BOOK OF ABSTRACTS
and modelling course guide

3rd INTERNATIONAL WORKSHOP
GYPWORLD

9 - 13 MAY 2022

UNIVERSITY OF ALMERÍA
CAMPUS UNIVERSITARIO. CARRETERA SACRAMENTO

GYPWORLD: A Global initiative to understand gypsum ecosystem ecology
Book of abstracts and modelling course guide

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University of Almería, Spain.

Book of abstracts and modelling course guide: Key speakers, Oral presentations and Poster presentations

Editors: Juan Francisco Mota, Esteban Salmerón Sánchez and María Encarna Merlo Calvente.

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Cover photo: Juan Francisco Mota. Gypsum outcrop in the "Karst en Yesos de Sorbas" Nature Area.

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GYPWORLD WORKSHOP PROGRAMME

3rd INTERNATIONAL WORKSHOP
GYPWORLD
A Global initiative to understand gypsum ecosystem ecology

9-13 MAY 2022 - ALMERÍA (SPAIN)
Programme

Monday-09/05/22 – d/m/y

9.00-9.30   Registration

9.30-11.00   GIS and niche modelling training course

11.00-11.30   BREAK

11.30-13.30   GIS and niche modelling training course

13.30-15.00   LUNCH

15.00-19.30   VISIT to Arboleas-*LAPIS SPECULARIS* – Guided by staff from the town hall of Arboleas

19.30-20.00   SNACK OFFERED BY THE CITY COUNCIL OF ARBOLEAS

Tuesday - 10/05/22 – d/m/y

9.00-10.00   Opening ceremony

       Chairman: Dr. Helga Ochoterena

10.00-10.45   KEY SPEAKER   Dr. Urgamal Magsar (Head of Laboratory of the Plant Systematics and Phylogenetic, Botanic Garden and Research Institute, Mongolian Academy of Sciences, Mongolia) – "Current vascular flora and plant conservation status of Mongolia".

10.45-11.15   BREAK

11.15-12.00   KEY SPEAKER   Prof. Undrakh-Od Baatar (Head, Central Asian Soil Science Society, Mongolia) – "Distribution of GYPSISOLS in Mongolia and its main plant vegetation".

12.00-13.30   ORAL SESSION I

12.00-12.15   Hilda Flores Olvera. *Drymaria* series *lyropetala* (Caryophyllaceae), a gypsophilous North American complex: taxonomic advances.

12.15-12.30   Mario Blanco Sánchez. Contrasting adaptive strategies and genetic variation in two dominant gypsophiles in response to drought.

12.30-12.45   Sara Palacio Blasco. Recent and ancient evolutionary events shaped the plant elemental composition of edaphisms. A phylogeny-wide analysis of Iberian and Chihuahuan Desert gypsum plants.

12.45-13.00   Roberto López Rubio. Are phylogenetic and functional distance good predictors of plant-plant competition? A common garden experiment with Mediterranean shrub species.

13.00-13.15   Michael J. Moore. Niche evolution in the Nyctagineae: a group with an ancestral affinity for gypsum?

13.30-15.00   LUNCH

15.00-15.30   POSTER SESSION I

Chairman: Dr. Antonio Mendoza Fernández

15.30-16.15   KEY SPEAKER Prof. Khabibullo Shomurodov (Institute of Botany, Academy of Science of the Republic of Uzbekistan, Taskent, Uzbekistan) – "Gypsophilous Vascular Plants of Uzbekistan: taxonomic composition, endemism and the state of rare species population".

16.15-17.00   ORAL SESSION II

16.15-16.30   Sergio Muriel Marín. Searching for lichen gypsophiles: checklist and substrate affinities.

16.30-16.45   Mariana Rodriguez Sánchez. Aridity and gypsum type shape the gypsophyte communities of the Chihuahuan desert.

16.45-17.00   López-Pujol. Why does the world's main producer of gypsum (China) have almost no gypsophytes?

17.00-17.30   BREAK

17.30-18.15   KEY SPEAKER   Dr. Helga Ochoterena (Department of Botany, Institute of Biology, National Autonomous University of México, México, México) – "Facing the challenges for the study of gypsophylous floras in México".

        TASTING ALMERIA (DE TAPAS)

Wednesday - 11/05/22 – d/m/y

        Chairman: Dr. Fabián Martínez Hernández

9.00-9.45   KEY SPEAKER   Prof. Wenju Li (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, China) – Mapping Asia Plants: Current status of floristic information and utilization of plant diversity and resources in Central Asia.

9.45-10.30   ORAL_SESSION III

9.45-10.00   Giovanni Spampinato. Plant communities patterns in Sicilian gypsum outcrops.

10.00-10.15   Ana I. García-Cervigón Morales. GYPWOOD: A research project to study plasticity and phenotypic variation in wood anatomy of gypsum chamaephytes in response to drought.

10.15-10.30   Alicia Montesinos. Nitrogen trade between plant species with different phenology.

10.30-11.00   BREAK

11.00-11.45   KEY SPEAKER   Prof. Mingxun Ren (Center for Terrestrial Biodiversity of the South China Sea, College of Ecology and Environment, Hainan University, Haikou, China) – "Karst flora on Hainan Island, China".

        Chairman: Carlos Salazar

11.45-13.30   ORAL SESSION IV

11.45-12.00   Andreu Cera. When disturbances favour species adapted to stressful soils: grazing may benefit soil specialists in gypsum plant communities.

12.00-12.15   Sonia Chamizo. Soil CO_2 efflux dynamics from different ground covers over gypsiferous marls.

12.15-12.30   Rocio Chaves Jimenez. "The Good Neighbour": *Erodium cicutarium* determines annual species assemblages at fine spatial scales in gypsum systems.

12.30-12.45 Laura de la Puente. An approach to the mechanisms of use of gypsum crystallization water by plants.

12.45-13.00 Alexander Rudov. Ecohydrological niche segregation among coexisting C3 and C4 desert shrubs in a gypsum-calcareous formation (NW Iran).

13.00-13.15 Ricardo Sánchez Martín. Changes in facilitative interactions in contrasting stress environments (gypsum and limestone). A model for understanding how traits and environments influence facilitative interactions.

13.15-13.30 Sarah Collins. How plant-microbial interactions affect water and nutrient dynamics in semiarid environments and its implications on plant performance and plant-plant interactions.

13.30-15.00 LUNCH

15.00-16.30 ROUNDTABLE Ecological Restoration of Gypsum Ecosystems

COMPANIES: SAINT GOBAIN / TORRALBA / E. Laguna (Technical director of CIEF, Generalitat Valenciana) / J. Lorite (Dpt. Botany, University of Granada, Spain) / J. Mota (Dpt. Biology and Geology, University of Almería, Spain)

16.30-17.00 POSTER SESSION II

17.00-17.30 BREAK

Chairman: Dr. Esteban Salmerón Sánchez

17.30-18.45 ORAL SESSION V

17.30-17.45 Cristina Dimitru. Effects of pollination and abiotic stress on plant-facilitation interactions.

17.45-18.00 Laura Ortiz Diaz. Functional diversity of experimental assemblages drives annual plant species responses to biological soil crusts in gypsum systems.

18.00-18.15 Yolanda Pueyo.Livestock grazing and aridity trade-offs on the conservation and forage quality of gypsum rangelands (NE Spain).

18.15-18.30 Sergio Cózar García. Comparative study of three methods for the determination of gypsum content in soils.

18.30-18.45 Fabián Martínez Hernández. Selection of a reserve network using the checklist of the intermountain west gypsophytes (North America).

18.45-19.00 Hossein Akhani. Gachsaran formation: The largest area of gypsum outcrops in SW Iran with unique flora and vegetation

19.00-19.30 CLOSURE

20.30-22.00 VISIT TO THE HISTORIC CENTRE OF ALMERIA

Thursday - FIELD TRIP 12/05/22 – d/m/y Flora and vegetation of the gypsum karst of Sorbas

KEY SPEAKERS: F. Pérez-García, F. Martínez-Hernández, A. Mendoza-Fernández, E. Salmerón-Sánchez.

9.00-13.00 VISIT TO LOS YESARES-Q

13.00-14.30 LUNCH

14.30-17.30   VISIT TO MAJADAS-Q

Friday - 13/05/22 – d/m/y

9.00-10.30   GYPWORLD Management Meeting

10.30-11.00   BREAK

11.00-13.30   GYPWORLD Management Meeting

13.30-15.00   LUNCH

SPONSORS

Ayuntamiento de Arboleas

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KEY SPEAKERS

Current vascular flora and plant conservation status of Mongolia

Magsar Urgamal

Botanic Garden and Research Institute of Mongolian Academy of Sciences, Ulaanbaatar, Mongolia. Correspondence: urgaa2007@gmail.com.

Mongolia is located in the mid-latitude (between 41°35'N–52°09'N and 87°44'E–119°56'E), between Russia and China, covering approximately 1.6 million km2, roughly equivalent to the size of western and central Europe. The flora of Mongolia is comprised of native species of different origins including boreal, steppe, desert, and mountainous elements of vegetation (Hilbig 1995; Gunin et al. 1999). The country is divided into sixteen phytogeographical regions which have various vegetation types (Grubov and Yunatov 1952), namely, alpine steppe, forest, meadow steppe, typical steppe, desert steppe, and desert (Gunin et al. 1999).

A brief history of listing of the flora of Mongolia and recent taxonomic revisions:

Historically, floristic studies have been very thoroughly conducted in this country, although recent updates are continuously being made. The first checklist of vascular plants included 1,897 species belonging to 555 genera and 97 families (Grubov 1955). Then, Grubov (1982) updated the checklist of vascular plants, which included 2,239 taxa from 599 genera and 103 families, with an identification key and information on their regional distribution and representative habitats. Later, Gubanov (1996) published a checklist with 2,823 higher plant species from 662 genera and 128 families, including notes on their regional distribution. More recently, Urgamal et al. (2014) updated the families of vascular flora according to APG III, with a total of 3,127 taxa that belong to 683 genera and 112 families. Since 2009, nine volumes of "Flora of Mongolia" series book with selected families have been published by Mongolian botanists, including Cyperaceae (Nyambayar 2009a), Apiaceae to Cornaceae (Urgamal 2009), Huperziaceae to Ephedraceae (Ulziikhutag et al. 2015), Asteraceae (Dariimaa 2014, 2021; Dariimaa and Saruul 2017), Ceratophyllaceae to Zygophyllaceae (Urgamal et al. 2020), Amaranthaceae s.l. (incl. Chenopodiacceae) (Tungalag 2020), Nymphaeaceae to Asphodelaceae (Urgamal et al. 2021).

In this study, we critically revised and updated the checklist of native vascular plants of Mongolia. The checklist comprises 3,041 native vascular plant taxa (2,835 species and 206 infraspecific species) from 653 genera and 111 families, including 7 lycophytes, 41 ferns, 21 gymnosperms, and 2,972 angiosperms. In the angiosperms, we identified the 14 families with the greatest species richness, ranging from 50 to 456 taxa. Species endemism is also noted here; 102 taxa are endemic to Mongolia, and 275 taxa are subendemic that co-occur in adjacent countries. Since 2014, a total of 14 taxa have been described new to science based on morphological evidences (Baasanmunkh et al. 2022).

Moreover, five genera and 74 taxa were newly added to the flora of Mongolia. Based on our critical revisions, names of three families, 21 genera, and 230 species have been changed in comparison to the previous checklist, "Conspectus of the vascular plants of Mongolia" (Urgamal et al. 2014).

New additions to the flora of Mongolia:

Since Urgamal et al. (2014), 13 new species and one infraspecific taxon from Mongolia have been described as new to science (Nobis 2014; Erst et al. 2015, 2016; Kechaykin and Kutsev 2015; Yurtseva et al. 2016; Alexeeva 2018; Gundegmaa and Kechaykin 2018; Ovczinnikova 2019a, 2020; Pyak and Pyak 2019; Zhao et al. 2019; He et al. 2020; Pyak et al. 2020). Many new records of vascular plants have also been reported (Nobis et al. 2014, 2019a; Doronkin et al. 2015; Urgamal et al. 2016, 2019; Baasanmunkh et al. 2019a, b, c, 2020a, b, 2021b, d; Bazarragchaa et al. 2019; Erst et al. 2019; Ovczinnikova 2019b; Knyazev 2020; Shiga et al. 2020; Yano et al. 2021), including five genera new to the country, i.e. Matthiola W.T.Aiton, Brassicaceae (German 2015), Onoclea L., Onocleaceae (Doronkin et al. 2015), Aldrovanda L., Droseraceae (Shiga et al. 2020), Hydrilla L., Hydrocharitaceae (Shiga et al. 2020), and Arctium L., Asteraceae (Javzandolgor et al. 2021). Additionally, some genera previously listed by Urgamal et al. (2014) were omitted from Mongolian flora based on recent studies. In particular, the genus Epipactis Zinn. (Orchidaceae), for example, had two species that have been proven absent in the country due to the inaccurate location written on the herbarium specimens (Baasanmunkh et al. 2021b). On the other hand, some genera were not listed in Urgamal et al. (2014); for example, the genus Phyllodoce Salisb. (Ericaceae) was found in northern Mongolia by Oyunmaa and de Priest (2011).

Furthermore, representatives of some genera, which are listed in the flora of Mongolia (Gubanov 1996; Urgamal et al. 2014), have been revised in recent studies (Podlech and Zarre 2013; Sukhorukov et al. 2013, 2019; Wang et al. 2014; Global Carex Group 2015; Duan et al. 2016; Drew et al. 2017; Kosachev 2017; Moore and Dillenberger 2017; Nosov et al. 2017; Pimenov 2017; Wiegleb et al. 2017; Boltenkov 2018; Gillespie et al. 2018; Madhani et al. 2018; Sinitsyna et al. 2018; Zhang et al. 2018; Barberá et al. 2019, 2020; Nobis et al. 2019b; Sramkó et al. 2019; Akan et al. 2020; Esput 2020; Friesen et al. 2020; Murakami et al. 2020; Nesom 2020; Ren et al. 2020; Zaika et al. 2020; Al-Shehbaz 2021; Al-Shehbaz et al. 2021; Liu et al. 2021).

Results:

The current checklist comprises 3,041 native vascular plant taxa (including 2,891 species, 116 subspecies, 29 varieties, and 12 nothospecies), belonging to 653 genera and 111 families (Table 1, Fig. 1). The updated checklist is divided into four major taxonomic groups: lycophytes (2 families and 4 genera), ferns and fern allies (12 families and 17 genera), gymnosperms (3 families and 6 genera), and angiosperms (94 families and 626 genera) (see Table 1 for detailed numbers of taxa). Among these, angiosperms comprise 2,972 taxa, which constitute 97% of Mongolian flora (Table 1). We cross-checked the occurrence of each taxon using GBIF (2021), which includes occurrence data for 2,249 taxa (73% of Mongolian flora).

Table 1. Number of native vascular plants taxa in each taxonomic group in Mongolia.

Major taxonomic groups	Family	Genus	Taxa
Lycophytes	2	4	7
Ferns and fern allies	12	17	41
Gymnosperms	3	6	21
Angiosperms	94	626	2,972
Total	**111**	**653**	**3,041**

There are 14 families with a high species richness (> 9 genera and > 57 taxa): Asteraceae (86 genera and 460 taxa) followed by Fabaceae (24 and 328), Poaceae (58 and 229), Rosaceae (26 and 167), Ranunculaceae (20 and 157), Brassicaceae (59 and 138), Cyperaceae (10 and 130), Lamiaceae (22 and 103), Amaranthaceae s.l. (30 and 94), Caryophyllaceae (20 and 97), Boraginaceae (24 and 78), Apiaceae (36 and 66), Polygonaceae (11 and 63), and Orobanchaceae (9 and 57) (Fig. 1).

The remaining 97 families comprise a smaller set of taxa. At the genus level, 14 genera represent a high species richness (> 24 taxa): *Astragalus* L. (127 taxa), *Artemisia* L. (103), *Carex* L. (99) *Oxytropis* DC. (97), *Potentilla* L. (76), *Saussurea* DC. (55), *Taraxacum* F.H.Wigg. (53), *Allium* L. (50), *Salix* L. (42), *Ranunculus* L. (41), *Pedicularis* L. (36), *Poa* L. (28), *Viola* L (27), and *Silene* L. (24)

Plant conservation status (IUCN Red List):

The first work on assessing plant species in Mongolia is assessed by IUCN Red List criteria in 2011 and second assessment in 2018. One of the key components of Mongolia's biodiversity conservation component is that they are based on international methods and methodologies assessment and protection measures at national and international levels.

According to regional assessment of the IUCN Red List (2nd series), 489 species of molluscs in Mongolia, moss 15 species, 40 species of algae, 34 species of mushrooms, 32 species of molluscs, or 610 species of plants (Table 1). As a result of the according to the 2nd series assessment of the Mongolian Plant Red List (IUCN) to the flora of Mongolia, 44 species (7.2%) were assessed as Critically Endangered (CR), 149 species (24.4%) of Endangered (EN), 214 species (35.1%) of Vulnerable (VU), 90 species (14.7%) of Threatened (NT), 48 species (7.9%) of Least Concern (LC), 60 species (9.8%) of Data Deficient (DD), and 5 species (0.8%) of Not Applicable (NA).

Today, we are planning to include 268 species in the new list of "Very rare plants of Mongolia", and also of 248 species in the list of "Rare plants of Mongolia" (Urgamal et al. 2019).

Distribution of GYPSISOLS in Mongolia and its main plant vegetation

Undrakh-Od Baatar

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Data on the distribution of gypsum-containing soils in Mongolia is presented. The location of gypsum materials in the 10< provinces will be also presented as geological information about gypsum in Mongolia. The characteristics of few Gypsumsols in the South-Gobi province is described according to WRB International Soil classification.
Also, we will show you the types of plant vegetations that are distributed on the Gypsumsols in Mongolia.

Gypsophilous Vascular Plants of Uzbekistan: taxonomic composition, endemism and the state of rare species population

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Gypsum deserts and semi-deserts of Central Asia are characterized by a specific flora. According to literature data (1,2), the gypsophile flora of Central Asia is not rich (2.6% of the entire flora of the region), but in terms of the presence of endemics and relict species, it is rich and is considered as oldest within the ancient Mediterranean flora. In Uzbekistan, gypsophile flora is widespread in the deserts of Kyzylkum and Ustyurt. Gypsophile vegetation is also found in the spurs of the Pamir-Alai (in the south of Uzbekistan in the Surkhandarya and Kashkadarya regions) and the Tien Shan ridges (Ferghana Valley). The flora of the gypsum desert of Central Asia in a broad sense, including upland gypsophytes, is estimated to include over 400 species, and most of the species belong to formations of upland gypsophytes on red formations. Especially characteristic among gypsophytes are species of the genera *Zygophyllum, Limonium, Cleome, Otostegia, Spirostegia, Haplophyllum, Reaumuria, Cephalorrhizum, Arthrophytum, Anabasis, Hammada*. Some species growing on red formation have a disjunct distribution. An example of this is *Zygophyllum bucharicum* from the section *Agrophylla*, most of whose representatives are concentrated in Africa. *Scrophularia leucoclada* grows on the red formation of the lower mountain belt, as well as along the dry beds in the buttes of the Kyzylkum. The closest relatives of this species — shrubby representatives of the genus — are found in Palestine. On the example of these and other species (1) showed the relationship of the gypsophile flora of red formations of Central and Western Asia.

According to our calculations, there are 251 species of gypsophile vascular plants of Central Asia, which is 2.6% of the total flora of Central Asia (9582 species). Of these, 118 species (47%) are endemic to the region. Gypsoclines (154 species) predominate, while pure gypsophiles comprise 97 species. 169 gypsophile species grow in Uzbekistan (out of a total of 4,350 species of the republic), of which 14 species (8,2%) are national endemics. Of 169 species, 46 are true gypsophiles and 123 species are distributed both in gypsum-bearing soils and other habitats (gypsoclines).

Polymorphic families in terms of the content of gypsophiles (at least 10 species) in Central Asia are the following families: Fabaceae (37 species), Asteraceae (36), Apiaceae (28), Amaranthaceae (25), Lamiaceae (20), Zygophyllaceae (13), Caryophyllaceae (12), Amaryllidaceae (10), Boraginaceae (10). The families Plumbaginaceae, Polygonaceae, Brassicaceae, Euphorbiaceae, Rubiaceae, Cleomaceae, Asphodelaceae, Poaceae contain from 3 to 9 species, and the remaining 14 families are represented by 1 species. *Astragalus* (26 species), *Ferula* (13), *Zygophyllum* (12), *Allium* (9), *Cousinia* (8) and *Jurinea* (8) are the genera with the highest number of gypsophile species.

In the flora of Uzbekistan, all 32 families include gypsophile species. As in the flora of Central Asia, the families with the highest number of gypsophiles are Asteraceae (26), Fabaceae (21), Apiaceae (19), Amaranthaceae (17). The families Boraginaceae, Amaryllidaceae, Caryophyllaceae, Zygophyllaceae, Lamiaceae Polygonaceae, Euphorbiaceae contain from 5 to 9 species. The number of gypsophiles in the remaining families does not exceed 4 species. The spectrum of leading genera in terms of the content of gypsophiles is headed by *Astragalus, Allium, Cousinia Jurinea Ferula, Zygophyllum, Euphorbia* and *Calligonum*, which contain 5-17 species.

Keywords

References

1) Popov M. G. 1923. Flora of gypsaceous layers (red lowlands) of Bukhara (fragment of Turkestan flora history). Trudy Turkestanskogo nauchnogo obshchestva [Works of Turkestan scientific society] 1: 27–64.
2) Momotov I.F. 1973 Vegetation cover of Uzbekistan and ways of its rational use. Volume 2. Fan. Tashkent. 1-403 pp .

Facing the challenges for the study of gypsophylous floras in México

Helga Ochoterena[1*], Hilda Flores-Olvera[1], Carlos Gómez Hinostrosa[1], Vinajel Torres Alba[1], Michael Moore[2]

[1]*Departamento de Botánica, Instituto de Biología, Universidad Nacional Autónoma de México. Ciudad Universitaria sn, Delegación Coyoacán, 04510, CdMx, Mexico. [2]Oberlin College, Department of Biology, 119 Woodland St., Oberlin, OH, USA. *Correspondence: helga@ib.unam.mx.*

Mexico is privileged to be one of the few megadiverse countries in the world. Housing between 25 to 30 thousand vascular plant species, it comprises about 10% of the world flora; moreover, the endemism for the country is in average around 50%. Despite this enormous richness, the country still lacks a floristic treatment and the need for further botanical expeditions is reflected by the frequent discovery of new species.

Mexican gypsum vegetation is mainly known from the extraordinary gypsum dunes of Cuatro Ciénegas, Coahuila. Nevertheless, several other localities are of major relevance for the gypsophilous flora in Mexico and are still in need of local floristic work. Although gypsum outcrops are scattered along the country, the most noticeable areas for these peculiar habitats are concentrated in the central plateau of the Chihuahuan desert and in the Sierra Madre Oriental. These regions have been considered as two biological provinces housing different and characteristic floristic and faunistic elements. Nevertheless, there are no studies devoted to compare the floristic diversity of both provinces with respect to gypsum vegetations.

Because many herbarium labels do not refer to gypsum, despite the plants having been collected on it, we used satellite images applying a short length infrared spectrum filter to infer the presence of gypsum by the acquisition of a light turquoise aspect when view through LandSat7 bands 7, 3 and 4 and Landsat 8 with layer. Unfortunately, the original source of information is not available any longer, but similar images can now be obtained through Google Earth Engine (https://code.earthengine.google.com/; Figure 1). Areas identified as potential gypsum outcrops were manually traced as corresponding polygons in Google Earth. Localities from herbarium specimens deposited in several herbaria and collected within three municipalities were georeferenced and mapped using ArcGIS and QGIS. The explicit reference of gypsum in some herbarium labels was used to corroborate the nature of the polygons and to refine them. All polygons were merged as a single layer using ArcMap 10.1. Intersections between the georeferenced localities and the polygons layer were used to select the specimens that potentially grow on gypsum, from which a species list was derived and confronted against other herbarium specimens and literature.

This method was used to create a floristic list of species growing on gypsum in the Cuatro Ciénegas municipality of the state of Coahuila, in the heart of the Chihuahuan desert plateau. With this method, the previous floristics accounts considering less than 40 species were increased to 297 species from gypsum soils, including 31 gypsophiles, 5 halogypsophiles, and three either gypsophiles or halogypsophiles.

Among the areas covered with noteworthy patches of gypsum outcrops in the Sierra Madre Oriental of Mexico, Galeana and the SE region of the state of Nuevo León stand out. To understand the floristic relevance of the gypsum outcrops from the Sierra Madre Oriental province, and to explore if the belonging to different biological provinces is reflected in the gypsophilous floristic composition, we applied the same method for two municipalities belonging to the Sierra Madre Oriental that have been relatively well collected and that possess numerous gypsum outcrops. These municipalities, Arramberri and General Zaragoza, cover together a surface of 4,123 km².

The preliminary results for the gypsophylous floras in the municipalities of Arramberri and General Zaragoza, pending polygons refinement and corroboration with herbarium specimens and literature, suggests an outstanding diversity, with 79 families, 258 genera and 364 species that grow on gypsum, with at least 24 restricted to gypsum, but this number is expected to increase with the herbarium and literature refinements. In comparing this diversity with that on the Cuatro Ciéneas municipality, although still preliminary, only 24 species are shared and neither of them is restricted to gypsum. The high diversity of this small area implies that the Sierra Madre Oriental gypsum outcrops might house one of the most important hot spots of gypsophiles in the world. This can be said even without taking into consideration other known areas of relevance for the topic, such as Galeana and San Antonio Peña Nevada.

We hope that our results stimulate the efforts to know the gypsophilous flora of Mexico and to understand their origin and evolution.

Keywords

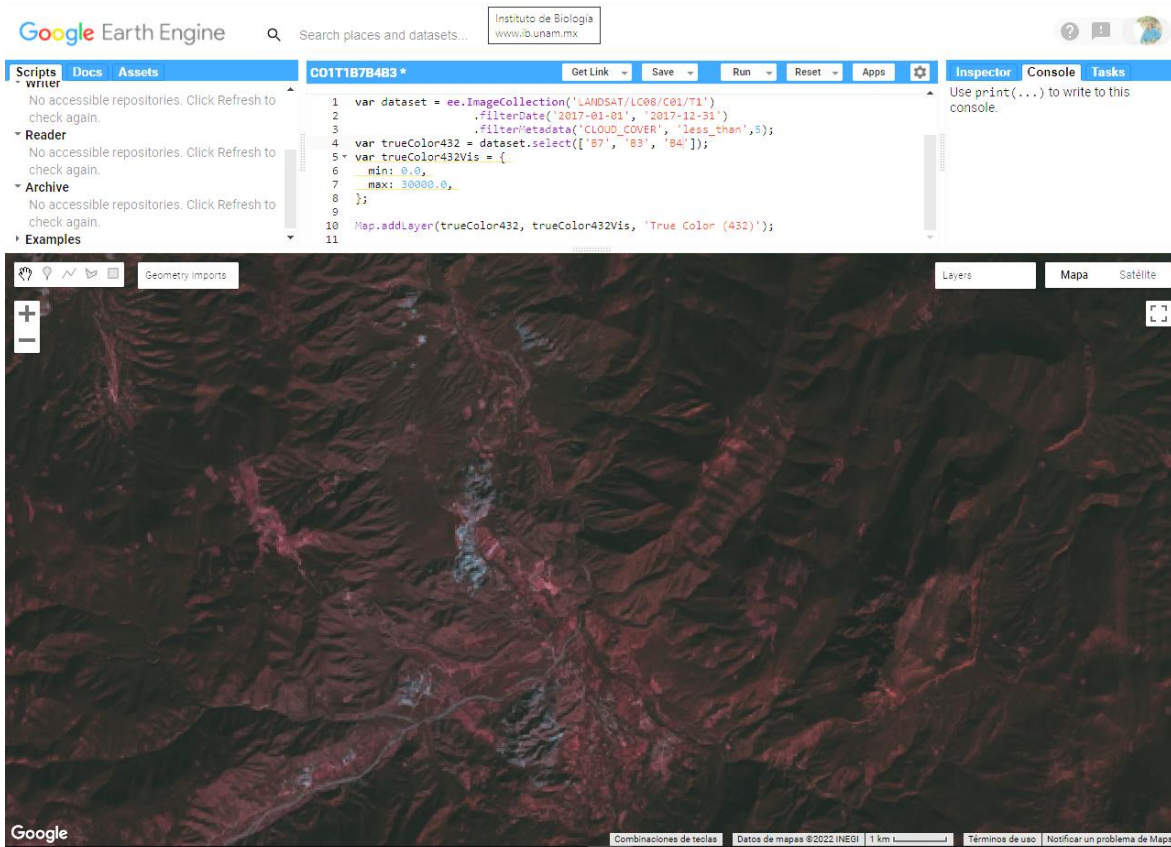Chihuahuan desert, Sierra Madre Oriental, Mexico, gypsum outcrops, biodiversity hot spot.

Figure 1. Satellite image around General Zaragoza, using Landsat 8 with a combination of three bands (7,3,4) through Google Earth Engine. The gypsum outcrops appear in light turquoise blue.

Mapping Asia Plants: Current status of floristic information and utilization of plant diversity and resources in Central Asia

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The geographical region of Central Asia comprises Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, and the Xinjiang Uygur Autonomous Region of China. Central Asia's temperate forests, steppes, and sandy deserts, including riparian tugai forests, have been identified by the World Wide Fund for Nature as Global 200 ecoregions, and the Mountains of Central Asia are considered biodiversity hotspots. The geographical and climatic environments of the Central Asian region embrace about 10 thousand vascular plant species, including a number of endemic species and genera. Here, we review the history of botanical investigations, floristic works and publications in this region, as well as key floras, checklists, herbaria and online databases, describe and analyze the diverse characteristics and utilization of plant diversity and resources of the region. we found that (1) the floristic work dating back to 1851 lays a solid but outdated foundation for botanical research in Central Asia today; (2) The vegetation geography of Central Asia can be divided into 5 provinces and 33 districts, and more than 65% species have a Central Asian geographical distribution pattern; (3) there are 9520 species of higher plants, 20% of which are endemic species, belonging to 138 families and 1176 genera, but all floras published in local and regional languages are limited in their global application; (4) Plant resource utilization can be grouped into 5 categories and 31 subcategories, including food, medicine, industry, environmental protection, construction, and plant germplasm. (5) the massive specimen collection stored in these countries' herbaria contains abundant information about biodiversity, but it has not been digitized; (6) The lack of an online biodiversity database or platform limits the application of biodiversity conservation in Central Asia. We therefore suggest that major efforts are taken to implement biodiversity conservation in Central Asia in the future.

Karst flora on Hainan Island, China

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Hainan Island, locating at south China and the north edge of tropical Asia, is an island with an area of 35,000 km². Hainan Island harbors vast rainforests with high levels of biodiversity, with more than 5000 vascular plants among which ~ 500 are endemic to this island. Such rich biodiversity is mainly due to its high mountains, spatial-temporal dynamics in rainfalls associated with monsoons, and habitat heterogeneity caused by different types of soils and rocks. About 400 km² of karst (limestone landscape) were found on Hainan Island, largely distributed at the west and south part of this mountainous island. Totally about 1500 vascular plants in 181 families (750 genera) can be found in karst regions on Hainan Island, of which 65 species are Hainan-endemic. The karst flora on this island is largely pantropical, with some belong to temperate zone. There are 27 plant species on Hainan's karst regions are included into national or provincial protection lists as endangered or rare species.

ORAL COMMUNICATIONS

ORAL SESSION I

Drymaria series *lyropetala* (Caryophyllaceae), a gypsophilous North American complex: taxonomic advances.

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Gypsum endemism is remarkably common across Caryophyllales. Among them, Caryophyllaceae stands out for the number of taxa growing on gypsum soils in North America. Within Caryophyllaceae, the American genus *Drymaria* has the highest number of gypsophile species. Mexico is the center of diversity for the genus, with 40 of the 50 species occurring there, including 23 species endemic to the country. In focusing on the evolution of gypsophilous lineages on the Chihuahuan Desert and the Sierra Madre Oriental, *Drymaria* deserves special attention as these biological provinces host 17 of its species, most of them growing on gypsum. Yet, a detailed taxonomic work is still needed to solve species circumscriptions and phylogenetic relationships within the genus. In 1961, Duke proposed an infrageneric classification of *Drymaria* that included 17 series based on morphological characters, but this is still in need of phylogenetic testing. The focus of the current study is on the gypsum endemic series *lyropetala*, which comprises up to six species: *D. coahuilana*, *D. elata*, *D. lyropetala*, *D. pratheri*, *D. subumbellata* and *D. suffruticosa*. However, in some treatments this has been reduced to four species, with *D. lyropetala* including two to three varieties.

To test the circumscription and phylogenetic position of the species within *Drymaria* series *lyropetala*, morphometric and molecular phylogenetic analyses were conducted including several individuals from all taxa in addition to representative species of other series within the genus.

Preliminary molecular studies using ITS, *matK, trnL-trnF, ndhF-rpl32* and a detailed morphometric analysis of 17 characters revealed two unresolved groups that include: 1) *D. coahuilana-D. lyropetala-D. pratheri*, and 2) *D. elata-D. suffruticosa-D. subumbellata.* The species in the first group have a much wider distribution than those in the second group. The lack of resolution within the first group corroborates the close relationships within the *D. lyropetala-pratheri-coahuilana* complex, which we suggest could be reduced to a single polymorphic species. Nevertheless, more population sampling and the use of other molecular markers more appropriate for population genetics are desirable before these taxonomic decisions are formally made.

This work is a first step to explore morphological and molecular characters to support future work aiming to solve the taxonomic problems within *Drymaria*.

Keywords
Caryophyllales, Chihuahuan Desert, Mexico, Sierra Madre Oriental.

Contrasting adaptative strategies and genetic variation in two dominant gypsophiles in response to drought.

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Gypsum soils in the Mediterranean basin house large numbers of gypsophiles, plants tightly restricted to gypsum soils that often lack effective dispersal mechanisms. Therefore, adaptive evolution and adaptive phenotypic plasticity might likely play a key role in the persistence of populations of these species under the increased aridity driven by climate change. While the presence of genetic variation in ecologically-important functional traits is the substrate for evolution through natural selection, adaptive phenotypic plasticity may equally buffer the impact of environmental change by providing rapid changes to the phenotype. Therefore, evaluating which traits are adaptive, the presence of genetic variation of such adaptive traits, and their plasticity is key to predict future responses of gypsophiles to climate change. We identified functional traits under selection, their genetic variation, and phenotypic plasticity in maternal families of two dominant Iberian gypsophiles grown in two contrasting and realistic watering conditions (well-watered and drought) using a common garden experiment. We randomly selected maternal families of *Centaurea hyssopifolia* and *Helianthemum squamatum*, measured a wide set of morphological, phenological and physiological traits clearly linked to drought response, and quantified reproductive fitness of each plant. Using phenotypic selection analyses, we identified adaptive traits in each experimental treatment, i.e. those influencing individual fitness. For both species, selection was stronger in the drought treatment, as shown by the higher number of traits under selection and the intensity of selection for such traits. However, the two species showed contrasting adaptive strategies to cope with drought. While *H. squamatum* showed an adaptive drought-escape strategy, with an advanced and extended reproductive phenology and faster growth rates associated with higher fitness, *C. hyssopifolia* exhibited a drought-tolerance strategy, showing thicker leaves that favored longer flowering and fruiting periods. Furthermore, we found genetic variation for several adaptive traits in both treatments in *H. squamatum*, but *C. hyssopifolia* lacked adaptive genetic variation in both watering conditions, indicating that evolution by natural selection may be limited in the latter. Finally, both species responded plastically to water stress, and we detected genetic variation for plasticity of most traits, indicating that adaptive phenotypic plasticity may evolve through natural selection as an adaptive response to cope with drought. Our results highlight that drought is an important selective pressure for gypsophiles, and that trait plasticity can evolve independently of the evolution of the trait mean in gypsophiles, contributing to improve our understanding of potential adaptive responses to climate change in these species.

Keywords
Genetic variation, gypsophiles, microevolution, phenotypic plasticity, phenotypic selection analyses.

Recent and ancient evolutionary events shaped the plant elemental composition of edaphisms. A phylogeny-wide analysis of Iberian and Chihuahuan Desert gypsum plants.

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The analysis of plant elemental composition and the underlying factors affecting its variation are a current hot topic in ecology. Ecological adaptation to atypical soils may shift plant elemental composition. However, few previous studies have evaluated its relevance against other factors like the phylogeny, climate or fine-scale soil conditions.

We evaluated the effect of the phylogeny, environment (climate, soil), and affinity to gypsum soils on the elemental composition of over 220 taxa typical of two key gypsum floras of the world: the Iberian Peninsula and the Chihuahuan Desert. We developed a new statistical tool (Multiple Phylogenetic Variance Decomposition, MPVD) to decompose total explained variance by different factors across all nodes in the phylogenetic tree of target species (covering 120 MY of Angiosperm evolution).

Our results highlight the relevance of phylogeny on the elemental composition of plants both at early (with the development of key preadaptive traits) and recent divergence times (with the diversification of Iberian and Chihuahuan gypsum floras concurrent with the aridification of the Miocene-Oligocene and the accumulation of gypsum deposits worldwide). Strong phylogenetic effects on the elemental composition of plants were also detected at the Eocene in the Chihuahuan gypsum flora, matching an important period of plant diversification in the Chihuahuan Desert concurrent with the formation of extensive gypsum deposits in this area. Despite the predominant phylogenetic effect, plant adaptation to gypsum soils had a strong effect on the elemental composition of plants, particularly on S concentrations.

Widespread gypsophiles (*i.e.* plants belonging to a lineage restricted to gypsum with a broad geographic distribution) of different lineages converged on increased S, Mg and, to a lower extent, Ca foliar concentrations.

Are phylogenetic and functional distance good predictors of plant-plant competition? A common garden experiment with Mediterranean shrub species

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Mediterranean shrublands that develop on basic substrates in the centre of the Iberian Peninsula stand out for their high diversity (up to 48 species in less than 64 m²). This is remarkable because these communities develop in habitats subjected to strong climatic and edaphic restrictions, which cause a strong species filtering resulting in similar functional patterns. In this context, biotic interactions are likely to be intense and main determinants of community assemblage and it would be expected that negative interactions such as competition would prevail. Therefore, more closely related species are expected to compete more intensively as they tend to have more similar trait values and use resources in a more similar way. In addition, the increased constraints posed by droughts may strengthen these plant-plant interactions. We conducted a common garden experiment to test whether the intensity of competition between individuals of 20 Mediterranean shrub species was determined by their degree of similarity (both phylogenetic and functional) and whether such competitive interactions were exacerbated under a drought treatment. To estimate the intensity of competition, we measured traits related with growth (biomass) leaf morphology (specific leaf area; SLA, and leaf dry matter content; LDMC) and physiological (chlorophyll fluorescence, Fv/Fm) in four focal species (*Helianthemum hirtum, Thymus vulgaris, Koeleria vallesiana* and *Helichrysum serotinum*) growing in pots either alone, with a conspecific neighbour and with a neighbour belonging to up to 16 different species from 13 different families. Although each focal species was affected by functional and phylogenetic similarity in different ways, highlighting the complexity of plant-plant interactions, certain general patterns emerge. The intensity of competition between individuals of the same species was always higher. Competition intensity was also slightly higher between species from the same family, but no effect of similarity on competition intensity was detected with species from other plant families. Individuals under the drought treatment were more stressed (lower Fv/Fm), showed lower biomass and produced leaves consistent with adaptive plastic responses to drought (lower SLA and higher LDMC). We found that under increased drought conditions, realized niches became narrower and the intensity of plan competition is exacerbated regardless of the functional similarity of neighbours. Our results provide important insights into the competitive patterns driving the structure of Mediterranean dwarf-shrub communities. Some niche differentiation remains despite the intense abiotic filter on the species assemblage, allowing species to grow within short distances.

Keywords

Competition, functional similarity, gypsophiles, phylogenic relatedness, plant interaction.

Niche evolution in the Nyctagineae: a group with an ancestral affinity for gypsum?

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Nyctaginaceae tribe Nyctagineae comprises 12 genera and approximately 200 species of herbs and shrubs with a global distribution but with a center of diversity in arid and semi-arid regions of southwestern North America. Gypsum endemism is remarkably common across Tribe Nyctagineae, with at least 13 species confined to gypsum; these 13 species are found in North America and in the Horn of Africa region, and represent 5 of the 12 genera. Moreover, there are two clades of gypsum endemics known in Nyctagineae (within the genera *Acleisanthes* and *Anulocaulis*), and in any area of gypsum soils where Nyctagineae occur, essentially all local species of Nyctagineae may be found growing on gypsum (whether they are endemics or not). Here we reconstructed a nearly complete (~85% of species) species-level phylogeny of Nyctagineae using nuclear ITS and plastid spacer regions in an effort to understand the evolution of gypsum endemism across the tribe. We then used the resulting trees to reconstruct niche evolution in the tribe for key climate and soil variables to explore correlations between gypsum affinity and abiotic niche variables. For niche evolution analyses, occurrence data from iDigBio, GBIF, and SEINet for all taxa were downloaded and cleaned for poor-quality data. Then, 19 climate variables from the Worldclim database and 11 soil variables from the ISRIC-World Soil Information database were extracted for every occurrence point and mean values were calculated for each taxon, for each variable. Niche reconstructions for each variable were conducted on the phylogenetic trees using ape and PHYtools in R. We found a minimum of 8 origins of gypsum endemism across Nyctagineae on two continents. Variables related to temperature often exhibited high variability across the phylogeny, but precipitation variables were much less variable, suggesting that drought tolerance may be a key adaptation for the tribe. Among the soil variables, a relatively high soil pH was correlated with gypsum endemism. Although preliminary, evidence on foliar gypsum biomineralization is also presented, demonstrating that the ability to synthesize gypsum crystals in leaves may be at least partly responsible for the strong affinity of Nyctagineae to gypsum soils.

Keywords
Caryophyllales, gypsum, niche evolution, Nyctaginaceae, Nyctagineae, phylogeny, soils.

ORAL SESSION II

Searching for lichen gypsophiles: checklist and substrate affinities

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Lichens are one of the dominant life-forms in Biological Soil Crust communities in gypsum ecosystems. These organisms play important roles in driving ecosystem function and providing ecosystem services. Although there are numerous studies focused on these organisms, their taxonomy, ecology, or functionality, until the moment, there are no studies compiling lichen species present in gypsum ecosystems. Additionally, the affinity for the gypsum substrate has been treated scarcely. To solve these gaps, we have compiled a worldwide checklist of lichen species growing on gypsum soils and analysed their affinity for gypsum substrate. Two bibliographic databases (Web of Science and Matticks) were used employing different keywords in the search (i.e gypsum, gypsiferous, etc.). Additionally, bibliographic information from countries with gypsum soils was also revised. The specificity for the gypsum substrate was also analysed for the most represented species from gypsum soils in the Iberian Peninsula (ca. 50 species), based on GBIF and IGME data and employing ArcGis software. A total of 323 articles were checked, containing 5979 records of lichen species growing on gypsum soils from 26 countries. These records correspond to a total of 339 lichen species. These results show major differences in species composition and richness between countries. Spain and Germany are the countries with more lichen species growing on gypsum (162 and 114 respectively), followed by Italy and Poland (61 and 53 species). Outside Europe, only a few countries have a significant number of species such as the United States and Morocco with 44 species or Iran, with 37. It is important to highlight the low or absent number of species found from southern hemisphere countries (i.e. Argentina, Australia, Chile, South Africa), except from Namibia (26 species), reflecting the lack of studies in these gypsum lands. At a worldwide level, *Squamarina lentigera* (369 records), *Psora decipiens* (356) and *Diploschistes diacapsis* (304) are the most represented species from gypsum soils. The analyses of the affinity for the substrate showed differences in the species gypsum affinities ranging from strict gypsophiles to gypsovags. However, other species are not specialists and occur accidentally on gypsum substrates. This checklist is an important tool for the study of biodiversity and further ecological and biogeographical studies. The analysis of the affinity for the substrate provides a detailed list of species ranked by their percentage of occurrence on gypsum soils, and supports the existence of lichen gypsophiles.

Keywords
Database, gypsophiles, gypsovags, gypsum, lichen checklist.

Aridity and gypsum type shape the gypsophyte communities of the Chihuahuan desert

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Plant establishment and distribution are highly determined by abiotic factors like substrate and climate. Therefore, different and limiting soil characteristics and climates will impose different restrictions, resulting in the differentiation of plant communities. Gypsum soils are an outstanding study system to test the effect of these factors on the plant communities of gypsophytes due to their restrictive chemical and physical characteristics and the arid climate they are distributed.

In this study, we described gypsum plant communities along a latitudinal and climatic gradient in the Chihuahuan Desert, the most biodiverse desert in America that harbors the largest gypsum areas and diverse flora of gypsophytes. We identified the effect of the substrate type (sand or consolidated rock) and aridity (relation between average monthly precipitation and temperature) on plant diversity. We hypothesized that more limiting conditions (i.e. higher aridity and sandy soil) will imply a lower plant diversity. We recorded species' identity and their cover percentage and obtained the aridity index from 196 subplots within 32 plots in five localities from south USA to northern Mexico. The taxonomic (richness, inverse Simpson index, and evenness) and phylogenetic (Rao, mean pairwise distance, and the mean nearest taxon distance) indexes were obtained. To test whether environmental variables and their interaction are key factors on community diversity, we fitted LMMs and GLMMs, and permutational analysis test (PERMANOVA) to recognize the effects of aridity and substrate type on species composition.

We identified 155 taxa from 84 genera and 41 families. Richness ranged from 1 to 15 species per subplot. The PERMANOVA showed differences between localities. Generalized linear mixed models showed a negative and significant effect of aridity on the inverse Simpson index, a positive one on evenness, and none on the phylogenetic indexes. Substrate type had a significant negative effect on richness, evenness, inverse Simpson, and Rao. Thus, sandy substrates showed less species, evenness, and phylogenetic diversity, than those on consolidated rock, probably due to the dynamic nature of the sand. Sand is a poorly consolidated soil, which could result in poor water retention, the lack of deposition of organic matter and thus a poor nutrient availability, factors that can affect root and plant establishment.

We conclude that aridity and substrate type seem to be strongly shaping communities of gypsophytes along the latitudinal gradient in the Chihuahuan Desert.

Why does the world's main producer of gypsum (China) have almost no gypsophytes?

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China is the world's main producer of gypsum, and has the largest concentration of gypsisols of any country. China is also one the largest countries of the world in terms of land area (second, with ca. 9.3 million km^2) and plant diversity (third, with ca. 33,000 vascular plants). Unexpectedly, the reported number of gypsophytes (plants growing exclusively on gypsum) and species linked (to any degree) to gypsum substrates is very low (1). The simplest explanation is that China has actually a very poor gypsum flora, which could be due to a series of reasons that may include: (i) the areas where gypsum soils are concentrated (the western provinces of Xinjiang, Qinghai, Inner Mongolia, and Gansu) have been particularly instable since the Pliocene, having favoured flora extinction processes; and (ii) these gypsum-rich areas are characterized by low ruggedness and small environmental (climatic) gradients, factors that are generally associated to diversification events. Alternatively, the Chinese gypsum flora would be richer, and the low number of reported gypsum plants could have multiple reasons including: (i) the fact that gypsum areas are far away from the main China's biodiversity hotspots (subtropical and tropical areas of central and southern China, which are the areas that receive by far more attention from botanists); (ii) the geographic remoteness of most gypsum areas, which are located hundreds (if not thousands) of km from the main Chinese academic and research centers; (iii) the view that floristic studies are "old-fashioned", which make most young and middle-aged (Chinese but also foreign) scholars to focus their research efforts on other "more fashioned" fields such as genetics/genomics or ecology; (iv) the difficult access to many original sources by the foreigners, which are often only in Mandarin; and (v) the conflicting political situation of some areas (e.g. riots in Xinjiang and Qinghai), which may pose an additional barrier to doing floristic studies in these areas.

Keywords
China, floristic richness, floristic studies, gypsophytes, remoteness, old-fashioned.

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ORAL SESSION III

Plant communities patterns in Sicilian gypsum outcrops

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The relationship between soil and vegetation has always drawn the attention of researchers, particularly for those substrates that place severe limits on plants, such as the gypsum substrates. In this study, we analyze the specificity of gypsum outcrop vegetation of Sicily with the aim to assess the role of gypsophytes in the gypsum community and improving the knowledge about this vegetation on which conservation efforts need to be addressed.

Gypsum outcrops are quite widespread in Sicily, especially in the central and southern part, where constitute ecological "islands" in the environmental matrix of "gessoso-solfifera" substrates such as marls, clays and various types of limestone. The vegetation survey was carried out with the phytosociological approach. The plant community assemblages were classified using PC-ORD 4.34 software. A hierarchical Cluster Analysis was performed.

Several plant communities are characterised by gypsophyte as ephemeral therophytic vegetation with *Chaenorhinum rupestre*, the rock communities with *Sedum gypsicola* subsp. *trinacriae* and *Petrosedum ochroleucum* subsp. mediterraneum, the chasmophytic cliffs vegetation with *Brassica villosa* subsp. *tineoi* and the bryophyte community with *Tortula revolvens*.

The rule of gypsophytes (distinguishing narrow and wide gypsophyte, gypsovag and accidental) to biodiversity of each plant communities was evaluated with the Shannon index.

Overall we found that gypsophytes are relevant in plant communities growing directly on gypsum or on thin layers of lithosol poor-nutrient, in low productive and most stressful environments, while on more developed soils the role of gypsophytes in the vegetation is not very important.

Gypsum plant communities allow us to recognize and characterise the gypsum habitat in Sicily, to assess the conservation status which is threatened by justifying its inclusion in the European red list of habitats

Keywords
Gypsum outcrops, habitat, plant communities.

GYPWOOD: A research project to study plasticity and phenotypic variation in wood anatomy of gypsum chamaephytes in response to drought

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Semiarid ecosystems are highly vulnerable to expected changes in climate, particularly to increasing aridity due to climate change. In many cases, plants could respond by adjusting their distribution ranges, but migration will be strongly limited in edaphic specialists linked to particular substrates. This is the case of plant communities living on gypsum soils. Gypsum outcrops usually occur under arid and semiarid climates and the plant communities they hold are highly diverse and include large numbers of endemics that could be negatively affected by climate change. Some gypsum specialist chamaephytes are highly plastic in their physiological and phenological responses to drought, but the response of their hydraulic system is still unknown despite it is key to face cavitation, the main physiological risk derived from water scarcity.

To fill this gap, we are starting a recently funded project in which we will use quantitative wood anatomy to (1) explore the range of variation in wood anatomy of wide gypsophiles, narrow gypsophiles and gypsovags across environmental gradients in the Iberian Peninsula; (2) determine the plastic response to drought of wood anatomy in two wide gypsophiles, *Helianthemum squamatum* and *Lepidium subulatum*, and its variation among populations coming from contrasted climatic conditions; and (3) assess the phenotypic integration of wood anatomy with other phenotypic traits in natural populations of different species, as well as the plasticity of integration in response to drought in *H. squamatum* and *L. subulatum*. These aims will allow us to test several hypotheses related to intra-specific and intra-generic adjustments to increasing aridity levels.

We will measure different functional traits related to drought response, and will collect the root collar of individuals from different gypsophile and gypsovag species across their distribution ranges. Root collars will be processed following standard procedures to obtain and digitize histological preparations that will allow us analyzing their quantitative wood anatomy, including lumen size, density and grouping of conductive vessels, as well as estimated hydraulic conductivity. We will also collect *H. squamatum* and *L. subulatum* individuals from two common garden experiments designed to test their respective plastic responses to drought and their root collars will be processed in a similar way.

Results of this project will provide answers to relevant questions in the current context of climate change and biodiversity loss, allowing the development of management actions to favor the conservation of these highly diverse communities that are considered as a Priority Habitat (1520) by the European Union.

Keywords
Gypsophiles, gypsovags, *Helianthemum squamatum*, *Lepidium subulatum*, phenotypic integration, phenotypic plasticity, quantitative wood anatomy.

Nitrogen trade between plant species with different phenology

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Plants can exchange resources, potentially covering plants' demands during periods of scarcity. This study firstly tested whether N is redistributed among plant species based on their nutritional temporal demand (i.e. phenology). Field 15N labelling experiments showed that 15N is transferred between neighbor plants, mainly from low N-demand (late flowering species, not growing yet) to high N-demand plants (early flowering species, currently flowering-fruiting). Considering segregation in plant species' phenology is a world-wide pattern in many ecosystems, this can be a key overlooked ecological process in community ecology and ecosystem functioning.

Keywords
Plant community ecology, N transfer, phenology, Nitrogen demand, stable isotopes, plant cooperation.

ORAL SESSION IV

When disturbances favour species adapted to stressful soils: grazing may benefit soil specialists in gypsum plant communities

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Herbivory and extreme soils are drivers of plant evolution. However, little research has been done on the effect of grazing on plant communities rich in edaphic endemics in extreme soils. We evaluated the effect of different grazing intensities on the assembly of perennial plant communities growing on gypsum soils. We considered the contribution of species gypsum affinity and key functional traits of species such as traits related to gypsum specialisation (leaf S accumulation) or traits related to plant tolerance to herbivory such as leaf C and N concentrations. The effect of grazing intensity on plant community indices (i.e. richness, diversity, community weighted-means (CWM) and functional diversity (FD) indices for each trait) were modelled using GLMMs. We analysed the relative contribution of interspecific and intraspecific trait variation (ITV) in shifts of community index values. Livestock grazing may benefit gypsum plant specialists during community assembly, as species with high gypsum affinity, and high leaf S contents, were more likely to assemble in the most grazed plots. Grazing also promoted species with traits related to herbivory tolerance, as species with a rapid-growth strategy (high leaf N, low leaf C) were selected under high grazing conditions. Species that eventually formed gypsum plant communities had sufficient functional variability among individuals to cope with different grazing intensities, as intraspecific variability was the main component of species assembly for CWM values. The positive effects of grazing on plant communities in gypsum soils indicate that livestock may be a key tool for the conservation of these edaphic endemics.

Keywords
Edaphism, functional diversity, gypsophile, gypsovag, gypsophily, intraspecific variability, mineral nutrition, plant–herbivore interactions,

Soil CO$_2$ efflux dynamics from different ground covers over gypsiferous marls

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Quantification of carbon balance in terrestrial ecosystems is necessary to understand the global carbon balance and for the adequate management of these systems. However, there is a high uncertainty in current estimations largely due to the limited knowledge of the contribution of respiratory activity to net carbon exchange. Soil respiration is the dominant contributor to total ecosystem efflux, but the biotic and abiotic factors that control this process are not completely understood, and the information is particularly limited for drylands. In these environments, plant patches are interspersed in a soil matrix often colonized by biocrusts. These are communities of cyanobacteria, algae, fungi, bacteria, lichens, and bryophytes that live in the soil surface intimately associated with soil particles and have a key role in soil CO$_2$ exchange. However, their effect on CO$_2$ fluxes may greatly depend on the biocrust type and the soil type. While biocrust effect on soil CO$_2$ efflux over limestone soils has been more often reported, information over gypsiferous soils is scarcer. The objective of this study was to analyze soil CO$_2$ efflux in two biocrust types, cyanobacteria- and lichen-dominated biocrusts, and compare it with bare soil and soil under plant, over gypsiferous soils in a semiarid ecosystem in SE Spain (Tabernas Desert, Almeria). Soil CO$_2$ molar fraction (χ_s) was recorded at 2 cm and 5 cm soil depths below each surface cover with solid-state sensors and the CO$_2$ efflux (F_s) from the 0-5 cm soil was determined using the gradient method. Our results show that moisture exerted a first-order control on F_s. Thus, F_s rapidly increased after rainfall and then gradually decreased as soil dried out. The highest F_s was observed following the first rainfalls after the summer period, and showed lower values in the next rainfalls due to substrate consumption. F_s followed the trend: soil under *M. tenacissima* > lichen > cyanobacteria > bare soil. However, during small rainfalls occurring in spring, biocrusts were more responsive to rainfall than vegetation and showed the highest F_s. The response of F_s to moisture and temperature depended on the ground cover and soil moisture stage. Moisture exerted a greater influence on F_s in lichen and soil under grass, while temperature had a greater effect on F_s in cyanobacteria and bare soil. Our findings support the use of high-frequency measurements to characterize rapid responses of soil CO$_2$ efflux to changing environmental conditions, and the necessity of accounting for the different representative ground covers from drylands for a more accurate estimation of carbon balance in these regions.

Keywords
Carbon balance, cyanobacteria biocrust, drylands, lichen biocrust, *M. tenacissima*, soil respiration.

"The Good Neighbour": *Erodium cicutarium* determines annual species assemblages at fine spatial scales in gypsum systems.

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Unravelling mechanisms involved in species coexistence is a key topic in vulnerable Mediterranean gypsum systems. Water and light availability are known to act as primary abiotic filters in plant community performance, while plant-plant interactions determine the species assembly processes at fine spatial scales. However, it is still not clear if there is any key species of the plant community that shapes plant-plant interactions at fine spatial scales and to what extent this effect would be modulated by abiotic conditions. Annual plant communities are excellent models to experimentally evaluate coexistence mechanisms because of the small size and short life cycle of participant species, which allows to easily manipulate entire communities. The aim of this study was to evaluate the effect of *Erodium cicutarium* as a key component of our study system, combined with light and water availability scenarios on taxonomic, functional, and phylogenetic diversities, by manipulating the densities of this species, along with abiotic conditions, in natural annual plant assemblages. We selected *E. cicutarium* because, despite its well-documented competitive ability (even invasive), little is known on its effects as a native plant. We assessed the functional diversity of six traits involved in leaf economics spectrum (specific leaf area and leaf dry matter content), competitive ability (maximum plant height and root:shoot ratio) and reproductive traits (seed mass and reproductive ratio). High densities of *Erodium* within assemblages induced changes in the species composition of the neighbour plants, and promoted higher taxonomic diversity, especially under unfavourable conditions (shade and drought). When average irrigation conditions were combined with shadow, high densities of *Erodium* resulted in a phylogenetic divergence of the assemblage, and a higher functional diversity of the reproductive ratio. These results suggest that limiting similarity among coexisting species could be the main ecological process in restrictive light availability conditions, probably driven by traits related to the photosynthetic efficiency. Conversely, when the average irrigation was combined with full light conditions, high densities resulted in a phylogenetic convergence, which suggests that in most benign conditions species of certain clades (i.e., Poaceae and Asteraceae) were able to take advantage and became dominant in the assemblage. To sum up, we found that, unlike the effect of *Erodium* in exotic systems, in native communities it promoted species coexistence. This positive effect could be mediated not only by indirect interactions via competition of *Erodium* with dominant species, which may promote species evenness but also by direct positive interactions with neighbours.

Keywords
Coexistence, Functional diversity, Phylogenetic diversity, Plant-plant interactions, Taxonomic diversity.

An approach to the mechanisms of use of gypsum crystallization water by plants

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Water is one of the most limiting factors for plant survival in the atypical gypsiferous soils. However, gypsum contains two water molecules in its crystalline structure prone to be used by plants during the driest season (Palacio *et al*, 2014; Palacio *et al*, 2017; de la Puente *et al*, 2021). The mechanisms behind this water up-take process have not been described yet, but it has been suggested that it could involve dissolution processes (Huang *et al*, 2020) due to root exudation or microbial activity. The principal objective of our study was to corroborate the use of this crystallization water by *Helianthemum squamatum,* grown in pots. We also studied root exudation, soil microbial composition and plant physiological parameters (transpiration, stomatal conductance, assimilation rate and water use) of the plants to gain knowledge on the processes related to gypsum crystallization water use.

Plants were subjected to two crossed treatments: a labelling treatment; in which plants were grown in a gypsum soil whose gypsum crystallization water was enriched in deuterium, and, a drought treatment, in which plants were subjected to a progressive decrease in water supply during 23 days. We analysed the isotopic composition of water in the xylem sap of plants and in the soil extracted in a vacuum cryogenic distillation line. Plants physiological status was analysed with an infrared gas analyser and monitoring. Plant water use through the weight of pots during the drought treatment. Phospholipid fatty acid (PLFA) analyses were used to estimate microbial biomass and root exudations were extracted following the method in Teodoro *et al*, (2019) and analysed with UHPLC/Q-TOF-MS.

The isotopic composition of the xylem sap varied between substrate conditions, drought treatments and their interaction. However, values of xylem water of all plants fully aligned with the evaporation line of free water, ruling out the possibility of crystallization water use by these plants. In addition, the labelling treatment of the soil led to a partial sterilization of the soil. Differences between experimental soils also caused different patterns of responses to drought, root exudation and photosynthesis in labelled pots. Drought had a significant effect on certain root exudate production and on the abundance of AMF.

These results call for caution in the interpretation of Bayesian Mixing Models, which should be carefully contrasted with the biplot δ^2H-$\delta^{18}O$ of sources and consumers, as this method could lead to the wrong choice of sources used by plants. We compare our results with previous studies on the same species conducted in the field and conclude that the factors that allow the crystallization water uptake by plants during a long drought period in the field were not satisfactorily reproduced in our pot experiment. In particular, the effect negative of both drought and D-labelling on AMF communities could be behind the observed results

Keywords
Crystallization water of gypsum, drought, stable isotopes of water, water sources.

Ecohydrological niche segregation among coexisting C₃ and C₄ desert shrubs in a gypsum-calcareous formation (NW Iran)

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Xerophilic desert shrubs belong to multiple functional types and frequently show hydrological niche segregation. The understanding of water use in such co-occurring species is crucial to predict climate aridification impacts on desert ecosystems. This is in particular the case for the Irano−Turanian gypsum deserts - highly biodiverse but at the same time vulnerable and poorly studied ecosystems.

We aimed to unravel the ecohydrological strategies of five co-existing desert shrubs growing in gypsum deserts in NW Iran.

Soil and xylem sampling for isotope analyses was performed in spring and summer. Xylem and soil water extraction was performed by cryogenic vacuum distillation. Oxygen and hydrogen isotope composition were determined. Statistical analyses were run to determine the ecohydrological strategies of the investigated species.

Species-season interactions could explain differences in xylem sap isotopic composition. Plant gypsum affinity and photosynthetic pathways did not have a significant effect on the water use strategies. Three basic water use strategies relying on contrasting utilization of free topsoil moisture and deep soil water have been revealed in the different species.

Water use strategies in Iranian desert shrubs may vary dramatically even in closely related congeneric species. Further studies on the poorly studied xerophilic Irano−Turanian eudicots are necessary to fully understand their ecohydrological strategies.

Keywords

Caryophyllales, desert shrubs, gypsum, Iran, niche segregation, stable isotopes, water use.

Changes in facilitative interactions in contrasting stress environments (gypsum and limestone). A model for understanding how traits and environments influence facilitative interactions

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Facilitative interactions are those in which one species (nurse) alters the environment in a way that enhances the performance of a second species (facilitated). These positive interactions bind community species in intricate ecological networks, helping preserve species otherwise lost. Ecological networks are useful tools that synthesize, in a static picture, how interactions are organized in biological communities. However, species interactions in nature can be complex and fluctuate depending on the ecological context. Analyzing the patterns that cause these shifts can reveal whether they are predictable based on the traits of the interacting species and the local environmental contexts in which they occur. Here, we explore how abiotic stress derived from growing in stressful gypsum outcrops constrains those shifts compared to less stressful communities developed in the contiguous limestone areas. Specifically, we hypothesize that the rewiring of facilitative interactions is more limited in stressful than in mild environments. We present evidence of a distinct pattern in the rewiring of facilitative interactions in two types of edaphic environments with contrasting stressful conditions. In gypsum environments where there is a firm reliance on facilitation, rewiring is limited to recruiting beneath nurse species with traits that enable them to overcome gypsum's harsh stressful conditions. However, when environments show milder abiotic conditions (i.e., limestones), rewiring is more flexible, though it is still constrained to recruit under species phylogenetically closer to the common nurses of each facilitated species. This understanding may help us predict how different communities may respond to perturbations.

Keywords

facilitation, functional constraints. gypsum, networks, phylogenetic constraints, rewiring, species turnover.

How plant-microbial interactions affect water and nutrient dynamics in semiarid environments and its implications on plant performance and plant-plant interactions

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Despite the known relevance of plant-microbial interactions in arid and semiarid ecosystems, it is less clear to what extent they buffer variation in nutrient and water availability, which could decouple plant-access to resources from precipitation pulses. Here, we explore the potential buffering effect of mycorrhizal fungi and biocrusts on the variability of nutrient and water availability to determine how they can influence plant dependence on precipitation patterns and how this conditions plant performance and plant-plant interactions mediated by nutrient transfer. To evaluate the role of mycorrhizal fungi and biocrusts, we will compare plant performance (water and nutrient content) and N transfer between plants in the presence or absence (reduced abundance) of microbiota. Under field conditions, we selected vegetation patches with a focal species growing in a patch and growing alone nearby (<1 m) on both bare soil (less biocrust) and on soil with a greater abundance of biocrust and compare plant performance as well as N transfer between plants in the presence or absence (or reduced abundance) of mycorrhizae and under two different scenarios of water variability (constant and variable). We expect that a greater presence of microbiota would have a buffering effect on the variability in nutrient and water availability leading to improved plant performance and a decrease in N transfer given that more transfer is expected with contrasted nutrient content between plants which is more prone to occur in more variable environments.

Keywords
Biocrusts, facilitation, gypsum, mycorrhizal fungi, plant-microbial interactions, pulse-dynamics, semiarid ecosystems.

ORAL SESSION V

Effects of pollination and abiotic stress on plant-facilitation interactions

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A constant water availability can enhance plants' flowering period, so the plants flowering sequentially tend to overlap. A higher overlap may affect plant-plant interactions mediated by pollinators, resulting in either facilitation or competition. We tested whether a constant water availability results in higher flowering overlap, promoting stronger plant-plant interactions mediated by pollinators. Under field conditions, we selected vegetation patches that harbour two plant species with sequential phenology. We randomly assigned these patches to two different water treatments, variable and constant, and we monitored the phenology weekly. In order to assess whether flowering overlap promotes stronger plant-plant interactions, we compared the pollination visits in a focal plant in each vegetation patch and a conspecific growing isolated close to it. We expect that constant water availability enhances flowering overlap between the two species in the patch, resulting in a more contrasted pollination visit rates between the conspecific plants growing in the vegetation patch and alone. Finally, a higher visit rate in the associated plant compared to the isolated one will suggest facilitation mediated by pollination, while a lower rate will suggest competition. Our results could highlight that studying single ecological interactions may provide unrealistic outcomes because ecological interactions can interact among them.

Keywords
Ecological interactions. competition, facilitation, pollinators.

Functional diversity of experimental assemblages drives annual plant species responses to biological soil crusts in gypsum systems

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Biological soil crusts (BSC) form a very conspicuous, lichen-dominated biotic layer on gypsum soils in drylands. Previous studies in these systems pointed to multiple, even opposite effects of BSC on plant assembly, depending on species identities, phenological plant phase, functional traits and BSC disturbance level. Nevertheless, there still remain several controversial and poorly understood aspects. For instance, to what extent do physical *vs*. chemical effects of BSC participate in plant assembly processes? and how does BSC interact with the functional properties of the species assemblage to determine subsequent dynamics of coexisting species?

Our aim is to assess mechanisms driving the assembly of gypsophilous annual plants, and how this process can be modulated by the so widespread BSC with contrasting functional structure of the trait maximum plant height (MPH). We turned to an experimental approach by manipulating the initial functional diversity of the trait MPH of the entire annual plant community in a common garden trial along with BSC conditions. We set three functional diversity scenarios based on the trait MPH and three BSC disturbance scenarios in a complete factorial design. We manipulated the initial plant species composition of experimental assemblages by sowing 20 seeds of six species per pot as follows: 1) all coexisting species were large sized, 2) small sized, or 3) had a wide range of plant sizes. The BSC disturbance scenarios in pots consisted of 1) intact portions of BSC, 2) tiny fractions of BSC resulting from the mechanical disaggregation and 3) bare soil. Our results showed that lichen dominated BSC strongly affected the assembly of gypsophilous annual plants in a complex, multifaceted manner, because of shifting effects throughout the plant life cycle, with opposed consequences for plant performance. We demonstrated that BSC act as a physical barrier for annual plant establishment, which may represent a source of substantial stochasticity for plant assembly at a heterogenous fine spatial scale. However, once annual plants establish, BSC facilitates plant growth and fitness. Chemical effects were only detected in the establishment of large size scenarios. Importantly, we found evidence that the own functional diversity structure of the community, may also drive the assembly process, by activating alternative coexistence mechanisms such as niche partitioning or competition symmetry, depending on BSC conditions and on species identity. Our study highlights the complex relationships between these two conspicuous biological components of gypsum systems, and draws the attention to the role of intrinsic functional properties of species assemblages to drive assembly processes.

Keywords

Experimental assemblages, functional diversity, gypsum soil system, maximum plant height, niche complementarity, competition symmetry, plant-lichen interaction.

Livestock grazing and aridity trade-offs on the conservation and forage quality of gypsum rangelands (NE Spain)

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Rangeland-based livestock production constitutes elemental livelihood for many people inhabiting gypsum environments in drylands. Their subsistence heavily relies on the maintenance of the ecosystems productivity, biodiversity and the services they provide. However, there is still not enough evidence of the interactive effects that livestock grazing and aridity have on their conservation. In this work, we assessed the simultaneous effects of livestock grazing and aridity on the conservation (i.e., community structure, diversity and biomass), productivity and forage quality (i.e., forage C:N ratio and fiber composition) of semi-arid gypsum rangelands, NE Spain. We found that increasing livestock grazing level lead to a reduction in community plant cover, thus enhancing semi-arid Mediterranean rangelands vulnerability to land degradation, especially under more arid environments. However, we did not find any adverse effect of livestock grazing on plant community structure (e.g., woody encroachment) nor plant species richness (e.g., most palatable species extinction), although increasing level of grazing by domestic livestock caused changes in plant species composition. Finally, we found out an aridity driven trade-off between forage C:N ratio and forage fiber index and that, interestingly, livestock grazing modulated it by improving forage nutritional value. Altogether, our results provide further insights about the proper management of semi-arid gypsum rangelands, pointing out that the maintenance of traditional livestock loads can be a suitable option proven that rangelands conservation is not severely affected.

Keywords
Plant community structure, plant community composition, pasture quality, rangeland management, structural equation model (SEM),

Comparative study of three methods for the determinaton of gypsum content in soils

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Many studies on gypsum plants or gypsophytes make estimates about the gypsum content of the soils to which these plants appear associated. However, few individualized analyzes have been carried out on this important parameter.

The analysis of different methods for determining the gypsum content of soils is of great interest in this area, but the absence of comparative studies between them makes it difficult to discriminate one in favor of the other. For this reason, in this study it is proposed to carry out a comparison between two methods of analysis; the Thermogravimetric method and the Bassanite method against the use of a halogen moisture analyzer HX204, highly recognized and used by different professionals and companies due to its great reliability. Five soil samples associated with the presence of gypsophila plants were taken and the respective protocols were carried out, using for each case a series of soil samples sifted through a <2mm sieve and another series of samples grinded by a RETSCH MM 400 grinder. The gypsum levels obtained showed that the thermogravimetric method, even though it is the oldest, provided similar results to a greater extent to those provided by the HX204 halogen moisture analyzer, establishing significant differences with respect to the Bassanite method. Thus, the variation between the halogen analyzer and the thermogravimetric method ranges between 3%-7%, while if we compare the Bassanite method and the halogen the variation is between 10%-14%. Simultaneously, a second comparison was established that determined that the results are more reliable when sifted soil samples are used. The results obtained in this work could facilitate the study of soils rich in gypsum in a specific way and thus allow users to dispense with estimates that falsify the results.

Keywords

Bassanite method, gypsophytes, gypsum content, halogen moisture analyzer HX204, thermogravimetric method.

Selection of a reserve network using the checklist of the intermountain west gypsophytes (North America)

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In recent years, enormous advances have been made in understanding the ecology, distribution and evolution of gypsophytes all around the world. In North America, important gypsum outcrops are present to the southwest. These gypsum habitats in western North America face the same conservation problems reported throughout the world. For example, Utah is known to have significant gypsum outcrops, which have several endemic and rare species.

Despite the importance of gypsum species for conservation, available information on these gypsophytes is scattered throughout the literature, and in many ways is imprecise and scarce. In this work, our main objectives were: 1. To compile the available information on the plant species living in gypsum outcrops within the Intermountain West biogeographical region. 2. To perform a map of richness of these gypsophytes. 3. To do a selection of a reserve network using the checklist of the intermountain west gypsophytes (North America).

The floras of the states of Colorado, Arizona and Utah were consulted for the checklist, as well as the Intermountain Flora and other sources. Presence data for both gypsovags and gypsophytes were taken from the Intermountain Region Herbarium Network (http://intermountainbiota.org/portal/Web) and GBIF (Global Biodiversity Information Facilities in http://www.gbif.org/). Moreover the locations of some gypsophytes visited in 2018 throughout the Intermountain have also been used.

After the bibliographic review we have compiled about 122 species that show some preference for gypsum soils, of which nearly a third are restricted to them. All this information has been georreferenced and we have calculated a richness map for all the gypsophytes using 10-km-side MGRS (Military Grid Reference System) grids as OGUs (Operational Geographical Units).

For the spatial analysis of the distribution of this flora, the concept of richness was used, as well as the MARXAN program for the selection of reserves. In this case the OGUs (Operational Geographical Units) were grids of 10 km. In total, gypsum flora was recorded in 2005 OGUs. The grids with greater richness were 29 gypsophytes. The analysis with MARXAN selected 33 OGUs for the best solution.

Gachsaran formation: The largest area of gypsum outcrops in SW Iran with unique flora and vegetation

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Gachsaran formation stretches from the border of Iran-Iraq to the north-eastern end of the Persian Gulf, in the southern foothills of Zagros Mountains with c. 1300 km long. The formation has an exposure area of 20.400 km^2, comprising 25.3% of the total gypsum outcrop of Iran. This large geological body is characterized by outstanding geological, economical and socio-biodiversity features. The name of this formation comes from the city of Gachsaran in Kohkiloyeh va Boyer Ahmad Province meaning "the Land of Gyps". The largest oil reservoirs of Iran are located in this area. The nomadic lifestyle is a main socio-economic feature links with rich herbal and ephemeral vegetation during moist season and poor vegetation during hot season pushing the people to move their herds to the milder area of the Zagros highlands. Although the area of "Gachsaran formation" is smaller than "Upper-Red formation" in Northern Iran (comprising 73% of the Iranian gypsum outcrops), the Gachsaran is unique by large area of almost pure gypsum outcrops, large rocky gypsum mountains, well developed arboreal vegetation and well-developed biological crust.

Despite good data on the flora of the area, there is almost no study on the extend of many endemics, vegetation and characterization of gypsophily among large number of species growing in the region. What makes this area of high interest is occurring large number of endemic species from several lineages of vascular plants. Some of these species have been recently described with very limited distribution range. We visited three permanent karstic lakes in the area with beautiful rich-vegetation. The vegetation of the area consisted of open Almond shrubland (*Prunus scoparia*/*P. arabica*) and several communities dominated by subshrub species including *Physorhynchus chamaerapistrum, Pteropyrum naufelum*, *Platychaete aucheri*, *Ebenus stellata*, *Astragalus baba-alliar* and *Pycnocycla caespitosa*. The ephemeral and annual flora is rich with many species belonging to grasses and legumes. The vegetation of the three studied wetlands in the area is well correlated with water salinity. In all three lakes, *Phragmites australis* occur in deeper parts of the lake with dense submerged layer of Charophytes. The two larger lakes (Barm-Shoor and Barm-Alvan) with salty water are surrounded by dense Tamarisk communities belonging to *Tamarix arceuthoides* and *T. tetragyna*. *Bolboschoenus* sp. plays a main role in the vegetation of shallow water parts. The surrounding vegetation varies according to water depth, soil salinity, disturbance and grazing intensity. *Aeluropus littoralis* occur in all three lakes in moist and salty soils. The water of Darya Morghi lake is fresh to brackish with diverse flora and absence of *Tamarix* community. The study of this huge gypsum area with rich biodiversity is of great importance for gypsum scientific community. We have started a Ph.D. research plan to explore the flora and vegetation of Gachsaran formation with special attention to the conservation issues and correlation of the flora with the gypsum content of the soil.

POSTERS

Biochemical responses of *Capparis spinosa* in gypsum and non-gypsum soil

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A high gypsum content can have a significant impact on plants that live in gypsum habitats. Gypsovags, which can be found in both gypsum and non-gypsum soil, may have evolved functional adaptations to live in this environment. Physiological and biochemical adaptation are expected to play important roles. Despite the fact that several studies have been conducted on the elemental adaptation of plants in gypsum habitats. However, more research is needed on biochemical regulations.

Capparis spinosa is a widespread species that can survive in a variety of habitats including salt marshes, gypsum soil, calcareous soil, and some mountain habitats. We chose habitats with very low gypsum content as non-gypsum soil and a site with higher gypsum content that had previously been used as a gypsum mine. In early July, we collected leaf and fruit of the study species in Kazeron, southern Zagros. Following lab processing, we determined elemental traits of leaves in two locations using ICP-OES and measured total phenol content (TPC), total flavonoids content (TFC), flavonols, and anthocyanin using spectrophotometry.

C. spinosa fruits had higher levels of TPC and flavonols and lower levels of TFC in gypsum habitats, according to the findings. Anthocyanin levels were not significantly different in either habitat. Furthermore, elemental analysis of this species' leaves revealed that C. spinosa leaves contained more K, Ca, and Mn in non-gypsum soil and more Mn in gypsum soil.

Gypsum soil has stressful conditions, especially with higher sulphate levels. Plants in stressful environments have higher TPC, according to our knowledge. Previous research found that *C.spinosa* had high Na levels in saline habitats and high S levels in gypsum soil. This species has functional adaptations that allow it to adapt to various habitats and soil conditions.

Keywords
Caper, Elemental traits, extreme habitats, gypsum soil

Species-specific effect of seed biopriming with biocrust-forming cyanobacteria on germination and seedling root growth of dryland native plants

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The difficulty and economic cost of restoration projects in drylands often make them unfeasible. For decades, restoration actions have focused on the recovery of the vegetation using individuals from plant nurseries. To lower costs under large scale projects or to act on hard-to-reach places, seeding arises as an easier and spatially manageable strategy, but success rates are very low with seed mortality usually above 90%. New seed treatments are emerging to enhance the speed and rate of germination and improve further plant survival and establishment and increase the success of restoration under harsh environmental conditions, like gypsum environments. One seed improvement technique is biopriming, that includes the inoculation of seeds with beneficial organisms such as cyanobacteria. In this study, the effect of biopriming seeds with native biocrust-forming cyanobacteria on germination percentage and root elongation was evaluated.

Four indigenous plant species (*Macrochloa tenacissima* (L.) Kunth, *Thymus hyemalis* Lange, *Plantago ovata* Forssk. and *Stipa capensis* Thunb.) were chosen because of their high representativeness in southeastern Spain drylands. Biopriming was carried out during 26 hours, including the following treatments: seeds exposed to deionized water, culture medium (BG11), cyanobacteria exudate and complete inoculum (exudate + cyanobacteria biomass). Seed biopriming was conducted with four different native biocrust-forming cyanobacteria: *Nostoc commune*, *Tolypothrix distorta*, *Trichocoleus desertorum* and *Leptolyngbya frigida*. All the essays were realized under controlled conditions inside a phytotron (25ºC with 16/8 hours of photoperiod). Germination monitoring was carried out with different durations according to the life cycle of the plant (15 days for annuals and one month for perennial). In addition, radicle length was measured after 7 days since germination for each seed.

In the case of annual plants (*S. capensis* and *P. ovata*), no significant effect of the biopriming, either with the cyanobacteria inoculum or the exudate, was detected on seed germination, while regarding perennials (*M. tenacissima* and *T. hyemalis*), significant effects were found depending on the cyanobacteria inoculant. For *T. hyemalis*, the exudates of the four cyanobacteria species led to significantly higher germination rates than the other treatments, while in *M. tenacissima*, both the complete inoculum and the exudate of *T. desertorum* induced the highest gemination rates. Regarding radicle length, no significant effect of biopriming was found for the perennial plants. In contrast, the radicle length of annual plants was increased by the biopriming with the exudate and biomass of nitrogen-fixing cyanobacteria (*N. commune* and *T. distorta*). Overall cyanobacteria did not show an inhibitory effect on the studied species.

These results suggest that seed biopriming with cyanobacteria can improve plant establishment in drylands making restoration actions less costly and more successful. However, its efficiency should be evaluated for the specific introduced plants, as biopriming effects appear to be highly species-dependent.

Keywords
Cost-effective restoration, nitrogen-fixing cyanobacteria, annual plants, perennial plants.

Analysis and representativeness of gypsophytes in the province of Cuenca (Spain).

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The province of Cuenca is located in the centre of the Iberian Peninsula, where 32 gypsophytes have been identified (1), which are mainly distributed in the regions of La Alcarria, La Mancha, eastern Manchuela (Levantine area) and eastern Serranía Baja (Maestracense area).

The aim of this work is to elaborate a territorial analysis in 10x10 km squares based on the distribution and abundance of gypsophytes, taking as a variable the degrees of gypsophilia proposed for the different taxa specialists in these environments (1). To develop this territorial analysis, the Provincial Gypsophilia Index (PGI) has been established, which is no more than a weighted formula of the degrees of gypsophilia taking into account all the gypsophytes present in the province; however, in order to achieve a more territorially adjusted assessment, the Local Gypsophilia Index (LGI) is proposed, which only takes into account in the weighting, the taxa that can potentially occur in a region or territory smaller than the province.

The highest values for the PGI are reached in the region of La Alcarria and in the northernmost part of La Mancha Alta. If IGL is applied, the maximum values are widely spread over the comarca of La Alcarria, La Mancha Alta and the eastern Serranía Baja. However, as proposed in the Atlas of the Unique and Endangered Flora of Cuenca, a protected area corresponding to the gypsum zones ("yesares") and salt marshes of Barajas de Melo, Tarancón and Belinchón (2), where the highest PGI and IGL values of the province are found, should be added to this network.

Keywords
Gypsophytes, flora, gypsicolous communities, conservation, Cuenca.

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Global assessment of the conservation status of gypsum plants

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Although gypseous habitats are present in many regions of the world, where they host a highly diversified and specialized flora. Despite their relevance and global distribution, gypsum plant communities have received less attention than other plant communities sustained on special substrates. One of the main consequences of this oblivion is their under-representation on National Red Lists and other similar inventories, which are an essential tool when recognizing and promoting the importance of preserving vulnerable taxa and giving priorities to their conservation and management. Through this work, we are trying to assess this issue by gathering information on the conservation status of over 1200 gypsophilic taxa included in a global checklist. We aim to understand how well-protected these habitats are in terms of their inclusion in national laws or

scientific reports. For further understanding, analyses by species affinity to gypsum and the extent of their distribution have been done, along with a comparison of the total number of protected taxa among geographic regions.

The challenge of restoring biocrust in gypsipherous environments

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Biocrust or Biological Soil Crust are associations of several living organisms comprising cyanobacteria, algae, microfungi, lichen and mosses that frequently dominate the interplant spaces in gypsum-rich ecosystems where they regulate nutrients and water cycling, stabilize soil and influence soil food webs and plant growth. These key roles and associated ecosystems services are threatened by activities, such as energy and mineral extraction, grazing, agriculture, and recreational activities that decrease biocrust cover and shift the community composition to early stages in the successional trajectory. Biocrust natural recovery after disturbance is very slow and classical restoration techniques focused on plant recovery do not usually assure biocrust rehabilitation, being the inclusion of biocrusts in gypsum-rich ecosystem restoration practices a keystone to properly restore these ecosystem functions and resilience. Our team have addressed the development of effective methods based on biocrust-forming cyanobacteria inoculation to restore biocrusts in degraded ecosystems, including those rich in gypsum. We present a summary of our main results. After identifying and isolating representative native biocrust-forming cyanobacteria strains from different ecosystems, we selected those with key functional attributes and easy and fast to culture. We compared the effect of these strains on different soil types under diverse indoor inoculation strategies, finding an excellent performance of *Nostoc commune* and a mixture of cyanobacteria in developing a new biocrust and improving key soil properties of all soils in the short term. To produce the necessary biomass for field inoculations, we optimized their culture by growing them using fertilizers-made media that were compared with the traditional chemicals-made media. Fertilizers-made media allowed cyanobacteria reaching equal or higher growth rates and promoting higher soil improvements than those made with pure chemicals at significant low production costs. The following step was to evaluate the effects of cyanobacteria and biocrust community inoculation on soils under field conditions where abiotic stresses, such as soil erosion, are constraining biocrust-inoculant survival and growth. The hardening of cyanobacterial inocula and habitat amelioration strategies to reduce abiotic stress after inoculation (covering with different types of meshes, native plant-based stabilizers and mulches, etc) were applied to overcome these barriers. Our results showed that, at the short term, application of the cyanobacterial inoculum alone had a limited effect on the formation of the induced cyanobacterial biocrust, in contrast with the significant high biocrust development found in the long term. The application of habitat amelioration techniques improved the performance of cyanobacteria and biocrust community inoculants at the short term. This is reflected in an increase in chlorophyll a, and soil organic carbon content, decrease in albedo due to surface darkening with cyanobacterial growth and high aggregate stability.

Keywords
Cyanobacteria, dryland restoration, inoculation.

Analysis of the accumulative capacity of the native flora of peridotites in Andalusia: Sierra Nevada (el Almirez) and Sierra Bermeja.

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Previous researches have documented the existence of plants with special adaptations on peridotite soils ("serpentines"). Among these adaptations, the ability of some of them to accumulate various heavy metals, especially nickel. Phytoremediation is a biotechnological process that takes advantage of hyperaccumulation, chemical transformation and chelation within plant tissues to reduce heavy metal contamination in the soil.

Peridotites, like other types of ultramafic rocks, are rich in iron and magnesium, and are widely distributed throughout the globe, so that many investigations have established the existence of accumulating plants in them. Until now, only prospecting studies have been carried out in Sierra Bermeja, in which the detection of heavy metals by staining was sought, but limited to nickel. The objective of this research is the prospection of potentially hyperaccumulative autochthonous plant species in two regions in the south of the Iberian Peninsula, Sierra Nevada (Pico del Almirez) and Sierra Bermeja, hardly investigated, as opposed to similar studies carried out in other places such as Sierra de Mijas (Malaga).

In this research, more than 30 chemical elements were analyzed, including several heavy metals such as cadmium or lead, in different samples of soils and leaves of various species. Using the bioconcentration factor, BAF, the accumulation capacity of these species is evaluated by relating the contents of the soil with those of the leaves.

The extraction and analysis of soils and plants have been carried out on a physical treatment first consisting of sifting and grinding. One gram of each grinded soil sample was sent for analysis to the CEBAS service, where they were subjected to plasma emission spectrometry.

Among the results obtained, it should be noted that the analyzed individuals of *Alyssum serpellyfolium* from Sierra Bermeja have a BAF greater than that of the same species in Almirez. In addition, the data show that the Mg/Ca ratio is lower in the peridotite soils of El Almirez than in Sierra Bermeja, as well as the difference in concentration of other minerals. After a general, quick analysis, we conclude more research is needed on the peridotite soils in these two areas in order to comprehend their nature, differences and relation to vegetation.

Keywords
Alyssum serpyllifolium, bioconcentration factor (BCF), peridotites, phytoremediation, ultramafic.

The ecohydrology of gypsum ecosystems: a remote sensing approach.

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Gypsum soils impose stressful conditions to arid zone vegetation, which results in edaphic restriction processes that favor the occurrence of specific flora (1). In addition to the hypotheses that rely on the chemical nature of gypsum, the hydric characteristics of gypsiferous soils have also been considered for the explanation of gypsophily. Recent studies have demonstrated that some gypsophytes make significant use of gypsum crystallization water (2). Furthermore, edaphic drought spatially defines gypsum plant communities, promoting hydrological niche segregation (3). Here we develop a landscape-level approach based on remote sensing techniques to elucidate the ecohydrological processes associated with gypsum vegetation. We used the Land Surface Water Index (LSWI) and Normalized Difference Vegetation Index (NDVI) to evaluate the differences in the annual dynamics and the structural vegetation types of 13 gypsum outcrops and their periphery along an aridity gradient in Andalusia. The indices, derived from the processing of the 2016-2020 time series of Sentinel-2 satellite images, are subrogated of land cover water content and vegetation primary productivity, respectively. Results showed that the water content of the ground cover was higher in most arid outcrops than in the periphery throughout the year, and particularly during the summer drought months. Regarding the sites, both the gypsum soils covered only by annual grasslands and the gypsiferous tomillares significantly differed in their ecohydrological behavior, although a clear segregation among vegetation types was not identified. Despite the possible water advantages of gypsum soils in arid areas, we found no evidence that this leads to differences in primary production of vegetation, suggesting that the chemical nature of gypsum imposes a low water use efficiency in gypsum vegetation.

Keywords
Aridity, ecosystem functioning, gypsophily, gypsum outcrops, hydrological niche, NDVI, LSWI.

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Study and identification of new gypsicolous taxa in inner gypsum outcrops of andalusia

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Limonium (Plumbaginaceae) is a cosmopolitan genus composed of more than 400 species. The main centre of diversification of this genus is located in the Western Mediterranean area. Species of this genus usually grow in small, isolated areas, on saline or gypsum substrates. This is the case of *L. quesadense* Erben, an endemic species that grows on the gypsum outcrops in the inner basins of Jaen province (southeastern Iberian Peninsula). In some cases, identification of taxa belonging to this genus is difficult, possibly due to its recent diversification and the high intraspecific variability caused by hybridization processes. Maybe, this is the case of *L. quesadense*, a species that shows a great morphological variability thorough its range of distribution, that makes difficult, in some cases, to differentiate this taxon from other species of the genus *Limonium*.

Bearing this in mind, in the present study, we have considered to genetically characterize the populations of *L. quesadense* in the whole distribution area of the species. This would allow us to clarify if the morphological differences found in some of its populations are just a consequence of genetic differences among them. In addition, genetic characterization would allow us to establish the existing phylogenetic relationships of this taxon with other potentially related.

To achieve this objective, plant material belonging to different localities comprising the whole distribution area of the species was collected and stored. In addition, samples from *L. alicunense* F. Gómiz, a species closely related to *L. quesadense*, were also collected. DNA from up to four individuals per locality was extracted, and from each of them, nuclear ribosomal DNA (ITS regions) and three plastidial DNA regions (*matK, rbcL* and *trnL-F*), commonly used in phylogenetic studies of Plumbaginaceae family, were amplified and sequenced.

Our analysis revealed that westernmost populations of *L. quesadense*, (from Alcaudete) showed clearly differentiated nuclear sequences from any other *Limonium* species, being related with taxa belonging to the *L. ovalifolium* complex. Moreover, the rest of the analysed populations of *L. quesadense*, as well as the samples from *L. alicunense*, showed a characteristic additivity pattern that may be indicative of hybridization events, specifically with *L. tabernense* Erben, endemic to Desierto de Tabernas (Almeria province). On the other hand, all plastidial sequences, both from *L. alicunense* and *L. quesadense* showed the same single haplotype, which showed a complete identity with that belonging to *L. tabernense*.

These results would not rule out the existence of ancient hybridization processes, in which *L. tabernense* would be involved. It is still necessary to delve into clarification of those possible events of hybridization. If morphological data support this, it would be possible to suggest a new taxon in the Alcaudete localities. Moreover, considering the lack of differences between *L. alicunense* and *L. quesadense* populations, it may be necessary to reconsider the taxonomic status of both taxa.

Facilitation mediated by the nutrients transfer between plants in gypsum communities in the south of Alicante

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Nitrogen is a necessary resource for plant survival. In arid environments, in addition to being scarce, its availability is concentrated in temporal pulses. In this context, the ability to accumulate and redistribute it within the plant, or between individuals through facilitation processes, could be beneficial. To study these processes, stable isotopes are used as tracers. A tracer containing stable isotopes of nitrogen (^{15}N) and carbon (^{13}C) was applied to some plants (donors) from a sample of 187 individuals. Leaves were collected from all individuals (potential donors and receivers) before and after tracer application, and throughout the phenological cycle of each plant, to quantify the ^{15}N, ^{13}C and total nitrogen and carbon present in them. Here, we present the first results of the application of this technique on the gypsum plants in the south of Alicante. We characterise the natural levels of these resources and their range of variation, the degree of enrichment mediated by facilitation, as well as the trends of nutrient accumulation and redistribution over time in five gypsum species.

Keywords
Donor, facilitation, gypsum plants, receiver, stable isotopes.

Restoration of gypsum habitats in the autonomous community of the region of Murcia. Actions in Sierra de la Pila

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In this communication we present the results of the first work carried out in the restoration of gypsiferous habitats degraded due to gypsum extraction activity, after having been abandoned without having carried out the subsequent restoration of the altered area.

The action has been carried out in the area of the Regional Park "Sierra de la Pila" in the well-known Yesares de Peña Zafra de Arriba (Fortuna), within the SCI ES6200003 "Sierra de la Pila".

The main objective has been to restore the vegetation cover of the dominant community in the gypsum of the territory, corresponding to the optimal association in the Alicante sub-sector (Murcian-Almeriensian Province), Thymo moroderi-Teucrietum libanitidis Rivas Goday & Rigual 1957 ex Alcaraz, P. Sánchez, De la Torre, Ríos & J. Álvarez 1991, dominated by Teucrium libanitis L., a structural species of the Priority Habitat 1520: Iberian Gypsicolous Steppes (Directive 92/43/EEC), where the plant species have been unable, on their own, to re-colonise the degraded area naturally. *Thymus moroderi* Pau ex Martínez, *Helianthemum squamatum* (L.) Dum. Cours, and *Reseda barrelieri* var. *barrelieri* Bertol. ex Müll. Arg. have been used as companion gypsophytes and subgypsophytes to carry out the restoration of the vegetation cover, as well as the restitution of their populations.

The techniques used for the establishment of the different species are discussed, as well as the behaviour observed 20 months after planting. In addition, the colonising character of other associated species after the adaptation of the land is discussed.

Keywords
gypsicolous steppes, restoration, Southeastern Spain, *Teucrium libanitis*

Gypsum habitats in the Plant Micro-reserves network of the Valencian Community (E of Spain)

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Gypsum habitats and other salt-affected habitats are often rich in endemic, threatened and rare or plants species. Some genera, and especially *Limonium* (Plumbaginaceae), are paradigmatic for its high amount of threatened species. Most of these singular species have a marked trend to occur in some microhabitats that occupy small areas and have a widespread distribution pattern. These strict ecological preferences implies that their conservation should be performed mostly through *in situ* measures, combined with *ex situ* techniques. Despite the interest and originality of the biodiversity of halophytic habitats, there are few examples of conservation of this group of species. For this reason, the relevant case of plant conservation in the Valencian Community is analysed. In this region, located in the eastern fringe of continental Spain, the gypsum habitats occupy approximately 12.220 ha (0,53% of the territory) and consist of interior outcrops of gypsum and gypsiferous marls, mainly belonging to the Keuper (Triasic) facies.

This region has been a worldwide pioneer in the protection of microhabitats through Plant Micro-Reserves (PMR), which currently form the world's most dense network of protected micro-areas focused on wild flora. 11 PMR (which cover 54,45 ha) include the habitat type "Iberian gypsum steppes (*Gypsophiletalia*)" considered as priority habitat for conservation by the European Union's Habitats Directive, and also as habitat protected by regional regulations. These PMR are dedicated to the conservation and management of gypsum habitats and provide protection to many species, mainly vascular plants but also to the cryptogamic flora, mainly bryophytes and lichens, that include numerous species exclusive to this type of habitat.

PMR with gypsiferous habitats are home to 750 populations of 317 species, but most of them are not gypsophytes, since some of these PMR also include other climatophilous habitats into their boundaries. Among these gypsophytes, 9 species belonging to the genus *Limonium* and other threatened species (i.e., *Chaenorhinum exile*, *Ferula loscosii*, *Teucrium lepicephalum*) stand out for their hyperendemicity and higher risk of extinction. The conservation of these plants and other notable gypsophytes and halo-nitrophytes is complemented by gene banks, which currently store seeds of the most threatened species, as well as some experiences of conservation translocations.

Keywords

Gypsum habitats, *in situ* conservation, Plant Micro-Reserves, Valencian Community.

Acknowledgments

Spatially explicit runoff and erosion modelling to promote water and nutrient harvesting from induced biocrusts to introduced plants in dryland restoration projects

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Land degradation is estimated to affect up to 20% of global drylands and is continuously spreading due to climate change and land-use intensification. Once the pressure on the ecosystem ceases, the ecosystem could not be able to recover its original stage and when possible, it may take a long time. Thus, it is important to speed up the process with active restoration, especially in areas that have been intensively exploited, such as quarries. However, in drylands, traditional restoration usually fails because of the harsh environmental conditions that limit plant establishment and growth. Recent studies analysing the relationships between plant redistribution in drylands and ecohydrological processes reveal that runoff water redistribution exerts an important effect on vegetation survival and suggest that future restoration activities may recreate these processes. In this study, we aim to verify the feasibility of using spatially distributed modelling to identify the best plant-biocrust configuration to optimize water capture by plants and minimize erosion, before a restoration action in drylands. A degraded hillslope inside a gypsum quarry, located in SE Spain, was selected as study area. The slope was monitored and reconstructed by using a terrestrial laser scanner and all several properties related to soil hydrology and erosivity were measured. Using this information, we simulated runoff and erosion using the Limburg Soil Erosion Model (LISEM) and obtained reliable results, with an RMSE of only 15% compared to the real erosion measured during one hydrological year. Once the model was validated, we used it for the simulation of water redistribution and soil erosion under three different vegetation spatial scenarios: (i) increasing vegetation cover as moving to the lowest part of the slope; (ii) staggered pattern; (iii) and plants located in the areas of water flow accumulation. Each one was simulated for two rainfall intensities (15mmh[-1] and 55mmh[-1] for 30min), two plant sizes (25x25 cm and 50x50 cm), and with and without biocrust presence. According to our results, the configuration that most reduced erosion was the one with plants located in the areas of higher flow accumulation. However, differences between the tested scenarios were not so marked, with a 4-17% reduction in erosion and a 2-24% reduction in runoff during the preliminary stage of restoration and a 5-28% and 13-19% reduction in runoff and erosion in the latter stages. Finally, we demonstrated that erosion could be lessened by 70-90% with active biocrust restoration, thus highlighting the importance of post-mining restoration to improve soil conditions and reverse degradation consequences. Based on this, we can conclude that the proposed technique could be presented as a sustainable tool to improve the outcome of dryland restoration actions by previously selecting the scenario that maximizes the supply of water and nutrients to plants while reducing erosion.

Keywords
Biological soil crusts, drylands, quarry restoration, runoff, sediment yield, spatially distributed models.

Gypsophyte count for each 10 km UTM grid in the province of Madrid

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With the data obtained in the field over the last 30 years in the Middle Tajo Basin (1), in the provinces of Cuenca, Guadalajara, Madrid and Toledo, and the potential information that can be obtained from them, after their analysis in the elaborated databases (2). On this occasion, we present the distribution and abundance of gypsophyte species in the province of Madrid using the UTM grid of 10 km. In this way, it is possible to know very quickly which areas have gypsophyte species and their abundance.

To achieve this objective, we started from the selection of gypsophyte species proposed by Mota et al, (3) present in the province of Madrid and we counted their presence for each UTM grid of 10 x 10 km of the whole territory of Madrid. The analysis of the information obtained by means of cartographic outputs allows us to visualise the location of the main areas hosting gypsophytes.

The results obtained show that the areas located in the south-eastern sector of the province between the axis of the A4 road and the axis of the A2 road concentrate the distribution of gypsophytes and that outside these areas, it can be observed that the number of gypsophytes is residual.

This information allows us to assess whether these gypsum localities, which according to the European Habitats Directive are classified as priority habitats, have environmental protection and their conservation should be considered.

The analysis of the cartography shows no major surprises, since the distribution of gypsum in Madrid is fairly well known and has been studied since the last third of the 20th century. However, gypsum has been detected in areas that have been little explored and studied, such as the valley of the Pantueña stream and, above all, in the extreme south and east of the municipality of Madrid, in the districts of Villa de Vallecas and Vicálvaro, with the presence of gypsophytes in an area with practically no environmental protection and with serious urban development threats. It would be urgent to take measures to conserve these localities, which represent the limit of the global distribution area of many gypsophyte endemisms of the southern Iberian plateau.

Keywords
Madrid, Tagus Basin, conservation, cartography, habitats directive.

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Spontaneous succession in gypsum quarries: a good ally for restoration?

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Gypsum areas cover a vast part of the Iberian Peninsula, which makes Spain a power in the production of this mineral, a fundamental raw material for modern societies. Gypsum quarries have the most obvious impact on biodiversity and the landscape. Gypsum outcrops have a high percentage of endemic plants and unique vegetation, considered a priority by the European Union in the design of the Natura-2000 Network. Delimiting appropriate protected areas and restoring the naturalness of landscapes altered by gypsum mining are two key strategies to prevent biodiversity loss. For the implementation of restoration strategies, understanding the development of successional processes triggered by the mining operation itself can be of great help. Ecosystem restoration at post-mining and post-industrial sites not only represents an important part of contemporary restoration ecology, but should be integrated into mine planning from the outset. The fact that gypsum is an inclement substrate for plants suggests that spontaneous succession may be a very important process when proposing restoration strategies. To fully document the processes of spontaneous primary succession in gypsum quarries and to evaluate their interest for restoration, 10 permanent plots of 20 x 50 m were proposed, with nested subplots, in which the evolution of the vegetation was recorded for 13 years in a quarry in Sorbas (Spain, Almeria) where exploitation ceased about 20 years ago.
Through species-area relationships (SARs), the evolution of these plots was compared to five others located in two areas of the same mining lease in which an active restoration was carried out (2011), and yet to five additional ones with natural vegetation (gypsicolous scrubland).
Furthermore, the spontaneous primary succession pattern found was compared to those recorded in 28 quarries distributed throughout other territories of the Iberian Peninsula. The results obtained show that an ecological pattern of spontaneous primary autosuccession is widely repeated in Iberian gypsum quarries, which is capable of regenerating the pre-existing natural vegetation. This pattern occurs whenever a layer of gypsum constitutes the pit floor on which the vegetation with an affinity for this substrate can be reestablished. This successional process can be as effective as active restoration.

Keywords
Ecological restoration, Endangered species, Gypsophile, Gypsophily, Passive restoration, Permanent plots, Primary succession, Species-Area Relationships (SAR).

Biological soil crusts help to determine the ecological succession of gypsum soils

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Gypsum soils are found in many parts of the world. Almería, which is located at the south of Spain, is one of the places that harbours these special environments. The great biodiversity associated with gypsum outcrops has led them to be catalogued as a priority habitat by the UE Habitats Directive. However, the integrity of these places is at risk due to the mining activity developed in gypsum quarries. In this context, the preservation and restoration of this areas are fundamental to the planet. For this reason, understanding the microbial community that confers specific physico-chemical properties to the soil is essential to protect gypsum soils correctly and this is where Biological Soil Crusts (BSC) stand out.

According to what we have mentioned, the objectives are the following: 1. Determine and compare, by establishing the patterns of microbial succession, the diversity levels of the microbiomes of natural environments and those artificially modified by mining. 2. Study the influence of the canopy on the taxonomic diversity and species abundance. 3. Generate basic knowledge that can be applied in the restoration strategies of gypsum ecosystems.

The study area is located in the Gypsum Karst Natural Park of Sorbas (Almería, Spain), where six different soil environments were selected: selenitic gypsum (K), massive gypsum (S), soils with organic horizon (O), restored areas (R), quarries of recent abandonment (Q1) and quarries of ancient abandonment (Q3). In each of them, three samples of the BSC were taken, distinguishing bare soil and canopy under the species *Gypsophila struthium,* the most frequent gypsophyte present in all the selected environments. After the isolation of the total DNA present in soil sample, barcoding libraries of the 16S region of prokaryotic rDNA were prepared and sequenced with a high-throughput approach on Illumina MiSeq platform. Subsequently, the OTUs (Operational Taxonomic Units) were determined by using Greengenes as a reference database (1).

According to the results, the most abundant microorganisms are cyanobacteria and proteobacteria. The latter presented a more generalist distribution, being found in all environments. Cyanobacteria appeared in all bare soil samples from all environments and, only in some cases, under the canopy. In addition, these photosynthetic bacteria dominated, along with other groups, in the altered environments (Q1, Q3 and R), so they behaved as primocolonizers.

The analysis of the taxonomic spectrum showed that these soil environments are able to recover a high diversity, even in the initial stages of the succession. The species abundance differs widely between the environments due to several factors such as the stages of the temporal succession and the influence of the canopy. Cyanobacteria is the group which helped more in differentiating the environments. This type of studies are crucial to the understanding of ecological succession in gypsum soils.

Keywords
Cyanobacteria, microbial community, quarries, barcoding, restoration ecology

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Distribution of the gypsum soils of Mexico and advances in their botanical study

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Gypsum soils occur mainly in arid regions around the world and represent a challenge for plant establishment. They are associated with a diverse flora of endemic taxa, so their study is important to understand the evolutionary processes involved in the adaptation of the species to these harsh environments. Due to the long distances and the inaccessibility of some places in Mexico, botanical explorations within the country have been heterogenous, so it is logical to think that the study of the gypsum ecosystems follows this same pattern. To identify how well explored the gypsum habitats are in Mexico, we conducted an exhaustive literature review and herbaria revision to generate a database of species known to inhabit gypsum in the country. With this, we aim to identify the gypsum soils in Mexico and to determine how well sampled they are. This study is necessary in order to estimate the richness of vascular plant species recorded in each locality and how many of the species can be considered as gypsophytes. Every species recorded was classified as gypsovag or gypsophyte using literature references and the existence in herbaria of records from the same species outside gypsum. We projected all the records onto a map and used the observations richness tool of the DIVA-GIS 4.2 program to estimate the collecting efforts according to the botanical records in different gypsisols. Our database contained a total of 4,880 vascular plant records distributed among 14 states of Mexico. Gypsum soils are scattered throughout the country but the highest concentration occurs in the arid regions at the north and northeastern portion. Most of the records were located in the Chihuahuan Desert and the Sierra Madre Oriental biogeographical provinces. Nevertheless, gypsum is also present in tropical regions in the states of Colima, Guerrero, Jalisco, and Oaxaca. The analysis showed the Cuatrociénegas Basin (Coahuila) as the most sampled region, followed by Santo Domingo Tonalá in Oaxaca. Additional well represented gypsum outcrops corresponded to the Galeana, Aramberri, and Zaragoza municipalities in Nuevo León. The database comprised 1,470 vascular plant species, of which 205 are considered to be gypsophytes. We hope that this study will encourage the botanical exploration of gypsum outcrops across Mexico. Particularly, we expect that the exploration of the gypsisols situated in the tropical portion of the country will considerably increase the number of gypsicolous plants recorded in Mexico and may lead to the discovery of new gypsophyte species.

Keywords
Chihuahuan Desert, Cuatrociénegas, gypsicolous flora, gypsophytes, tropical gypsum outcrops.

Studying the Vegetation of Gypsum Ecosystems in Cyprus

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Gypsum ecosystems are found mainly in arid and semi-arid areas, where the annual precipitation is low and insufficient to leach the gypsum, evaporation is intense and therefore, gypsum is accumulated in the soil. They host sparse and scattered vegetation, with species that are specialized in gypsum soil type. In Cyprus, gypsum ecosystems are included in Annex I of the Habitat Directive as priority habitat 1520*- Gypsum steppes (Gypsophiletalia), characterized by *Campanula fastigiata, Gypsophila linearifolia* (Critically Endangered) and *Teucrium salaminium* (Endemic). Currently there is insufficient knowledge on their distribution and ecology on the island. The aim of the study was to provide a first comprehensive account of the extent and distribution of these vegetation communities in Cyprus. We sought to answer three research questions a) whether the gypsum substrate and gypsophytes are present together, b) whether there is a gypsum substrate without the presence of gypsophytes and c) whether the gypsophytes can be found in a different to gypsum soil type.

A total of 27 sites with a uniform gypsum soil substrate were pre-selected before field studies, in order to find potential locations of the gypsum ecosystem based on a national soil map. Sites have different extent due to habitat fragmentation by human activities, while altitude ranges from 50-400 m. For each site, biophysical information (Area, Coordinates, Altitude, Aspect, Slope), floristic information and data about human impact were collected. A representative flora checklist for the gypsum ecosystems of Cyprus was prepared with a total of 98 plant species and subspecies recorded, belonging to 34 families. Furthermore, flora species were divided into five different categories (gypsophiles, gypsoclines, gypsovags, waifs and gypsophobes), based on their presence on gypsum substrate.

In areas with a different soil type, other than gypsum, none of the characteristic gypsophilous species of Cyprus were identified. In the western part of the island, although there are extensive gypsum outcrops, none of the characteristic gypsophilous species were found. Further research is required to identify the causes of non-existence of gypsophilous vegetation in these areas. A new endemic species for Cyprus (*Rostraria hadjikyriakou*) identified and recorded for the first time in five locations (Rizoelia National Forest Park, Kalavasos, Maroni, Alona and Aradipou), in Cyprus.

In conclusion, further research of gypsum ecosystems is quite promising, corroborated also by the discovery of new locations for *Rostraria hadjikyriakou,* with prospects of discovering new flora species linked to the special geological and climatic conditions of gypsum ecosystems and learn more about the ecology of these restricted ecosystems.

Calcarenitophily and the *Hypericum hispanicum* case: Is it physical or chemical?

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The phenomenon of edaphism, or restriction of a species to a certain type of very specific and unusual substrate, has been attributed to physical or chemical causes(1). However, restrictions of both natures can synergistically coincide. Rupicolus vegetation taxa inhabit in a rather peculiar and restrictive environment, this connection can be considered in a broad sense an edaphism. When, in addition to the rock biotope, the restriction is to a certain type of rock, we are obviously facing a full-fledged edaphism.

The eminently calcareous and calcareous-dolomitic massif of Sierra de Gádor is known for having a rich rocky flora. This includes endemic taxa or stenochorous of high conservation value. In this group, *Gadoria falukei* Güemes & Mota stands out, an endemic monotypic genus, from a single locality, which stands vertically or overhanging Miocene calcarenites (middle or lower Tortonian), linked to a certain oozing of the rock. In the same sierra, also on Upper Miocene (but Upper Tortonian) calcarenite, *Hypericum hispanicum* (Pau) M.A. Alonso, Agulló, J.L. Villar, Juan & M.B. Crespo, but in a very different habitat: on karstified calcarenite outcrop, of gentle slope, under strong sunlight. The flora of this habitat is very particular, due to the concurrence of clearly rocky elements (e.g. *Teucrium intricatum*) with elements of the xerophytic scrub-thyme (*Satureja cuneifolia*, *Fumana ericoides*, etc.). These habitats in the "grey zone" between rupicolous biotopes and scrub are known, and classical phytosociology pointed out a type of community for these plain rocky outcrops. These communities are characterized by *Launaea lanifera* Pau, Melica sp. and *Galium ephedroides* Willk. The case of the latter is curious since it is a rare plant (its presence in Europe is restricted to Almería and Málaga) that does not co-occur, on a fine scale, with *H. hispanicum*, even though it thrives in this type of biotopes (or maybe just because of that). But *H. hispanicum* differs notably from the other taxa in one important detail: it is exclusive to calcarenite rocks, not being able to establish itself in plain rocky outcrops of limestone, calcoschist, calcareous-dolomite or dolomite, which are nearby. We are beginning to study the restriction imposed by calcarenite. We cannot rule out due to the influence of a physical or chemical characteristic of that type of rock, or a combination of both. Without ruling out the entry into play of a third type of actor: the rock biota, given that lichens (some endolithic) and algal biofilms have been found on the rock.

Keywords
Aridity, calcarenite, edaphism, endemism, Sierra de Gádor, rupicolous vegetation,

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Assessing the effects of warming and competition on the adaptative response to water stress of a gypsum shrub

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Plant communities in the Mediterranean region are exposed to water stress, especially during the dry season, and drought is a key factor in the development of plants in these environments. Furthermore, the negative effects of drought will be accentuated due to climate change. Plant populations can cope with environmental change migrating to more favorable habitats. However, migration is often limited in species with specific edaphic requirements, such as gypsophiles. Therefore, processes such as adaptive phenotypic plasticity and evolution through natural selection are key to guaranteeing the viability of gypsophiles' populations in the increased aridity imposed by climate change. In natural conditions, gypsophiles confront not only water stress, but also combinations of other abiotic and biotic stresses, including heat stress associated to warming and competition. Despite its importance, it is virtually unknown whether the adaptive response to water stress of gypsophiles may be affected by the occurrence of simultaneous stresses. The occurrence of warming or competition may alter the plastic response to drought, inducing additive, synergistic, or antagonistic responses. For instance, drought may induce a conservative phenotype, but competition may favor faster, more acquisitive responses. Similarly, the occurrence of warming or competition may alter the adaptive value of traits in unknown directions. Using multivariate common gardens with populations of the gypsum chamaephyte *Helianthemum squamatum*, we will assess the effect of warming and intraspecific competition on adaptive population differentiation and plasticity to drought, both within and across generations (transgenerational plasticity). Temperature will be manipulated using open top chambers (OTCs), and we will change the densities of individuals simulating the sparse and dense plant patches that occur in natural conditions. Furthermore, we will estimate the potential evolutionary response to water stress and whether it is modified by warming and competition. *Helianthemum squamatum* is an excellent model because it is one of the most dominant gypsophiles of the Iberian Peninsula, previous studies have reported lower reproductive fitness in dry and hot conditions, and lower survival in the presence of conspecific individuals, indicating that these stresses are key selection pressures for this species. We predict that the co-occurrence of both warming, and competition stresses may modify the adaptive traits in response to drought, and the genetic variation for traits, impacting the potential response to selection. Consequently, we will enhance our understanding on how gypsophiles' populations will respond to climate change, using a more realistic approach with multivariate environments.

Keywords
Adaptive evolution, common gardens, evolutionary potential, gypsum plants, gypsophiles, multivariate environments, plasticity.

Mismatching between scientists' and protected areas manager's perceptions of biocrusts' relevance and the legal framework for its conservation

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Biological soil crust or "biocrusts" are complex communities composed of associations between soil particles and eukaryotic algae, cyanobacteria, lichen, and/or bryophytes growing together with heterotrophic micro-decomposers in a faunal food web. Scientific evidence shows that biocrusts play a key role in drylands where they perform all vital ecosystem functions and provide many benefits to people (i.e., ecosystem services). In addition, recent studies reveal that global change has negative impacts of biocrust communities which in turn might have important implications for their maintenance and, hence, for the functioning and resilience of dryland ecosystems (e.g. increased soil erosion, biodiversity loss and disruptions of the carbon, water and nitrogen cycles). In this adverse scenario of biocrusts threats, little is known about the legal framework that ensures their conservation, and the perception of the scientific and management community concerning the relevance and needs of biocrusts' legal protection. In this study, we want to 1) evaluate the existing legal framework for biocrusts conservation in Spain, and 2) to explore the social perception of biocrusts' researchers and protected areas' managers around these biological communities and their legal status of conservation. The content analysis of legal documents for biodiversity conservation reveals that biocrusts are not implicitly incorporated into the legal framework for biodiversity conservation. Thus, their actual conservation depends on indirect measurements oriented towards preserving different habitats or ecosystem components related to biocrusts (e.g., soils). The absence of management goals and actions specifically oriented towards biocrusts may hinder the future conservation of these keystone communities. These results contrast with the analysis of the social perception. As observed by the analysis of ~100 online surveys, both scientists and protected areas managers coincide about the biocrusts relevance, the potential negative implication of their threats, and the need to adopt science-based conservation actions to ensure their conservation. We also identify potential causes that explain the mismatch between biocrusts' scientific and management relevance and the existing legal framework for their conservation evidencing a need to strengthen the science-policy gap by producing research that better informs policy about the role of these keystone communities and promotes evidence-based conservation policies.

Keywords
Drylands, biocrust conservation, biological soil crusts, science-policy gap

First data on seed endophytes of annual plants growing on gypsum soils

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Increased severity and frequency of droughts by climate change is expected to hinder plant growth and survival. Gypsum soils are distributed through arid and semiarid climates wich stressful environmental conditions and chemical nature represents a physiological challenge for plant development that have derived in multiple plant adaptations. Recent studies have highlighted the role of bacterial endophytes in stress resistance in plants under a wide range of environmental situations. However, little is known about the role of endophytes in the tolerance of wild plants to water stress in gypsum substrates. This work aims: i) to characterize the endophyte communities occurring inside seeds of annual plants that grow in gypsum soils; ii) to determine whether these communities vary at the species level; iii) relation with the species affinity for this type of substrate; iv) to determine if these communities are modulated by the level of water stress in terms of diversity.

Seeds of 14 species of annual plants were collected from 14 plots located in an experimental gypsum area south of Madrid where 7 plots were kept under a partial water exclusion treatment (45% of rainfall reduction) and 7 with control treatment with no water restrictions. The microbiome of seed endophytes of each annual plant species was identified through DNA extraction (DNEASY PLANT KIT de Qiagen) by sequencing amplicons of the V5–V7 region of the 16S. Blocking primers were used in order not to amplify DNA from mitochondria and chloroplast. The effect on seed endophytes diversity and composition of species with experimental drought was tested.

Each annual plant had a specific community of seed endophytes in terms of composition and diversity but *Bacillus* and *Cutibacterium* genera, two plant growth promoting bacteria (PGPB) were the most representative in the bacterial diversity of seed endophytes. The experimental drought had no significant effects on the composition and diversity of endophytes. We are pending of DNA sequencing results of 6 species with contrasted gypsum affinity to test whether the degree of soil specialization determines the composition and diversity of seed endophytes in annual plants growing on gypsum soils.

The preliminary analyses of our study represent an advance on the knowledge of seed endophyte communities in gypsum soils and show that under stressful environments endophytes could not have effect on plant's drought resistance.

Keywords
Annual plants, drought, gypsum special substrates, seed microbiome, PGPB, water stress resistance.

Acknowledgments

Selection of priority areas for the conservation of gypsophilous flora in Alicante province (Southeast Iberian Peninsula)

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In the framework of research and conservation of the gypsicolous flora of Alicante (SE Spain), we have analyzed the distribution of the gypsophytes present using the Spanish checklist published a few years ago. Thus, we show its known distribution in a 1km^2 UTM grid on a layer in which the Alicante gypsum substrates appear.

Of the 25 species with gypsophily values ≥ 3, some of them reaching value 3, far exceed their distribution of gypsum stains, so they should be considered at least as gypsovagus, as is the case of: *Centaurium quadrifolium* subsp. *barrelieri, Guiraoa arvensis, Launaea fragilis, Launaea pumila,* and *Teucrium carolipaui* subsp. *Carolipaui.*

The remainder species with value 3 can be considered as subgypsophytes since they not only grow on gypsum but, above all, on saline soils, while the other 13 can be considered as true gypsophytes.

Thus, have taken into account 20 species to choose the areas of greatest interest for gypsophytes conservation in Alicante province, by calculating the Species Richness (Rn) per 1 km^2 grid cell, as well as by means of the Continuous Richness (Rc) obtained from the presence of rare species present in each grid cell. In addition, we have applied the threat index (Ti) to assess the presence of protected species.

After analyzing the 546 squares with the presence of at least 1 of the 20 species analyzed, it is noticed that the first 5 squares with the highest number of species (11-12 species present) are located in Villena, in the NW of Alicante, in areas where gypsums outcrops are located in the vicinity of salt marshes, so they are mutually enriched with the presence of gypsophytes and subgypsophytes.

On the other hand, the rarest species found in some of the 546 grid cells analyzed are *Gypsophila tomentosa, Jurinea pinnata, Lepidium cardamines, L. subulatum* and *Sonchus crassifolius.*

The grid cells holding a higher Rc values are also found in Villena, some of them overlapping with those that also have a higher Rn rate. For the degree of threat we have considered the species included in the Decree setting up the Catalog of Endangered Flora Species in the Valencian Community, thus we consider 9 strictly protected species. When applying the index of Del Valle & al. we also find an assessment to protect the study areas based on the threatened species. In this case, the coefficients applied to the species are added according to their degree of protection and endemicity.

We noticed that 3 of the 5 squares housing the highest values of Rc (XH8279, XH8673, XH8674), as well as 2 similar ones for Rn (XH8180, XH8279) are outside of the two main Valencian Community's networks for *in situ* protection of wild plants: the network of Natural Protected Areas and the network of Plant Micro-Reserves. Regarding the Threat Index, the squares with the highest score are those in which *Teucrium lepicephalum* appears (YH5377 and YH5477, both in La Nucía), they would be the ones of greatest interest and conservation risk since they do not match any protection figure. Excluding the presence of *T. lepicephalum* the squares reaching the highest value are XH8279 and XH8379, both placed in Villena.

A gypsum ecosystem in the Namib Desert of Namibia

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The Namib Desert is renowned for its desert dunes, some of which are regarded as the highest sand dunes on Earth. Beyond this sand sea, north of the Kuiseb River, lies a poorly understood ecosystem on vast gypsum plains. It is here that lichens make up the majority of the biomass of producers. These systems are sensitive and can take hundreds of years to recover when disturbed.

The aim of this communication is to introduce the gypsum plains of Namibia which occur in the vicinity of the Gobabeb-Namib Research Institute and to provide a very broad overview of the geology, soil and biodiversity of this ecosystem. It is envisaged that this contribution will trigger interest among GYPWORLD participants to favourably consider this site for future expeditions.

The desert plain is covered by different forms of gypsum; crystalline gypsum is exposed in ancient river beds. Wind-eroded ancient plains (2.6 my old) are comprised of gypsisols covered by quartz stones and a dense layer of lichens in places. Gypsum crusts are variable in thickness, with gypcrete lying just beneath the soil surface which is comprised of powdery gypsum.

In this extremely dry environment (<22 mm per annum), biological soil crusts bind the soil and allow for the formation of lichen communities. Hypoliths live underneath quartz rocks in the contact zone with the underlying gypsum and derives all its moisture from fog captured by the rock. More than 20 lichen species are found on the gypsum plain, either attached to quartz pebbles or directly on gypcrete and soil. Lichens are an important food source for desert micro-fauna, such as *Cauricara eburnea* (Tenebrionidae) that feeds on *Lecidella crystallina*. Although higher plants are rarely encountered on the gypsum plain, drought tolerant species of *Arthraerua*, *Salsola* and *Zygophyllum* do occur occasionally.

Our current project will focus on the total genomic DNA that will be isolated from the soil crust (top 1 mm). An *in-silico* analysis using Primer-BLAST will be done to determine the most applicable primer sets to use for the sequencing step of this study. Metabarcoding of the DNA samples will be done using an Illumina platform for the Next-Generation Sequencing of the identified barcodes. The data obtained will be analyzed according to stringent criteria for data filtering and taxonomic assignment to determine the biodiversity and relative abundance of the different taxa of fungi, algae, and bacteria present.

Effect of natural biocrust successional dynamics on microbial biomass in gypsum soil

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Gypsum ecosystems are important refuges for biocrusts supporting a high diversity of lichens and mosses, including rare, vulnerable and endangered species. These biocrusts possess high resistances to ambient stresses and low requirements of water and nutrients and are capable to survive and spread under the harsh environmental conditions that gypsum habitats impose. Inhabiting in the upper millimeters of the gypsum soils as complexes of macro-and microscopic organisms, they play crucial roles in the functioning of these ecosystems, such as moisture retention, nutrient cycling, soil fertilization, and soil stabilization. Biocrusts mediate enrichment of carbon and nitrogen in gypsum-rich soils stimulating microbial activity. Thus, after a disturbance, early successional biocrust colonizes the soil surface and chemical, biochemical and physical properties of their underlying soil layers start to change as a result of the biocrust release of exopolysaccharides and other organic metabolites that increase nutrients and water availability for soil microbial community increasing soil microbial biomass. It is also known that late successional stages of biocrusts, usually dominated by lichens in these ecosystems, produce large amounts of exopolysaccharides and phospholipid fatty acid than early and it is expected that biomass carbon of microbes will have higher values. However, how the soil microbial biomass evolves in a gradient from lower to greater biocrust developmental stage on gypsum-rich soil has not been evaluated. The objective of this work is to analyze the changes in microbial biomass in gypsum soils colonized by different biocrust types representing successive steps in natural biocrust succession. The study was conducted in the Tabernas desert, a badlands system characterized by a complex geomorphology and with bare, eroded and poorly developed soils formed from a gypsiferous marl. Soil samples were taken under communities of incipient and developed cyanobacteria, and two lichen biocrusts, dominated by pioneer lichen species, *Diploschistes diacapsis* and *Squamarina lentigera*, and in bare soil. The sampling was conducted at two depths (0-1cm) and (1-5cm), obtaining 4 samples for the 5 communities at 2 depths, for a total of 40 representative samples. The physicochemical and biological properties were analyzed. Substrate induced respiration (SIR) at 25°C was also measured and used as an indicator of soil microbial biomass. Our results show that the shallowest layers (0-1cm) showed higher SIR than the deeper layers in all cases. Moreover, we found that total soil organic carbon and the microbial biomass carbon were significantly influenced by biocrust type (or stage of development) and depth. The microbial biomass increased from the bare soil (41,03 µg/ g soil) to the most developed biocrusts, the lichen biocrusts (200,92 µg/ g soil). The highest values were found under the *S. lentigera biocrust* (331,01 µg/ g soil). In addition, the microbial biomass was higher beneath the more developed cyanobacteria - and lichen-dominated biocrusts (mean value of 188,15 µg/ g soil) than beneath the bare soil and less developed incipient cyanobacteria biocrusts (mean value of 64,97 µg/ g soil). These findings demonstrate the contribution of biocrusts to soil microbial biomass and their more significant role as the biocrust is more developed.

Keywords
Biocrust, drylands, gypsum soil,soil microbial biomass, substrate induced respiration, soil organic carbon.

MODELLING TRAINING COURSE

Original teaching material for introducing the use of species distribution modelling, a tool for inferring taxa dynamics

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INTRODUCTION

1.1. General information on species distribution models (SDM)

The analysis of the relationship between species and environment has always been a major theme in ecology, from Humboldt to De Candolle and up to the present day. The combination of climatology and environmental factors has historically been used to explain the world's major vegetation patterns. The quantification of these species-environment relationships represents the core of predictive geographic modelling in ecology, these models are generally based on various hypotheses of how environmental factors may determine the distribution of species and communities (Guisan and Zimmerman, 2000). This modelling has recently gained importance as a tool for studying the impact of accelerated changes in land use and other environmental changes on the distribution of organisms, and in general, as a tool used in conservation planning (Guisan and Zimmerman, 2000; Austin, 2002; Araujo and Guisan, 2006; Guillera-Arroita et al., 2015).

In a context of rising temperatures and global change (IPCC, 2018), we can effectively establish strategic conservation objectives through Species Distribution Models (SDMs), identifying areas where the most vulnerable species are at their optimum, as well as areas that have the potential to host them (Guisan and Zimmerman, 2000; Guisan and Thuiller, 2005; Araujo and Guisan, 2006), this area depends on the degree of causal relationship between the predictor variables and the distribution of the species when constructing the model (Araujo and Guisan, 2006). Furthermore, reliable and detailed information on the spatial distribution of species is important for species conservation management, especially in the case of rare species of conservation concern (Gogol-Prokurat, 2011; Qin et al., 2017; Fois et al., 2018). The use of SDMs is recognised by conservation biologists as a very promising and cost-efficient way of working for species conservation (Fois et al., 2018), especially when species distribution data are incomplete (Rodriguez et al., 2007; Williams et al., 2009; Fois et al., 2018). Studies using SDMs include the analysis of the effects of anthropogenic climate change, as well as predictions of biological invasions, among others (Guisan and Thuiller, 2005).

Despite the difficulties in predicting the response of biodiversity to multiple drivers of change, many studies use models and apply their findings to conservation, management and risk studies (Guisan et al., 2013). In the last 20 years, more than 6000 studies were found (in peer-reviewed articles) that use or mention SDMs as a biodiversity modelling tool, of which more than half using them sought to apply their results to at least one type of biodiversity assessment, including forecasting the effects of climate change on biodiversity, protected area site selection, habitat restoration and/or species translocation (Araujo et al., 2019). Modelling of rare species with very specific ecological requirements shows good potential for predicting habitat suitability at a local scale (Gogol-Prokurat, 2011; Peñas et al., 2011). In this context of rapid global change, studies to improve predictions of species range shifts and thus assist in decision-making are crucial for biodiversity conservation at the global level (Benito et al., 2014; Guillera-Arroita et al., 2015).

SDMs are empirical models based on statistical or theoretical response surfaces (Guisan and Zimmerman, 2000), also defined as statistical models that use observed distribution data to infer ecological requirements and map their potential distribution (Austin, 2002). Species data can be presence, presence-absence or observed abundance. Environmental predictors should be selected to reflect the three main influences on species:

limiting factors for ecophysiology, changes in natural systems and available resources (Guisan and Thuiller, 2005). Identifying the factors affecting species distribution has been an important unresolved issue in ecology (Araujo and Guisan, 2006), sometimes learning about which variables are good predictors of species distribution is sufficient for some applications, however, for others in-depth knowledge about the species is required (Guillera-Arroita et al., 2015).

Although theoretical and empirical work on the ecological niche concept remains fragmented (Guisan and Thuiller, 2005) and the factors controlling species distributions are unknown (Araujo and Guisan, 2006), the usefulness of the niche concept in predicting species distributions has been demonstrated (Bradie and Leung, 2017). In fact, species distribution models are also known as environmental niche models and have become the most widely used tool for making predictions and assessing questions about species distribution and redistribution under climate change scenarios (Lembrechts et al., 2019). Taking into account future climate scenarios (IPCC, 2018), SDMs are a very useful tool for predicting how species will behave (Araujo and New, 2007; Austin and Van Niel, 2011; Benito et al., 2014; Fois et al., 2018; Lembrechts et al., 2019), as well as for searching for new populations, taking the presence of current ones as a reference (Williams, 2009; Gogol-Prokurat, 2011; Fois et al., 2018). However, there are some limitations to these models based on empirical relationships, as for different species there can be a large variability of predictions with different modelling approaches (Araujo and New, 2007).

Species with small ranges and specialised habitat requirements represent a particular challenge for the representation of their statistical range in these models, for three reasons: 1) these species often have both small distributions and small sample sizes, which produce problems that can compromise model robustness (Pearson et al., 2007; Williams et al., 2009); 2) SDMs work with the niche where species are present, not their fundamental niche, which incorporates any inherent sampling bias in the data; for species with a narrow range, the chance of erring in identifying a narrow climatic distribution with a fundamental niche limitation is high, when in fact this distribution may reflect another type of ecological limitation (dispersal barriers, biotic interactions or edaphic constraints); 3) finally, species with very small or limited ranges that are habitat specialists typically have patchy or patchy distribution of occurrences, so defining a general range extent becomes less useful, from a management perspective, than understanding the species' habitat occupancy (Williams et al. , 2009).

1.2. Preparation of the working software
#### 1.2.1. Spreadsheet (Excel o similar)
You will need to have software installed on your computer that allows you to edit spreadsheets such as Excel or similar. If your computer does not have Microsoft's Office package installed, you can resort to free software such as Open Office on https://www.openoffice.org/?redirect=soft

1.2.2. Plain text editor (Wordpad or similar)
In addition, we must have software installed on our computer that allows plain text editing such as Wordpad or similar. If our computer does not have Microsoft's Office package installed, we can resort to free software such as Open Office available on https://www.openoffice.org/?redirect=soft

1.2.3. QGIS

QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, printing, and analysis of geospatial data. QGIS functions as geographic information system (GIS) software, allowing users to analyze and edit spatial information, in addition to composing and exporting graphical maps. QGIS supports raster, vector and mesh layers. Vector data is stored as either point, line, or polygon features. Multiple formats of raster images are supported, and the software can georeference images.
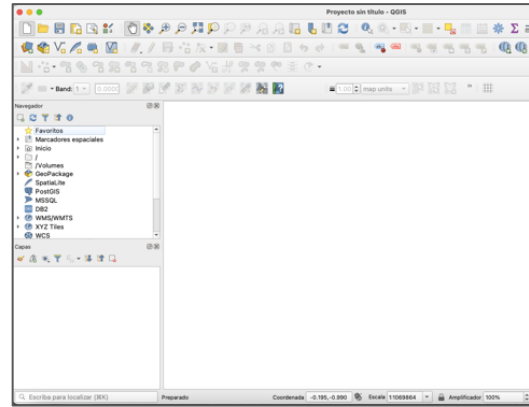
QGIS supports shapefiles, personal geodatabases, dxf, MapInfo, PostGIS, and other industry-standard formats. Web services, including Web Map Service and Web Feature Service, are also supported to allow use of data from external sources.

The download of this software is available on https://www.qgis.org/es/site/forusers/download.html

And tutorials in several languages are available on https://www.qgis.org/en/docs/index.html

1.2.4. Google Earth Engine

The Google Earth Engine **code editor** will be used (https://earthengine.google.com). To use this tool, it is necessary to register on the website and it is highly recommended to use a **Gmail account** that is linked to a **Google Drive** storage space.

Google Earth Engine is a cloud computing platform for processing satellite imagery and other geospatial and observation data. It provides access to a large database of satellite imagery and the computational power needed to analyze those images. Google Earth Engine allows observation of dynamic changes in agriculture, natural resources, and climate using geospatial data from the Landsat satellite program, which passes over the same places on the Earth every sixteen days. Google Earth Engine has become a platform that makes Landsat and Sentinel-2 data easily accessible to researchers in collaboration with the Google Cloud Storage. Google Earth Engine provides a data catalog along with computers for analysis; this allows scientists to collaborate using data, algorithms, and visualizations. The platform provides Python and JavaScript application programming interfaces for making requests to the servers, and includes a graphical user interface for developing applications.
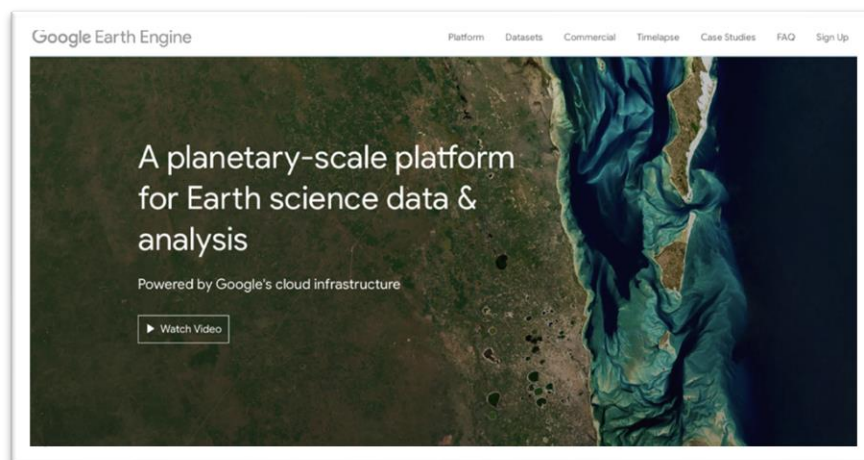
1.2.5. MaxEnt

The Maximun Entropy-MaxEnt algorithm (Phillips et al., 2006), is widely recognized as the most widely used tool, especially for small sample sizes and for species whose distribution is poorly known (Elith et al., 2006; Pearson et al., 2007; Williams et al., 2009; Gogol-Prokurat, 2011), because it only requires information on presence, rather than presence-absence, and because, especially in the case of rare or hard-to-find species, opportunistic data (e.g. presence-only data) often represent the majority of available datasets (Virgili et al., 2017), and both continuous and categorical environmental variables can be applied (Guisan and Thuiller, 2005). Another advantage is that the MaxEnt algorithm provides an explicit spatial map with a simple interpretation of habitat suitability, the model can also be replicated to test its robustness by measuring the importance of each variable with a jackknife test, it can also be projected into the future under climate change conditions (Elith et al. 2011), thus establishing appropriate conservation measures (Pearson et al., 2007; Fois et al. 2018).

To estimate the effects of each environmental factor on the distribution of the species we can rely on the area under the curve (AUC) and to evaluate it we use the scale recommended by Swets (1988) to estimate the predictive capacity of the model: AUC values of < 0. 5 correspond to low accuracy, 0.5 indicate probability with no effect of the variables, 0.5-0.6 are not predictive, 0.6-0.7 indicate poor accuracy, 0.7-0.8 indicate fair accuracy, 0.8-0.9 indicate good accuracy and AUC >0.9 indicate excellent accuracy. If the AUC is lower when a predictor is excluded, this could suggest that the other predictors are not able to explain the distribution of the species as accurately as if we kept it. Conversely, if the AUC is higher when we remove a predictor, then this suggests that its inclusion has caused the model to over-fit the field data, and therefore explains no more than the other factors do (Aschcroft et al., 2011). One of the most discussed topics in distribution modelling is the concept of ecological niche (Guisan and Zimmerman, 2000; Guisan and Thuiller, 2005; Araujo and Guisan, 2006; Bradie and Leung, 2017). Biotic and abiotic factors produce the differentiation between a "realised" niche, where the species is found, and a "fundamental" niche, which is the area where abiotic conditions occur that could allow the species to be found (Guisan and Thuiller, 2005; Pearson et al., 2007; Phillips et al., 2006).

Access to the download of this software is available on
https://biodiversityinformatics.amnh.org/open_source/maxent/

In addition, it will be necessary to have the Java console installed and updated, available on
https://www.java.com/es/download/ie_manual.jsp
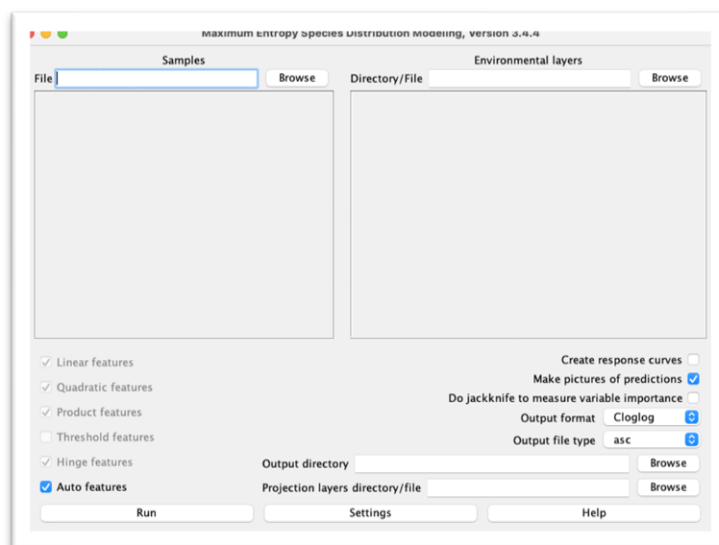
2. PREPARATION OF ENVIRONMENTAL VARIABLES

TASK 1

·**Open Google Earth Engine** and sign in with your email account (preferably with a Gmail account). Select the **Try the Code Editor** option to access the working environment.

·In the **Script** tab we can create a new **Repository**, with a new **Folder** where we can compile all the processes for the treatment of the information layers. We can see that the address collects the data of our user with which we have accessed the code editor website.

·**Create a working region** using the geometry tools in the map view. It can be a regular or irregular polygon. The recommendation **for practice is not to choose a too large area** as it will slow down all processes. You can name your working region as you want, but the recommendation is not to use long names, neither include symbols.

2.1. Digital Elevation Model

We propose to use the dataset from the Shuttle Radar Topography Mission (SRTM, see Farr et al. 2007) digital elevation data is an international research effort that obtained digital elevation models on a near-global scale. This SRTM V3 product (SRTM Plus) is provided by NASA JPL at a resolution of 1 arc-second, approximately 30m (NASA, 2020).

However, depending on the area of the world we are analyzing, we can find other images available in Google Earth Engine that may be more interesting. We must always take into account the pixel size so that it fits correctly with the rest of the information layers.

VERY IMPORTANT! Elements of the code highlighted in grey can be adjusted either to change the information processing parameters or for selection and downloading.

Code

```
// Import the dataset and select the elevation band.
var dataset = ee.Image('NASA/NASADEM_HGT/001');
var elevation = dataset.select('elevation');
// Add a white background image to the map.
var background = ee.Image(1);
Map.addLayer(background, {min: 0, max: 1});
// Set elevation visualization properties.
var elevationVis = {
  min: 0,
  max: 3500,
};
// Set elevation <= 0 as transparent and add to the map.
Map.addLayer(elevation.updateMask(elevation.gt(0)), elevationVis, 'elevation');
var products = ee.Terrain.products(elevation);
Map.addLayer(products.updateMask(elevation.gt(0)), elevationVis, 'elevation');
 Export.image.toDrive({
  image: elevation,
  description: 'DEM',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {
    cloudOptimized: true
  }
});
```

Check the range of elevations to adjust the layer information.

Check the folder name on Google Drive.

Check the scale.

Check the working region name.

2.1.1. Topographic variables

The different topographic variables that can be used are basically the result of the DEM treatment, therefore, to the extent that this layer of information is more precise, we will achieve topographic layers of greater precision. In any case, it must be taken into account that **the correlation between these variables and the elevation (DEM) layer can be high.**

2.1.1.1. Aspect

Aspect is the compass direction that the slope of the terrain faces. An aspect of 0 means that the slope is North-facing, 90 East-facing, 180 South-facing, and 270 West-facing.

Code


```
// Import the dataset and select the elevation band.
var dataset = ee.Image('NASA/NASADEM_HGT/001');
var elevation = dataset.select('elevation');

// Add a white background image to the map.
var background = ee.Image(1);
Map.addLayer(background, {min: 0, max: 1});
// Set elevation visualization properties.
var elevationVis = {
  min: 0,
  max: 3500,
};
// Set elevation <= 0 as transparent and add to the map.
Map.addLayer(elevation.updateMask(elevation.gt(0)), elevationVis, 'Elevation');
var aspect = ee.Terrain.aspect(elevation);
Map.addLayer(aspect.updateMask(elevation.gt(0)), elevationVis, 'aspect');
 Export.image.toDrive({
  image: aspect,
  description: 'aspect',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {cloudOptimized: true}});
```
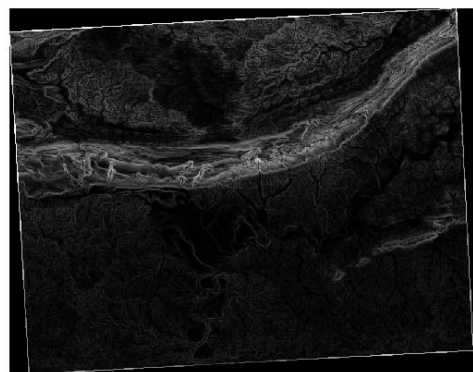
2.1.1.2. Slope

Slope informs about how steep the terrain is.

Code


```
// Import the dataset and select the elevation band.
var dataset = ee.Image('NASA/NASADEM_HGT/001');
var elevation = dataset.select('elevation');

// Add a white background image to the map.
var background = ee.Image(1);
Map.addLayer(background, {min: 0, max: 1});

// Set elevation visualization properties.
var elevationVis = {
  min: 0,
  max: 3000,
};
// Set elevation <= 0 as transparent and add to the map.
Map.addLayer(elevation.updateMask(elevation.gt(0)), elevationVis, 'Elevation');
var slope = ee.Terrain.slope(elevation);
```

```
Map.addLayer(slope.updateMask(elevation.gt(0)), elevationVis, 'slope');

 Export.image.toDrive({
  image:slope,
  description: 'Slope',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {cloudOptimized: true}});
```

2.1.1.3. HillShadow

To get a better impression of the terrain, it is possible to calculate a hillshade, which is a raster that maps the terrain using light and shadow to create a 3D-looking image.

Code

```
// Import the dataset and select the elevation band.
var dataset = ee.Image('NASA/NASADEM_HGT/001');
var elevation = dataset.select('elevation');

// Add a white background image to the map.
var background = ee.Image(1);
Map.addLayer(background, {min: 0, max: 1});

// Set elevation visualization properties.
var elevationVis = {
  min: 0,
  max: 3500,
};

// Set elevation <= 0 as transparent and add to the map.
Map.addLayer(elevation.updateMask(elevation.gt(0)), elevationVis, 'Elevation');

var hillShadow = ee.Terrain.hillShadow(elevation, 194,73,0,false);
Map.addLayer(hillShadow.updateMask(elevation.gt(0)), elevationVis, 'hillShadow');

 Export.image.toDrive({
  image:hillShadow,
  description: 'hillShadow',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {cloudOptimized: true}});
```
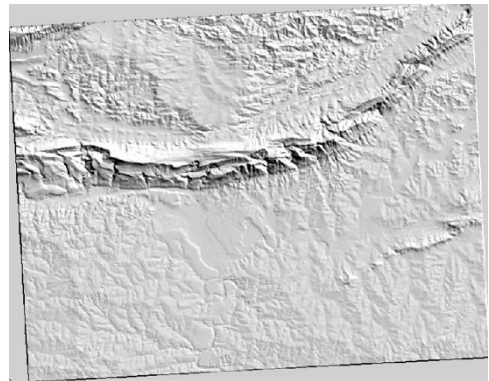
TASK 3

These topographic variables can also be obtained by processing the DEM raster layer directly in QGIS using the raster processing plugins.

- Download the DEM layer in the Google Drive you have previously created in TIFF format with a pixel resolution of 30 meters.

·Open the QGIS program and load the DEM layer.
·Calculate the topographic variables following the steps: RASTER menu- RASTER ANALYSIS-
ASPECT/SLOPE/HILLSHADOW/TPI/TRI
·These commands can also be accessed through the process toolbox- GDAL - ANALISIS RASTER -
ASPECT/SLOPE/HILLSHADOW/TPI/TRI

2.1.2. Remote sensing variables

From the data collections of different satellite images (Landsat, MODIS, etc.) layers of different environmental indices and variables can be produced. In the Google Earth Engine environment, the processing and downloading of this information can be accessed.

VERY IMPORTANT! These layers of remotely sensed variables will be downloaded in ".tiff" format, so they will be subsequently loaded into the QGIS software for alignment. The ".tiff" format must be translated into ".asc" format after alignment. After obtaining the layers in ".asc" format and once aligned, the layer has to be edited in the plain text editing program to introduce the line of code "NODATA_value -99999" in the sixth line of text (after "cell size") of the .asc layer. This process of preparing the environmental information is essential before inputting it as inputs into the modelling software. The modelling was done by running the MaxEnt programme.

This tutorial proposes the use of the Landsat 8 satellite image series, but by altering the collection selection code, different images can be processed.

> **TASK 4**
> · Generate and download the NDVI and EVI layers in Google Earth Engine from the supplied code.
> · Load these layers into QGIS.
> · Observe that both the scale and the boundaries of the zones are homogeneous and coincident.

### 2.1.2.1. Normalized Difference Vegetation Index (NDVI)

The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land (Weier & Herring, 2000).

Code

```
var dataset =
ee.ImageCollection('LANDSAT/LC08/C01/T1_8DAY_NDVI')
        .filterDate('2013-01-01', '2021-03-31');
var colorized = dataset.select('NDVI');
print(colorized)
var ndvi=colorized.reduce(ee.Reducer.mean());
print(ndvi)

var ndvi_crop=ndvi.clip(geometry);

var colorizedVis = {
  min: 0.0,
  max: 1.0,
  palette: [
```
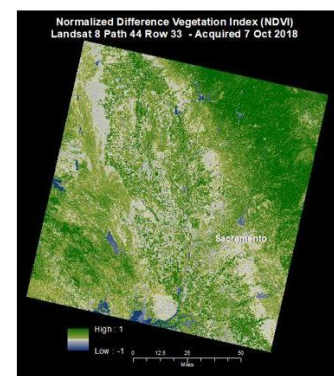
```
    'FFFFFF', 'CE7E45', 'DF923D', 'F1B555', 'FCD163', '99B718', '74A901',
    '66A000', '529400', '3E8601', '207401', '056201', '004C00', '023B01',
    '012E01', '011D01', '011301'
   ],
 };

 Map.addLayer(ndvi_crop, colorizedVis, 'Colorized');

 Export.image.toDrive({
   image: ndvi_crop,
   description: 'NDVI',
   folder: "Google_engine",
   scale: 30,
   region: geometry,
 fileFormat: 'GeoTIFF',});
```

2.1.2.2. Enhanced Vegetation Index (EVI)

Landsat Enhanced Vegetation Index (EVI) is similar to Normalized Difference Vegetation Index (NDVI) and can be used to quantify vegetation greenness. However, EVI corrects for some atmospheric conditions and canopy background noise and is more sensitive in areas with dense vegetation. So, the enhanced vegetation index (EVI) is an 'optimized' vegetation index designed to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences (Huete et al. 2006).


Enhanced Vegetation Index (EVI)
Landsat 8 Path 44 Row 33 - Acquired 7 Oct 2018
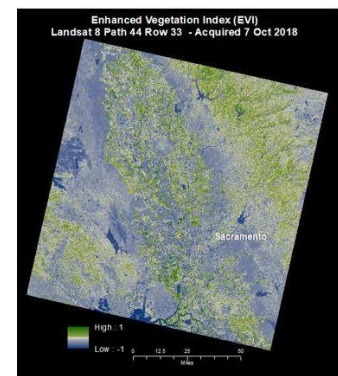
Code
```
    //Crear variable coleccion
    var LandsatEVI =
    ee.ImageCollection('LANDSAT/LC08/C01/T1_ANNUAL_EVI').filterBounds(geometry).filterDate('201
    3-04-01', '2021-03-01');
    //Reducir la colección a una imagen
    var landsatEVIredu = LandsatEVI.reduce (ee.Reducer.mean ());
    //Añadir imagen reducida al mapa
    Map.addLayer(landsatEVIredu,{max: 3000, min: 0}, 'LandsatEVIredu');
    print (landsatEVIredu)
    Export.image.toDrive({
      image: landsatEVIredu,
      description: 'EVImedia_13_21',
      folder: "Google_engine",
      scale: 30,
      region: geometry,
      fileFormat: 'GeoTIFF',
      formatOptions: {
        cloudOptimized: true
      }
    });
```

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2.1.2.3. Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) is known to be strongly related to the plant water content. It is therefore a very good proxy for plant water stress. The Normalized Difference Water Index (NDWI) (Gao, 1996) is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. (Gao, 1996). NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space. Remote sensing of environment, 58(3), 257-266.).
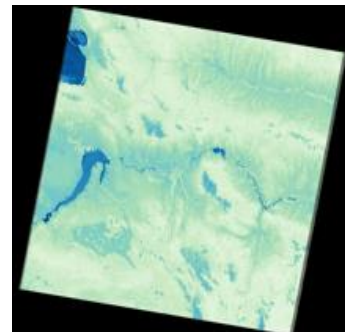
Code

```
//Crear variable coleccion
var LandsatNDWI =
ee.ImageCollection('LANDSAT/LC08/C01/T1_ANNUAL_NDWI').filterBounds(geometry).filterDate('2013-04-01', '2021-03-01');
//var landsatmediana = LandsatNDSI.median();
//var landsatmedia = LandsatNDSI.mean();
//Reducir la colección a una imagen
var landsatNDWIredu = LandsatNDWI.reduce (ee.Reducer.mean ());

//Añadir imagen reducida al mapa
Map.addLayer(landsatNDWIredu,{max: 3000, min: 0}, 'LandsatNDWIredu');
print (landsatNDWIredu)
Export.image.toDrive({
  image: landsatNDWIredu,
  description: 'Landsat8NDWImedia_13_21',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {
    cloudOptimized: true
  }
});
```

2.1.2.4. Surface Reflectance (SR)

Landsat Surface Reflectance measures the fraction of incoming solar radiation reflected from Earth's surface to the Landsat sensor. (U.S. Geological Survey, 2015, Landsat surface reflectance data (ver. 1.1, March 27, 2019): U.S. Geological Survey Fact Sheet 2015-3034, 1 p., https://doi.org/10.3133/fs20153034.).

Code

```
/**
 * Function to mask clouds based on the pixel_qa band of Landsat 8
SR data.
 * @param {ee.Image} image input Landsat 8 SR image
```
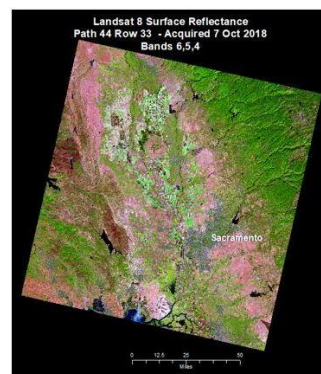
```
 * @return {ee.Image} cloudmasked Landsat 8 image
 */
function maskL8sr(image) {
  // Bits 3 and 5 are cloud shadow and cloud, respectively.
  var cloudShadowBitMask = (1 << 3);
  var cloudsBitMask = (1 << 5);
  // Get the pixel QA band.
  var qa = image.select('pixel_qa');
  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudShadowBitMask).eq(0)
          .and(qa.bitwiseAnd(cloudsBitMask).eq(0));
  return image.updateMask(mask);
}
//Crear variable coleccion
var SR = ee.ImageCollection('LANDSAT/LC08/C01/T1_SR').filterBounds(geometry).filterDate('2013-
04-01', '2021-03-01').map(maskL8sr);

//Reducir la colección a una imagen
var SRmediared = SR.reduce (ee.Reducer.mean ());
//var visParams = {bands: ['B11_median', 'B6_median', 'B4_median'],min: 0,max: 3000,gamma: 1.4,};
//Añadir imagen reducida al mapa
//Map.addLayer(landsatmediana, visParams, 'Landsatmediana');
Map.addLayer(SRmediared,{max: 3500, min: 0, bands:['B11_mean', 'B6_mean', 'B4_mean']},
'SRmediared');
print (SRmediared)
Export.image.toDrive({
  image: SRmediared,
  description: 'SRmedia_13_21',
  folder: "A_google_engine",
  scale: 30,
  region: BET,
  fileFormat: 'GeoTIFF',
  formatOptions: {
    cloudOptimized: true
  }
});
```

2.1.2.5. Land Surface Temperature (LST)

The Land Surface Temperature (LST) is the radiative skin temperature of the land surface, as measured in the direction of the remote sensor. It is estimated from Top-of-Atmosphere brightness temperatures from the infrared spectral channels of a constellation of geostationary satellites (Meteosat Second Generation, GOES, MTSAT/Himawari). Its estimation further depends on the albedo, the vegetation cover and the soil moisture. LST is a mixture of vegetation and bare soil temperatures. Because both respond rapidly to changes in incoming solar radiation due to cloud cover and aerosol load modifications and diurnal variation of illumination, the LST displays quick variations too. In turn, the LST influences the partition of energy between ground and vegetation, and determines the surface air temperature.

Code

//cloud mask
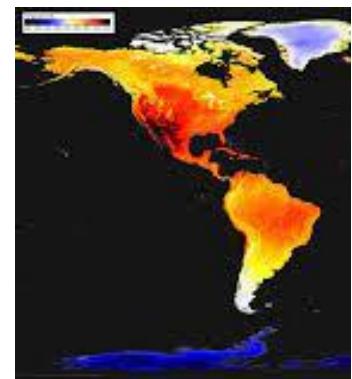
```
function maskL8sr(col) {
  // Bits 3 and 5 are cloud shadow and cloud, respectively.
  var cloudShadowBitMask = (1 << 3);
  var cloudsBitMask = (1 << 5);
  // Get the pixel QA band.
  var qa = col.select('pixel_qa');
  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudShadowBitMask).eq(0)
           .and(qa.bitwiseAnd(cloudsBitMask).eq(0));
  return col.updateMask(mask);
}

//vis params
var vizParams = {
bands: ['B5', 'B6', 'B4'],
min: 0,
max: 3500,
gamma: [1, 0.9, 1.1]
};

var vizParams2 = {
bands: ['B4', 'B3', 'B2'],
min: 0,
max: 3500,
gamma: 1.4,
};

//load the collection:
 {
var col = ee.ImageCollection('LANDSAT/LC08/C01/T1_SR')
.map(maskL8sr)
.filterDate('2013-01-01','2021-03-31')
.filterBounds(geometry);
}
print(col, 'coleccion');

//imagen reduction
{
var image = col.median();
print(image, 'image');
Map.addLayer(image, vizParams2);
}

//median
{
var ndvi = image.normalizedDifference(['B5',
'B4']).rename('NDVI');
var ndviParams = {min: -1, max: 1, palette: ['blue', 'white',
'green']};
print(ndvi,'ndvi');
Map.addLayer(ndvi, ndviParams, 'ndvi');
```

```
}

//select thermal band 10(with brightness tempereature), no calculation
var thermal= image.select('B10').multiply(0.1);
var b10Params = {min: 291.918, max: 302.382, palette: ['blue',
'white', 'green']};
Map.addLayer(thermal, b10Params, 'thermal');

// find the min and max of NDVI
{
var min = ee.Number(ndvi.reduceRegion({
reducer: ee.Reducer.min(),
geometry: geometry,
scale: 30,
maxPixels: 1e9
}).values().get(0));
print(min, 'min');
var max = ee.Number(ndvi.reduceRegion({
reducer: ee.Reducer.max(),
geometry: geometry,
scale: 30,
maxPixels: 1e9
}).values().get(0));
print(max, 'max')
}

//fractional vegetation
{
var fv =(ndvi.subtract(min).divide(max.subtract(min))).pow(ee.Number(2)).rename('FV');
print(fv, 'fv');
Map.addLayer(fv);
}
//Emissivity
var a= ee.Number(0.004);
var b= ee.Number(0.986);
var EM=fv.multiply(a).add(b).rename('EMM');
var imageVisParam3 = {min: 0.9865619146722164, max:0.989699971371314};
Map.addLayer(EM, imageVisParam3,'EMM');

//LST in Celsius Degree bring -273.15
//NB: In Kelvin don't bring -273.15
var LST = thermal.expression(
'(Tb/(1 + (0.00115* (Tb / 1.438))*log(Ep)))-273.15', {
 'Tb': thermal.select('B10'),
'Ep': EM.select('EMM')
}).rename('LST');
Map.addLayer(LST, {min: 20.569706944223423, max:29.328077233404645, palette: [
'040274', '040281', '0502a3', '0502b8', '0502ce', '0502e6',
'0602ff', '235cb1', '307ef3', '269db1', '30c8e2', '32d3ef',
'3be285', '3ff38f', '86e26f', '3ae237', 'b5e22e', 'd6e21f',
'fff705', 'ffd611', 'ffb613', 'ff8b13', 'ff6e08', 'ff500d',
```

```
'ff0000', 'de0101', 'c21301', 'a71001', '911003'
 ]},'LST');

Export.image.toDrive({
  image: LST,
  description: ' LST',
  folder: "Google_engine",
  scale: 30,
  region: geometry,
  fileFormat: 'GeoTIFF',
  formatOptions: {
    cloudOptimized: true
  }
});
```

VERY IMPORTANT! There are a lot of remote sensing indices and variables that can be used depending on the characteristics of the area and the species to be modelled. See for example: https://land.copernicus.eu/global/products/sa for Surface Albedo or TOC Reflectance.
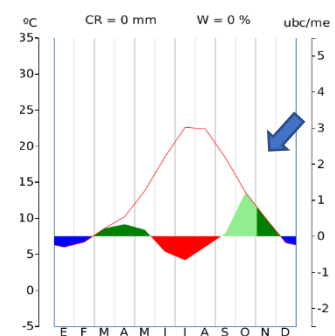
2.1.3. Climatic variables

Climate data are available on the WorldClim platform with a resolution of up to 1 arcsec, approximately 1 km. This information can be processed and downloaded via Google Earth Engine (Datasets-Climate and Weather).

In this tutorial we propose obtaining current climate data through the platform http://diagramasbioclimaticos.com (Montero de Burgos & González Rebollar). This website allows bioclimatic data to be generated through interpolation at any point, creating a data collection station at the selected coordinates. In this case, points can be selected where "virtual stations" were located within our study area. Once the stations were located and the meteorological data downloaded from them, the information on temperature and precipitation was interpolated by classical krigging method in QGIS, throughout the territory occupied by the raster layers of environmental and topographic variables obtained previously, using elevation (obtained from the DEM) as a covariate. Once the interpolation was obtained, it was applied to the different raster layers of climatic variables (temperature, precipitation, ETP).

2.1.3.1. Temperature (T)

Estacion:	Monterrey, Almeria, España, [37.025806 --2.895444], 1222.000000 m.s.m.										
Ref:											
CRT:	204.25										
	T	P	ETP	CP	IBP	IB	IBR	IBL	IBC	IBS	ISS
Jan	6.00	48.10	22.40	2.43	-0.30	-0.30	-0.30	-0.30	0.00	0.00	0.00
Feb	6.70	68.30	30.33	2.56	-0.16	-0.16	-0.16	-0.16	0.00	0.00	0.00
Mar	8.60	94.50	59.94	1.72	0.22	0.22	0.22	0.22	0.00	0.00	0.00
Apr	10.20	56.50	81.35	0.62	0.54	0.33	0.33	0.33	0.00	0.00	0.21
May	13.80	33.00	104.95	0.14	1.26	0.18	0.18	0.18	0.00	0.00	1.08
Jun	18.50	6.20	140.14	-0.19	2.20	-0.43	0.00	0.00	0.00	-0.43	2.20
Jul	22.60	4.10	168.34	-0.22	3.02	-0.66	0.00	0.00	0.00	-0.66	3.02
Aug	22.40	20.30	168.24	-0.10	2.98	-0.30	0.00	0.00	0.00	-0.30	2.98
Sep	18.40	20.10	87.49	0.04	2.18	0.08	0.08	0.08	0.00	0.00	2.10
Oct	13.60	70.00	54.94	1.34	1.22	1.22	1.22	0.00	1.22	0.00	0.00
Nov	10.00	70.00	25.91	3.13	0.50	0.50	0.50	0.48	0.02	0.00	0.00
Dec	6.60	81.90	24.74	3.89	-0.18	-0.18	-0.18	-0.18	0.00	0.00	0.00

As can be seen in the attached images, the data provided by the website http://diagramasbioclimaticos.com includes the temperatures for the different months of the year. From this data it is easy to make a selection for the calculation of derived variables such as the average annual temperature, the average winter/summer temperature, the average temperature of the coldest month or the warmest month.

2.1.3.2. Precipitation (P)

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Similarly, layers can be calculated for the derived precipitation variables. The average annual precipitation, or the average winter/spring/summer/autumn precipitation.

Estacion:	Monterrey, Almeria, España, [37.025806 - -2.895444], 1222.000000 m.s.m.									
Ref:										
CRT:	204.25									
	T	P	ETP	CP	IBP	IB	IBR	IBL	IBC	IBS	ISS
Jan	6.00	48.10	22.40	2.43	-0.30	-0.30	-0.30	-0.30	0.00	0.00	0.00
Feb	6.70	68.30	30.33	2.56	-0.16	-0.16	-0.16	-0.16	0.00	0.00	0.00
Mar	8.60	94.50	59.94	1.72	0.22	0.22	0.22	0.22	0.00	0.00	0.00
Apr	10.20	56.50	81.35	0.62	0.54	0.33	0.33	0.33	0.00	0.00	0.21
May	13.80	33.00	104.95	0.14	1.26	0.18	0.18	0.18	0.00	0.00	1.08
Jun	18.50	6.20	140.14	-0.19	2.20	-0.43	0.00	0.00	0.00	-0.43	2.20
Jul	22.60	4.10	168.34	-0.22	3.02	-0.66	0.00	0.00	0.00	-0.66	3.02
Aug	22.40	20.30	168.24	-0.10	2.98	-0.30	0.00	0.00	0.00	-0.30	2.98
Sep	18.40	20.10	87.49	0.04	2.18	0.08	0.08	0.00	0.08	0.00	2.10
Oct	13.60	70.00	54.94	1.34	1.22	1.22	1.22	0.00	1.22	0.00	0.00
Nov	10.00	70.00	25.91	3.13	0.50	0.50	0.50	0.48	0.02	0.00	0.00
Dec	6.60	81.90	24.74	3.89	-0.18	-0.18	-0.18	-0.18	0.00	0.00	0.00

2.1.3.3. Potential evapotranspiration (ETP)

In our experience, the most significant ETP is usually the one calculated from the annual average and the one that refers to the summer months when drought is most severe. However, this is a perception that may be altered depending on where we are in the world.

Estacion:	Monterrey, Almeria, España, [37.025806 - -2.895444], 1222.000000 m.s.m.									
Ref:										
CRT:	204.25									
	T	P	ETP	CP	IBP	IB	IBR	IBL	IBC	IBS	ISS
Jan	6.00	48.10	22.40	2.43	-0.30	-0.30	-0.30	-0.30	0.00	0.00	0.00
Feb	6.70	68.30	30.33	2.56	-0.16	-0.16	-0.16	-0.16	0.00	0.00	0.00
Mar	8.60	94.50	59.94	1.72	0.22	0.22	0.22	0.22	0.00	0.00	0.00
Apr	10.20	56.50	81.35	0.62	0.54	0.33	0.33	0.33	0.00	0.00	0.21
May	13.80	33.00	104.95	0.14	1.26	0.18	0.18	0.18	0.00	0.00	1.08
Jun	18.50	6.20	140.14	-0.19	2.20	-0.43	0.00	0.00	0.00	-0.43	2.20
Jul	22.60	4.10	168.34	-0.22	3.02	-0.66	0.00	0.00	0.00	-0.66	3.02
Aug	22.40	20.30	168.24	-0.10	2.98	-0.30	0.00	0.00	0.00	-0.30	2.98
Sep	18.40	20.10	87.49	0.04	2.18	0.08	0.08	0.00	0.08	0.00	2.10
Oct	13.60	70.00	54.94	1.34	1.22	1.22	1.22	0.00	1.22	0.00	0.00
Nov	10.00	70.00	25.91	3.13	0.50	0.50	0.50	0.48	0.02	0.00	0.00
Dec	6.60	81.90	24.74	3.89	-0.18	-0.18	-0.18	-0.18	0.00	0.00	0.00

The other calculated indices (described on the website) may be interesting, however, we have not tested them to generate subtract layers. When this process is done, it should be taken into account that there may be high correlation with temperature and precipitation information.

> **TASK 5**
>
> ·Open the QGIS program and load the ALMERIA_DEM layer.
> ·Open the spreadsheet ALMERIA_ESTACIONES.xsl.
> ·Save this information as plain text .CSV.
> ·Project the station points in QGIS and create a layer in shape format.
> ·Open the spreadsheet as a layer: LAYER – ADD LAYER - ADD DELIMITED TEXT LAYER
> ·Calculate the climatic variables following the steps: OPEN process toolbox- SAGA - RASTER CREATION
> ·TOOLS- REGRESSION KRIGING
> - o Points: Select ALMERIA_ESTACIONES
> - o Attribute: Select T/P/ETP
> - o Predictor: Select "elevation" as a covariable from ALMERIA_DEM layer.
> - o Maximum search distance: 15000 (This value depends on how large the study area is).
> - o Number of points: Minimum: 5 (This value depends on the number of available stations).
> - • Save your process and name the final raster layer.

2.1.3.4. Climate Stability Index (CSI)

In addition, new Climate Stability Index (CSI) could be used. The CSI considers bioclimatic variables for two different time ranges: (1) from Pliocene (3.3 Ma) to the present (CSI-past map set), using 12 time periods of PaleoClim representing warm and cold cycles; and (2) from present to the year 2100 (CSI-future), using nine general circulation models of climate change of four periods available from WorldClim. CSI is an

index that can be re-calculated according to particular criteria and objectives (e.g., temperature variables); maps are, therefore, customizable to every user. https://doi.org/10.1038/s41597-022-01144-5
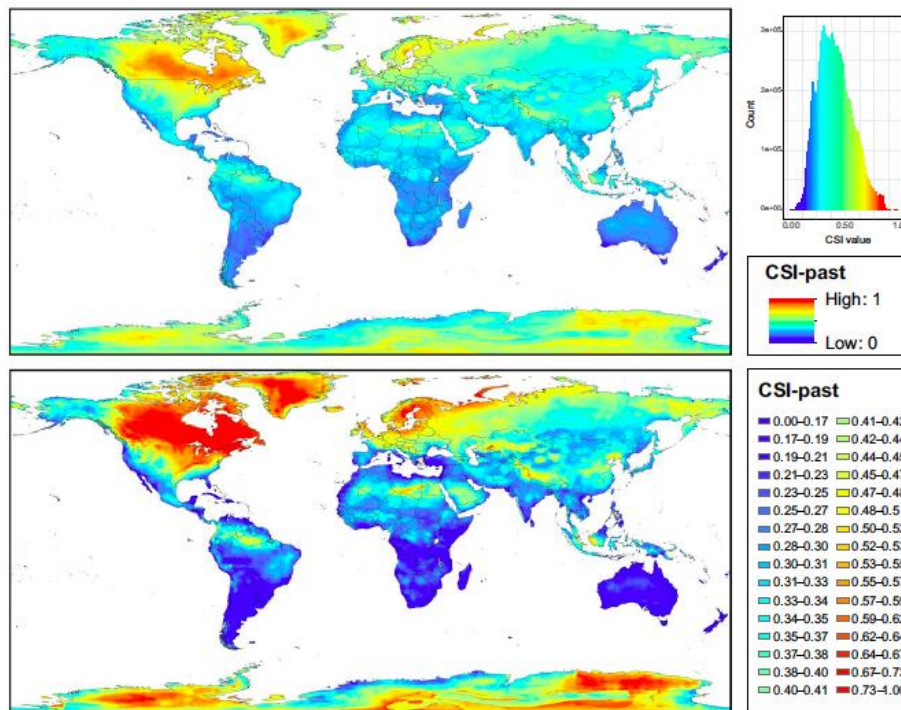
2.1.3.5. Other datasets

- The CHELSA database (https://chelsa-climate.org; Karger et al., 2017) host Bioclimatic data at 30 arc-second resolution.

- On the SoilGrids database (https://soilgrids.org/; Hengl et al., 2017) edaphic and lithological variables are available at the same resolution.

3.   PREPARATION OF THE MODELLING

3.1. Variables selection
3.1.1.   Collinearity analysis

To avoid collinearity issues in the sets of environmental variables, and in order to select only non-redundant ones a correlation analysis may be conducted to select the less correlated variables. A correlation below 70% in the environmental variables may be an acceptable value, following Dormann et al. (2013).

3.1.3.   Variance inflation factor (VIF) analysis

To rule out multicollinearity of environmental variables, in addition we can perform a VIF (Variance Inflation Factors) analysis with R software (Fox, 2016; Fox and Monette 1992; Fox and Weisberg, 2011; Heiberger, 2020; Hijmans, 2018). According to this methodology, the value for the VIF analysis must be less than 5 (or additional variables with a high VIF may be excluded until all remaining variables had VIF < 10).

Code (R software is required)

```
INSTALL DISMO PACKAGE AND ALL ITS DEPENDENCIES (RUN ONLY ONCE).
install.packages("dismo", dep=TRUE)
install.packages("plotmo", dep=TRUE)
install.packages("rgeos", dep=TRUE)
install.packages("HH", dep=TRUE)
LOAD THE NECESSARY LIBRARIES (RUN WHENEVER YOU WORK WITH THE SCRIPT)
library(raster) #WORKING WITH RASTER DATA
library(HH) #VARIANCE INFLATION FACTOR
library(rgeos) # GEOMETRIC OPERATIONS WITH GEOGRAPHIC INFORMATION
library(dismo) # LIBRARY FOR DISTRIBUTION MODELS
# we import maps in the .asc format
#check extension
> extent(raster name)
class     : Extent
#check resolution
> xres(raster name)


################################################################
# CORRELATION ANALYSIS OF PREDICTOR VARIABLES
################################################################

#LIST OF VARIABLES (also extension asc.aux)
list.variables <- list.files(path="C:\\...",pattern='*.asc', full.names=TRUE)
#LIST of VARIABLES (only .asc)
list.variables <- list.files(path="C:\\...",pattern='*.asc', full.names=TRUE)
variables<-stack(list.variables)
> names(variables)
 [1] "Aspect"    "DEM"       "EVI"
 [6] "Hillshade" "Hillshadow" "LST"       "NDSI"       "NDVI"
[11] "NDWI"       "Pendiente" "Thermal"

#TRANSFORM MAPS INTO A TABLE
```

variables.table<-as.data.frame(variables)

#DELETA NULL VALUES
variables.table<-na.omit(variables.table)

# CORRELATION MATRIX
help(cor)
variables.correlation<-cor(variables.tabla)
#DISTANCE MATRIX ('ABS' = ABSOLUTE VALUE, TO ELIMINATE NEGATIVE
CORRELATIONS)
help(as.dist)
help(abs)
variables.dist<-as.dist(abs(variables.correlation))
variables.dist

CLUSTERING OF VARIABLES ACCORDING TO DISTANCE (SMALLER DISTANCE =
HIGHER CORRELATION)
help(hclust)
variables.cluster<-hclust(1-variables.dist)

#CALCULATE THE VARIANCE INFLATION FACTOR
result.vif<-vif(variables.tabla)
result.vif

3.2. Species occurrences

Occurrence points included those obtained during our own fieldwork and those obtained from the biodiversity database GBIF.

TASK 7
·Download a species data collection from GBIF (Preferably of some species from Almeria).
·Transform this data collection in order to make it loadable on QGIS as a Shapefile.
·Project this data in GQIS.
·Examine the data set in order to find any suspicious or erroneous data.
·If you find any errors, please remove them.

3.3. Run MaxEnt

To open MaxEnt, click on the maxent.bat file. To begin, you must provide a Samples file. This file is the presence localities in .csv format (task 5). Navigate to this file by clicking the Browse button under Samples, or you can type in the file path. Next you have to provide the Environmental Layers used for the model. This will be the folder that contains all your environmental layers in ASCII format (they must have an .asc file extension) with the same geographic bounds, cell size, and projection system. Navigate to this folder by clicking the Browse button under Environmental Layers, or type in the file path. Notice how you can change the environmental layers to either continuous or categorical. If any of the layers you include in your environmental layers are categorical (e.g., vegetation type), make sure you change them by clicking on the down arrow and choosing categorical. An Output folder also needs to be selected. This will be the folder where all the MaxEnt outputs will be stored. For this exercise, we will use the folder created earlier named Outputs. Navigate to this folder by clicking the Browse located next to the Output Directory, or type in the file path.
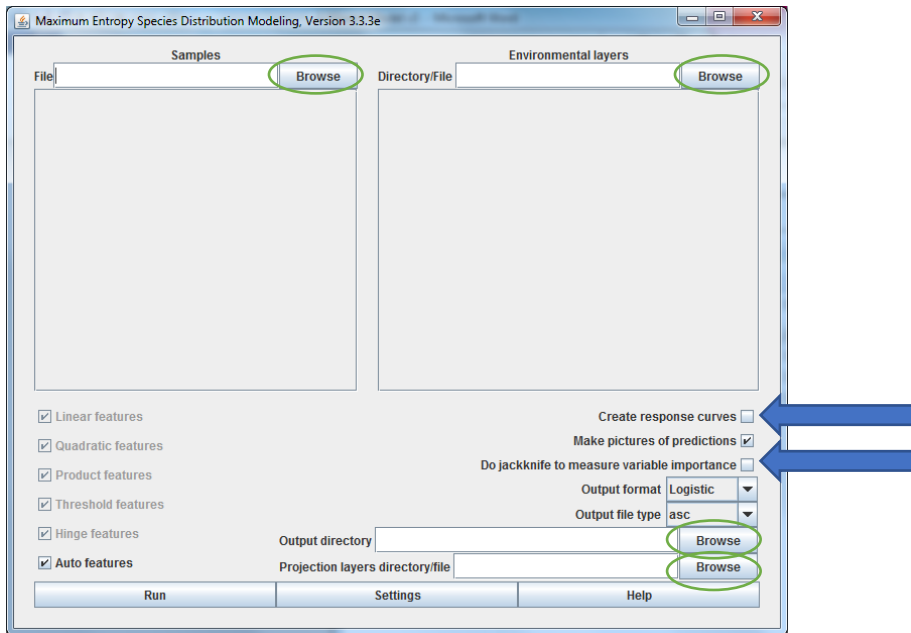
Make sure that the Create Response Curves, Make Pictures of Predictions, and Do jackknife to Measure Variable Importance boxes are all checked.

Keep the Auto Features box checked and leave the Output Format as Logistic and the Output file type as .asc.

> **TASK 8**
>
> ·Load the species data collection.
> ·Load the environmental variables collection from Almeria (Gypworld_modelling_workshop).
> ·Run MaxEnt.
> ·Check and share the result form the website.
> ·Load the resulting raster layer in Qgis.

For more information on how the software works, please refer to the guides provided in the course information
(http://ibis.colostate.edu/webcontent/ws/coloradoview/tutorialsdownloads/a_maxent_model_v7.pdf).

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