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Effects of abiotic and anthropogenic factors on the spatial distribution of *Quercus faginea* in the Spanish Central Pyrenees

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ABSTRACT

Species distribution is usually explained by abiotic factors, particularly, climatic variables which are often considered as the most important drivers of species distribution. Nevertheless, when investigating the underlying causality in species distribution, the importance of those factors together with the role of anthropogenic factors (land-use variables) must be considered. Particularly in the Mediterranean basin where natural ecosystems underwent important transformations due to anthropogenic pressure in the territory. In this work we studied the effects of abiotic and anthropogenic factors on *Quercus faginea* distribution identifying the key factors that shape its distribution in the Spanish Central Pyrenees. Data on presence-absence of *Q. faginea* species, abiotic variables and anthropogenic variables were derived by GIS from digital sources and aerial photographs. We used Bayesian model averaging to identify the key factors that affect the spatial distribution of *Q. faginea*. ~~Than~~ Then we applied hierarchical partitioning to estimate the relative importance of each key factor. In the Spanish Central Pyrenees, on a broad scale, abiotic variables, i.e. climate and lithology, were identified as underlying factors that shape the spatial distribution of *Q. faginea*. The presence of recently introduced plantations and previous livestock pressure had a negative effect on *Q. faginea* distribution; which represent the anthropogenic disturbance effect on this species. This study indicated that in this mountain area and at our regional scale, although abiotic factors have a great importance in explaining the underlying causality in *Q. faginea* distribution, anthropogenic factors can not be neglected.

Keywords

Species distribution models (SDM), explanatory models, Bayesian model averaging, hierarchical partitioning, land use variables.

Introduction

The understanding of the factors that influence the distribution of species is of interest because they enable us to estimate the drivers of species distribution across a study region. To model the relationship between species and their environment, ecologists often use empirically based statistical models (e.g. Coudun et al. 2006; Segurado and Araújo 2004; Thuiller et al. 2004). Statistical models of species distribution (i.e. presence-absence of species) derive relationships between the dependent variable and the values of a set of explanatory variables such as temperature, slope or elevation. These techniques can be used for two purposes: (i) to explore the underlying causality of species distribution (by examining the statistical significance of the influence of explanatory variable upon the dependent variable) and/or (ii) prediction of the distribution of species it self (by using the derived relationship between the dependent variable and predictors to project the predicting map), but in many cases, statistical models are only used to predict spatial distribution of species, while the explanation of the underlying causality tend to be a secondary consideration. As a consequence, there is a few modeling studies which addressed such purpose (e.g. Graham et al. 2004; Nally 2000).

Often, the spatial distribution of terrestrial species is studied with regard to abiotic variables only (climatic variables), which are often the most important drivers of species distributions (Guisan et al. 1995; Heegaard 2002; Lehmann et al. 2002). Moreover, human activities as well (e.g. agricultural and livestock activities and reforestations) might influence the spatial distribution of terrestrial species. Particularly, in the Mediterranean Basin which is recognized as one of the Earth's biodiversity hotspot (Myers et al. 2000), human activities have played a fundamental role in the fragmentation of communities and the loss of species (Maltez-Mouro et al. 2009). For instance, the plantations made recently in the Spanish mountains have replaced the native forests with faster growing species (Perry 1998); this fact has led to a reduction in the total ranges of species and landscape diversity (Lasanta et al. 2009). In this sense, along with the influence of abiotic factors, the anthropogenic disturbances must be considered when investigating the underlying causality in species distribution.

The main objectives of this study were to explore and understand the effects of abiotic and anthropogenic factors on *Q. faginea* forests in the Spanish Central Pyrenees. Our main question was to determine the main factors that explain the occurrence of *Q. faginea* forests in the Spanish Central Pyrenees.

Q. faginea was the subject of the study because it is sensitive to abiotic and anthropogenic factors. It is a winter-deciduous tree that often does not exceed high-shrub stature because of anthropogenic disturbances or environmental limitations (Maltez-Mouro et al. 2009). The *Q. faginea* forest species is considered as an important structural component of native plant communities in many mesic forests in Mediterranean environments (Rey Benayas et al. 2005) holding a wide diversity of animal and plant communities, and thus is of great interest for ecosystem conservation (Rey Benayas et al. 2005). Regardless of its huge importance as a structural species of the ecosystems, and its important role as a fixative of rural populations, providing several main resources to the rural populations (source of timber and acorn), *Q. faginea* has not been much studied, compared to other species.

Methods

Study area and species

The study was conducted in the Spanish Central Pyrenees, between 42.49 N and 42.41 N and between 0.32 W and 0.10 E (Fig. 1), which encompassed a wide elevation range (500-3000 m a.s.l.). The 4394-km2 area included about 325 villages and had clear rural character. In the area, the climate is quite variable, with oceanic characteristics in the west and a Mediterranean influence in the easternmost portion (Lasanta 2002). Mean annual rainfall is >800 mm year $^{-1}$ in the lowest localities. This value is overcome in the rest of the area; above 1500 m the precipitation is higher than 1500 (Vicente-Serrano et al. 2004). The intra annual variability is very high, and the rain season extends from October to June. At the lowest elevations, mean annual temperature varies between 9 ºC and 11 ºC and, at the highest elevations$\geq$(1500 m), it is 6 ºC. The relief of the study area is placed in parallel bands with a NW-SE direction (Vicente-Serrano et al. 2004). In the north part the Axial Pyrenees (2500-300 m of altitude). The next band corresponds to Eocene flysch areas (800- 2200 m of altitude). The third band correspond to the Ebro depression (400-800 m of altitude), forming a wide valley. The landscape is a mosaic of natural and semi-natural forests, shrublands, grasslands, agricultural fields, and urban areas.

In the Central Pyrenees *Q. faginea* is considered as one of the most abundant species; it occurs naturally, it is not artificially reforested. Its communities form a transition belt between conifer-sclerophyllous forests of *Q. ilex* and *Pinus halepensis* and high mountain forests of *P. sylvestris*, *P. nigra*, *Fagus sylvatica* and *Abies alba* (Jiménez et al. 1998; Loidi and Herrera 1990). The facility of hybridization of *Q. faginea* with other species of the same gender *Quercus* (i.e. *Q. pubescens*) causes the existence of numerous hybridogenic populations in the study area and many of individuals are difficult to identify (Himrane et al. 2004; Loidi and Herrera 1990), so here we considered those hybrids (mainly *Q. subpyrenaica*) within *Q. faginea* species.

Species data

The distribution map of *Q. faginea* in the Spanish Central Pyrenees was derived from the Spanish National Forest Inventory map (IFN3; MMA 2007). In IFN3 map, 3 principal tree species were considered for each patch and classified as first, second or third most dominant tree specie, based on the estimation of the degree of their presence (explained in percentage) in that patch. In this study, all patches where *Q. faginea* was the first, second or third dominant species, were selected to build the distribution map of this species in the study area. Overall, the percentage of presence of *Q. faginea* varied from 20% (in the patches where considered as third dominant specie) to 90 % (in the patches where considered as first dominant specie). The derived map was imported into a GIS for further processing; this process included edges of patches correction and elimination for each patch of the areas where *Q. faginea* was absent. This action was done by visual interpretation of the ortho-rectified, 0.5-m resolution aerial photographs (1:30 000), obtained from the Spanish National Plan of Aerial Ortophotographs (IGN 2006). The accuracy of the final map (96%) was quantified by sampling 200 random points and calculating confusion matrices (Congalton 1991).

Data sampling was based on 20-m^2 grid layers that represented the entire dependent and independent variables, within which 2000 pixels were chosen randomly (*Q. faginea* were occurred in 900 samples) using the ArcGIS extension, Hawth’s Analysis Tools 3. 27. The distance of 400-m was considered as a minimum threshold in selecting sampling (see statistical analysis section), thereby avoiding spatial-autocorrelation in data analysis (Legendre 1993). To avoid non-representative sampling, each patch (polygon) of *Q. faginea* forests was represented by a minimum of five records of occurrence.

Abiotic data

The explanatory variables were chosen based on previous studies (Austin 2007; Guisan and Zimmermann 2000; Purves et al. 2007). Our approach relies on the combination of abiotic variables that might have a direct or indirect influence on *Q. faginea* species (Corcuera et al. 2004; Lansac et al. 1994; Mediavilla and Escudero 2004), and anthropogenic variables that reflect the anthropogenic disturbances. Following Coudun et al. (2006), we selected abiotic variables that have an influence on (1) biophysical processes (elevation, slope, aspect, terrain curvature, and lithology), (2) frost conditions (number of frost days per year and mean monthly minimum temperature), (3) drought (water balance and mean monthly maximum temperature). We expected that most of the *Q. faginea* would occur at 600-900 m a.s.l., in areas that had a sizable water balance, and characterized by moderate temperature, and a southern slope aspect.

The topographic variables, elevation (m.a.s.l), slope (degrees), aspect (north/south), and terrain curvature (concavity/convexity), were derived from a Digital Elevation Model of Aragón (CITA 2009) at 20-m resolution using ArcGIS 9.2 (ESR 2006). To obtain north/south orientation the cosines of aspects were calculated. The data for climatic variables, obtained from the Climatic Atlas of Aragon (DMA 2007) at 100-m resolution. These variables averaged over the period 1971-2000 and included water balance (mm), number of frost days per year, and mean monthly maximum and minimum temperatures (ºC). The methodology used for the elaboration of the climatic maps based essentially on the combination of local and global interpolation methods. Likewise, a set of topographic (e.g. latitude, longitude, and insolation derived from the Digital Elevation Model at 100-m resolution) and geographic variables (which quantified the distance to rivers and Cantabrian Sea) were used as independent variables to explain the spatial variability of the climatic factors. The following equation was used to predict the values of the climatic variable in areas without information:

$z(x) = b_0 + b_1P_1 + b_2P_2 + \ldots + b_nP_n$

Where z is the predicted value in the point x, $b_0, \ldots, b_n$ are the coefficient of the regression, and $P_1, \ldots, P_n$ are the values of the set of independent variables in the point x.

Furthermore, data regarding water balance was obtained subtracting the mean annually precipitation by the potential evapo-transpiration. The later variable was calculated using Hargreaves equation (Hargreaves 1975). In this study the climatic maps were downscaled from the original grid (100-m^2 grid to a 20-m^2) using nearest-neighborhood interpolation. The map of litology was derived from the geological map of Aragón (CITA 2007) and reclassified in 2 classes: flysch-limestones rocks and other types of rock.

Anthropogenic data (land-use variables)

Several land use variables that might influence the spatial distribution of *Q. faginea* were used in this study. First, the distance to the nearest village is used to account for human activities concentrated around villages (i.e. agricultural practices), and to quantify the human influence on *Q. faginea* forests in the study area. In addition, to determine whether *Q. faginea* was influenced by the wood-harvesting associated with mining, we quantified the distance to the nearest mine. Beside, to assess the extent to which livestock activities affected the spatial distribution of *Q. faginea*, we included two explanatory variables: cost distance to pastures and cost distance to livestock roads (see below). The extensive reforestation with pine plantations that has occurred in the area within the last 50 year might have influenced the spatial distribution of *Q. faginea*; therefore, the distance to the nearest pine plantation was included in the analyses. We expected that *Q. faginea* would ~~be~~ occurs far from villages and mines, and rare near pastures and livestock roads, but more common in older abandoned areas. In addition, we expected *Q. faginea* to be affected negatively by pine plantations.

The map of villages was obtained from a map of settlements of Aragon (CHE 2009) and a map of mines was derived from a map of CORINE Land Cover 2000 5th level project (IGN 2002). Raster layers were created based on the Euclidean distances to the nearest village and mine within each pixel. Livestock variables (cost distance to pastures and cost distance to livestock roads) were derived from a map of CORINE Land Cover 2000 5th level project (IGN 2002) and a livestock roads map of Aragón (DMA 2010) respectively. The Cost distance function calculates the least accumulative cost for moving from each pixel to the source pixel (in this case pasture or livestock road) using slope as cost layer. Cost distance raise with an increasing of slope up to 35º; beyond that steepness, areas are essentially inaccessible (maximum cost) to livestock. To identify a variable that best reflected the effect of pine plantations on *Q. faginea* forests. First, the map of pine plantations (*P. sylvestris* and *P. nigra*) in the study area was derived from Spanish National Forest Inventory map (IFN3; MMA 2007). Then, the Euclidean distance to the nearest plantation was calculated for each pixel using ArcGIS 9.2 (ESR 2006).

Statistical analysis

First, collinearity between all pairs of independent variables was investigated using Pearson's correlation coefficient. The test of correlation indicated that several pairs of the explanatory variables were strongly correlated ($r > 0.7$), so to solve this problem only the variables that was thought most likely to be biologically important was used in the modeling (Graham 2003). The final set of potential explanatory variables included: slope, aspect, terrain curvature, water balance, number of frost days per year, distance to the nearest plantation, distance to the nearest village, distance to the nearest mine, cost distance to livestock roads, and cost distance to pastures. Spatial autocorrelation was tested for the *Q. faginea* distribution map (pixels of 20-m^2)

here using the row-standardized Moran's I test (Cliff and Ord 1973). Spatial autocorrelation decrease monotonically above a lag of fifteen map pixels (~300 m). Therefore, the distance of 400-m was considered as a minimum threshold in selecting sampling (Millington et al. 2007).

To model the *Q. faginea* responses to abiotic and anthropogenic factor we used Bayesian model averaging (Madigan and Raftery 1994). BMA incorporates model selection and parameters estimation uncertainties into inference and prediction (Hoeting et al. 1999; Raftery et al. 1997), producing more accurate predictions than methods that select a single best model (Thomson et al. 2007; Wintle et al. 2003). We used the function ''bic.glm'' in the ''BMA'' package (Raftery et al. 2009) in R (R Development Core Team 2009), which performs BMA for GLM (binomial error distribution and a logit link function). This function use Bayesian Information Creterion (BIC) to compare models and "leaps and bounds" algorithm to identify the most probable models (Raftery et al. 1997; Thomson et al. 2007). In the BMA approach the posterior probability that a variable had a nonzero coefficient in the predictor model Pr ($\beta vs \neq 0$) is used as a measure of the influence of that variable on the response. Explanatory variables with high values of Pr ($\beta vs \neq 0$) contributed most to model fit, whereas explanatory variables with low values of Pr ($\beta vs \neq 0$) were included only in less probable models (Nally et al. 2008; Thomson et al. 2007). We considered explanatory variables that had values of Pr ($\beta vs \neq 0$) > 0.75 to be ''key factors,'' (Nally et al. 2008; Viallefont et al. 2001).

Because more than one key factor was identified in our analysis, we performed the hierarchical partitioning (HP) to determine relative importance of each key factor (Nally et al. 2008). Here we used the HP to estimate the "independent" contribution of each "key factor" to the total variance explained by the model (Chevan and Sutherland 1991; Nally et al. 2008). We used the ''hier.part'' package for R (Walsh and Nally 2008). Log-Likelihood goodness of fit measure was used. A logistic model is most appropriate here as the dependent variable is binary (presence vs. absence). Note that the hierarchical partitioning, as currently implemented in the "hier.part" package, depends on monotonic relationship between the response and the explanatory variables (Luoto et al. 2006). To improve the linearity of relationship between key factors and response variable, these variables were log-transformed (Heikkinen et al. 2005) except for litology which is a dummy variable.

Results

Identifying "key factors"

BMA identified most influential factors that affected the distribution of *Q. faginea* in the Spanish Central Pyrenees. Among the 11 explanatory variables included in the model, the following six were identified as key factors, i.e. variables that had a Pr (βvs $\neq 0$) > 0.75: three abiotic variables (lithology, slope, and water balance) and three anthropogenic variables (cost distance to pastures, cost distance to the livestock roads and distance to the nearest plantation). BMA suggested that aspect, terrain curvature, number of frost days per year, distance to the nearest village and distance to the nearest mine were unimportant in explaining the *Q. faginea* probability of occurrence [Pr (βvs $\neq 0$) < 0.25].

All identified key factors had high probability of inclusion in the final model, with [Pr (βvs $\neq 0$) > 0.94], indicating strong relationships with occurrence of *Q. faginea* in the model-building data. Water balance and cost distance to the livestock roads had negative effect on *Q. faginea* occurrence, as the posterior means (PM+SD) for the coefficients associated with each variable were negative (Table 1), which means that the probability of occurrence of *Q. faginea* increase with a decreasing of water balance values, and in zones near livestock roads and were accessible to livestock. Slope, litology, distance to the nearest plantation, and cost distance to pastures had a positive effect in *Q. faginea* occurrence (Table 1), indicating that the probability of *Q. faginea* occurrence increase with increasing slope values (the cross tabulation between slope and *Q. faginea* distribution maps reflected that most (> 90%) of the areas occupied by *Q. faginea* had a slope angle of 5-30º, with the majority between 10º and 15º), also indicating a higher probability of *Q. faginea* occurrence, in litological zones formed by flysch-limestone rocks which are located away from introduced plantations than in other zones. Finally, this result indicate that the probability of occurrence increase with an increasing of cost distance to pastures, which means that there is more probability to find *Q. faginea* in inaccessible areas from pastures lands to livestock, than in other areas.

Independent explained variance

In HP, the key factors had different independent contributions in the total explained variance. This method suggests that the abiotic factors together explained more then 66% of the total independent variance, which reflect the importance of those factors on the distribution of *Q. faginea*. Interestingly, water balance had a highest independent contribution (33.36%), litology (17.02%) was the second most important variable followed by slope (16.36%). The anthropogenic factors explained almost 34% of the total independent variance, a great part was explained by distance to the nearest plantation (14.20%) and cost distance to pastures (10.74%), these 2 variables had a negative effect on *Q. faginea* occurrence therefore reflect the anthropogenic disturbance. ~~cost~~ Cost distance to livestock roads (8.30%) had clearly lowest independent contribution of all key factors.

Discussion

Effects of abiotic factors

The spatial distribution of *Q. faginea* in the Spanish Central Pyrenees was explained in great part by the abiotic factors; particularly, climate, lithology and slope. Changes in precipitation and soil water recharge can have a significant effect on the establishment of *Q. faginea* plants (Corcuera et al. 2004) and an increase in the soil water recharge favors the growth of *Q. faginea*. Moreover, our study indicated that water balance had a negative relationship with the occurrence of *Q. faginea*, due to the particularity of the Central Pyrenees, where water balance becomes positive with the increased elevation while the temperature, on the other hand, is characterized by very low values in winter (elevation, water balance, and mean monthly minimum temperatures were strongly correlated). The cross tabulation between elevation and *Q. faginea* distribution maps reflected that in the Central Pyrenees all the areas occupied by this species were located between 450 m and 1500 m of altitude. The species does not raise the high elevated lands (situated above 1500 m of altitude) because of freezing temperatures that inhibit the establishment and growth of seedlings. As in our study, Sánchez de Dios et al. (2006) found that *Q. faginea* forests in the Iberian Peninsula were associated to continental areas with low precipitation. The phenological pattern of *Q. faginea* in northeastern Spain is similar to those of species that have deep roots and can access deep water reserves (Pilar and Gabriel 1998). Our study showed that the presence of *Q. faginea* is associated with areas that are characterized lithologically by flysch-limestone rocks and are rich in calcium carbonate, which generates calcareous soils that are suited to the establishment and growth of this species (Ceballos and Torre 1979; Jiménez et al. 1998). In addition, the probability of *Q. faginea* presence increased with an increase in slope due to the competition from agricultural activities. The traditional management has been maintained for centuries, based on an integral used of land resources. This fact implies important transformations in natural space. The *Q. faginea* forest located in low slopes was cut and the lands used for cereal cultivation (Lasanta 1989), which restricted this species to poor soils and stony hillsides, this result reflected that the occupation of shallow slope by *Q. faginea* is not a natural process, but is a result of the anthropogenic disturbance.

The importance of anthropogenic factors

This study reflected that anthropogenic factors play a second role in affecting the spatial distribution of *Q. faginea*, and act as restrictive factors that inhibit its spatial extension. Particularly, livestock grazing and introduced plantations had negative effects on *Q. faginea* distribution representing the anthropogenic disturbances. The probability of *Q. faginea* occurrence decrease in areas close to pine plantations, this result is in agreement with some recent studies (Echeverria et al. 2006; Teixido et al.), which suggested that native forests can be severely affected by the presence of introduced species, particularly, those that are characterized as fast growing and having dispersal abilities. In the Central Pyrenees, *Q. faginea* forests were extensively deforested to increase the amount of arable land, especially for the cultivation of cereals (Lasanta 1989). Most of those lands were abandoned after a few decades of exploitation. During the ultimate 50 year, some of the abandoned lands were reforested with pine plantations by the Spanish forestry service in order to restore the ecological diversity lost through agricultural intensification (Amo et al. 2007), while the remainder has undergone natural re-vegetation, i.e. secondary succession (see below). The introduced plantations spread to the detriment of *Q. faginea* and other species (Amo et al. 2007) and currently, occupy areas that were occupied by native *Q. faginea* forests before. In addition, our results showed that *Q. faginea* probability of occurrence decreased in areas close to pastures and were essentially accessible to livestock. In areas that are subject to livestock overgrazing, the regeneration of tree populations is practically impossible (Barbero et al. 1990). Livestock eliminates seedlings, which diminishes recruitment and, consequently, hinders species regeneration (Cierjacks and Hensen 2004). At some areas of the Central Pyrenees, the *Q. faginea* forests were used directly as “dehesas” system (Barbero et al. 1990; Montserrat 1990), i.e., a silvo-pastoral system with sparse *Q. faginea* and perennial grass layers. Likewise, the *Q. faginea* forests located between 1200-1600 m a.s.l. were cut down, and summer livestock pastures were created (Lasanta et al. 2005), which has relegated this species to areas that have poor soils and stony hillsides. Furthermore, the *Q. faginea* forests were overexploited for the production of firewood used as source of combustible during that period. In contrast, the occurrence of *Q. faginea* seemed to be favored in areas near livestock roads and of facile accessibility to livestock, although this variable had a weaker effect (low independent explained variance). This fact is probably associated with the high acorn production near livestock roads, as consequence of silvicultural practices (thinning, pruning) applied by forestry service alongside the livestock roads, which maintain the health of

Q. faginea stands closed to livestock roads. The BMA approach suggested that distance to the nearest village did not affect the occurrence of *Q. faginea*, which might be because of rural exodus campaigned by the abandonment of croplands. Since the early 20th C., a significant progressive decrease in anthropogenic pressure has occurred. Under those circumstances, the exploitation of the land has been more concentrated spatially, and other areas have experienced a reduction in extensive use and an increase in the abandonment of many croplands (Lasanta et al. 2000). In abandoned agricultural fields, secondary succession is a natural process in which progressively mature and stable vegetation develops (Gallego et al. 2004; Tatoni et al. 2004). In the Central Pyrenees, secondary succession is well known (Molinillo et al. 1997; Montserrat 1990), and the first plants of *Q. faginea* appear in abandoned fields about 100 year after abandonment (Montserrat 1990), which explains why recently abandoned fields are not colonized by *Q. faginea* despite the recent reduction in anthropomorphic pressure in the region (Lasanta and Vicente-Serrano 2006).

Conclusion

This study has demonstrated that abiotic variables were the main underlying factors that shape the distribution of *Q. faginea* in the Spanish Central Pyrenees. The spatial distribution of this species is determined by abiotic factors operating on a broad scale, i.e. lithology and climate. The anthropogenic factors, particularly the recent addition of plantations and previous livestock pressure, affected negatively the distribution of *Q. faginea* in the study area.

Much attention has been focused on the role of abiotic variables as drivers of terrestrial tree species distribution. However, our study exemplified how anthropomorphic changes in land use could affect the distribution of terrestrial tree species, especially in the Mediterranean region where natural ecosystems underwent a large modification caused by changes in the anthropomorphic use of land.

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Table 1 This table contains the explanatory variables introduced in the BMA (Variables), posterior probability that a variable had a nonzero coefficient Pr ($\beta_{vs} \neq 0$), posterior means and standard deviation (PM+SD) for the coefficients associated with each variable, and independent explained variance (%I) for the explanatory variables with Pr ($\beta_{vs} \neq 0$)>0.75 (key factors, bold) is explained as a percentage of the total explained variance for the full model.

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Variables	**Pr ($\beta_{vs} \neq 0$)**	**PM+ SD**	**%I**
Lithology	**100%**	**0.632±0.190**	**17.023**
Aspect	24.5%	-0.001±0.018	0
Slope	**100%**	**0.324±0.031**	**16.361**
Curvature	01.3%	0.001±0.015	0
Water balance	**100%**	**-0.354±0.000**	**33.363**
Number of frosts days	05.0%	0.003±0.001	0
Cost distance to pastures	**100%**	**0.014±0.000**	**10.741**
Cost distance to the livestock roads	**100%**	**-0.017±0.000**	**08.302**
Distance to the nearest mine	11.7%	-0.001±0.000	0
Distance to the nearest village	03.8%	-0.002±0.000	0
Distance to the nearest plantation	**94.5%**	**0.159±0.172**	**14.207**

Figure1. (a) The Central Pyrenees, north of the Aragon Autonomous Community, northeastern Spain. (b) Digital Elevation Model of the study area, grey scale indicates the elevation range (m) above sea level. White patches represent the *Q. faginea* distribution.