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# **Case Study**

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# Changes in forest landscape due to agricultural activities and their influence on natural ecosystems: the eastern Galician mountains

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**Abstract:** Forest and agricultural landscapes are vital in relation to biodiversity. Protection policies in such areas should include incentives to enable the common landuse practices. Conservation cannot be addressed in the short term because these landscapes have evolved as socio-ecological systems and provide optimal conditions for biodiversity maintenance. They occur in areas where agriculture has not changed significantly as in the eastern Galician mountains. The landscape dynamics has been shaped by human involvement during centuries. We analyzed how the landscape has evolved according to environmental, socioeconomic and historical changes with the aim of proposing actions for its conservation. The study focused on the recovery of natural hardwood forests which have been intensively exploited since ancient times. Over the past few centuries, these forests have been transformed to agricultural land, felled for use in the naval, metallurgical and railway industries, expropriated from the Church, and affected by wildfire; more recently, have been replaced by fast growing species. Today, broadleaved forests cover small areas of rugged land where the topography often precludes other land uses. In conclusion, although the landscape in the study area has undergone a major transformation, now this land is a priority for biodiversity conservation.

**Keywords:** Vegetation dynamics, agrosilvopastoral systems, *Quercus* spp., NW Iberian

# 1 Introduction

Tree species belonging to the genus *Quercus* (oak species in a broad sense) dominate in a large part of the temperate forests in subtropical transition areas in the northern hemisphere. Oak species represent one of the dominant species of the climax vegetation in temperate areas, with around 400 species occurring worldwide, many of which are found in Mexico [1].

In the eastern Galician mountains there is evidence of the presence of *Quercus* species since the Cretaceous Era and their diversification during the Tertiary period [2]. Deciduous forests dominated for many centuries during the Quaternary period [3] and then in the last glacial phase, as indicated in numerous palynological studies [4].

Despite their autochthonous character, the current forest ecosystems are not only result of the vegetation dynamics during the last interglacial cycle [5]. In addition to natural evolution, these forests have been shaped by human intervention, as indicated by their proximity to villages and the management traditions still observed today. Species such as oak, hazel, lime, alder, ash, cherry, beech and birch thrived during the aforementioned period and remain abundant today as a result of human activity [6].

Data from the 4th Spanish National Forest Inventory indicate the importance of these forests: pure stands of *Quercus robur* L. or mixed stands with other broadleaved species cover a total area of 246,445 ha in Galicia, i.e. about 18% of the total forest area [7]. The data appear to suggest that the region is suitable for growth of the species [8].

However, the area occupied by these stands has decreased gradually over time. The first indications of deforestation of these forests appeared after the Quaternary period and the last glacial phase, between 7,700 and 7,300 B.C. [9]. The reasons for this decline are diverse and include the extraction of timber for domestic and industrial use, as well as land clearing for establishment of crops and pasture, forest exploitation

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by the naval, iron and railway industries, and forest fires. More recently, silvicultural management such as pollarding or felling of the best trees [10,11], as well as reforestation with pine and eucalyptus, have contributed to the reduction of forest stands [12]. The stands, which often survive on inaccessible steep slopes, are important in relation to biodiversity conservation. Their location has had a double effect. Thus, the difficult access to these oak lands has prevented any alternative land use, and it has allowed many valuable oaks to survive to the present day [13].

One of the first efforts made to improve the forest management was the 1992 Galician Forest Plan. This plan, development of which indicated increased awareness of sustainable forest management, proposed that the area occupied by broadleaved species should be increased to 410,000 ha by 2032 [1].

The exploitation system in the eastern Galician mountains is an agricultural-silvicultural-grazing system adapted to the diversity of the mountain environment, based on cereal crops and extensive grazing with orchard crops or fruits. This model of social-economic organization has shaped the particular landscape in

the area. In the resulting structure, agricultural land is located at the bottom of valleys and the villages in the middle slopes, ideally with a sunny orientation. The orchard crops appear between buildings, surrounding the village and give way to chestnut stands or fields of rye. Bushes dominate on the high slopes, with periodical burning carried out to regenerate grasslands. Meadows are located on the lower slope close to rivers. The shaded slopes, away from villages and with high levels of humidity, are scarcely affected by anthropogenic pressure and act as refuges of the best examples of the primeval forests [13] (Figure 1).

The landscape dynamics in the eastern Galician mountains in the last century was marked by development of the forest area. An understanding of the current status and future management predictions must take into account the historical development of forest stands. Therefore, the aim of the present study was to describe the natural development of the broadleaved forests in this area by using oak species as an example. This knowledge based on historical information can be used now and in the future as a complementary tool for developing conservation strategies.



**Figure 1.** Photograph illustrating the exploitation system in the eastern Galician mountains: agricultural-silvicultural-grazing system (the impact of new infrastructures on the landscape can be observed in the background, at the top of the picture) (source: corresponding author)

The study objectives were as follows: i) to describe the natural history of broadleaved forests in the eastern Galician mountains; ii) to identify conservation strategies based on existing historical information; iii) to determine whether the application of silvicultural practices can aid restore native forests and landscape restoration; and iv) to establish the value of the conservation work carried out to date.

# 2 Location and description of the physical environment (abiotic and biotic factors)

The study area is located in the northwest of the Iberian Peninsula within the Autonomous Community of Galicia (Spain), occupying an area of more than 100,000 hectares. The average elevation is 939 m and slopes greater than 15% are present in half of the region. The parent rock is heterogeneous with granites, schist, slates and quartzite giving rise to acidic soils. The climate is Humid Oceanic with some Mediterranean influence south. The annual precipitation varies between 700 to more than 2500 mm; the summer precipitation is about 100 mm, but in many areas is near to 300 mm [3]. The potential vegetation comprises deciduous forests including different oak species, mainly *Quercus robur* along with other species such as chestnut, birch and beech. These forests occupy more than 450,000 hectares in Galicia from sea level to an elevation 1100-1200 m. This type of forest, locally called "fraga", requires a dominant oceanic climate to develop under ideal conditions. These species define different associations included in the order Quercetalia roboripetraeae [14].

# 3 Sources of information: chorological and historical information

We began this study by obtaining chorological information and analyzing changes in land due to human activity. The importance of these two aspects has been highlighted by different authors [15,16]. Examination of chorological information enables the origin of vegetal formations and the natural changes that occur in their distribution to be determined [17]. This information was obtained from studies of the potential vegetation [14] and from graphical maps showing the distribution of the different vegetation series [18,19]. The chorological information was particularly useful for analyzing changes related to the natural distribution of the vegetal formations under study.

Information about land modifications due to human management was obtained from several sources. Although landscape changes often occur naturally, they are affected by transformations arising as a result of human intervention. As our study focuses on the latter, the historical information was completed with more recent data included in the Annual Agrarian Statistics (from 2005 to present), National Forest Inventories (NFIs), Galician Agrarian Data, and Forest Plan of Galicia of 1992. All databases used were essential for our purposes because each provides a different type of information (e.g. agrarian, forestry, and predictions for the future), although used differently. For example, the Forest Plan of Galicia data showed that the increase in the area covered by natural broadleaved forests during the last few decades is probably the result of natural development, but may also be influenced by other factors such as the abandonment of agricultural land (Figure 2).

### 4 Results and discussion

The changes in the forest landscape include a long period of dominance by oaks [13,18]. In the study area intensive harvesting and timber extraction have been carried out for centuries, due to the abundance of high-quality timber, such as oak, beech and chestnut. However, Forestry Administration reforestation policies have recommended planting fast-growing species such as pine and eucalyptus [20]. Although these factors played a very important role in shaping the landscape dynamics, recent changes in the productive system have also been a major factor [19]. Also, the rural demands have changed considerably during the last centuries, including a decrease in agriculture and extensive cattle farming and much less use of wood and firewood [21].

However, during the Middle Age, before these socioeconomic changes, several factors led to a significant reduction in afforested areas. This decline extended throughout the second half of the 19th century when there was a sharp reduction in forest land, later giving rise to uninterrupted growth of tree surface [22,23]. As a result of reforestation, the increase in forest surface was very important after the Spanish Civil War and recently during the late 20th century due to the abandonment of agricultural land and reforestation with native species [24,25]. These practices were driven by private owners and the public administration [26].

During the second half of the 19th century, similar



**Figure 2.** Photograph exemplifying the increase in the natural broadleaved forests during the last few decades by natural regeneration in abandoned agricultural land and grasslands (source: corresponding author)

several events took place that to those occurring at the beginning of the 21st century. On the one hand, the abandonment of human activities that once played a significant role in the deforestation process, such as the use of firewood, agriculture and extensive pasture in mountain areas, production of iron, and shipbuilding [24]. On the other hand, the expansion of exotic species quantitatively compensated for the loss of native species [27]. Today, the expansion of fast growing exotic species is common and is leading to a change in land use (mostly from agricultural to forest use). The result is a decrease in production of agricultural crops and an increase in forest plantations. One of the most important consequences of this process is the loss of biodiversity and the impact on the landscape.

Examples of a high level of reforestation took place between the above mentioned periods (i.e. in the 20th century) [18]. Before the Spanish Civil War (1936), the complexity and failure of administrative systems, such as Forest Districts, forced the reforestation growth by private owners. Only any public administration (Deputation of Pontevedra) changed this system by signing agreements with the Forest Owner's Council [20].

After the Civil War, some changes were made to the Forest Administration and it was proposed that owners without any training in forest management should not be involved in reforestation work. The work was led by the Spanish Forest Patrimony and the Provincial Councils, under a consortium that financed and managed the plantations [20]. It was assumed that there would be no benefits received from the timber sold. This assumption caused some problems and by way of compensation the financial input to the silvicultural management carried out in these new forests created until the 1970s was the highest in the Forest Administration history [18]. This reforestation effort was accompanied by other changes in the rural demands, although they did not mean an increase in the average forest area per owner. The application of silvicultural management practices with the aim of improving and restoring native broadleaved stands is considered to enable integration of the natural landscape as part of the cultural and environmental heritage [10,11].

The reforestation was carried out over many hundred thousand hectares until the end of the 20th century. During the 1940s, more than 60,000 ha in Galicia and approximately 30,000 ha in Asturias were afforested. In the following fifteen years the reforestation work affected

an area of 15,000 ha per year and around 30,000 ha, respectively [20].

The rate of reforestation has since decreased and by the end of the 20th century was around 10,000 ha per year in Galicia (186,164 ha total) [20]. During these years changes were made to enable Spain to enter the European Economic Community (EEC). Perhaps the most important change, besides the economic organization, was the conversion of the agrarian sector. During the 1980s, both European and national policies provided grants to encourage the abandonment of agricultural activities. The structure of medium and large-sized farms was thus reorganized. However, much exploitation disappeared and the amount of agricultural land decreased [25]. Much of the area covered by autochthonous broadleaved species before the 1950s was converted to crop land and when this was subsequently abandoned during the 1990s it was covered by shrubs [26].

The Common Agricultural Policy (CAP) (EEC 2080/92) took this problem into account and attempted to compensate for the decrease in agricultural activities by promoting different resources, including forestry [19]. However, because of the land ownership structure, with small areas per owner, the abandonment of agricultural involved a large number of smallholders. This was an important problem for application of the CAP and made it impossible to have a great impact, though an important increase in reforestation was achieved, as shown by data from NFIs [7].

European regulations brought about since 1992 have also had other important effects on natural forests. These regulations were made in response to the continuous demands for conservation of the natural resources, which had notably increased during the preceding decades. This was reflected by the creation of the N2000, Directive 92/43/ EEC, which included these natural forests as habitats of community interest. As a result of the changes during the last thirty years, the new forest owners include usual farmers and urban dwellers. However, these new owners do not have any experience in forest management. Both tend to seek immediate benefits provided by planting fast growing species [19,26].

Study of the changes that occurred between the second and fourth NFI (1993-2011) is important to enable quantification of the changes in land use. This comparison highlights a decrease in the area of agricultural land, which has been replaced by unproductive land, protective forests or fast growing species, especially eucalyptus [7,28].

Forest fire is another factor of great historical importance in shaping the landscape. During the late 1970s, the 1980s and more recently, in 2006, forest fires

have had a great impact on the previous repopulations of extensive unproductive lands. The origin and the reasons for the forest fires often remain a puzzle to which there is no simple answer. The occurrence of forest fires depends on several factors, including the following: i) the land property structure, ii) ignorance about the risks of forest fires, iii) the relationship between the rural inhabitants and the land. Identification of these factors enables a framework to be drawn for identifying why during the last forty years forest fires in Galicia have represented more than half of all forest fires occurring in Spain.

# 5 Conclusions

Rural demands are continually subjected to change, including changes in agriculture, extensive cattle farming, firewood production, and exploitation of timber for the naval, iron and railway industries. Reforestation has played a fundamental role in shaping the forest landscape, particularly in relation to fast growing species such as pines and eucalyptus, implying important changes in the productive system.

The changes carried out in the last few decades explain the distribution of the landscape area with a commom rural management system (agricultural-silvicultural-grazing) adapted to the environmental diversity. This framework is completed with a predominance of small farm owners and a tendency for agrarian practices to be abandoned. The property is often inherited by town or city dwellers with no interest in agrarian or forest practices. The absence of interest drives the emergence of unproductive land with the consequent risk of forest fires occurrence.

The application of silvicultural practices with the aim of improving and restoring native broadleaved forests would enable the recovery of the natural landscape as part of the cultural and environmental heritage. This would minimize the effects of forest fires and the spread of unproductive areas and also maximize diversification of forest products, improve biodiversity and stimulate the interest of the new landowners.

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