1 The relict ecosystem of *Gymnosporia senegalensis* (Lam.) Loes. in an agricultural
2 plastic sea: past, present and future scenarios

3

4

5 Antonio J. Mendoza-Fernández^{1,2*}, Fabián Martínez-Hernández¹, Esteban Salmerón-
6 Sánchez¹, Francisco J. Pérez-García¹, Blas Teruel¹, Encarna Merlo¹, Juan Mota¹

7

8

9 ¹ Departamento de Biología y Geología, CEI·MAR and CECOUAL, Universidad de
10 Almería, Almería, Spain

11

12 ² Departamento de Botánica, Unidad de Conservación Vegetal, Universidad de
13 Granada, Granada, Spain

14

15

16 * Corresponding author

17 E-mail: amf788@ual.es

18

19

20

21

22

23 Acknowledgements

24 This study has been made possible through the projects ‘CEIJ-012 Integrated study of
25 coastal sands vegetation (AREVEG)’ and ‘CEIJ-009 Integrated study of coastal sands
26 vegetation (AREVEG II)’ sponsored by CEI·MAR; ‘Assessment, Monitoring and
27 Applied Scientific Research for Ecological Restoration of Gypsum Mining
28 Concessions (Majadas Viejas and Marylen) and Spreading of Results
29 (ECORESGYP)’ sponsored by the company EXPLOTACIONES RÍO DE AGUAS
30 S.L. (TORRALBA GROUP) and ‘Provision of services, monitoring and evaluation of
31 the environmental restoration of the mining concessions Los Yesares, María Morales
32 and El Cigarrón’ sponsored by the company Saint Gobain Placo Iberica S.A.

33

34 Abstract

35 *Gymnosporia senegalensis* is a shrub belonging to the *Celastraceae* family,
 36 which is native to tropical savannahs. Its only European populations are distributed
 37 discontinuously along the south-eastern coast of the Iberian Peninsula, forming plant
 38 communities with great ecological value, unique in Europe. As it is an endangered
 39 species that makes up plant communities with great palaeoecological significance, the
 40 development of species distribution models is of major interest under different
 41 climatic scenarios, past, present and future, based on the fact that the climate could
 42 play a relevant role in the distribution of this species as well as in the conformation of
 43 the communities in which it is integrated. Palaeoecological models were generated for
 44 the Maximum Interglacial, Last Maximum Glacial and Middle Holocene periods. The
 45 results obtained showed that the widest distribution of this species, and the maximum
 46 suitability of its habitat, occurred during the Last Glacial Maximum, when the
 47 temperatures of the peninsular southeast were not as contrasting as those of the rest of
 48 the European continent and were favored by higher rainfall. Under these conditions,
 49 large territories could act as shelters during the glacial period, a hypothesis reflected
 50 in the model's results for this period, which exhibit a further expansion of *G.*
 51 *senegalensis*' ecological niche. The future projection of models in around 2070, for
 52 four Representative Concentration Pathway (RCP) according to the fifth report of the
 53 Intergovernmental Panel on Climate Change IPCC, showed that the most favorable
 54 areas for this species would be Campo de Dalías (southern portion of Almería
 55 province) as it presents the bioclimatic characteristics of greater adjustment to *G.*
 56 *senegalensis*' ecological niche model. Currently, these areas are almost totally
 57 destroyed and heavily altered by intensive agriculture under plastic, also causing a

severe fragmentation of the habitat, which implies a prospective extinction scenario in the near future.

Introduction

Gymnosporia senegalensis (Lam.) Loes. [= *Maytenus senegalensis* (Lam.) Exell] is a very thorny deciduous shrub belonging to the *Celastraceae* family, which grows up to three meters or higher. It is native to the African tropical savannahs [1-3]. Worldwide, it can be found in Africa in the southern area that expands from South Africa to Angola; throughout the east in Mozambique, Tanzania, Uganda, Kenya and Madagascar; in sub-Saharan Africa from Senegal to Ethiopia and Eritrea. It is also disseminated through the Maghreb, especially in Morocco and Algeria, as well as on the Canary Islands. In Asia, it stretches across the Arabian Peninsula, Saudi Arabia, Yemen and Oman; and seems to reach India punctually [4].

The northernmost populations are located in Europe (Spain), where it is distributed in Alicante and Malaga provinces [5,6], growing in scrubs at the most thermal areas of the southeast coastal region [7] between sea level and 300 (600) masl [8-11]. The Spanish populations seem to be adapted to a semi-arid Mediterranean climate modulated by a high proportion of dewfall from marine origin and no-frost events [12].

The presence of *G. senegalensis* in the Iberian flora dates back to the Lower Cretaceous, and is related to the palaeogeographic and palaeoclimatic history of the Mediterranean Basin [13,14]. In the last period of the quaternary, the Holocene, studies about paleoclimatic and palaeoecological trends even confirm the coexistence of this species in deciduous *Quercus* forests [15,16]. Thus, the present case represents an interesting and complex study of the distribution dynamics of a severely threatened

plant species in the northernmost limit of its distribution, for which the implementation of a species distribution model could foster further understanding. In recent times, species distribution models (hereinafter SDMs) have been globally recognized as a useful tool in nature conservation and management, for instance, to refine the threat status of a species [17,18]. When applied to distribution data, they can predict distributions across geographic landscapes by multiple responses, improve image analysis or remote-sensing in order to lead the search for poorly known species [19-23], thus providing perceptions into the species' habitat, range and abundance [24-26]. Furthermore, several authors as Elith & Leathwick [27], Benito et al. [28], Fois et al. [29] or de Luis et al. [30,31] used SDMs based on the extant localities as well as the respective current and future climate scenarios to predict the possible variation in the environmental niche of certain plant species, inferring ecological and evolutionary insights.

From a conservationist point of view, several Acts in Spain, enacted at regional and national level, currently protect this plant species [32-35], which is considered to be under vulnerable conservation status. Furthermore, this is a characteristic species for plant communities with high ecological significance [36-40] included in the Habitat Directive [41] as Priority Habitat (ANNEX I. cod. 5220* Arborescent Scrubs with *Ziziphus*). The landscape resulting from the arrangement of this vegetation in hemispherical clusters is outstanding and unique in the European context [42], in a way that is difficult to interpret, and which has resulted in different readings about its dynamics [43,44]. In addition to the landscape value, this habitat's conservation may have positive effects that stretch beyond the characteristic community of plant species. For instance, authors as Rey et al. [45] highlight that a satisfactory management of *Ziziphus* bunches will probably lead to the conservation of many

other species. Some studies show that up to 25 woody plants species present in this habitat can be gathered beneath the *Ziziphus* canopy [46], and more than 80 insect species use *Ziziphus* floral resources [47]. Wild flora has proven to be a reservoir of beneficial invertebrates for the different agricultural systems, including not only pollinators, which play a fundamental role in the functioning of ecosystems being responsible for pollinator service of numerous plant species [48,49], but also predators that might contribute positively to the biological control as an effective way to reduce pest populations surrounding orchards, vineyards or even greenhouses [50-52]. The loss of key (or minority) invertebrates consequently leads to the loss of those functions performed by them (functional diversity), which weaken and endanger the stability of these ecosystems if they cannot be replaced by other taxa [53].

For a better understanding of the palaeoecological significance of this plant species, to promote conservation measures and to identify key areas of interest, the aims of this study were to (i) model the ecological niche of *G. senegalensis* in the Iberian Peninsula using three projections in the past – Mid-Holocene (ca. 6 ka BP), LGM: Last Glacial Maximum (ca. 22 ka BP), and Interglacial Maximum (ca. 120 ka BP); (ii) evaluate the variations in the potential habitat of *G. senegalensis* modelled for the future (year 2070) in the four possible scenarios according to the representative concentration pathways (RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.5); (iii) compare the retrospective and prospective results with the ecological niche model obtained from bioclimatic current data.

Material and methods

Study area

The study area is located in the south and southeast of Spain. More specifically, it corresponds to the coastal area biogeographically encompassed by the Baetic and Murcian-Almeriense provinces. This territory is characterized by a Mediterranean climate, with thermo-Mediterranean thermotype, modulated from dry to semiarid ombrotype, according to the bioclimatic classification proposed by [54]. It coincides with hotspots for plant biodiversity in southern Spain in terms of rarity and endemism [55-57], and includes semiarid as well as arid areas, which are considered among the most vulnerable ecosystems to global change drivers [58-60].

Presence data

Presence data were collected through a wide bibliographical search combined with intensive fieldwork. Furthermore, digital sources were checked to gather distribution information on the species such as GBIF [4], ANTHOS [61] and FAME project (Threatened Flora of Andalusia Database) [62], adding details about herbaria records (HUAL, GDA, GDAC, JAEN, MGC & MUB) as well. The bibliographical data, particularly those taken from the Internet, were carefully filtered in order to only manage reliable information. All records were gathered using the WGS84 reference coordinate system; the information from databases was transformed by QGIS [63], so that it was unified. A total of 1821 georeferenced presence records of *G. senegalensis* were obtained (Fig 1 and S1 Table).

Fig 1. Presence records of *G. senegalensis* in Europe. The localities are represented by dots and detailed in S1 Table.

Environmental variables

WorldClim [64] provides data on 19 bioclimatic variables considered as broadly significant from the biological point of view when modelling distribution areas [65]. Past bioclimatic data for the Mid-Holocene (ca. 6 ka BP), Last Glacial Maximum (ca. 22 ka BP), and Interglacial Maximum (ca. 120 ka BP) were used in the present study. For the current distribution modelling, bioclimatic variables were generated from the climatic data period (1960-1990). The future estimation (2070) assumed the four Representative Concentration Pathways for emissions (RCPs), according to the fifth report from the IPCC [66]. Bioclimatic data were downloaded from the Community Climate System Model (CCSM4) as the main reference for the distribution tests. This model simulates the global climate using four separate submodels for the atmosphere, earth, oceans and sea ice [67]. These bioclimatic data have a 30-second resolution, except for the Last Glacial Maximum, for which only data at 2.5 minutes were available. Each environmental variable map was adjusted to the Iberian Peninsula mask without Portugal.

To rule out the multicollinearity on the 19 bioclimatic variables, a VIF (Variance Inflation Factors) analysis was performed with the R software (S1 Fig and S2 Table) [68-70]. According to this methodology VIF value must be under 5; thus, six bioclimatic variables were selected (BIO02, BIO03, BIO08, BIO09, BIO15, BIO19) to execute the modelling process (Table 1).

Table 1. Modeling process variables

BIO02	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO03	Isothermality (BIO2/BIO7) ($\times 100$)
BIO08	Mean Temperature of Wettest Quarter
BIO09	Mean Temperature of Driest Quarter
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO19	Precipitation of Coldest Quarter

Bioclimatic variables (Bi) selected in the VIF analysis, from the 19 variables available on WorldClim website.

179

180 **Species distribution modeling (SDMs)**

181 MaxEnt 3.3.3 [71] was used to model the potential habitat of *G. senegalensis*
 182 in the different proposed scenarios. The application of the Maximum Entropy
 183 principle to estimate ecological niche modelling and potential distribution areas
 184 follows the studies of Phillips et al. [72] and Phillips & Dudík [73]. Said software has
 185 been used in many fields of science proving its validity [74-77], being widely
 186 recognized as the most used tool, even for small sample sizes and poorly known
 187 species' distributions [24]. The modelling process is able to indicate suitable
 188 conditions for species in areas where their presence has not been registered or
 189 evidenced; several studies supported the reliability of SDMs [21]. Since this process
 190 is iterative, the modelling outcomes can highlight other factors related to the physical
 191 environment, anthropogenic influences or conditions of growth and reproduction of
 192 the species [78-80].

193 MaxEnt can operate with information about presence, which often represents the
 194 largest set of available data [81]. Only-presence-data algorithms usually represent the
 195 spatial distribution of the fundamental ecological niche of a species, while algorithms
 196 based on presence-absence data characterize more closely the distribution of the
 197 effective ecological niche [82]. The present study has been conducted with presence
 198 data alone, since a presence-absence modelling might generate controversies in light
 199 of the recent dynamics of the largest *G. senegalensis* population. Land changes due to
 200 the evolution of intensive crops in the province of Almeria [83], which may result in
 201 defining an area with optimal characteristics for this species as an area of absence,
 202 could offer an incorrect outcome and decrease biological significance in the
 203 interpretation of the model [84,85].

In the MaxEnt configuration, 1000 was established as the maximum iteration parameter; the convergence limit was set at 0.00001 with a value of 0.001 for regularization [72]. Hinge and threshold functions were disabled, leading to easily interpretable response curves and further adjustment to the Ecological Niche Theory [86]. The program produced a set of maps in which each pixel represents a value between 0 and 1, being thus interpreted as an index of habitat suitability. It also allowed for the generation of response curves for the species in relation to the variables used, noting their suitability, the evaluation of optimal values, the tolerance intervals and the various variables' thresholds.

Potential distribution of *G. senegalensis* in Europe

MaxEnt models' results for *G. senegalensis* were adjusted by comparing its distribution with the presence of species that characterize different habitats together with [11,83,87], such as *Periploca angustifolia* Labil. (they coexist in the association *Mayteno europaei-Periplocetum angustifoliae* Rivas Goday & Esteve; *Ziziphus lotus* (L.) Lam, (both species subsist in the association *Gimnosporio europaei-Ziziphetum loti* F. Casas), or mesophilic species such as *Buxus balearica* Lam. and *Cneorum tricocon* L. (the three coexist in the association *Cneoro tricocci-Buxetum balearicae* Rivas Goday & Rivas Mart.). Chorological data for these plant species were obtained from GBIF and ANTHOS databases (op. cit). In addition, the current final map that describes the potential habitat of *G. senegalensis* and its decrease in Europe were designed as contiguous areas by combining presence records, species modelling, and photo-interpretation of polygons performed in the Spanish SIOSE project [88] as was done by Mendoza-Fernández et al. [89].

229

230 **Results and discussion**

231 **Potential habitat models in the past**

232 The model obtained for the Last Glacial Maximum (LGM) showed a
 233 significant dominance of the *G. senegalensis* habitat towards the southeast and the
 234 east of the Iberian Peninsula (Fig 2 and S2 Fig), exhibiting high suitability in areas
 235 nowadays submerged, and along the coastal plains of Almeria province. Probably, the
 236 populations were more stable in said area, acting as a genetic diversity reservoir in the
 237 glacial period. Médail and Diadema [90] identify the existence of such shelters as a
 238 crucial event in a context of global change. Furthermore, since the LGM possibly
 239 represented the most favorable scenario for this plant, the idea that *G. senegalensis*
 240 could not be as xerophyte an element as considered may be reinforced. During this
 241 period, weather conditions became more humid than in the Mid-Holocene and the
 242 Interglacial Maximum. In addition, in the case of the southern Iberian Peninsula, the
 243 temperature decrease was not as extreme as in other parts of Europe, favoring a
 244 climate characterized by relatively mild temperatures and intense rainfall [91]. On the
 245 contrary, the resulting model for both the Mid-Holocene and the Last Interglacial
 246 periods did not show such habitat suitability for the plant. While the results for both
 247 periods were quite similar, it should be noted that the Mid-Holocene scenario
 248 presented a medium suitability for this plant since the modelling process was very
 249 strict with the bioclimatic variables developed for this time interval. The outcome of
 250 this period subsequent to the LGM, where the niche model showed the greatest
 251 habitat amplitude for *G. senegalensis* in the southeast of Spain, may be understood as
 252 the consequence of a delay in the dynamics of the *G. senegalensis* populations from

the LGM long-lasting the Mid-Holocene period, as previous studies in Sierra de Gador suggest [16], which shows the gradual decline of *G. senegalensis* and other deciduous *Quercus* genus species that might have been more widely distributed during the LGM.

Fig 2. Past models for *G. senegalensis*. Plots of potential habitat of *G. senegalensis* in the past – a: Interglacial Maximum (ca. 120 ka BP); b: Last Glacial Maximum (ca. 22 ka BP) Mid-Holocene (ca. 6 ka BP)– and d: Present.

Models for the potential habitat towards the future (2070)

The results of the future models with a projection for the year 2070 showed a slight variation in suitability among them, in which neither considerable habitats increase nor a significant decrease of it was observed. In the different scenarios, the zones exhibited small geographical variations, which slightly expand or reduce *G. senegalensis*' ecological niche (Fig 3). However, habitat suitability was not altered, remaining permanent, with intermediate values in the four models. The results reinforce the thesis of *G. senegalensis*' mesophilic behavior, and contrary to expectation, the global temperature increases projected in the different RCPs scenarios could predict the probable deterioration of the habitat. Nevertheless, a specific area was highlighted, the coastal plain in the south of the province of Almeria (from sea level to 350 masl approx.), where the four models corresponding to each RCPs scenario remained constant in terms of suitability, and offered the maximum values for all models. This fact makes this area a very probable one where potential *G. senegalensis* habitat is predicted in any of the 2070 scenarios. In addition, it supports the idea that this would be the most suitable area for the plant, in light of the

four possible futures with an irradiative effect increase. Despite the fact that this area might be treated in the short term as one of the few habitats in the European continent available for this plant, it is currently a very altered territory, especially due to land-use changes resulting from the proliferation of intensive agriculture, which has reached up to 90% of the potential area of this species [83,89,92,93].

Fig 3. Future models for *G. senegalensis*. Plots of the potential habitat projected into the future according to the representative concentration pathways a: RCP 26; b: RCP 45; c: RCP 60; d: RCP 85.

Current extent of occurrence in Europe

The results achieved by combining presence records, species modelling, and photo-interpretation of polygons demonstrated that *G. senegalensis*' current extent of occurrence (EOO) in Europe is approximately 166721.2 ha, less than 47% of the suitable potential area (Table 2 and Fig 4).

As can be observed in Fig 1, there are no presences of *G. senegalensis* in the east coast of Andalucia (province of Almeria) as well as in a significant part of the Murcian coast. This is an important point to take into consideration when interpreting the modelling results, since this area is the driest in the Spanish southeast, but where *Z. lotus* and *P. angustifolia* plant communities develop and grow. Unifying the distribution of the aforementioned species in a single map helped to realize that *G. senegalensis* exhibits a less xerophytic behavior than *Z. lotus* and *P. angustifolia*, since the former does not coexist with the latter in the Murcian-Almeriense bordering zone, thus proving *G. senegalensis*' more mesophilic character (S3 Fig).

The slight probability of presence recorded to the north and west of Spain may be caused by common temperature variables or the coincidence of the summer drought period, related to the savannoid character of this plant, since there is no evidence of any past or current presence in these areas.

In order to achieve higher accuracy in establishing the influence of bioclimatic scenarios, models of singular thermophilic and xerophilous species that coexist with *G. senegalensis* could be compared in equal space-time conditions [91]. Hence, several models from different communities may be obtained and thus their spatial-temporal dynamics analyzed. In addition, indirect gradient variables corresponding to the physical characteristics of the territory (elevation, orientation, slope, geology, etc.) could be included in the model (at least at present and future predictions), since they might show a good correlation with the patterns of species distribution by combining resource gradients and direct gradients [94].

Table 2. EOO of *G. senegalensis* in Spanish political divisions and Europe.

	Available EOO (ha)	Suitable area (ha)	Remaining EOO (%)
Andalucia	149952.1603	284747.7731	52.6614
Murcia	11079.9679	32266.6956	34.3387
Valencia	5689.0772	31891.6983	17.8387
Europe	166721.2055	348906.1669	47.7840

Values extracted from the detailed map of land uses of Spain (SIOSE).

Fig 4. Potential EOO *G. senegalensis*. In green color polygons of the available habitat.

Conclusions

1. From a palaeoecological point of view, the glaciation conditions favored the extension of the potential niche for *G. senegalensis* in the Iberian southeast, demonstrating that this plant does not have as xerophytic a behavior as *Z. lotus* or *P. angustifolia*, since the LGM model is the one that presents the highest suitability. This fact may be related to an increase in humidity in that period [95]. This conclusion is consistent with two other types of evidence:

a.- the presence of *G. senegalensis* growing and showing its maximum abundance in deciduous forests located in Sierra de Gador during the Mid-Holocene according to palynological studies,

b.- the link between *G. senegalensis* with *C. tricoccon* and *B. balearica*, which have mesothermophilic characteristics, capable of generating debate on the *Gymnosporia-Periploca-Ziziphus* trilogy, which was considered until now as a set of Ibero-African species with a hyperxerophytic conduct. This could explain the absence of *G. senegalensis* from Cabo de Gata to the Murcia region, being this area the most arid and with the smallest rainfall in the entire southeast, where conversely both *Z. lotus* and *P. angustifolia* are frequent.

2. In the near future, still affected by Global Change, the southern part of the province of Almeria may become the most suitable area for *G. senegalensis* in the Iberian Peninsula. However, the natural area available for this plant's development might be limited by the proliferation of intensive crops, which already occupy more than 90% of the habitat in this zone. This would cause a serious conservation problem for this species and increase its extinction risk due to massive occupation, fragmentation and land-use changes.

3. Although the area known as Campo de Dalias (southern portion of Almeria province) has suffered the greatest habitat loss in terms of the extent of occurrence and occupancy area, this is a key territory for the future of the species, as demonstrated by the distribution models generated throughout this research. Therefore, safeguarding the last remaining redoubts of the Spanish *G. senegalensis* communities here is considered absolutely essential.

4.- In addition to conserving some semi-natural stronghold for this species formation in the aforementioned area, there are two additional strategies that may favor its preservation. The first one relates to the use of this species with the aim to establish hedges, vegetal fences [44] or small clusters that serve as a refuge for pollinators and predatory species of insects or other harmful pests for crops. In general, insects are considered one of the most effective animal groups in the pollination processes, thus their presence in natural systems is essential. Nevertheless, intensive agriculture and continuous landscape modification through land-use changes are associated with the decrease in the population of pollinators [96], and/or severe alterations in their population concentrations [97]. Moreover, the agricultural use of pesticides and broad-spectrum chemicals produces a decrease not only in pest insects but also in all the entomofauna associated with these systems, thus affecting the insects of less altered neighboring habitats [98]. The combination of *Gimnosporia* and *Ziziphus* bunches could considerably improve this strategy, and hence favor a more sustainable development model in an area where highly intensive agriculture production can be understood as a industrial system if inputs and residues are attended to [83].

The second strategy of great interest would be the creation of green spaces, by means of peri-urban parks, where some of the remaining fragments of this community that cannot be conserved within a legally protected area, may be integrated.

Acknowledgements

This study has been made possible through the projects ‘CEIJ-012 Integrated study of coastal sands vegetation (AREVEG)’ and ‘CEIJ-009 Integrated study of coastal sands vegetation (AREVEG II)’ sponsored by CEI-MAR; ‘Assessment, Monitoring and Applied Scientific Research for Ecological Restoration of Gypsum Mining Concessions (Majadas Viejas and Marylen) and Spreading of Results (ECORESGYP)’ sponsored by the company EXPLOTACIONES RÍO DE AGUAS S.L. (TORRALBA GROUP) and ‘Provision of services, monitoring and evaluation of the environmental restoration of the mining concessions Los Yesares, María Morales and El Cigarrón’ sponsored by the company Saint Gobain Placo Iberica S.A. We thank Beatrice Antolin for reviewing the English translation of the text.

References

1. Archibold OW. Ecology of world vegetation. London: Chapman & Hall; 1995.
doi.org/10.1007/978-94-011-0009-0
2. Bobe R. The evolution of arid ecosystems in eastern Africa. J Arid Environ. 2006;66(3): 564-584. doi.org/10.1016/j.jaridenv.2006.01.010

- 395 3. Verdcourt B, Trump EC. Common poisonous plants of East Africa. London:
396 Collins; 1969.
- 397 4. GBIF.org. GBIF Home Page. c2019 [cited 2019 Nov 10]. Available from:
398 www.gbif.org
- 399 5. Güemes J, Crespo B. *Maytenus senegalensis* (lam.) Exell subsp. *europaeus*
400 (Boiss.) Rivas Martínez, comb. nov. (Celastraceae), y noticias diversas acerca
401 del mismo. Anal Jardin Bot de Madrid. 1990;48: 86-88.
- 402 6. Blanca G, Cabezudo B, Cueto M, Fernández López C, Morales Torres C. Flora
403 Vascular de Andalucía Oriental. Sevilla: Consejería de Medio Ambiente. Junta
404 de Andalucía; 2009.
- 405 7. López González GA. Los árboles y arbustos de la Península Ibérica e Islas
406 Baleares (Especies silvestres y las principales cultivadas). Tomo II. Madrid:
407 Mundi-Prensa; 2001.
- 408 8. Castroviejo S, Aedo C, Benedí C, Laínz M, Muñoz Garmendia F, Nieto Feliner
409 G, et al. Flora Ibérica. Plantas Vasculares de la Península Ibérica e Islas
410 Baleares. Madrid: Real Jardín Botánico de Madrid; 1997.
- 411 9. Pérez Latorre AV, Navas D, Gavira O, Caballero G, Cabezudo B. Vegetación
412 del Parque Natural de las sierras Tejeda, Almijara y Alhama (Málaga-Granada)
413 España. Acta Bot Malac. 2004;29: 117-191. doi.org/10.24310/abm.v29i0.7228
- 414 10. Pérez García FJ, Cueto M, Jiménez Sánchez ML, Garrido J, Martínez
415 Hernández F, Medina-Cazorla JM, et al. Contribución al conocimiento de la
416 flora de Andalucía: citas novedosas e interesantes de la provincia de Almería.
417 Acta Bot Malac. 2003;28: 233-237. doi.org/10.24310/abm.v28i0.7290

- 418 11. Díez-Garretas B, Asensi A, Rivas-Martínez S. Las comunidades de *Maytenus*
419 *senegalensis* subsp. *europaeus* (Celastraceae) en la Península Ibérica. Lazaroa.
420 2005;26: 83.
- 421 12. Uclés O, Villagarcía L, Moro MJ, Canton Y, Domingo F. Role of dewfall in the
422 water balance of a semiarid coastal steppe ecosystem. Hydrol Process. 2014; 4:
423 2271-2280. doi.org/10.1002/hyp.9780
- 424 13. Quézel, P. Definition of the Mediterranean region and the origin of its flora. In:
425 C. Gomez-Campo C, editor. Plant conservation in the Mediterranean area.
426 Geobotany 7. Dordrecht: W. Junk; 1985. pp 9-24.
- 427 14. Blanca G. Origen de la flora de Andalucía. In: Valdés Bermejo E, editor.
428 Introducción a la flora de Andalucía. Sevilla: Junta de Andalucía; 1993. pp 19-
429 35.
- 430 15. Carrión JS, Munuera M, Dupré M, Andrade A. Abrupt vegetation changes in
431 the Segura Mountains of southern Spain throughout the Holocene. J Ecol.
432 2001;89(5): 783-797. doi.org/10.1046/j.0022-0477.2001.00601.x
- 433 16. Carrión JS, Sánchez-Gómez P, Mota JF, Yll R, Chaín C. Holocene vegetation
434 dynamics, fire and grazing in the Sierra de Gádor, southern Spain. Holocene.
435 2003;13(6): 839-849. doi.org/10.1191/0959683603hl662rp
- 436 17. Peñas J, Benito B, Lorite J, Ballesteros M, Cañadas EM, Martinez-Ortega M.
437 Habitat fragmentation in arid zones: A case study of *Linaria nigricans* under
438 land use changes (SE Spain). Environ Manag. 2011;48(1): 168-176.
439 doi.org/10.1007/s00267-011-9663-y
- 440 18. Peterman WE, Crawford JA, Kuhns AR. Using species distribution and
441 occupancy modeling to guide survey efforts and assess species status. J Nat
442 Conserv. 2013;21: 114-121. doi.org/10.1016/j.jnc.2012.11.005

- 443 19. De Siqueira MF, Durigan G, de Marco Júnior P, Peterson AT. Something from
444 nothing: using landscape similarity and ecological niche modeling to find rare
445 plant species. *J Nat Conserv.* 2009;17: 25-32. doi.org/10.1016/j.jnc.2008.11.001
- 446 20. Williams JN, Seo C, Thorne J, Nelson JK, Erwin S, O'Brien JM, et al. Using
447 species distribution models to predict new occurrences for rare plants. *Divers*
448 *Distrib.* 2009;15: 565-576. doi.org/10.1111/j.1472-4642.2009.00567.x
- 449 21. Fois M, Cuena-Lombraña A, Fenu G, Bacchetta G. Using species distribution
450 models at local scale to guide the search of poorly known species: Review,
451 methodological issues and future directions. *Ecol Model.* 2018;385: 124-132.
452 doi.org/10.1016/j.ecolmodel.2018.07.018
- 453 22. Guirado E, Alcaraz-Segura D, Rigol-Sánchez JP, Gisbert J, Martínez-Moreno
454 FJ, Galindo-Zaldívar J, et al. Remote-sensing-derived fractures and shrub
455 patterns to identify groundwater dependence. *Ecohydrology.* 2018;11(6): e1933.
456 doi.org/10.1002/eco.1933
- 457 23. Guirado E, Blanco-Sacristán J, Rigol-Sánchez JP, Alcaraz-Segura D, Cabello J.
458 A multi-temporal object-based image analysis to detect long-lived shrub cover
459 changes in drylands. *Remote Sens.* 2019;11(22): 2649.
460 doi.org/10.3390/rs11222649
- 461 24. Elith J, Anderson RP, Dudík M, Ferrier S, Guisan A, Hijmans R, et al. Novel
462 methods improve prediction of species' distributions from occurrence data.
463 *Ecography.* 2006;29: 129-151. doi.org/10.1111/j.2006.0906-7590.04596.x
- 464 25. Guisan A, Zimmermann N. Predictive habitat distribution models in ecology.
465 *Ecol Model.* 2000;135(2-3): 147-186. doi.org/10.1016/S0304-3800(00)00354-9

- 466 26. Guisan A, Tingley R, Baumgartner JB, Naujokaitis-Lewis I, Sutcliffe PR,
467 Tulloch AIT, et al. Predicting species distributions for conservation decisions.
468 Ecol Lett. 2013;16(12): 1424-1435. doi.org/10.1111/ele.12189
- 469 27. Elith J, Leathwick JR. Species distribution models: ecological explanation and
470 prediction across space and time. Annu Rev Ecol Evol Syst. 2009;40: 677-697.
471 doi.org/10.1146/annurev.ecolsys.110308.120159
- 472 28. Benito BM, Lorite J, Pérez-Pérez R, Gómez-Aparicio L, Peñas J. Forecasting
473 plant range collapse in a Mediterranean hotspot: When dispersal uncertainties
474 matter. Divers Distrib. 2014;20(1): 72-83. DOI: 10.1111/ddi.12148
- 475 29. Fois M, Cuenca-Lombraña A, Fenu G, Cogoni D, Bacchetta G. The reliability of
476 conservation status assessments at regional level: Past, present and future
477 perspectives on *Gentiana lutea* L. ssp. *lutea* in Sardinia. J Nat Conserv.
478 2016;33: 1-9. doi.org/10.1016/j.jnc.2016.06.001
- 479 30. De Luis M, Bartolomé C, Óscar C, Álvarez Jiménez J. *Gypsophila bermejoi* G.
480 López: A possible case of speciation repressed by bioclimatic factors. PLoS
481 One. 2018;13(1): e0190536. doi.org/10.1371/journal.pone.0190536
- 482 31. De Luis M, Álvarez Jiménez J, Labarga JM, Carmen B. Four climate change
483 scenarios for *Gypsophila bermejoi* G. López (Caryophyllaceae) to address
484 whether bioclimatic and soil suitability will overlap in the future. PLoS One.
485 2019;14(6): e0218160 doi.org/10.1371/journal.pone.0218160
- 486 32. Anon. Decreto 104/1994, de 10 de mayo, por el que se establece el Catálogo
487 Andaluz de Especies de Flora Silvestre Amenazada. BOJA. 1994;107: 7948-
488 7953.
- 489 33. Anon. Ley 8/2003, de 28 de octubre, de la Flora y la Fauna Silvestres. BOE.
490 2003;288: 42808-42830.

- 491 34. Anon. Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la
492 Biodiversidad. BOE. 2007;299: 51275-51327.
- 493 35. Anon. Decreto 23/2012, de 14 de febrero, por el que se regula la conservación y
494 el uso sostenible de la flora y la fauna silvestres y sus hábitats. BOJA. 2012;60:
495 114-163.
- 496 36. Rivas Goday S, Rivas-Martínez S. Matorrales y tomillares de la Península
497 Ibérica comprendidos en la clase Ononido-Rosmarinetea Br.-Bl. Anales Inst Bot
498 Cavanilles. 1968;1025: 1-297.
- 499 37. Parras JM, Peinado M, Alcaraz F. Sobre la vegetación termófila de la cuenca
500 mediterránea de Granada y sus áreas limítrofes. Lazaroa, 1985;8: 251-268.
- 501 38. Peinado M, Alcaraz F, Martínez-Parras JM. Vegetation of southeastern Spain.
502 Flora et vegetatio mundi, X. Berlin and Stuttgart: J. Cramer; 1992.
- 503 39. Rivas-Martínez S, Fernández-González F, Loidi J, Lousã M, Penas A.
504 Syntaxonomical checklist of vascular plant communities of Spain and Portugal
505 to association level. Itinera Geobot. 2001;14: 5-341.
- 506 40. Rivas-Martínez S, Díaz González TE, Fernández-González F, Izco J, Loidi J,
507 Lousã M, et al. Vascular plant communities of Spain and Portugal. Itinera
508 Geobot. 2002;15(1): 5-432.
- 509 41. Anon. Directiva 92/43/CEE del Consejo, de 21 de mayo de 1992, relativa a la
510 conservación de los hábitats naturales y de la fauna y flora silvestres. DOCE.
511 1992;206: 7-50.
- 512 42. Mendoza-Fernández AJ, Salmerón-Sánchez E, Martínez-Hernández F, Pérez-
513 García FJ, Lahora A, Merlo E, et al. Intensive Habitat Loss in South Spain:
514 Arborescent Scrubs with Ziziphus (5220*). In: Musarella CM, Cano Ortiz A,

- 515 Quinto Canas R, editors. Habitats of the World - Biodiversity and Threats,
516 IntechOpen; 2019. doi.org/10.5772/intechopen.85286.
- 517 43. Pérez-Latorre AV, Gavira O, Cabezudo B. Phenomorphology and
518 ecomorphological characters of *Maytenus senegalensis* L. shrublands in the
519 Iberian Peninsula: A comparison with other Mediterranean plant communities.
520 Flora. 2010;205: 200-210. doi.org/10.1016/j.flora.2009.04.002
- 521 44. Manzano Cano J. *Maytenus senegalensis* subsp. *europaea* en la península
522 ibérica: distribución, ecología, fitosociología y conservación. Acta Bot Malac.
523 2020;45: Forthcoming.
- 524 45. Rey PJ, Cancio I, Manzaneda AJ, González-Robles A, Valera F, Salido T,
525 Alcántara JM. Regeneration of a keystone semiarid shrub over its range in
526 Spain: habitat degradation overrides the positive effects of plant-animal
527 mutualisms. Plant Biol. 2018;20(6): 1083-1092. doi.org/10.1111/plb.12870
- 528 46. Rey PJ, Alcántara JM, Manzaneda AJ, Sánchez-Lafuente AM. Facilitation
529 contributes to Mediterranean woody plant diversity but does not shape the
530 diversity-productivity relationship along aridity gradients. New Phytol.
531 2016;211: 464-476. doi.org/10.1111/nph.13916
- 532 47. González-Robles A. Disrupción de los mutualismos planta-polinizador de
533 *Ziziphus lotus* (L) Lam por pérdida de hábitat y degradación del paisaje:
534 consecuencias para el flujo génico y la conservación de sus poblaciones en el
535 sureste semiárido de España. PhD Thesis. Universidad de Jaén. 2019. Available
536 from: <https://dialnet.unirioja.es/servlet/tesis?codigo=255239>
- 537 48. Rathcke BJ, Jules ES. Habitat fragmentation and plant-pollinator interactions.
538 Current Sci. 1993;65: 273-277.

539 49. Gill RJ, Baldock KCR, Brown MJF, Cresswell JE, Dicks LV, et al. Protecting
540 an Ecosystem Service: Approaches to Understanding and Mitigating Threats to
541 Wild Insect Pollinators. *Adv Ecol Res.* 2016;54: 135-206.
542 doi.org/10.1016/bs.aecr.2015.10.007

543 50. Rojas Rodriguez J, Rossetti MR, Videla M. Importance of flowers in field
544 margins for insect communities in agroecological farms from Cordoba,
545 Argentina. *FCA UNCUIYO*, 2019;51(1): 249-259.

546 51. López García GP, Mazzitelli ME, Fruitos A, González M, Marcucci B, Giusti
547 R, et al. Pollinator and predator insects biodiversity in vineyards
548 agroecosystems of Mendoza, Argentina. Considerations for habitat
549 management. *FCA UNCUIYO*. 2019;51(1): 309-322.

550 52. Cotes B, González M, Benítez E, De Mas E, Clemente-Orta G, Campos M, et
551 al. Spider Communities and Biological Control in Native Habitats Surrounding
552 Greenhouses. *Insects*. 2018;9(1), 33. doi.org/10.3390/insects9010033

553 53. Loreau M, Mouquet N, Gonzales A. Biodiversity as spatial insurance in
554 heterogeneous landscapes. *Proc Natl Acad Sci.* 2003;100: 12765-12770.
555 doi.org/10.1073/pnas.2235465100.

556 54. Rivas-Martínez S, Asensi A, Díaz-Garretas B, Molero J, Valle F, Cano E, et al.
557 Mapa de series, geoserias y geopermaseries de vegetación de España, Memoria
558 del mapa de vegetación potencial de España. *Itinera Geobot.* 2007;17: 5–436.

559 55. Cañadas EM, Giuseppe F, Peñas J, Lorite J, Mattana E, Bacchetta G. Hotspots
560 within hotspots: Endemic plant richness, environmental drivers, and
561 implications for conservation. *Biol Conserv.* 2014;170: 282-291.
562 doi.org/10.1016/j.biocon.2013.12.007

- 563 56. Médail F, Quézel P. Biodiversity hotspots in the Mediterranean basin: Setting
564 global conservation priorities. *Conserv Biol.* 1999;13: 1510-1513.
565 doi.org/10.1046/j.1523-1739.1999.98467.x
- 566 57. Mendoza-Fernández A, Pérez-García FJ, Martínez-Hernández F, Salmerón-
567 Sánchez E, Medina-Cazorla JM, Garrido-Becerra JA, et al. Areas of endemism
568 and threatened flora in a Mediterranean hotspot: Southern Spain. *J Nat Conserv.*
569 2015;23: 35-44. doi.org/10.1016/j.jnc.2014.08.001
- 570 58. Foley JA, Defries R, Asner GP, Barford C, Bonan G, Carpenter SRF, et al.
571 Global consequences of land use. *Science.* 2005;309: 570-574.
572 doi.org/10.1126/science.1111772
- 573 59. Kéfi S, Rietkerk M, Alados CL, Pueyo Y, Papanastasis VP, ElAich A, et al.
574 Spatial vegetation patterns and imminent desertification in Mediterranean arid
575 ecosystems. *Nature.* 2007;449: 213-217. doi.org/10.1038/nature06111
- 576 60. Klausmeyer KR, Shaw MR. Climate Change, Habitat Loss, Protected Areas and
577 the Climate Adaptation Potential of Species in Mediterranean Ecosystems
578 Worldwide. *PLoS One.* 2009;4(7): e0006392
579 doi.org/10.1371/journal.pone.0006392
- 580 61. Anthos. Information System of the plants of Spain. Real Jardín Botánico, CSIC
581 - Fundación Biodiversidad. c2000 [cited 2020 Feb 5] Available from:
582 www.anthos.es.
- 583 62. FAME. Sistema de Información sobre Flora Amenazada y de interés en
584 Andalucía; c2014 [cited 2019 Jun 12] Available from: [http:](http://www.juntadeandalucia.es/medioambiente/site/rediam)
585 [//www.juntadeandalucia.es/medioambiente/site/rediam](http://www.juntadeandalucia.es/medioambiente/site/rediam)

- 586 63. QGIS Development Team. (2020). QGIS Geographic Information System.
587 Open Source Geospatial Foundation Project. c2020 [cited 2020 Mar 20].
588 Available from: <https://www.qgis.org/es/site/>
- 589 64. Worldclim. Global Climatic Data. c2018 [cited 2019 Dec 10]. Available from:
590 <http://www.worldclim.org>.
- 591 65. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. Very high resolution
592 interpolated climate surfaces for global land areas. *Int J Climatol*. 2005;25(15):
593 1965-1978. doi.org/10.1002/joc.1276
- 594 66. Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, et al. IPCC,
595 2013. *Climate Change 2013: The Physical Science Basis. Contribution of*
596 *Working Group I to the Fifth Assessment Report of the Intergovernmental*
597 *Panel on Climate Change*. Cambridge and New York: Cambridge University
598 Press; 2013.
- 599 67. Gent PR, Danabasoglu G, Donner LJ, Holland MM, Hunke EC, Jayne SR, et al.
600 The community climate system model version 4. *J Climate*. 2011;24(19): 4973-
601 4991. doi.org/10.1175/2011JCLI4083.1
- 602 68. Fox J. *Applied regression analysis and generalized linear models*. Thousand
603 Oaks: Sage Publications; 2016.
- 604 69. Fox J, Monette G. Generalized collinearity diagnostics. *J Am Stat Assoc*.
605 1992;87(417): 178-183. doi.org/10.1080/01621459.1992.10475190
- 606 70. Fox J, Weisberg S. *An R companion to applied regression*. Thousand Oaks:
607 Sage Publications; 2011.
- 608 71. Phillips SJ, Dudík M, Schapire RE. Maxent software for modeling species
609 niches and distributions (Version 3.4.1). c2020 [cited 2020 Mar 15]. Available
610 from: http://biodiversityinformatics.amnh.org/open_source/maxent/

- 611 72. Phillips SJ, Anderson RP, Schapire RE. Maximum entropy modeling of species
612 geographic distributions. *Ecol model.* 2006;190(3-4): 231-259.
613 doi.org/10.1016/j.ecolmodel.2005.03.026
- 614 73. Phillips SJ, Dudík M. Modeling of species distributions with Maxent: new
615 extensions and a comprehensive evaluation. *Ecography.* 2008;31(2): 161-175.
616 doi.org/10.1111/j.0906-7590.2008.5203.x
- 617 74. Baldwin RA. Use of maximum entropy modeling in wildlife research. *Entropy.*
618 2009;11(4): 854-866. doi.org/10.3390/e11040854
- 619 75. Deblauwe V, Barbier N, Couteron P, Lejeune O, Bogaert J. The global
620 biogeography of semi-arid periodic vegetation patterns. *Global Ecol Biogeogr.*
621 2008;17(6): 715-723. doi.org/10.1111/j.1466-8238.2008.00413.x
- 622 76. Guisan A, Thuiller W. Predicting species distribution: offering more than
623 simple habitat models. *Ecol Lett.* 2005;8(9): 993-1009. doi.org/10.1111/j.1461-0248.2005.00792.x
- 625 77. Riordan EC, Rundel PW. Modelling the distribution of a threatened habitat: The
626 California sage scrub. *J Biogeogr.* 2009;36(11): 2176-2188.
627 doi.org/10.1111/j.1365-2699.2009.02151.x
- 628 78. Peterson AT, Nakazawa Y. Environmental data sets matter in ecological niche
629 modelling: an example with *Solenopsis invicta* and *Solenopsis richteri*. *Global*
630 *Ecol Biogeogr.* 2008;17(1): 135-144. doi.org/10.1111/j.1466-8238.2007.00347.x
- 632 79. Warren DL, Glor RE, Turelli M. Environmental niche equivalency versus
633 conservatism: quantitative approaches to niche evolution. *Evolution.* 2008;62:
634 2868- 2883. doi.org/10.1111/j.1558-5646.2008.00482.x

- 635 80. Bucklin DN, Basille M, Benschoter AM, Brandt LA, Mazzotti FJ, Romañach SS,
636 et al. Comparing species distribution models constructed with different subsets
637 of environmental predictors. *Divers Distrib.* 2015;21(1): 23-35.
638 doi.org/10.1111/ddi.12247
- 639 81. Virgili A, Racine M, Authier M, Monestieza P, Ridoux V. Comparison of
640 habitat models for scarcely detected species. *Ecol Model.* 2017;346(24): 88-98.
641 doi.org/10.1016/j.ecolmodel.2016.12.013
- 642 82. Zaniwski AE, Lehmann A, Overton JM. Predicting species spatial distributions
643 using presence-only data: a case study of native New Zealand ferns. *Ecol*
644 *Model.* 2002;157: 261-280. doi.org/10.1016/S0304-3800(02)00199-0
- 645 83. Mota JF, Peñas J, Castro H, Cabello J, Guirado JS. Agricultural development vs
646 biodiversity conservation: the Mediterranean semiarid vegetation in El Ejido
647 (Almería, southeastern Spain). *Biodivers Conserv.* 1996;5(12): 1597-1617.
648 doi.org/10.1007/BF00052118
- 649 84. Hirzel AH, Hausser J, Chessel D, Perrin N. Ecological-niche factor analysis:
650 how to compute habitat- suitability maps without absence data? *Ecology.*
651 2002;83(7): 2027-2036. doi.org/10.1890/0012-9658(2002)083[2027:
652 ENFAHT]2.0.CO;2
- 653 85. Hirzel A, Guisan A. Which is the optimal sampling strategy for habitat
654 suitability modelling. *Ecol Model.* 2002;157(2-3): 331-341.
655 doi.org/10.1016/S0304-3800(02)00203-X
- 656 86. Stohlgren TJ, Ma P, Kumar S, Rocca M, Morisette JT, Jarnevich CS, et al.
657 Ensemble habitat mapping of invasive plant species. *Risk Anal.* 2010;30(2):
658 224-235. doi.org/10.1111/j.1539-6924.2009.01343.x

- 659 87. Mota J, Cabello J, Cueto M, Gómez F, Giménez E, Peñas J. Datos sobre la
660 vegetación del sureste de Almería (Desiertos de Tabernas, Karst en Yesos de
661 Sorbas y Cabo de Gata). Almería: Servicio Publicaciones Universidad de
662 Almería; 1997.
- 663 88. SIOSE. Sistema de Información sobre Ocupación del Suelo de España. c2020
664 [cited 2020 Jan 20]. Available from: www.siose.es
- 665 89. Mendoza-Fernández AJ, Martínez-Hernández F, Pérez-García FJ, Garrido-
666 Becerra JA, Benito BM, Salmerón-Sánchez E, et al. Extreme habitat loss in a
667 Mediterranean habitat: *Maytenus senegalensis* subsp. *europaea*. Plant Biosyst.
668 2015;149(3): 503-511. doi.org/10.1080/11263504.2014.995146
- 669 90. Médail F, Diadema K. Glacial refugia influence plant diversity patterns in the
670 Mediterranean Basin. J Biogeogr. 2009;36(7): 1333-1345.
671 doi.org/10.1111/j.1365-2699.2008.02051.x
- 672 91. Carrión Y, Ntinou M, Badal E. *Olea europaea* L. in the north Mediterranean
673 Basin during the Pleniglacial and the Early-Middle Holocene. Quat Sci Rev.
674 2010;29(7-8): 952-968. doi.org/10.1016/j.quascirev.2009.12.015
- 675 92. López Martos JM. Artineras, mirar desde el cielo para reconstruir el paisaje
676 primitivo del Campo de Dalías. Farua. 2014;17: 153-172.
- 677 93. Mendoza-Fernández AJ, Pérez-García FJ, Martínez-Hernández F, Medina-
678 Cazorla JM, Garrido-Becerra JA, Merlo Calvente ME, et al. Threatened plants
679 of arid ecosystems in the Mediterranean Basin: A case study of the south-
680 eastern Iberian Peninsula. Oryx. 2014;48(4): 548-554.
681 doi.org/10.1017/S0030605313000495

94. Guisan A, Weiss SB, Weiss AD. GLM versus CCA spatial modeling of plants species distribution. *Plant Ecol.* 1999;143(1): 107-122. doi.org/10.1023/A:1009841519580
95. Weniger G-C, de Andrés-Herrero M, Bolin V, Kehl M, Otto T, Potì, et al. Late Glacial rapid climate change and human response in the Westernmost Mediterranean (Iberia and Morocco). *PLoS One.* 2019;14(12): e0225049. doi.org/10.1371/journal.pone.0225049
96. Aizen MA, Garibaldi LA, Cunningham SA, Klein AM. How much does agriculture depend on pollinators? Lessons from long- term trends in crop production. *Ann Bot.* 2009;103: 1579-1588. doi.org/10.1093/aob/mcp076
97. Winfree R, Bartomeus I, Cariveau D. Native Pollinators in Anthropogenic Habitats. *Annu Rev Ecol Evol Syst.* 2011;42: 1-22. doi.org/10.1146/annurev-ecolsys-102710-145042
98. Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin E. Global pollinator declines: Trends, impacts and drivers. *Trends Ecol Evol.* 2010;25(6): 345-353. doi.org/10.1016/j.tree.2010.01.007

Supporting information

- S1 Fig. Results of VIF analysis.** Cluster analysis of the 19 bioclimatic variables (bi_sp) used in the VIF analysis. Abbreviations are listed in Table S2.
- S2 Fig. Results of gains and Roc curve.** MaxEnt analysis of the variables.
- S3 Fig. Distribution of *Z. lotus*, *C. Tricoccon*, *B. Balearica* and *P. angustifolia*.** Records at 10km² in south and east of Spain.

- 706 **S1 Table. Presence records of *G. senegalensis*.** Geographic coordinates of presence
- 707 records gathered from several sources.
- 708 **S2 Table. Bioclimatic variables (Bi).** Variables available at WorldClim website.

Figure1

a:

b:

c:

d:

0 100 200 300 400 km

Figure2

a:

b:

c:

d:

0 100 200 300 400 km

Figure3

Figure4