Distribution area of *Juniperus oxycedrus* L. in Central Spain (Madrid)

Distribution de Juniperus oxycedrus *L. dans la région de Madrid (Espagne)*

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Abstract

The Iberian populations of Juniperus oxycedrus *L. subsp.* oxycedrus *have been studied by several authors who consider their condition as unfavourable. In the Madrid Region, current status, dynamic and distribution area are unknown even when their populations, specifically those who form arborescent shrubs, are included in the type 5210 (Habitat Directive 92/43/EEC). These formations are developed in austere Mediterranean mountain typical of agro ecosystems of high value that have interesting dynamics of recolonization, especially in those areas where agricultural and livestock systems have suffered a setback. This study aims to understand the distribution of juniper in the region of Madrid as the first step to identify and assess the dynamic changes in recent decades.*

To update the cartography of this species the available information has been checked and completed with photointerpretation and fieldwork. Based on this cartography and the information relating to the physical and biotic variables four types of juniper were differentiated by multivariate methods. On the other hand, two types of dynamics were recognized and it was studied in depth the genesis of changes produced in these forests in the last decades.

Keywords: *Juniperus oxycedrus* subsp. *oxycedrus*, woodland structure, Guadarrama Range, Land-use change, Mediterranean landscape.

Résumé

Les populations ibériques de Juniperus oxycedrus *L. subsp.* oxycedrus *L. ont été étudiées par plusieurs auteurs qui considèrent leur état de conservation comme mauvais. Dans la région de Madrid, la situation actuelle, la dynamique et l'aire de répartition de ces junipéraies sont mal connues, même si celles qui sont arborescentes sont incluses dans le type 5210 (directive Habitat 92/43/CEE). Ces formations sont développées dans des ambiances montagnardes méditerranéennes continentales, où se développent des agro-écosystèmes de grande valeur présentant une dynamique intéressante de recolonisation, liée à la déprise agricole. Cette étude vise à mieux comprendre la répartition du Cade dans la région de Madrid, première étape à la compréhension et à l'évaluation des changements dynamiques intervenus dans les dernières décennies.*

Pour mettre à jour la cartographie de cette espèce, l'information disponible a été vérifiée et complétée par photo-interprétation et sur le terrain. Sur la base de cette cartographie et les informations relatives aux variables physiques et biotiques, quatre types de junipéraies ont été différenciés par des méthodes multivariées. D'autre part, deux types de dynamiques ont été reconnus et il a été étudié en profondeur la genèse de changements qui se produisent dans ces forêts dans les dernières décennies.

Mots clés : *Juniperus oxycedrus* subsp. *oxycedrus*, structure forestière, Sierra de Guadarrama, changement de l'utilisation des terres, paysage méditerranéen.

Introduction

The formations of *J. oxycedrus* L. subsp. *oxycedrus* in Madrid Region are usually developed in middle mountain austere systems of high landscape value. The information about this species in this region is very limited. The first references on its presence in the Iberian Peninsula considered this species typically Mediterranean, occupying the altitudinal lower areas to the formations of *Quercus pyrenaica* Willd., generally on south-facing slopes, with steep slopes (Rivas-Martínez, 1964). This species can appear either in formations in which dominates the tree and shrub layer, or in mixed masses with individuals of *Quercus faginea* subsp. *faginea* Lam., *Quercus ilex* subsp. *ballota* (Desf) Samp., *Quercus pyrenaica, Pinus nigra* Arnold. subsp. *salzmannii*, *Pinus pinaster* Ait. and *Pinus sylvestris* L. The floristic composition is very variable depending on the biogeographic region and the climatological, geographical and other environmental conditions of the places where each population is located (Costa Tenorio *et al*., 1993). The most frequent accompanying woody species belong to the genera *Cistus, Genista, Thymus* and *Lavandula.* Nevertheless, at present, basic aspects as its distribution area, ecology or the structure and function of its populations are not known in Madrid Region (Ríos Insúa 1987; García *et al*. 1999, 2000; Montesinos 2007).

In general, populations of *J. oxycedrus* are subjected to various threats. To global scale, the major risk is the reduction of the rainfalls and the increase of the temperatures due to the climate change. This could sharply reduce population recruitment and fertility, increasing their vulnerability to parasites and forest plagues, and intensify the interspecific competition, reducing its area of distribution (Montesinos & García 2009). To local scale, hunting and the recreative noisy activities can bother seed dispersers birds, impacting negatively on the biology of this species. In addition, urbanization of the territory and infrastructure construction fragment juniper populations taking them to a considerable state of degradation (Ríos Insúa 1987; García *et al.* 1999, 2000; Montesinos 2007).

Due to its ecological importance and the threats outlined above, the arborescent bushes of *Juniperus* spp. have been included in the list of the Habitat Directive 92/43, in particular, the habitat 5210 Arborescent matorral with *Juniperus* spp., which includes juniper formations of *J. oxycedrus* and *J. thurifera* L. (CD 92/43 EEC, 1992, Montesinos & García 2009). In Spain, the area occupied by the habitat 5210 in the Mediterranean biogeographical region is 503,278 ha, of which 1.83% is in Madrid Region (Montesinos & García 2009).

The aims of this study are: 1) to know the current distribution of the formations of *Juniperus oxycedrus* subsp. *oxycedrus* in Madrid Region, particularly those located in the piedmont and mountain slopes; 2) to elaborate the actual cartography of the species in this region; 3) to characterize the forest and biogeographic facies; and 4) to identify the populations dynamics occurred in a temporary wide series.

Methods

The study area corresponds to the entire Madrid Region located in the centre of the Iberian Peninsula (Figures 1 and 2).

To make the cartography of this species was carried out a preliminary analysis of existing cartographic information in digital format. Two different types of variables were considered: those that collect information on the distribution of species and those that collect information on abiotic variables. The last ones were used in the subsequent multivariate analysis. Among the first were considered, with different scales of precision: the cartography of the Third National Forest Inventory (Ministerio de Medio Ambiente y Medio Rural y Marino, 2007), the Vegetation Map of Madrid Region (Ingeniería y Gestión Medioambiental, 2006) and the Forest Map of the Madrid Region (Comunidad de Madrid 2009a).

The second ones include aspects such as geomorphology, lithology, bioclimatic belts, slopes, aspects, etc. (26 variables in total). All layers are managed in a format compatible with ArcGIS 9.3 (shapefile, coverage or GRID) referred to the WGS84 ellipsoid and UTM coordinates Zone 30. The information was integrated into a Geographic Information System which is intersected by overlaying techniques. Depending on the result of the overlapping, the fieldwork was designed for the checking *in situ* of the absence or presence

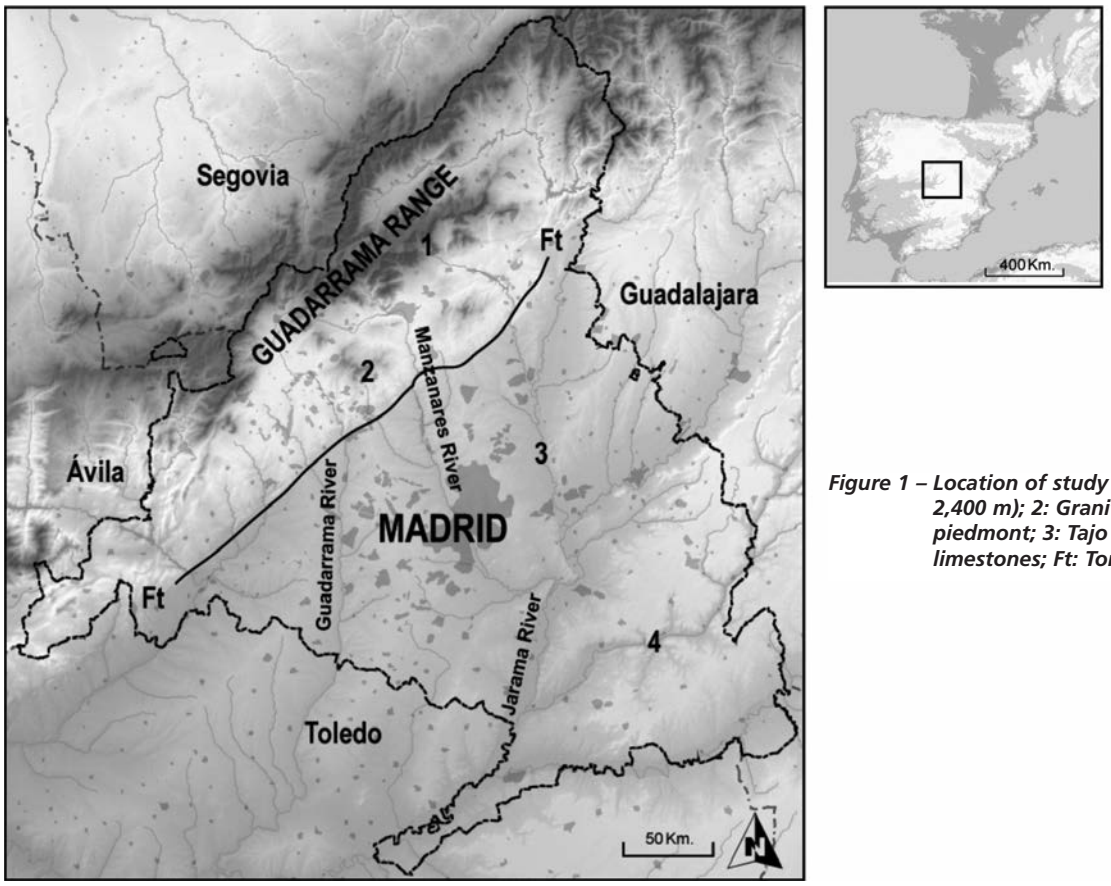

Figure 1 – Location of study area. 1: Sierra (1,800-2,400 m); 2: Granitic and metamorphic piedmont; 3: Tajo Basin; 4: Páramos over limestones; Ft: Torrelodones fault.

of juniper in the obtained polygons. Once we have identified possible mistakes, those were solved using orthophotography (Plan Nacional de Ortofotografía Aérea, 1:12,500) for those polygons that need to be redefined, created or deleted. The accuracy of the reference map unit depending on the type of area, establishing a minimum of 0.5 ha, similar to that used in other studies with this orthophotography scale in forest formations (SIOSE 2011). Also on the orthophotography were required some data about the phytostructure and percentages of canopy cover. If necessary, we worked with DGPS techniques (GPS Trimble Nomad 6GB) to refine the polygons shape. To this was added to the interpretation of the historical sequence of occupation by photointerpretation of flights of 1956 (United States Air Force), 1975 (Spanish Air Force) and orthophotography of 2009 (PNOA). This type of information allowed us to characterize the types of evolutionary dynamics.

To describe juniper populations a data matrix was made (Figure 3). The observations correspond to the juniper polygons and the variables to each of its abiotic and biotic characteristics. The elements of the matrix are the relative area (ha) of each variable (slope,

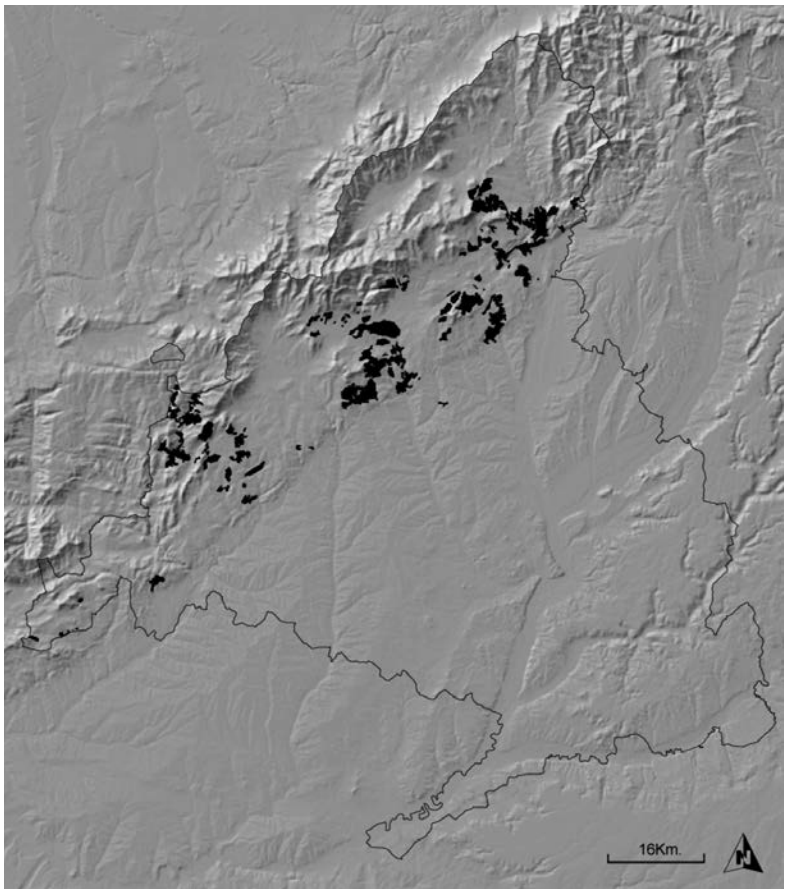

Figure 2 – Distribution area of* Juniperus oxycedrus *subsp.* oxycedrus *in Madrid Region.

lithology, bioclimatic belts, etc.) in each polygon. Subsequently, by means of multivariate ordination techniques (Principal Component Analysis) and hierarchical classification (squared Euclidean distance and Ward method), the main types of juniper and its characterization in terms of these variables were obtained (SPSS 19.0, 2011).

Finally, we analyzed the dynamics of juniper to know the progression, regression or stabilization of this species. To do this we compare the aerial photographs (USAF 1956) and the orthophoto of Madrid Region (PNOA 2009). At last, we checked the previously identified dynamics with fieldwork.

Results and discussion

Distribution area and characterization of *J. oxycedrus* subsp. *oxycedrus* in Madrid Region

From the cartographic and photographic analyses described above, the total area of juniper in this region was delimited (more than 18,700 ha, Figure 2). These populations are spread over a fringe that runs parallel to the Guadarrama Range along about 130 km in northeast-southwest direction. The lithology is mostly intrusive rocks (granites) and metamorphic rocks (gneisses) but, in the most eastern zone, is located a group of junipers over limestone (Cretaceous), slates and schists (Palaeozoic). The current cartography of *Juniperus oxycedrus* subsp. *oxycedrus* in Madrid shows that this subspecies is distributed principally by the piedmont, located about 800 m.a.s.l and on the

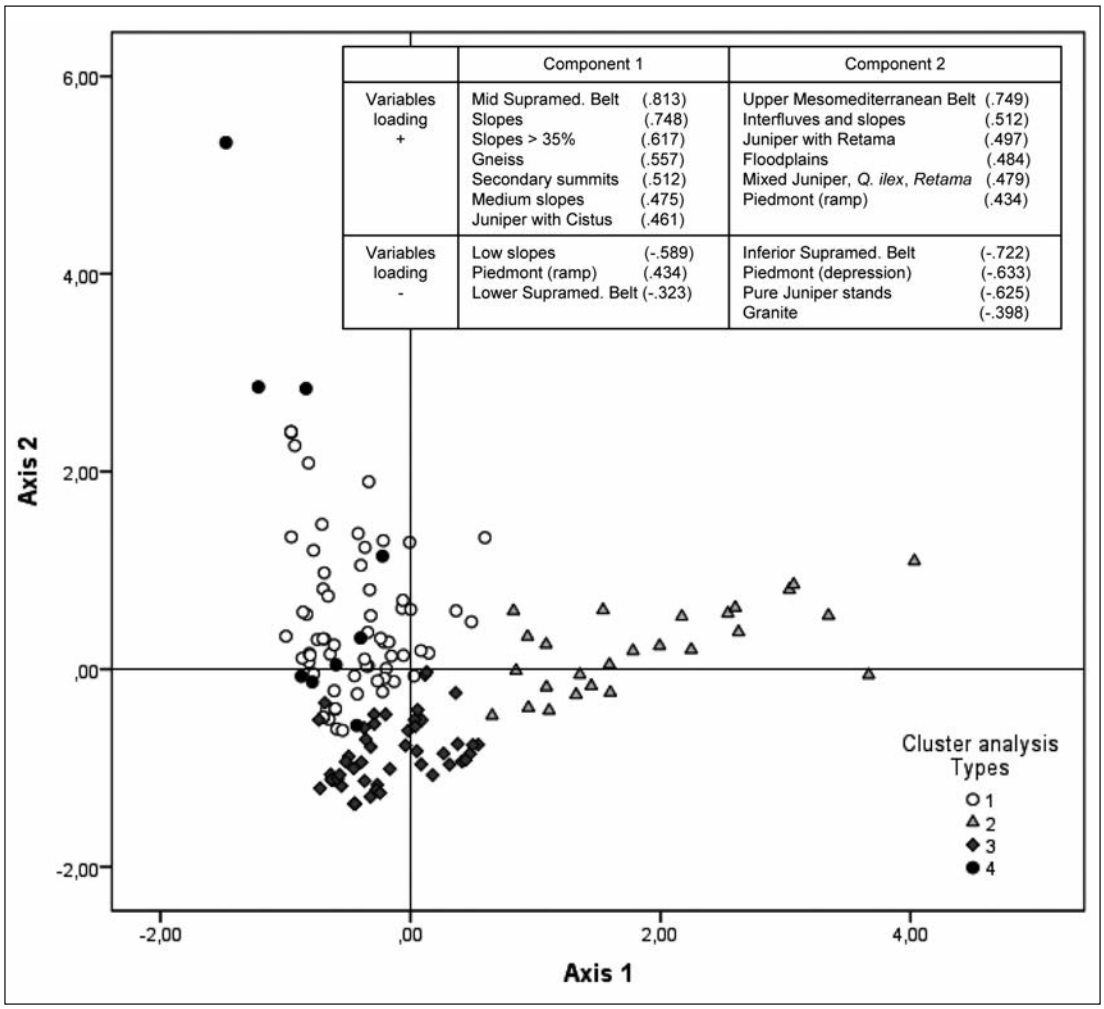

Figure 3 – Juniper typification from PCA and hierarchical clustering. Axis 1 variability is determined by a gradient of increasing slope and the appearance of geisses in the substrate. The axis 2 difference groups base on bioclimatic belts, the presence of granite on the substrate and the accompanying flora species. The results shows four different types of juniper.

slopes up to 1,700 m.a.s.l. Its lower limit is in Torrelodones fault (Figure 1), where the transition occurs from the arkosic sedimentary basin to the granitic massif. On the other hand, we detected only minor spots about 600 m.a.s.l.

The obtained cartography determines the limits of the species in this region. The techniques used allowed the identification of species. The reinterpretation of the orthophoto defines the shape and structure of the juniper areas, resulting in a real distribution adjusted to the current progression of the species. In the previous cartographic resources, several errors were found, mainly due to the identification as juniper patches other species with greater forest interest (such as *Quercus ilex* subsp. *ballota*).

The typification obtained as a result of multivariate analysis allowed to identify four types of juniper populations that synthesize the variability observed in the study area based on biotic and abiotic characteristics (Figure 3). Figure 4 shows the location of each type and 5 to 8 illustrate through photographs examples of these types.

The first type (Figures 4 and 5) is the best represented in terms of surface area (10,961 ha) and is developed mostly on granitic bedrocks (berrocal) and arkosic piedmont. This type is extended throughout longitudinal fringe from northeast to southwest. These mixed communities of juniper and oak with other Mediterranean shrubs (*Cistus ladanifer* L., *Retama sphaerocarpa* L., *Rosa* spp., *Rubus* spp., etc.) are associated with intense transformations derived from its management. This type is distributed on the upper Mesomediterranean belt or in the lower levels of the Supramediterranean belt, in an altitudinal range of 625 m.a.s.l. (570-1,200 m.a.s.l.). A spot of 5,250 ha stands out for its extension and is located around Hoyo de Manzanares village (Figure 4A).

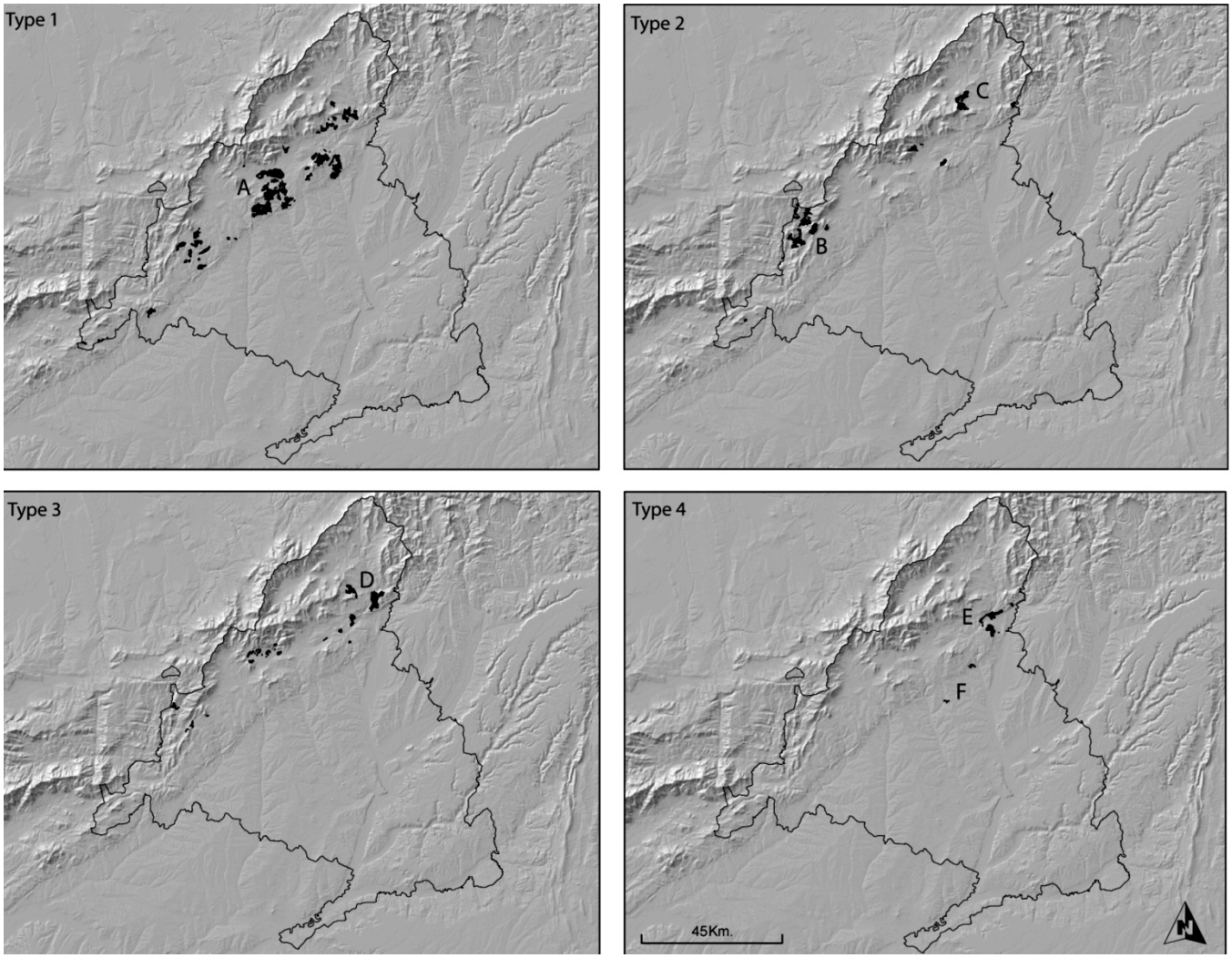

Figure 4 – Distribution area of the four types from PCA. Type 1 (A, Hoyo de Manzanares). Type 2 (B, Zarzalejo-Santa María de la Alameda; C, Garganta de los Montes-Lozoyuela). Type 3 (D, La Cabrera-El Berrueco). Type 4 (E, Torrelaguna; F, Colmenar Viejo-Tres Cantos).

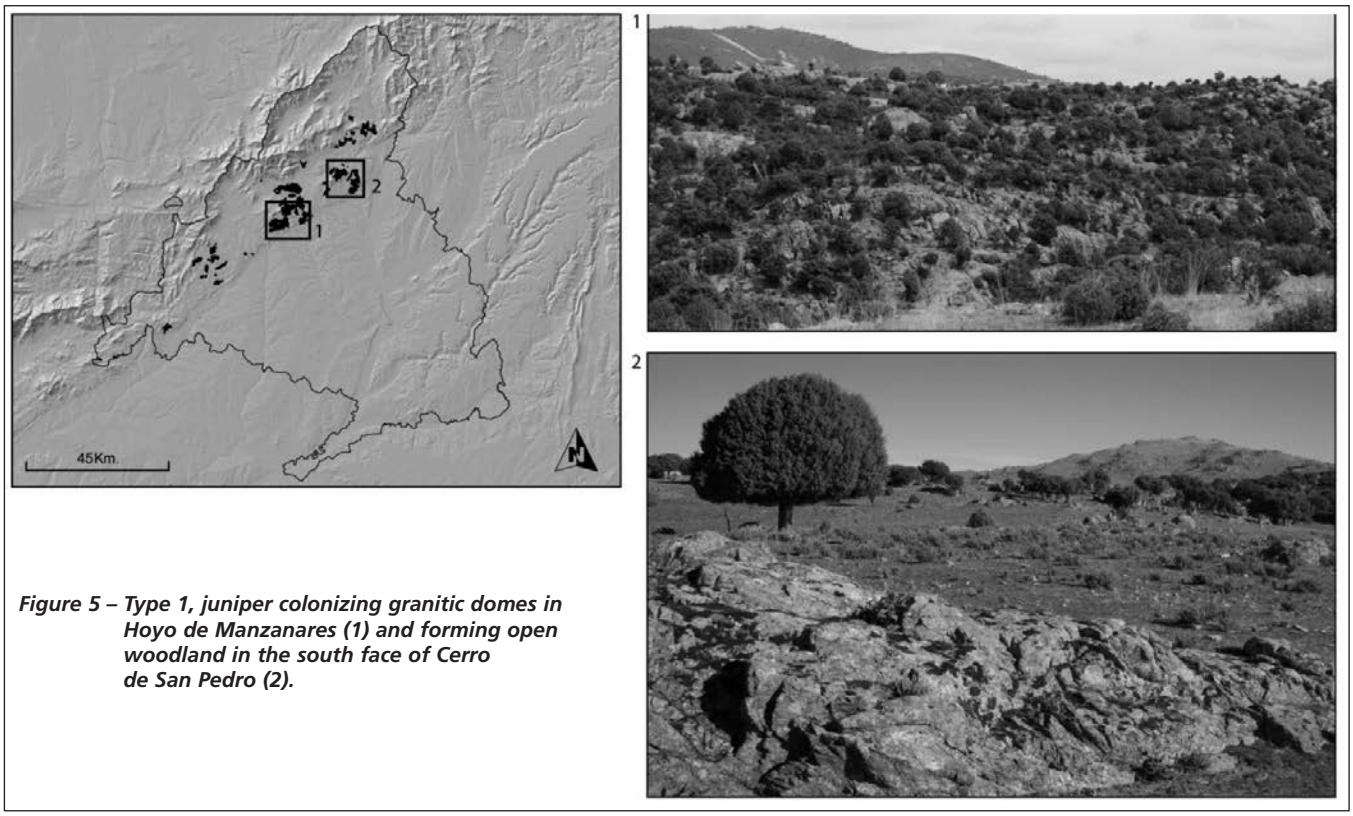

Figure 5 – Type 1, juniper colonizing granitic domes in Hoyo de Manzanares (1) and forming open woodland in the south face of Cerro de San Pedro (2).

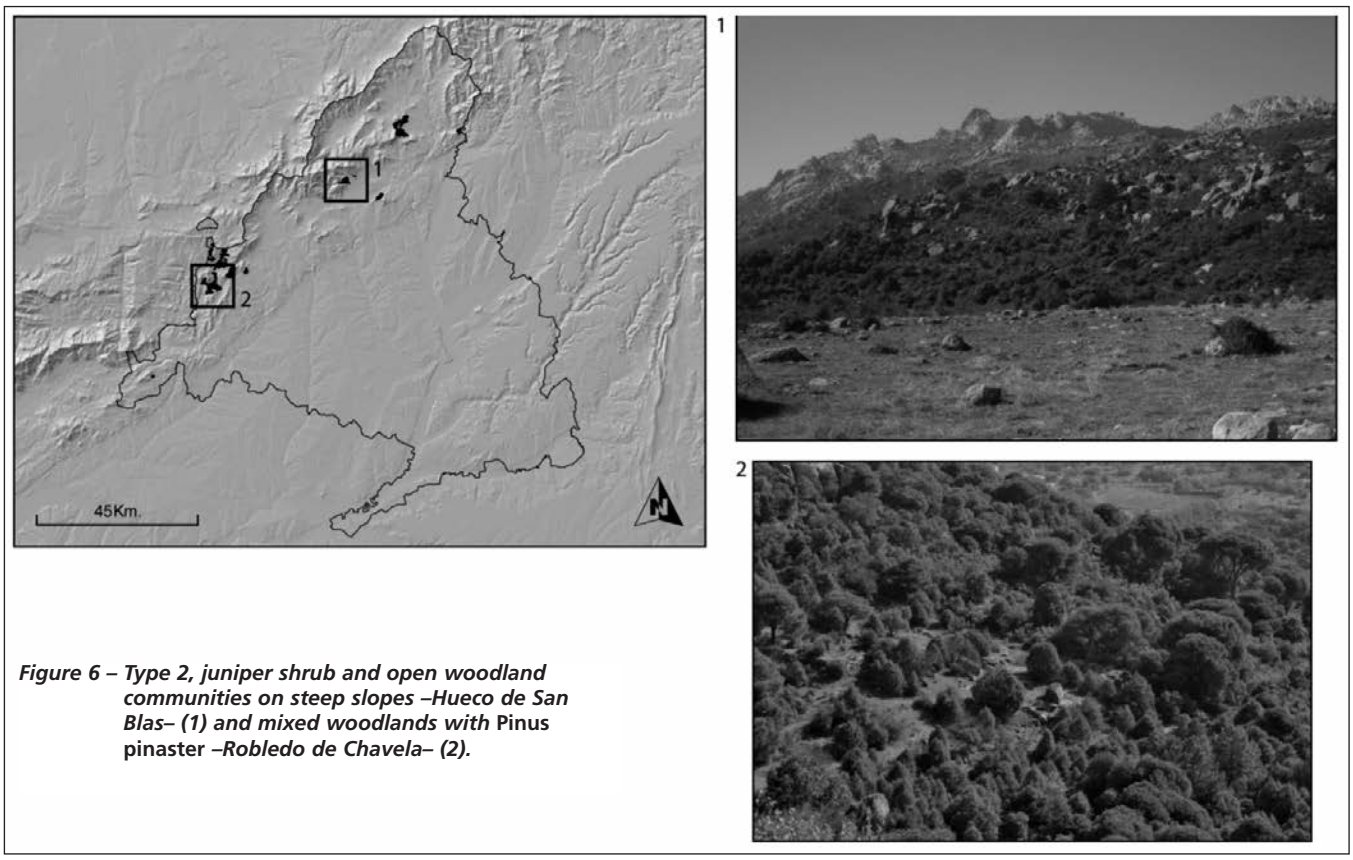

Figure 6 – Type 2, juniper shrub and open woodland communities on steep slopes –Hueco de San Blas– (1) and mixed woodlands with Pinus pinaster *–Robledo de Chavela– (2).*

The second type (Figures 4 and 6) is represented by mixed communities of juniper and *Quercus ilex* subsp. *ballota*, or *Q. pyrenaica*, or *Pinus* spp., accompanied by *Retama sphaerocarpa* and *Cistus* shrubs. These populations extend over 4,035 ha at 966 m.a.s.l. average altitude (768-1,734 m.a.s.l.). The best examples of these juniper formations can be found on steeped slopes of the upper Supramediterranean belt over metamorphic substrates

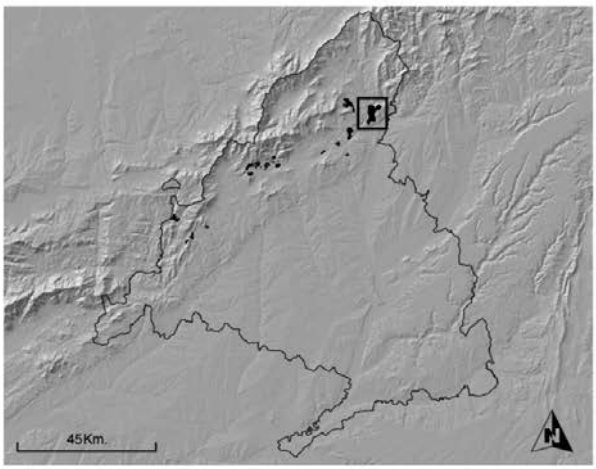

Figure 7 – Type 3, open woodland in El Berrueco.

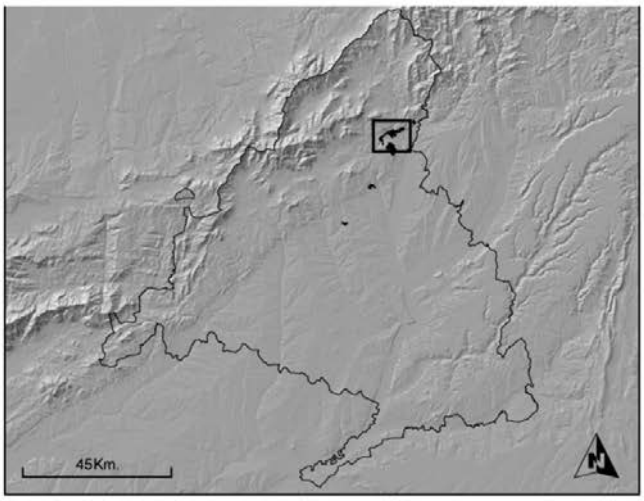

Figure 8 – Type 4, juniper shrub with* Quercus faginea *subsp.* faginea *in Torrelaguna.

(gneisses). One of this can be found in the southwest area (Figure 4B, Zarzalejo-Santa María de la Alameda) and another in the northeast area, at Garganta de los Montes-Lozoyuela area (Figure 4C).

The third type (Figures 4 and 7) are monospecific formations of *Juniperus oxycedrus* subsp. *oxycedrus* on granite massif at medium slopes. This type extends over 2,544 ha, on the lower Supramediterranean belt, from 785 to 1,260 m.a.s.l. La Cabrera-El Berrueco (Figure 4D) can be pointed out as good example of this type.

The fourth type (Figures 4 and 8) covers both the smallest extent area (1,216 ha) and altitudinal range (from 653 to 940 m.a.s.l.). It occupies the marly-limestone slopes (Figure 4E, Torrelaguna) and arkosic hills characteristic of distal sector of piedmont (Figures 4F. Colmenar Viejo-Tres Cantos). It corresponds to the Mesomediterranean belt, and is represented by mixed forest of *Juniperus oxycedrus* subsp. *oxycedrus* and *Quercus faginea* subsp. *faginea* with *Lavandula* spp. and *Retama sphaerocarpa* shrubs.

Juniper dynamics in Madrid Region

Using fieldwork and the historical and photographic resources (USAF 1945, 1956; Spanish Air force 1975; PNOA 2009) has been detected two dynamics types: a progressive dynamic colonisation and a significant increase of juniper density.

The *progressive dynamic* is highly visible on the territory, particularly in some piedmont areas. Progression appears in three different

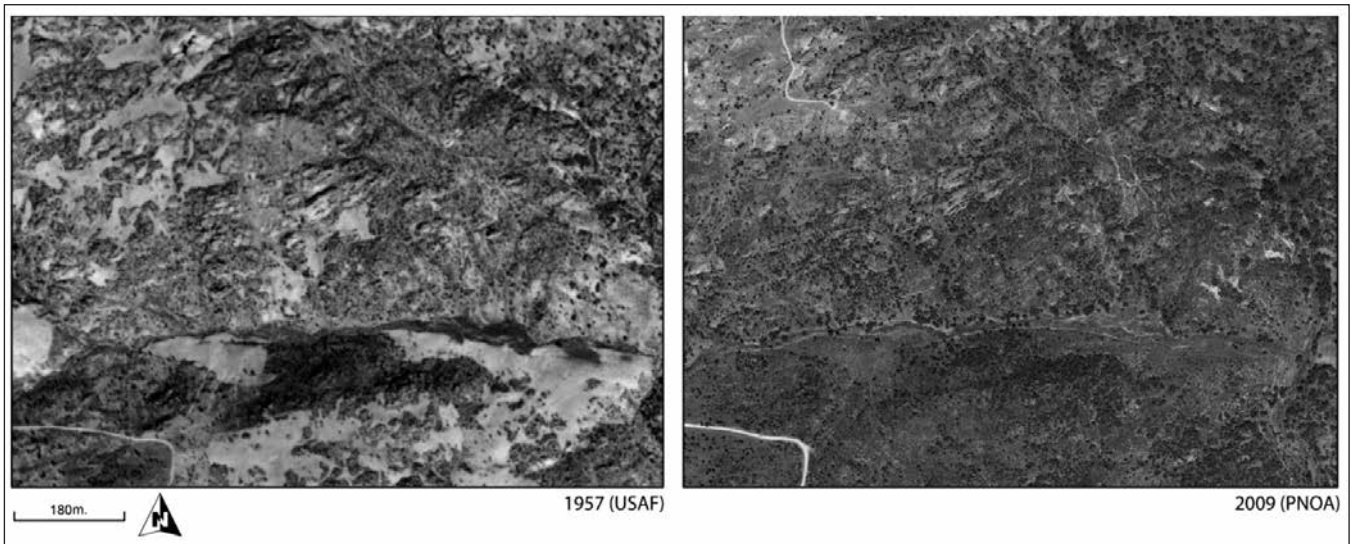

Figure 9 – Densification on abandonment grazing areas (Hoyo de Manzanares).

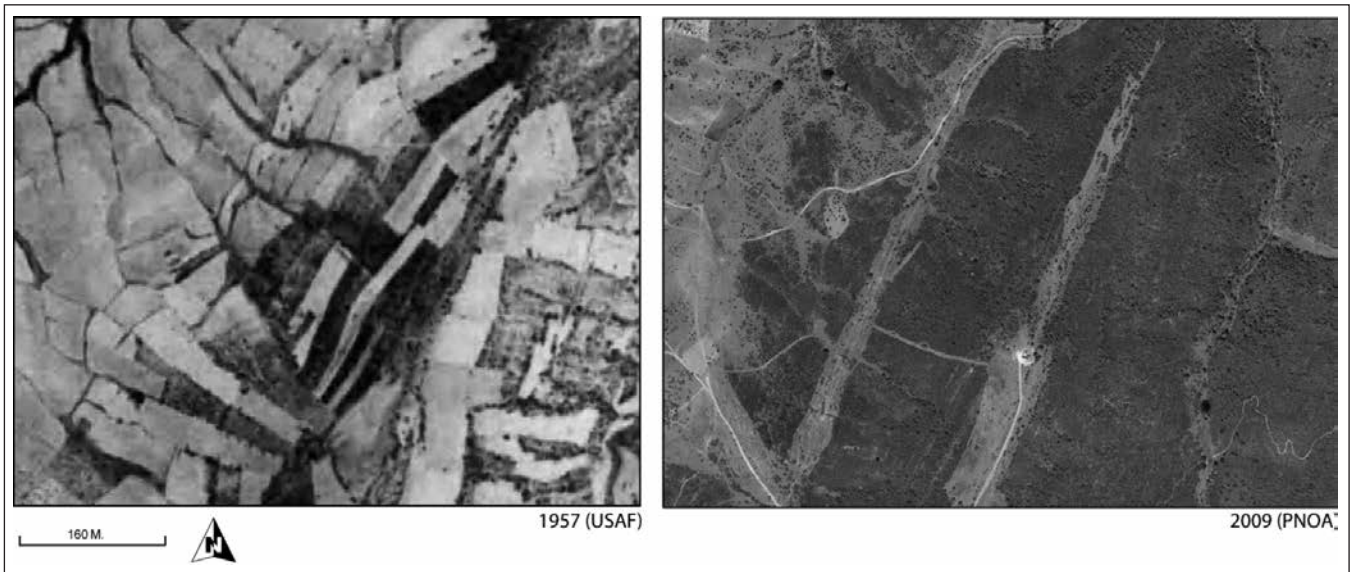

Figure 10 – Progression over ancient agricultural areas (El Berrueco).

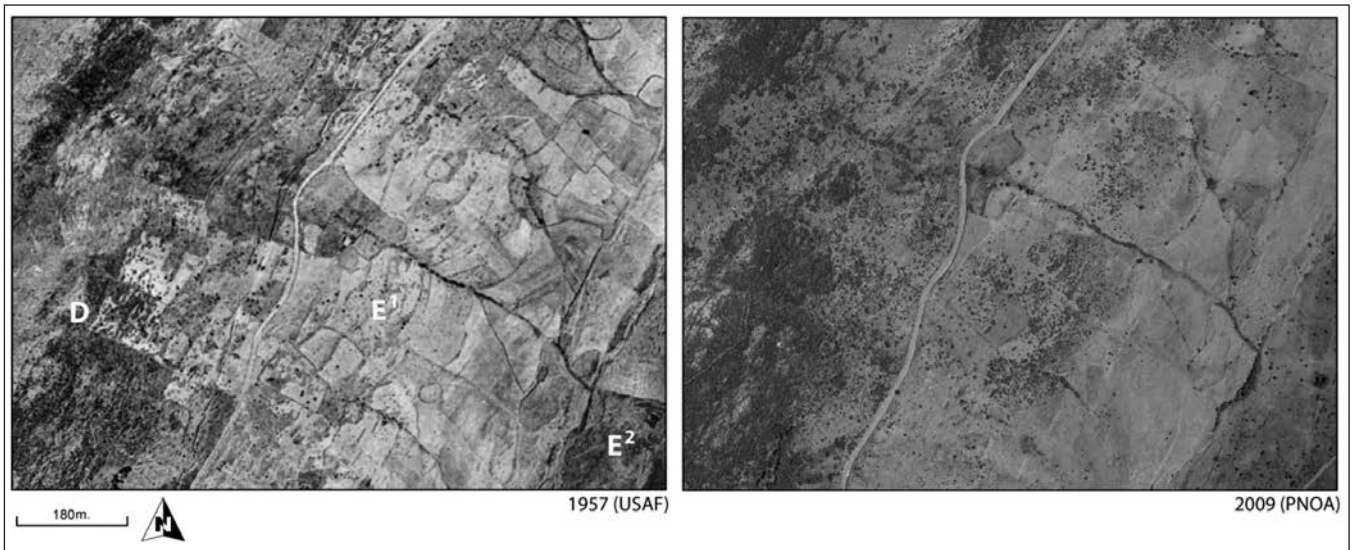

Figure 11 – Expansion on ancient grazing (E^1) and agricultural areas (E^2); densification (D) in Quercus *open woodland (Robledo de Chavela).*

forms: 1) either for colonization of uncultivated land or grazing areas, 2) for advancing over agricultural areas or 3) for progression on undergrowth canopy in forest formations. The first type is the most widespread process and it occupies ancient extensive grazing lands (Figure 9). The second type is located in Torrelaguna Basin (NE of Madrid Region) over limestone and loams substrates that, due to their greater fertility, have been productive until nowadays (Figure 10). The second type is normally over soft and removed soils (Gómez 1991) where juniper colonizes abandoned lands. And the third type has been observed in gaps of *Quercus ilex* subsp. *ballota* open woodland (Figure 11) or below *Pinus nigra* subsp. *salzmannii* and *Pinus pinea* L. canopy.

The other observed dynamic is the densification of juniper populations in abandoned grazing areas. These formations change their structure turning from open woodlands, with dispersal isolated trees generated for grazing, to more dense and complex forested areas. Both types of dynamics are consequence of land uses changes during second half of twentieth century. Until this moment, traditional agrosilvopastoral systems of Guadarrama Range and piedmont determined the structure and forest boundary. These land uses were based in the management of standing and transhumant herds (bovine, sheep and, to a lesser degree, goat). These herds used to graze (feed on) meadows from the valley bottom, temporary uncultivated lands, coppice and open woodlands and mountain pastures. At the same time public forest provided grazing land, charcoal and beams. Other land use was rye crop over slopes and stony glacis. This agrosystem limited the extension of woodlands by controlling the forest growth and allowing the development of grasslands (Gil & Pardo 2004; Sáez 2001; Manuel 1996).

The abandonment of traditional land uses in mountain areas during the second half of the twentieth century resulted in the progression of natural vegetation dynamics. Nowadays, seventy years later, can be observed a new forest landscape structure (López 2006; López *et al.* 2010; De las Heras *et al.* 2011; Fernández-Sañudo *et al*. 2007). Goat and sheep herds have disappeared in Guadarrama Range, with the progressive reduction of extensive grazing (Mangas 1981; Gil 2004). In addition with reduction in livestock production the farms are specialized in bovine (beef cattle or bucking bulls). But, dry lands (rye cultivation) were abandoned changing into extensive or semi-extensive pastoral system with seasonal grasslands and scattered juniper trees. A similar changing process has also occurred with the abandonment of traditional forest uses. There, on the contrary, hunting has become the main resource. This has significant consequences in forestry structure favouring allowing secondary succession and transforming open woodlands in dense shrub communities.

Conclusions

This research have provided a real and current cartography of the distribution of *Juniperus oxycedrus* subsp. *oxycedrus* in Madrid Region. This cartography allowed us to distinguish four types of juniper formations depending on biotic and abiotic parameters: juniper and oak formations with other mediterranean shrubs; mixed communities with *Quercus* and *Pinus* accompanied by mediterranean shrubs; monospecific formations; and mixed forest with *Quercus faginea* on marly-limestone slopes.

Similarly to the process suffered by other *Juniperus* trees as *J, thurifera*. Changes in land use and loss of multifunctionality of theseagroecosystems and forests have been the main causes of the expansive evolution of this species in the Madrid Region. These changes are translated essentially in two dynamics: the progression of these juniper masses on grasslands and non-cultivated lands next to them, and the densification juniper woodlands.

The results indicate the need for further research on the structure of these new areas of juniper, its viability as well as the advance in the knowledge of characteristics of juniper dynamics and their territorial significance, especially taking into account its importance as an European habitat listed in the Habitat Directive 92/43.

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References

Comunidad de Madrid., 2009a. *Mapa de Terreno Forestal de la Comunidad de Madrid*. Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio. Madrid, Comunidad de Madrid.

Comunidad de Madrid., 2009b. *Ortofotografía con resolución 50 x 50 m*. Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio. Dirección General de Urbanismo y Estrategia Territorial. Madrid, Comunidad de Madrid.

Coplaco, 1975. *Vuelo fotogramétrico*. Comisión de Planeamiento y Coordinación del Área Metropolitana de Madrid. Madrid, Ministerio de Obras Públicas.

Costa Tenorio, M., Gómez Manzaneque, F., Morla Juaristi, C. & Sáinz Ollero, H., 1993. Valoración fitogeográfica de la flora vascular de los sabinares albares de la Península Ibérica. *Ecología* 7 : 127-148.

De las Heras P., Fernández-Sañudo P., López Estébanez N. & Roldán Martín M.J., 2011. Territorial dynamics and boundary effect in a protected area in the central Iberian Península. *Cent. Eur. J. Geosci*. 3: 1-11.

DO, 1992. *Directiva 92/43/Cee del Consejo de 21 de mayo de 1992, relativa a la conservación de los hábitats naturales y de la fauna y flora silvestres*. DO L 206 de 22 del julio de 1992.

Ejército del Aire, 1975. *Vuelo fotográmétrico*. Centro Cartográfico y Fotográfico del Ejército del Aire, España.

Fernández-Sañudo P., López Estébanez N., Roldán Martín M.J. & De las Heras P., 2007. Relationship between socio-economic and natural dynamics in a Protected Natural Area (Parque Regional de la Cuenca Alta del Manzanares, Madrid, Spain). *In*: Bunce R.G.H., Jongman R.H.G., Hojas L. & Weel S. (eds.), *25 Years of Landscape Ecology: Scientific Principles in Practice. Proceedings of the 7th IALE World Congress*. Wageningen, The Netherlands, 8-12 July 2007: 736.

García D., Zamora R., Hódar J.A. & Gómez J.M., 1999. Age structure of *Juniperus communis* L. in the Iberian Peninsula: Conservation of remnant populations in Mediterranean mountains. *Biological Conservation* 87: 215-220.

García D., Zamora R., Gómez J.M., Jordano P. & Hodar J.A., 2000. Geographical variation in seed production, predation and abortion in *Juniperus communis* throughout its range in Europe. *Journal of Ecology* 88: 436-446.

Gil Sánchez L., 2004. *La transformación histórica del paisaje forestal en España*. Dirección General para la Biodiversidad, Ministerio de Agricultura, Pesca y Alimentación, Madrid.

Gil L. & Pardo F., 2004. The impact of traditional land use on woodlands: a case study in the Spanish Central System. *Journal of Historical Geography* 31: 390-408.

Gómez Manzaneque F., 1991. *Los sabinares de* Juniperus thurifera *L. de la Península Ibérica: cartografía, flora, tipificación y consideraciones paleobiogeográficas*. Tesis Doctoral. Universidad Autónoma de Madrid, Madrid.

Ingeniería y Gestión Medioambiental, 2006. *Mapa digital continuo de vegetación de la Comunidad de Madrid*. Dirección General de Urbanismo y Planificación Territorial, Consejería de Medio Ambiente y Ordenación del Territorio. Madrid, Comunidad de Madrid.

López Estébanez N., 2006. Dinámicas forestales sobre matorrales, *Juniperus thurifera* L. *Pinus sylvestris* L. y *Pinus pinaster* Aiton en el sector oriental del Sistema Central madrileño. Universidad de Alcalá de Henares. *Serie geográfica* 13 : 25-41.

López Estébanez N., Gómez Mendoza J., Gómez Mediavilla G., Madrazo García de Lomana G. & Sáez Pombo E., 2010. Forest dynamics in the Spanish Central Mountain range. *Landscape Archaeology & Ecology* 20: 98-110.

Mangas J.M., 1981. *El régimen comunal agrario de los concejos de Castilla*. Madrid.

Manuel Valdés, C.M., 1996. *Tierras y montes públicos en la Sierra de Madrid (sectores central y meridional)*. Serie Estudios. Ministerio de Agricultura, Pesca y Alimentación, Secretaría General Técnica, Madrid.

Ministerio de Medio Ambiente y Medio Rural y Marino, 2007. *III Inventario Forestal Nacional (1997-2007)*. Madrid.

Montesinos D., 2007. *Juniperus thurifera* : una especie dioica, vecera y relíctica. *Ecosistemas* 16 : 172-185.

Montesinos D. & García D., 2009. 5210 Matorrales arborescentes de *Juniperus spp*. *In*: Ministerio de Medio Ambiente y Medio Rural y Marino, *Bases ecológicas preliminares para la conservación de los tipos de hábitat de interés comunitario en España*. Madrid.

Plan Nacional de Ortofotografía Aérea (Pnoa), 2009. Instituto Geográfico Nacional, Centro Nacional de Información Geográfica, Ministerio de Fomento.

Ríos Insúa V., 1987. Contribución al estudio de la biología de *Arceuthobium oxycedri* (DC) M. Bieb (1819). *Boletín de Sanidad Vegetal-Plagas* 13 : 53-62.

Rivas-Martínez S., 1964. Esquema de la vegetación potencial y su correspondencia con los suelos en la España peninsular. *Anales del Instituto Botánico Cavanilles* 22 : 341-405.

Sáez Pombo E., 2001. *Montes públicos, territorio y evolución del paisaje en la Sierra Norte de Madrid*. Publicaciones de la Universidad Autonóma de Madrid, Comunidad de Madrid y Obra Social de Caja Madrid, 245 p.

Siose V.2., 2011. *Sistema de Información de Ocupación del Suelo en España*. Documento Técnico SIOSE 2005. D.G. Instituto Geográfico Nacional, Servicio de Ocupación del Suelo, S.G. de Cartografía. Madrid.

SPSS Inc., 2011. *SPSS 19.0 for Windows*. Chicago, Illinois, USA.

United States Air Force (Usaf), 1945. *Vuelo fotográmétrico del Ejército del Aire Eeuu*, *Serie A*. Centro Cartográfico y Fotográfico del Ejército del Aire, España.

United States Air Force, 1956. *Vuelo fotográmétrico del Ejército del Aire Eeuu, Serie B*. Centro Cartográfico y Fotográfico del Ejército del Aire, España.