	-	0.02
Betula pubescens Ehrh.	Directive EU	132	67,062.4	-	-	65.76	262.47	-	-	-	0.05
Carpinus betulus L.	Directive EU	1	3.0	-	-	0.25	3.01	-	-	-	-
Castanea sativa Mill.	Directive EU	431	74,658.0	2	0.6	6,096.46	192.91	5	20.0	-	3.42
Fagus sylvatica L.	Directive EU	278	322,958.0	1	2,005.6	64.36	156.84	20	844.3	113.60	116.79
Fraxinus angustifolia Vahl.	Directive EU	384	44,005.6	1	5.9	354.31	232.33	-	-	-	-
Fraxinus excelsior L.	Directive EU	77	44,281.2	1	1.7	129.99	222.36	-	-	-	2.23
Ilex aquifolium L.	RD289/03	157	104,278.0	-	-	75.46	102.06	-	-	-	-
Juglans regia L.	RD289/03	72	254,364.6	-	-	594.38	119.10	-	-	-	-
Juniperus communis L.	RD289/03	196	177,911.5	-	-	17.82	31.65	-	-	-	-
Juniperus oxycedrus L.	RD289/03	277	193,385.5	1	2.0	145.41	78.71	-	-	-	-
Juniperus phoenicea L.	RD289/03	158	143,798.2	-	-	81.94	156.13	-	-	-	-
Juniperus thurifera L.	RD289/03	208	111,359.0	4	10.9	2,434.67	268.14	-	-	-	-
Olea europea Brot.	RD289/03	60	65,912.4	-	-	268.98	106.21	-	-	-	-
Phoenix canariensis Hort.	RD289/03	4	40.5	-	-	6.97	3.41	-	-	-	-
Pinus canariensis C. Smith.	Directive EU	22	46,005.8	-	-	55.11	65.97	11	146.0	0.10	1.50

		Source-identified material						Selected material			
		Basic material				FRM		Basic material		MFR	
		Seed sources		Stands		Seeds	Plants	Stands		Seeds	Plants
Species	**Regulation**	**Nb**	**ha**	**Nb**	**ha***	**kg**	**(x1000)**	**Nb**	**ha**	**Kg**	**(x1000)**
Pinus halepensis Mill.	Directive EU	354	411,769.6	2	1.5	2,494.02	1,225.71	13	331.0	902.70	239.99
Pinus nigra Arn.	Directive EU	194	217,849.3	3	4,403.7	2,431.98	762.12	25	6,925.3	4,511.87	1,975.00
Pinus pinaster Ait.	Directive EU	321	608,246.5	-	-	22,030.51	1,059.95	41	1,665.1	5,540.66	1,463.02
Pinus pinea L.	Directive EU	99	67,541.2	-	-	2,429.80	540.77	12	746.4	9,901.10	1,520.03
Pinus sylvestris L.	Directive EU	209	296,171.2	1	108.8	15,833.50	1,418.51	59	3,309.5	2,909.17	2,875.34
Pinus uncinata Mill.	RD289/03	28	53,602.2	-	-	486.47	141.27	3	45.0	541.70	136.11
Pistacia atlantica Desf.	RD289/03	5	42.7	-	-	7.83	5.95	-	-	-	-
Prunus avium L.	Directive EU	197	161,068.3	1	0.4	607.58	181.30	-	-	34.00	1.86
Quercus canariensis Willd.	RD289/03	13	24,998.0	2	257.1	1,373.31	1.74	-	-	-	-
Quercus coccifera L.	RD289/03	194	210,139.6	-	-	1,747.24	2,511.46	-	-	-	-
Quercus faginea Lam.	RD289/03	281	179,104.7	1	142.8	6,378.91	13,598.63	-	-	-	1.00
Quercus ilex L.	Directive EU	735	611,612.9	-	-	48,646.54	17,214.82	-	-	-	0.70
Quercus petraea Liebl.	Directive EU	96	76,528.7	1	4.8	1,398.61	152.19	9	271.9	173.24	30.76
Quercus pubescens Willd.	Directive EU	19	1,488.4	2	28.8	164.17	553.27	-	-	-	-
Quercus pyrenaica Willd.	RD289/03	361	238,797.9	1	2,200.0	8,431.08	4,925.60	-	-	-	2.71
Quercus robur L.	Directive EU	107	236,420.1	-	-	1,508.98	3,722.30	20	251.4	929.23	148.41
Quercus suber L.	Directive EU	177	148,250.9	1	0.5	14,866.96	739.53	123	4,230.7	5,414.48	653.62
Sorbus aria Crantz.	RD289/03	151	154,250.2	-	-	35.44	263.23	-	-	-	-
Sorbus aucuparia L.	RD289/03	151	150,337.0	1	0.3	220.11	1,103.77	-	-	-	0.17
Tamarix gallica L.	RD289/03	42	1,461.2	-	-	0.45	1,749.35	-	-	-	-
Taxus baccata L.	RD289/03	100	69,386.0	-	-	14.88	67.47	-	-	-	-
Tilia cordata Mill.	Directive EU	4	98.9	1	0.2	0.19	246.94	-	-	-	0.60
Tilia platyphyllos Scop.	Directive EU	38	65,515.7	-	-	17.32	135.15	-	-	-	-
Ulmus glabra Huds	RD289/03	24	9,974.0	1	0.0	0.34	55.38	-	-	-	-

		Source-identified material						Selected material			
		Basic material				FRM		Basic material		MFR	
		Seed sources		Stands		Seeds	Plants	Stands		Seeds	Plants
Species	**Regulation**	**Nb**	**ha**	**Nb**	**ha***	**kg**	**(x1000)**	**Nb**	**ha**	**Kg**	**(x1000)**
Ulmus minor Mill.	RD289/03	103	2,407.3	-	-	47.78	61.97	-	-	0.15	-

References

Alberto FJFJ, Aitken SNSN, Alía R, et al (2013) Potential for evolutionary responses to climate change - evidence from tree populations. Glob Chang Biol 19:1645–61. doi: 10.1111/gcb.12181

Alia R, Garcia del Barrio JM, LIglesias S, et al (2009) Regiones de procedencia de especies forestales de España. O.A. Parques Nacionales, Madrid, Spain

Anonymous (2000) COUNCIL DIRECTIVE 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material. Off J Eur Communities 11:17–40.

Benito-Garzón M, Alía R, Robson TM, Zavala MA (2011) Intra-specific variability and plasticity influence potential tree species. Glob Ecol Biogeogr 20:766–788. doi: 10.1111/j.1466-8238.2010.00646.x

Breed MF, Stead MG, Ottewell KM, et al (2013) Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. Conserv Genet 14:1–10. doi: 10.1007/s10592-012-0425-z

Broadhurst LM, Lowe A, Coates DJ, et al (2008) Seed supply for broadscale restoration: Maximizing evolutionary potential. Evol Appl 1:587–597. doi: 10.1111/j.1752-4571.2008.00045.x

del Barrio JM, Alía R, Iglesias S, others (2001) Regiones de identificacion y utilizacion de material forestal de reproduccion.

Elena R (1997) Clasificación biogeoclimática de España peninsular y Balear : atlas clateres. Ministerio de Agricultura, Pesca y Alimentación, Madrid (España)

Farjat A, Reich BJ, Guinness J, et al (2017) Optimal Seed Deployment under Climate Change using Spatial Models : Application to Loblolly Pine in the Southeastern US. J Am Stat Assoc 112:909–920.

García del Barrio JM, Iglesias S, Alía R (2005) Regiones de Identificación y Utilización de Material Forestal de Reproducción. Regiones de procedencia en España realizadas por el métodod divisivo. Adenda. Ministerio de Medio Ambiente, Madrid

García del Barrio JMJM, Auñón F, Sánchez de Ron D, et al (2013) Assessing regional species pools for restoration programs in Spain. New For 44:559–576. doi: 10.1007/s11056-013-9363-y

Havens K., Vitt P., Still S., Kramer AT, Fant JB. 2015. Seed sourcing for restoration in an era of climate change. Natural Areas Journal, 2015 - BioOne

Hamann A, Koshy MP, Namkoong G, Ying CC (2000) Genotype-environment interactions in Alnus rubra : developing seed zones and seed-transfer guidelines with spatial statistics and GIS. For Ecol Manage 136:107–119.

Jiménez P, Diaz-Fernandez PM, Iglesias S, et al (2009) Strategy for the Conservation and Sustainable Use of Spanish Forest Genetic Resources. Inv Agrar Sist y Rec 18:13–19.

Kawecki TJ, Ebert D (2004) Conceptual issues in local adaptation. Ecol Lett 7:1225–1241. doi: 10.1111/j.1461-0248.2004.00684.x

Konnert M, Fady B, Gömöry D, et al (2015a) Use and transfer of forest reproductive material in Europe in the context of climate change. Bioversity International, Rome, Italy

Konnert M, Fady B, Wolter F, et al (2015b) Use and transfer of forest reproductive material Use and transfer of forest reproductive material in Europe in the context. European Forest Genetic Resources Programme (EUFORGEN), Bioversity International, Rome. Italy

Leimu R, Fischer M (2008) A Meta-Analysis of Local Adaptation in Plants. PLoS One 3:1–8. doi: 10.1371/journal.pone.0004010

Lindgren D, Ying CC (2000) A model integrating seed source adaptation and seed use. New For 20:87–104.

McLachlan JS, Hellmann JJ, Schwartz MW (2007) A framework for debate of assisted migration in an era of climate change. Conserv Biol 21:297–302. doi: 10.1111/j.1523-1739.2007.00676.x

Namkoong G (1969) Nonoptimality of local races. In: Proceedings of the tenth southern Conference on Forest Tree Improvement. Houston, Texas,

Nanson A (2001) The New OECD Scheme for the Certification of Forest Reproductive Materials. Silvae Genet 50:181–187.

O'Neill GA, Aitken SN (2004) Area-based breeding zones to minimize maladaptation. Can J For Res 34:695–704.

Parker WH (1992) Focal point seed zones: site-specific seed zone delineation using geographic information systems. Can J For Res 22:267–271.

Partel M, Szava-Kovats R, Zobel M, Pärtel M (2011) Dark diversity: shedding light on absent species. Trends Ecol Evol 26:124–128. doi: 10.1016/j.tree.2010.12.004

Pedlar JH, McKenney DW, Aubin I, et al (2012) Placing Forestry in the Assisted Migration Debate. Bioscience 62:835–842. doi: 10.1525/bio.2012.62.9.10

Ramírez-Valiente JA, Robledo-Arnuncio JJ (2015) Exotic gene flow affects fitness trait values but not levels of heritable trait variation in the southernmost population of Scots pine (Pinus sylvestris L. var. nevadensis). Biol Conserv 192:331–342. doi: 10.1016/j.biocon.2015.10.011

Rehfeldt GE, Tchebakova NM, Parfenova YI (2004) Genetic responses to climate and climate-change in conifers of the temperate and boreal forests.

Robledo-Arnuncio JJJJ, Gil LA (2005) Patterns of pollen dispersal in a small population of Pinus sylvestris L. revealed by total-exclusion paternity analysis. Heredity (Edinb) 94:13–22. doi: 10.1038/sj.hdy.6800542

Savolainen O, Pyhajarvi T, Knurr T, et al (2007) Gene flow and local adaptation in tees. Annu Rev Ecol Evol Syst 38:595–619. doi: 10.1146/annurev.ecolsys.38.091206.095646

Schwartz MW, Hellmann JJ, McLachlan JM, et al (2012) Managed Relocation: Integrating the Scientific, Regulatory, and Ethical Challenges. Bioscience 62:732–743. doi: 10.1525/bio.2012.62.8.6

Seddon PJ (2010) From Reintroduction to Assisted Colonization: Moving along the Conservation Translocation Spectrum. Restor Ecol 18:796–802. doi: 10.1111/j.1526-100X.2010.00724.x

Serra-Varela MJ, Alía R, Daniels RR, et al (2017a) Assessing vulnerability of two Mediterranean conifers to support genetic conservation management in the face of climate change. Divers Distrib. doi: 10.1111/ddi.12544

Serra-Varela MJ, Alía R, Daniels RR, et al (2017b) Assessing vulnerability of two

Mediterranean conifers to support genetic conservation management in the face of climate change. Divers Distrib 23:507–516. doi: 10.1111/ddi.12544

Serra-Varela MJ, Alía R, Pórtoles J, et al (2017c) Incorporating exposure to pitch canker disease to support management decisions of Pinus pinaster ait. in the face of Climate change. PLoS One. doi: 10.1371/journal.pone.0171549

Serra-Varela MJ, Grivet D, Vincenot L, et al (2015) Does phylogeographical structure relate to climatic niche divergence? A test using maritime pine (P inus pinaster Ait.). Glob Ecol Biogeogr 24:1302–1313. doi: 10.1111/geb.12369

Thomas CD (2011) Translocation of species, climate change, and the end of trying to recreate past ecological communities. Trends Ecol Evol 26:216–221. doi: 10.1016/j.tree.2011.02.006

Unger GMM, Vendramin GGG, Robledo-Arnuncio JJJ (2014) No Title. Mol Ecol 23:5435–5447. doi: 10.1111/mec.12946

Supplementary information

Appendix 1.

Appendix 1. Niche modelling

Environmental information

The natural distribution have been transformed in presence/absence data using a 1 x 1 km grid. For each point of the grid, climate data corresponding to the (1961–1990 period) were obtained using two different climatic models for the Iberian Peninsula (Gonzalo, 2007), and for the islands (Hijmans et al., 2004). The variables included mean annual (P), winter (WP), and summer (SP) precipitation, mean annual temperature (T), minimum temperature of the coldest month (MTC), maximum temperature of the warmest month (MTW), growing degree days (t>5°) (DD), total number of months under frost (t<0º) (F), duration of the drought period in months (P<2T) (DP). These variables were chosen because of their strong link with the physiology and growth of plant species (Bartlein et al., 1986; Prentice et al., 1992) and most of them have been used for modelling niche distribution of different forest species in Spain (Benito-Garzón, et al. XX). For instance, MTC discriminates species based on their ability to assimilate soil water and nutrients, and continue cell division, differentiation and tissue growth at low temperatures (lower limit), and chilling requirements for processes such as bud break and seed germination (upper limit). Altitude (ALT) was also considered.

Niche-Based Models of Species Climatic Envelopes

For each species following a maximum entropy modelling approach (Phillips et al., 2006) using the Maxent Software was used to obtain the area predicted for each of the different species. We obtained for each grid point the logistic probability of each species’ presence. For each climate change scenario, models relating species distributions to the nine bioclimatic variables were fitted by using MAXENT and projected into the future. As a background environmental file, we used half of the data grid points. The projection was made to all the points of the grid. We obtained the response curves for each variable, and the importance of each environmental variable (jacknife method).

Climatic asssignment

To establish the assignment to the region of provenance, points with logistic probabilities of occurrence higher than 0.4 were considered. The probability of assignment to each of the regions of provenance was established according to a multi-normal distribution based on the same climatic variables. The average probability for each region of use and region of provenance was computed.