PLANT SOCIOLOGY

formerly FITOSOCIOLOGIA

Volume 54 (2) - Suppl. 1 - December 2017

EDITO DALLA SOCIETA' ITALIANA DI SCIENZA DELLA VEGETAZIONE ONLUS - PAVIA - DIRETTORE RESPONSABILE PROF. E. BIONDI - SUPPLEMENTO 1 - VOLUME 2 - II° SEMESTRE 2017

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Journal of the Italian Society for Vegetation Science

Plant Sociology, Vol. 54, No. 2, Suppl. 1, December 2017, pp. 61-76
DOI 10.7338/pls2017542S1/06

PLANT SOCIOLOGY
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Vegetation Science

Towards a global checklist of the world gypsophytes: a qualitative approach

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Abstract
Interest in plants growing on special substrates has increased considerably in recent years. The studies on halophytes (plants restricted to saline soils) and serpentinophytes (those restricted to ultramafic rocks) are good evidence of this trend. Research on the phenomenon of gypsophily has not been developed as widely as the other two before-mentioned fields, but important progress has been reached. The existence of a global database about gypsophytes and territories with gypsum substrates would imply a big leap in quality. The bibliographical criterium was selected in order to build this compilation as the only preliminary way to face the problem. According to the research about reviewing of distribution and ecology patterns of 209 *taxa*, it is possible to asure that there are gypsum outcrops in 112 countries. In 71 of those countries some clues point to the existence of a flora on gypsum, in which clear and undoubted cases of plant species directly related to gypsum soils in 53 countries have been found. These results show, on the one hand, the need of a deep correction to increase the data contained in previous reviews on gypsum outcrops distribution and, on the other hand, the diffussion of gypsophily phenomenon in plant species. Although the presence of genuinely gypsophyte *taxa* is much higher in dry climates, gypsum outcrops also show floristic peculiarities in wet climates, such as a refuge for xerothermophilic *taxa*, which clearly fits within the phenomenon of gypsum edaphism.

Key words: biogeography, gypsophily, gypsophile, gypsum, flora, soil.

Introduction

Having pointed out that early humans moved across the primordial landscape, they must have been keenly aware of spatial variation in the natural world (Lomolino, 2001); among those variations the fact that different types of soil can give different types of vegetation was probably perceived. Nevertheless, it was not until Theophrastus (371-287 BC), that the first explicit statement on this subject was delivered: “For it is the differences of soil which give a special character to the vegetation. (However the word “special” is used here in a somewhat wide sense)” (Teophrastus, 1999).

Since then, scientists have begun to figure out and explain the existence of peculiar floras associated with different sorts of soils (the “special characters” of Teophrastus), so much so that a number of fruitful studies have been carried out on saline and serpentine soils. Although to a lesser extent, the study about plant ecology on gypsum environments has acquired great significance, especially in recent years. The study of this edaphism is not a small incentive (Mota *et al*., 2016): gypsum is a stressful environment that imposes severe restrictions on plants, where *taxa* are restricted to this type of substrate, with unique ecophysiological processes, some of them endemic of a region, or even rigurously local distributed species. Some of the gypsicolous *taxa* are endangered, thus they must also be considered from the perspective of Conservation Biology. In addition, gypsum is an industrial mineral; this fact could jeopardise the conservation of biodiversity, whose preservation and exploitation interest need to be harmonised. This poses a serious challenge (Mota *et al*., 2004, 2011).

In order to delve into this exciting topic and to be able to carry out studies that reach the gypsum outcrops worldwide, the global network of researchers GYPNET was constituted (http://gypnet.weebly.com). The first meeting took place in Aranjuez (Madrid, Spain), in 2016 March, and was conducted by Sara Palacio (Instituto Pirenaico de Ecología, Jaca) and Adrián Escudero (Rey Juan Carlos University, Madrid). This article, complemented by other published study – Mota *et al*. (2016) – are an attempt to reach that goal.

The development of this checklist is essential to understand the gypsophily phenomenon. It is true that previous lists elaborated by expert criteria cannot provide explanations about the mechanisms that make gypsofily possible, still they can be useful to put forward new hypotheses and try to verify (or not) the existing ones (Mota *et al*., 2016).

The main aim of the present study is to show the preliminary results stemming from the elaboration of the global checklist of gypsophytes, beginning with the review, on the one hand, of the flora in those countries with gypsum substrates, and on the other, providing the examples of *taxa* restricted to such substrates.

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Materials and methods

For the elaboration of a global checklist of gypsophilic flora, the inductive approach was adapted according to the proposals published by Mota *et al*. (2011, 2016). In relation to this idea, a gypsophyte is a plant that grows exclusively (or almost) on gypsum, although in this investigation other non-exclusive *taxa* were also contemplated, considering whether there were bibliographic testimonies about their preference for gypsum (gypsoclines), or even if they had been indicated as species related to this type of substrate. In short, all those species that those floras or other revised publications, indicated as related to gypsum were included in this first approach of the checklist, even if that relationship could not be documented.

The identification of all countries with gypsum outcrops, or at least with a mining of such material, regardless of whether there were gypsophyte citations, was also considered of great interest. In addition, the presence of *taxa* related to gypsum was compared to mining production, as this can be interpreted – with some limitation – as a proxy for the amount of the deposits and/or the anthropic pressure that could be borne by the possible gypsophytes. This strategy leaves the door open for future research, but it must be noted that there may be gypsum production from industrial or subterranean origin. Such production data are provided by USGS (2016), and refer to 2013 (last complete Mineral Yearbook, which includes all countries).

As has already been mentioned, the bibliographical criterion (species collected in the bibliography as characteristic of gypsum) was basically used for the elaboration of such checklist, which is a variant of the expert criterion (Mota *et al*., 2008, 2009), from data included in Floras, Virtual Floras online, Red Lists and taxonomic revisions. Vegetation studies were also a valuable source of information. In this sense, the syntaxonomic criterion (diagnostic or characteristics of sintaxta species, which are exclusive of gypsum) and the bioindicator criterion (*i.e.* species that grow or cohabit with other undoubtedly gypsophyte species, "ultragypsophytes") were also implemented. For the taxonomic scheme we adopted the one proposed by The Plant List (http://www.theplantlist.org/), although this fact meant correcting the names used in the consulted bibliography. One problem derived from the multiplicity of data sources was the edaphic behavior heterogeneity of studied species. While there were evidently many casuistic and nuances, a simple scheme was chosen based on the scale proposed by Mota *et al*. (2009). However, in this case only the two maximum gypsophily levels were taken into account: gypsophytes and gypsoclines (where halogipsophytes, gipsodolomitophytes and other types of biedaphic plants were also included).

Therefore, a restricted catalogue that included only the gypsophyte *taxa*, and in addition an extended catalogue that included both gypsophytes and gypsoclines were used. The bibliography consulted appears compiled in the references section. Among the documents consulted are 34 books and 102 scientific articles and other data sources.

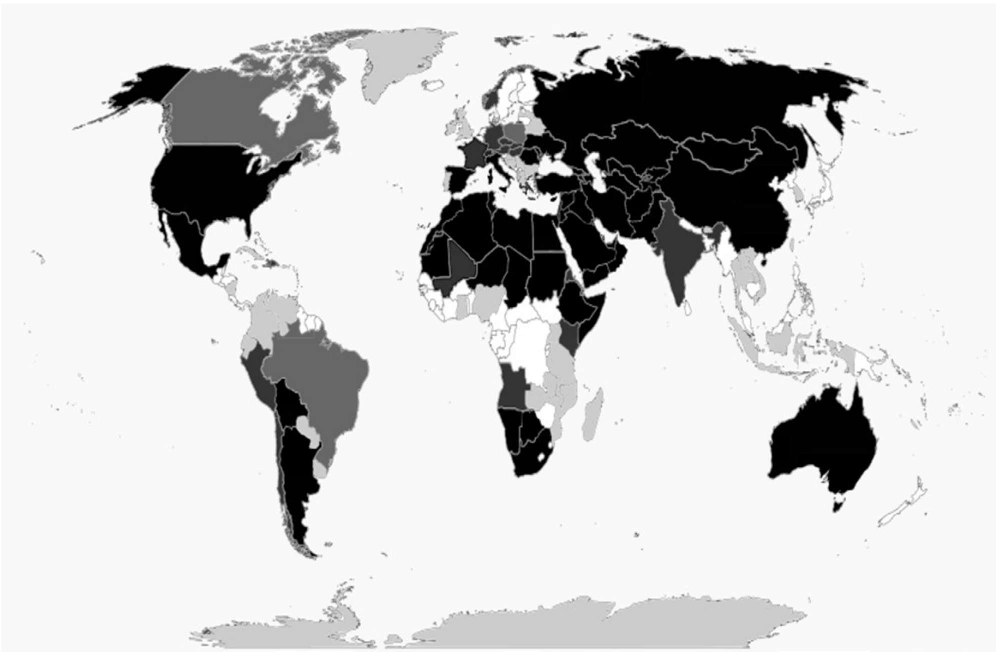

Fig. 1 - Global distribution of gypsum deposits and gypsophile flora: countries with proven presence of gypsophyte species (black), countries without gypsophytes but with presence of gypsoclines (dark grey), countries without presence of gypsophytes or gypsopclines, although there are distinguishable traces in flora vegetation (medium grey), Countries with gypsum deposits but without floristic or vegetation data linked to gypsum (light grey).

Results and Discussion

The results of the performed qualitative analysis are shown at the end of this section. Altogether, information about 112 countries (see Fig. 1), 208 cited *taxa* (145 gypsophytes, 146 gypsoclines and 10 suspicious species) has been sought. There are 71 countries with proven presence of gypsophyte species, without gypsophytes but with presence of gypsoclines, 53 countries are counted. There are three countries without presence of gypsophytes or gypsopclines, although with distinguishable traces in flora and vegetation. A total of 36 countries were able to catalogue as "with gypsum deposits but with no data about floristic or vegetation linked to gypsum". This latter fact confirms that the articles from Scopus database directly referring to gypsohily or gypsophytes include ten countries (Mota *et al*., 2016).

The first outcome, which can be extracted from the collected information, is that gypsum is an extremely abundant mineral, and that gypsum substrates are widespread in all contients, and under a number of different climatic conditions, and also that they occur in many geological and edaphic variants (soils with crusts, sands with no crusts, in gravel pits ("haswa"), mixed with clay, sands, marl, etc.). The general idea that gypsum soils are only present in arid and semiarid climates, does not fit with reality, since there are outcrops in very rainy areas too.

A fact beyond all discussion is the wider presence of confined *taxa* to gypsum environments in arid climates than in humid climates. Undoubtedly, gypsophilyis a more extended phenomenon than was believed until now. In this sense, the world map of gypsum soils and gypsum habitats published by Escudero *et al*. (2015) – based on the previous map by Verheye & Boyaddgiev (1997) – is a good starting point, but it could to be increased with numerous regional additions.This is one of the basic tasks that GYPNET should encourage.

Moreover, according to the classic definition of edaphism collected in the botanical dictionary of Font Quer (1982), and adding in brackets the necessary hints to fit the case of gypsum, gypsum edaphism can be defined as: 'the set of geobotanical phenomena dependent on the [gypsum] nature of soil'. Therefore, geobotanical phenomena linked to the gypsum nature of the soil can be described, which do not entail the confinement of endemic *taxa* to gypsum substrates. An example could be the fact that in humid zones gypsum substrates act as a refuge for xerophthermophilic *taxa*, which are absent (or almost) around gypsum outcrops. This occurs in areas as humid as the Alps, Germany, Poland, Nova Scotia (Canada) or the slopes of Sierra de Líbar (Spain). Another preconceived idea about gypsum outcrops, which should be delved into, is that such stressful conditions make gypsum soils largely unsuitable for the growth of trees (Rivas-Martínez & Costa, 1970; Palacio *et al*., 2007). According to this thesis, trees are absent or are very rare, and therefore, forests might not develop on gypsum. However, there are beech forests on gypsum soils in Germany (Schmid & Leuschner, 1998), holm-oaks and pinewoods in Sicily (Italy) on gypsum too (G. Spampinato, Mediterranean University of Reggio Calabria, com. pers.), etc. Denying the existence of forests on gypsum is difficult where there are gypsophyte trees (Poppendieck, 1981; Prado, 1998). Even in Spanish gypsum outcrops such assertion does not conform to reality (cf. Garrido-Becerra *et al*., 2016). What is certain is that vegetation on gypsum is more scattered and sparse than that on other types of neighbouring substrates, less stressful environments for vegetation. That lower productivity in gypsum soils could be a generalizable feature at the global level. As an example, the formations of *Acacia-Commiphora* woodland in East Africa and the Horn of Africa: the description of the facies in this biome on gypsum includes a reference to a more sparse distribution, especially when the presence of endemic gypsophytes is mentioned (Friis *et al*., 2016). In this regard, considering the lower competition with trees and shrubsland, a greater insolation as one of the drivers of the presence of certain species in gypsum (Palacio *et al*., 2007) is logical, although with the mentioned nuances.

The countries analyzed are detailed below.

Countries with proven presence of gypsophyte species

Afghanistan. Numerous gypsophyle species can be found here, such as *Mattiastrum sessiliflorum* Rech.f. & Riedl, *Ferula oopoda* (Boiss. & Buhse) Boiss. or *Acanthophyllum spinosum* (Desf.) C.A. Mey. Numerous gypsoclines as *Atraphaxis spinosa* L. or *Ferula foetida* (Bunge) Regel, can also be cited (Sadat, 1989; Podlech, 2012).

Algeria. This country has important gypsum deposits, and gypsum soils take up 7,966 km^2 (FAO, 1990). Two components of the flora with gypsum affinity can be recognized in this country. On the one hand, in the north under Mediterranean climate, there are outcrops that share floristic elements with the Iberian Peninsula (*e.g. Helianthemum squamatum* (L.) Dum. Cours.), while the southern outcrops, in the desert climate of the Sahara, can host other gypsophytes such as *Echium suffruticosum* Baratte (Quézel & Santa 1962-1963).

Argentina. This country has remarkable gypsiferous resources, widely distributed in the north. Outcrops with an associated gypsophile flora are found in the western part of the country, in the so-called Monte Desert biome – inner basins at the Andes foothills – where severe aridity conditions exist (Abraham *et al*. 2009, Devillers & Devillers-Terschuren 1996). As gypsophyte plants, *Halophytum ameghino*i Speg., *Polygala* *hieronymi* Chodat or *Atriplex argentina* Speg. have been cited (Devillers & Devillers-Terschuren 1996). In addition, the gypsophyte tree *Cochlospermum tetraporum* Hallier has been cited in the provinces of Salta and Jujuy, in the north, in the Chaco Serrano biome (Poppendieck 1981, Prado 1998). Knowing more data about the plant communities which this tree inhabits would be useful, since they probably contain other gypsophyte or gipsocline species.

Armenia. This country has several gypsum outcrops located on the slopes of its numerous mountain ranges. *Gypsophila aretioides* Boiss., *G. bicolor* (Freyn. & Sint.) Grossh. or *Lactuca takhtadzhianii* Sosn. can be cited as gypsophytes (Komarov, 1934-1964; Chemonics International Inc., 2000).

Australia. The island-continent has significant deposits of gypsum in Victoria, South Australia, Western Australia, Northern Territory and New South Wales. Still, not in all of them is a characteristic flora and vegetation recognizable. This occurs mainly in the southwestern area, under a Mediterranean climate. In Western Australia, gypsum dunes around saline lakes are significant (Mattiske, 1995a,b; FloraBase, 2015); here, *taxa* such as *Goodenia gypsicola* Symon or *Conostephium pungens* G.J. Keighery are present. The state of Southern Australia also has gypsiferous deposits, with gypsophytes such as *Austrostipa geoffreyi* S.W.L. Jacobs & J. Everett or *Melaleuca nanophylla* Carrick. (Symon, 2007). In the limit of their range, gypsocline *taxa* can be found in New South Wales, as is the case of *Kippistia suaedifolia* F. Muell. (PlantNET, 2015).

Azerbaijan. Gypsum outcrops have been located both in Nakhchivan exclave and in the rest of the country. Azeri flora has gypsophytes as *Scrophularia thesioides* Boiss. & Buhse, or several species of *Astragalus* genus as *A. argyroides* G. Beck, *A. onobrychioides* M. Bieb. and *A. sanguinolentus* M. Bieb. (Komarov, 1934-1964).

Bahrain. This small island has much of its territory occupied by sabkha (see Khan *et al*., 2006), some of which have a large gypsum presence (Bridges & Burhan, 1980). In these environments, gypsophytes species such as *Erodium glaucophyllum* (L.) L'Hér.; or halogypsophytes as *Panicum turgidum* Forssk. can be found (Al-Eisawi, 2003).

Bolivia. In the south of the country the "árbol del papel" is found (*Cochlospermum tetraporum*), a gypsophyte species already mentioned in the section dedicated to neighbouring Argentina (Poppendieck 1981, Prado 1998).

Botswana. In the eastern and southeastern areas of the country, the presence of stenochoric *taxa* linked to gypsum soils has been reported, such as *Euphorbia venteri* L.C. Leach ex R.H. Archer & S. Carter or *Blepharis bainesii* S. Moore ex C.B. Clarke, and, therefore, they can be considered as gypsophytes (Setshogo, 2005).

Chad. The north of the country is occupied by the Sahara desert, where gypsophytes as *Fagonia latifolia* Delile or *Helianthemum lippii* (L.) Dum. Cours. have been found, together with gypsoclines as *Zilla spinosa* (L.) Prantl or *Stipagrostis obtusa* (Delile) Nees (Le Houérou 1995; African Plant Database, 2015). In southern Bahr el Gazhal, deposits are located (Van Straaten, 2002), of which no floristic data are available. All these outcrops are low on gypsum purity; so that most of the consumed gypsum is imported (USGS, 2016).

China. This country is the world's leading producer of gypsum (132,000 kt per year [Crangle, 2016]). Outcrops with an associated peculiar flora are located especially in the arid region of Xinjiang, where Wu *et al*. (1994-2013) reported the presence of three *taxa* linked to gypsum substrates: *Astragalus arpilobus* Kar. & Kir., *A. oxyglottis* M. Bieb. and *Lachnoloma lehmannii* Bunge.This assessment is likely to be short, since in Chinese territory some *taxa* are present which are referred to as gypsophytes in neighboring countries (*Salsola affinis* C.A. Mey. ex Schrenk and *Seseli aemulans* Popov) or, at least, as gypsoclines, *Nitraria sphaerocarpa* Maxim., *Ferula canescens* (Ledeb.) Ledeb., etc. (Komarov, 1934-1964).

Cyprius. This island, along with Spain, are the only countries in Europe where gypsophilous vegetation is specifically protected (Anon., 2015). Some gypsophytes shared with other Middle East countries may be found, such as *Gypsophila linearifolia* (Fisch. & C.A. Mey.) Boiss. and *Herniaria hemistemon* J. Gay, or endemic elements as *Allium cyprium* subsp. *lefkarense* (Brullo, Pavone & Salmeri) Christodolus & Hand or Onobrychis venosa Desv. (Euro+Med, 2006-2015; Hand, 2009).

Egypt. The three deserts of the country have large gypsum outcrops (although often mixed with other materials such as sand and salts). In the Western Desert, the communities of *Resedeceae Randonia africana* Coss. monotypic genus (Abdallah, 1967; El Ghani & Marei, 2003) are remarkable. In the Eastern Desert there are also gypsophytes. Some of them show a rare biogeographic pattern, as *Moricandia sinaica* (Boiss.) Boiss., which reaches Somalia across the Red Sea coastline (African Plant Database, 2015). Some gypsophytes shared with Israel and neighbouring territories can be found in the Sinai Desert gypsum outcrops, such as *Haloxylon negevensis* (Iljin & Zohary) L. Boulos (Euro+Med, 2006-2015; Danin, 2015).

Ethiopia. This country has numerous deposits, totalling 1,423.4 km^2 of gypsum soils (FAO 1990). Outcrops with an associated peculiar flora are found mainly in the southeast of the country, in the Harerghe province, with gypsophytes as *Blepharis gypsophila* Thulin & Vollesen, *Kleinia gypsophila* J.-P. Lebrun & Stork, etc. (Thulin & Vollesen, 2015; Lebrun & Stork, 1989; African Plant Database, 2015). Yet, Ethiopian gypsum does not cease to amaze researchers, and recently two new *Nyctaginaceae* gypsophyles, endemic to Lele Hill (Bale province), have been discovered: *Commicarpus macrothamnus* Friis & O. Weber and *C. lelensis* Friis & Sebsebe (Friis *et al*., 2016).

Georgia. This transcaucasian republic has gypsum outcrops where several gypsophyte species have been cited, such as *Scabiosa meskhetica* Schchian or *Tragopogon marginatus* Boiss. & Buhse (Komarov, 1934-1964). Some of these *taxa* are endangered, as is the case of *Salvia compar* (Wissjul.) Trautv. ex Sosn (Eristavi *et al*., 2001). Curiously, despite having described this gypsophyle flora, gypsum production is scarce, only 0.13 kt per year (USGS, 2016).

Iran. This country has numerous gypsum outcrops and is the second producer of this material with 22,000 kt per year (Crangle, 2016). In addition, it has a rich associated flora widely distributed in almost all its geography. The south-western zone is worth noting, especially Ilam and Lorestan provinces – e.g. *Euphorbia acanthodes* Akhani or *Ferula behboudiana* (Rech. f. & Esfand.) D.F.Chamb.– (Akhani, 2004); western portion of Semman province – e.g. *Centaurea lachnopus* Rech.f. or *Acantholimon cymosum* Bunge – (Eftekhari & Asadi, 2001); and Yazd province – *Astragalus myrianthus* Beck or *Acanthophyllum sordidum* Bunge ex Boiss.– (Tilaki *et al*., 2011); as well as the northeastern area of the country, *i.e.* Khorasan province and surrounding areas – e.g. *Limonium sogdianum* (Pop.) Ikonn.-Gal. or *Onobrychis meshhedensis* (Širj. & Rech.) Ranjbar – (Eftekhari & Asadi, 2001). In addition, numerous gypsocline *taxa* from various typologies have been reported, such as halogypsophytes (e.g. *Hypocylix kerneri* Woł), calcareousgypsophytes (e.g. *Paracaryum luristanicum* Nábělek), gypsoserpentinophytes (e.g. Astragalus assadii Maassoumi & Podl.), etc. (Akhani & Ghorbanli, 1993; Akhani, 2004; Podlech, 1988).

Iraq. The area of gypsiferous soils in Iraq was estimated at 12,503,000 ha or 28.6% of all the agricultural soils in the country, (or 6.7% of all gypsiferous soils in the world). Gypsiferous soils are well represented in the Euphrates river basin in Iraq (Jaradat, 2002) and especially in the area of Mosul (Guest, 1966), whose "Mosul Marble" has been well-known since Assyrian times. Among the Iraqi gypsophytes, *Kaviria azaurena* (Mouterde) Sukhor., *Astragalus akhanii* Podlech, A. baba-alliar Parsa, etc. can be mentioned (Guest, 1966; Townsend & Guest, 1974).

Israel. The Flora Palaestina (Zohary & Feinbrum-Dothan, 1966-1986) mentions ten plants considered gypsophytes growing in Israeli territories (e.g. *Haloxylon negevensis* (Iljin & Zohary) L. Boulos, *Fagonia mollis* Delile, *Nasturtiopsis coronopifolia* subsp. *arabica* (Boiss.) Greuter & Burdet). Probably, this is a conservative estimation and the Israeli gypsophyle flora might be larger, given the presence in Israel of *taxa* recognized as gypsophytes in other territories, such as *Echium suffruticosum*, *Helianthemum kahiricum* Delile, etc. (Danin, 2015).

Italy. It is the second European producer and the tenth one in the world, with 4,100 kt per year (USGS, 2016). Although there are small outcrops across almost the whole country (Antolini, 1984), large deposits are located in Emilia Romagna, Sicily and, to a lesser extent, in Calabria. A number of gypsophytes grow on the Sicilian outcrops, such as *Brassica villosa* subsp. *tinei* (Lojac.) Raimondo & Mazzola, *Gypsohila arrostii* Guss., etc. (Gianguzzi *et al*., 2010). Emilia Romagna gypsum outcrops are very interesting from the bryophytes point of view (Aleffi *et al*., 2014), but as far as vascular plants are concerned, there is no component of gypsophytes, with the exception of *Allosorus persicus* (Bory) Christenh. This rupicolous fern has its only Italian population on gypsum rocks, thus it can be considered as a gypsophyte at national level (Pignatti, 1982). Recently, a group of researchers has developed a project to elaborate and analyse the checklist of Italian gypsophytes (Musarella *et al*., 2016)

Jordan. Some gypsiferous outcrops can be found in this country's deserts, although gypsum soils only occupy 0.8% of the national territory (FAO, 1990). In these zones, gypsophyte *taxa* such as *Herniaria hemistemon* or *Erodium glaucophyllum* can be found, as well as gypsocline species as *Nitraria retusa* (Forssk.) Asch. or *Limonium pruinosum* Kuntze (Zohary & Feinbrum-Dothan 1966-1986; Al-Eisawi, 1996; Musselman, 2007).

Kazakhstan. The country that occupies most of the Aral-Caspian depression, host in their deserts and steppes numerous gypsophytes, such as *Anabasis gypsicola* Iljin, *Ferula eremophila* Korovin, *Gypsophila aulieatensis* B. Fedtsch., etc. (Komarov, 1934-1964).

Kuwait. This small emirate has 354 km^2 of gypsum soils (FAO, 1990). In this country, some gypsophytes as *Diplotaxis harra* (Forssk.) Boiss. subsp. *harra* or *Herniaria hemistemon* have been mentioned, as well as several gypsocline *taxa* as *Haloxylon salicornicum* (Moq.) Bunge ex Boiss (Daoud & Al-Rawi 1985).

Kyrgyzstan. This country is largely occupied by the great mountain range of the Tian Shan ("Heaven mountains") and, along with others (Turkmenistan, Uzbekistan and Tajikistan), shows the presence of gypsum and gypsophytes not only in the lowlands, but also in the middle mountains, under very severe climatic conditions (especially in winter). Among the Kyrgyz gypsophyle flora, *Ferula gypsacea* Korovin, *Haplophyllum leptomerum* Lincz.& Vved., *Centaurea lasiopoda* Popov & Kult., etc. can be cited (Komarov, 1934-1964). Curiously, mining production is scarce:

0.113 kt per year (USGS, 2016).

Lebanon. Compared to the rest of the Middle East countries, the Lebanese gypsum substrates are scarce, and their production is only 0.11 kt per year (USGS, 2016). In this territory, *Astragalus guttatus* Banks & Sol. and *Prosopis farcta* (Banks & Sol.) J.F. Macbr. have been cited, which are *taxa* respectively considered as gypsophyte and gypsocline in other countries (Lebanon FLORA, 2016).

Libya. This country has deposits where gypsophytes as *Henophyton deserti* (Coss. & Durieu) Coss. & Durieu, *Diplotaxis harra* subsp. *harra*, *Helianthemum lippii*, etc. can be found (Euro+Med, 2006-2015, African Plant Database, 2015).

Mauritania. The deposits of this country are located in sabkha (Van Straaten, 2002). In such outcrops, gypsophytes as *Randonia africana*, *Fagonia latifolia* can be found; or halogypsophytes as *Frankenia thymifolia* Desf. (Le Houérou, 1995; African Plant Database, 2015).

Mexico. This country has large deposits and is the seventh producer in the world, 5,300 kt per year (USGS, 2016). Floristically, the most interesting outcrops are located in the north of the country, in several states under desert climate as Baja California – e.g. *Fagonia palmeri* Vasey & Rose – (Felger *et al*., 2012); Coahuila, – e.g. *Marshalljohnstonia gypsophila* Henrickson, or *Dyssodia gypsophila* B.L. Turner – (Henrickson, 1976; Powell & Turner, 1977); Chihuahua – e.g. *Tiquilia hispidissima* (Torr. & A. Gray) A.T. Richardson, or *Machaeranthera gypsophila* B.L. Turner – (Moore & Jansen, 2006; Anon., 1993–2015); Durango – e.g. *Dicranocarpus parviflorus* (A. Gray) A. Gray, or *Xanthisma gypsophilum* (B.L. Turner) D.R. Morgan & R.L. Hartm.– (Moore & Jansen, 2006); Nuevo León – e.g. *Erigeron gypsoverus* G.L. Nesom, or *Verbisina hintoniarum* B.L. Turner – (Nesom, 2007; Hinton & Turner, 2007) and San Luís Potosí – e.g. *Pellea ribae* A. Mend. & Windham, or *Sisyrinchium zamudioi* Espejo, López-Ferr. & Ceja – (Mendoza *et al*., 2001; Espejo *et al*., 1998). In the south, on the Pacific coast, frequently in rupicolous or subrupicolous positions among tropical deciduous forests, the outcrops of Colima are worth mentioning, with species such as *Graptopetalum glasii* Acevedo-Rosas & Cházaro or *Pinguicula colimensis* McVaugh & Mickel – which are also in Michoacán and Guerrero – (Acevedo-Rosas & Cházaro, 2003; Mc Vaugh & Mickel, 1963); Jalisco, with the gypsocline *Agave gypsophila* Gentry – which is also present in Colima and Guerrero – (García-Mendoza, 2003); and Oaxaca, with species as *Pinguicula medusina* Zamudio & Studnička (Zamudio & Studnicka, 2000). In the state of Campeche, in the middle of a tropical forest landscape, the outcrop of the Zoh-Laguna plateau is found, where there are some *taxa* listed as gypsophytes – e.g. *Holographis websteri* T.F. Daniels or *Lantana dwyeriana* Moldenke – even, *taxa* that could be called 'hygrogypsophytes' in "bajos" communities–e.g. *Fuirena stephani* Ramos & Diego – (Martínez & Galindo-Leal, 2002). The Mexican gypsum flora characterization began with the work of J. Valdés and H. Flores-Olvera (UNAM, México D.F.) (see Sánchez del Pino, 1999). Currently, H. Flores-Olvera, H. Otorena (also from UNAM) and M.J. Moore (Oberlin College, OH, USA) are elaborating a checklist of Mexican gypsophytes.

Moldova. This small country has gypsum areas on its border with Ukranie, where kastificacation phenomena exist (Klimchouk, 1996). The presence of the gypsophyte *Gypsophila collina* Ser. and the gypsocline *Astragalus exscapus* L. subsp. *exscapus* have been cited (Euro+Med, 2006-2015).

Mongolia. In the Gobi desert, there are considerable gypsum deposits, where several gypsocline *taxa* are present, some of them endemic, such as *Allium mongolicum* Regel, and *Cleome gobica* Grub. (Virtual Flora of Mongolia, 2015; Chimed-Ochir *et al*., 2010).

Morocco (including Western Sahara). Like its neighbor Algeria, there are two components in the flora with gypsum affinity: on the one hand, a northern-Mediterranean part, where there are outcrops with either endemic elements (e.g. *Perralderia paui* Font Quer), or species in common with the Iberian Peninsula (e.g *Lepidium subulatum* L.) (Deil, 2005; Fennane & Ibn Tattou, 2005). On the other, a Saharan component, with a desert climate where gypsophytes as *Fagonia latifolia* – or, according to Le Houérou (1995) halogypsophytes as *Suaeda vermiculata* Forssk. ex J.F.Gmel.– can be found (African Plant Database, 2015).

Namibia. In the Namib desert, there is abundant gypsum mainly on the surface, which is presented as gypsum-enriched sands and gravels; these gypsum-bearing sands grading between 30-90% gypsum (Van straaten, 2002). The *Arthraerua leubnitziae* (Kuntze) Schinz endemism can be cited as a gypsophyte; and *Tetraena stapfii* (Schinz) Beier & Thulin, and *Salsola tuberculata* (Fenzl ex Moq.) Schinz (Van Rooyen, 2010) as halogypsophytes. Furthermore, the communities on shallow soils (partly quartz covered) above gypsum crusts, which are integrated by *Brownanthus pubescens* (N.E. Br. ex C. A. Maass) Bulock, *Ruschia inconspicua* L. Bolus and *Portulacaria pygmaea* Pillans, deserve being mentioned (Jürgens, 2004).

Niger. In the country of the Ténéré Desert, considerable gypsum reserves can be found, especially in the I-n-Aridal area (Van Straaten, 2002), which are not significantly exploited (USGS, 2016). In this republic there are typically Saharan gypsophytes, like *Fagonia latifolia* or *Stipagrostis ciliata* (Desf.) De Winter, as well as gypsoclines as *Panicum turgidum* (Le Houérou, 1995; African Plant Database, 2015).

Norway. Within the Svalbards archipelago, in the western part of the Spitsbergen island, there is a region with great gypsum outcrops dating from the lower Permian period (Lauritzen, 1981). This is precisely the region is called Gipsdalen ('Land of Gypsum' in Norwegian) and is a part of a natural protected area, the Sassen-Bünsow Land National Park (Brekke & Hansson, 1990). At archipelago scale, *Carex marina* subsp. *pseudolagopina* (Sørensen) Böcher, *Juncus castaneus* Sm. and *Kobresia simpliciuscula* (Wahlenb.) Mack. can be considered as gypsophytes (Brekke & Hansson, 1990; Engelskjøn *et al*., 2003).

Oman. Although much of the Sultanate's geology is ultramafic, with Semail Ophiolite (Searle & Cox 1999), there are also gypsum materials (FAO, 1990) and the country is a major producer of this mineral (USGS, 2013). Gypsophytes as *Cleome glaucescens* DC., or *Physorhynchus chamaerapistrum* Boiss. Inhabit its outcrops, along with some gypsoclines as *Panicum turgidum* (Ghazanfar, 2007-2010).

Palestine (state of). With a one-off exception, all the gypsophyte flora present in southern Israel is also present in Cisjordanian territory, with gypsophyte *taxa* as *Halothamnus lancifolius* (Boiss.) Kothe-Heinr., *Herniaria hemistemon*, *Reseda muricata* C. Presl (Zohary & Feinbrum-Dothan, 1966-1986).

Pakistan. In this country, there are considerable gypsum deposits (USGS, 2013). Some *taxa* that have been cited as gypsophytes in neighboring countries are present, such as *Acanthophyllum sordidum* Bunge ex Boiss., or *Ferula oopoda* (eFloras, 2008; Komarov, 1934-1964). The ecological behaviour of this sort of *taxa* should be further explored.

Qatar. In this little Emirate, a gypsum desert appears in the west and north-west, particularly in the Dukhan area. There are elements shared with other parts of the Middle East, such as *Bassia muricata* (L.) Asch., or *Reseda muricata* (Norton *et al*., 2009).

Romania. The gypsum deposits of Transilvanian Basin are very important (especially those from the Cluj region). From the floristic point of view, several gypsoclines as *Centaurea phrygia* subsp. *razgradensis* (Velen.) Greuter, *Krascheninnikovia ceratoides* (L.) Gueldenst., etc. can be mentioned. *Gypsophila collina*, can be cited as gypsophyte (Kovás, 2008).

Russia. It is the ninth gypsum producer in the world (4,500 kt per year [USGS, 2016]). The cases of a peculiar flora and vegetation associated with gypsum occur in three clearly defined zones: Pinega river basin, beside the city of Arkhangelsk, in the Artic, with a dry and very cold cimate, where the gypsophyte *Gypsophila uralensis* subsp. *pinegensis* (Perf.) R. Kam –a local endemism- occurs, (Goryachkin *et al*., 2005). Secondly, Dagestan in the North Caucasus, where species such as *Astragalus onobrychioides* or *Thymus pulchellus* C.A. Mey are present, along with Lower Volga where *taxa* as *Astragalus amarus* Pall. or *Bienertia cycloptera* Bunge exist. In the last two mentioned areas, there are also some stepparic gypsoclines as *Krascheninnikovia ceratoides* among many others (Komarov, 1934-1964; Euro+Med, 2006-2015).

Saudi Arabia. Gypsum outcrops existin the deserts of this country, where gypsophytes such as *Moricandia sinaica*, *Diplotaxis acris* (Forssk.) Boiss., *Salvia deserti* Decne., etc. are present (Anon., 2014).

Somalia (including Somaliland). This country is one with the largest gypsum deposits in the world. In fact, gypsum soils extend 10,161 km^2, which is 16.2 % of the total national surface. A rich, peculiar and specific flora is associated with these large outcrops. The northern part of the country is home to several species, particularly in the regions of Sannag – e.g. *Helianthemum somalense* Gillett, *Otostegia ericoidea* Ryding, *Atriplex erigavoensis* Thulin; Bari region – e.g. *Helianthemum speciosum* Thulin, *Fagonia gypsophila* Beier & Thulin – and, especially, Nugal region – e.g. *Dorstenia gypsophila* Lavranos, *Euphorbia columnaris* P.R.O. Bally, *Aloe nugalensis* Thulin. In more southern areas of the country it is also possible to find species linked to gypsum substrates such as *Indigofera gypsacea* Thulin, or *Polygala gypsophila* Thulin (Thulin, 1993-2006, 2002, 2007; Ryding, 2005; African Plant Database, 2015).

South Africa. The country has a great geological variety, which includes gypsum. In fact, it produces 559.44 kt per year of this mentioned mineral (USGS, 2016). From a floristic point of view, the most outstanding outcrops are located in the southwest of the country, in arid conditions, in the Succulent Karoo and the Desert biomes. *Euphorbia melanohydrata* Nel has been reported as a gypsophyte taxon related to gypsum crusts (Jürgens, 2004), while *Stipagrostis subacaulis* (Ness) De Winter would match the gypsocline behaviour (Fish *et al*., 2015). Gypsum-related communities have been described, whose leading species deserve to be studied. This would be the case of T*etraena clavata* (Schltr. & Diels) Beier & Thulin, *Euphorbia brachiata* E. Mey ex Boiss., etc. (Nußbaum, 2003). In addition, it would be worth studying other cases, such as Sekhukhuneland locality, where a vegetation associated with a mixture of gypsum-ultramafic materials has been recognized (Siebert *et al*., 2003).

Spain. Is the first gypsum producer in the European Union and the sixth worldwide, with a production of 6,400 kt per year (USGS, 2016). Spanish gypsum outcrops (or aljezares) are the most extended and hold peculiar associated flora and vegetation that has been recognized since ancient times (see Mota *et al*., 2011, for the historical review), and are now enjoying protection at European level, as the Iberian gypsum steppes *Gypsophiletalia* (*1520), a priority habitat in the Directive Habitat (92/43/ECC) (Anon., 2013). Mota *et al* (2011) listed 41 gypsophyte and 41 gypsocline *taxa*. Still, this question cannot be considered closed, as the advances in taxonomy and chorology add new *taxa* to the gypsophyte list, e. g. *Chaenorhinum gamezii* Marchal & Güemes, *Linum castroviejoi* Mart. Labarga, Pedrol & Muñoz Garm., etc. (Güemes *et al*., 2014; Martínez Labarga & Muñoz Garmendia, 2015).

Sudan. This country has gypsosous soils (FAO, 1990) and outcrops that produce 132 kt per year. In this country there are typically Saharan gypsophytes such as *Stipagrostis ciliata*, as well as gypsoclines *taxa* such as *Limoniastrum guyonianum* Boiss. or *Echiochilon fruticosum* Desf. (Le Houérou, 1995; African Plant Database, 2015).

Syria. In relative terms, this country posseses one of the largest areas of gypsipherous soils in the world: 3,966 km^2, or 21.6 % of its extensión is gypsum soil (FAO, 1990). Gypsophyte *taxa* such as *Campanula fastigiata* Dufour ex Schult. or *Suaeda asphaltica* Boiss. Are present in these soils, as well as many gypsocline *taxa* such as *Nitraria retusa* or *Salsola orientalis* S.G. Gmel (Euro+Med, 2006-2015).

Tajikistan. This country has a lot of gypsum outcrops with a number of gypsophyte elements such as *Ferula kelifi* Korovin, *Lachnoloma lehmannii*, *Phlomoides gypsacea* (Popov) Adylov, Kamelin & Makhm (Komarov, 1934-1964)

Tunisia. This Maghreb country presents many gypsum outcrops, as they represent 9.3 % of its soils (FAO, 1990). It is possible to find endemic gypsophytes such as *Anarrhinum brevifolium* (Coss. & Kralik) D.A. Sutton and *Sixalix thysdrusiana* (Le Houér.) Greuter & Burdet. There are also many halogypsophytes and marsh-gypsophytes, like the species *Lavatera flava* Desf. (Le Houérou, 1995; Pottier-Alapetite, 1981).

Turkey. This country has a lot of gypsum deposits, being the fifth mundial producer, with 10,000 kt per year (USGS, 2016). Peculiar flora and vegetation associated with the gypsic deposits has been documented. The floristically interesting outcrops are distributed throughout the country. It is specially worth to mention localities such as Sivas – e.g. *Campanula sivasica* Kit Tan & Yıldız or *Elymus nodosus* (Nevski) Melderis subsp. *gypsicolus* Melderis–; Eskişehir – e.g. *Gypsophila simonii* Hub.-Mor. or *Achillea gypsicola* Hub.-Mor.–; Erzincan – e.g. *Scrophularia lepidota* Boiss. or *Thymus spathulifolius* Hausskn. & Velen.–; as well as Ankara – e.g. *Verbascum gypsicola* Vural & Aydoğdu or *Acantholimon anatolicum* Dogan & Akaydın – (Davis, 1965-1988; Ketenoğlu *et al*., 2000; Akpulat & Celik, 2005; Yildirim, 2012).

Turkmenistan. This country presents many gypsum outcrops both in the región of Karakum Dessert and in Kopet Dag Ranges, and specieally in Köýtendag Range, in Uzbekistan frontier. Rich gypsicolous flora grows on these substrates, with many endemic elements, such as *Cleome turkmena* Bobrov, *Mattiastrum turcomanicum* Brand, *Muretia oeroilanica* Korovin, etc. (Komarov, 1934-1964).

Ukraine. Gypsum outcrops are concentrated in two areas: Crimea (specially in Kerch Peninsula, Mindat, 1993-2016) and the westernmost part of the country, belonging to the Badenian Basin (Klimchouk, 1996; Peryt *et al*., 1998). *Gypsophila collina*, a rare pontic gipsophyte endemism, can be found on Crimean gypsum. In the continental part of the country different stepparian character gypsoclines have been cited, such as *Krascheninnikovia ceratoides* (Euro+Med, 2006-2015).

United Arab Emirates. In this country gypsum deposits are poorly represented and yield an insignificant production (USGS, 2016). Gypsophytes such as *Herniaria hemistemon* or gypsoclines like *Deverra tortuosa* (Desf.) DC. have been cited (Brown & Sakkir, 2004).

United States of America. This country is the second largest gypsum producer worldwide, with 11,500 kt per year (USGS, 2016). It has numerous deposits distributed almost throughout all the country, a fact that has been documented in the past (Adams *et al*., 1904). Those outcrops possess a peculiar flora associated and are located in the SW of the country, in states such as Arizona – e.g.*Tetraneuris verdiensis* R. A. Denham & B. L. Turner or *Gaillardia multiceps* Greene (Anon., 1993-2015) –; Colorado – e.g. *Cryptantha gypsophila* Reveal & C.R. Broome – (Reveal & Broome, 2006); New Mexico – e.g. *Nerisyrenia hypercorax* P.J. Alexander & M.J. Moore or *Townsendia gypsophila* Lowrey & Knight – (Alexander *et al*., 2014; Lowrey & Knight, 1994); Oklahoma – e.g. *Nama stevensii* C. L. Hitchc.– (Buckallew & Caddell, 2003); Texas – e.g. *Tiquilia hispidissima* (Torr. & A. Gray) A.T. Richardson or *Senecio warnockii* Shinners – (Moore & Jansen, 2006) and Wyoming – e.g. *Townsendia grandiflora* Nuttall or *Physaria macrocarpa* (A. Nelson) O'Kane & Al-Shehbaz – (Anon., 1993-2015). Furthermore, in other states *taxa* with certain preference for gypsum is present, as in the cases of California (e.g. *Eriogonum gossypinum* Curran), Kansas (e.g. *Psilostrophe villosa* Rydberg ex Britton), Nevada (e.g. *Artemisia pygmaea* A. Gray) and Utah (e.g. *Arctomecon humilis* Coville) (Anon., 1993-2015). Currently, M.J. Moore (Oberlin College, OH, USA) are preparing a checklist of USA gypsophytes.

Uzbekistan. Among all those countries that conform Central Asia, this is the one with the richest gypsophile flora. It is present both in lowlands (Kyzyl Kum Desert, and specially, Fergana Valley) and in the mountain side of Pamir-Alay (specially in Gissar Range). The number of Gypsophytes is probably around half hundred, with the presence of a large number of endemisms such as *Astragalus namanganicus* Popov, *Calligonum santoanum* Korovin, *Ferula primaeva* Korovin, *Hedysarum jaxarticum* Popov, etc. (Komarov, 1934-1964; Kasputina, 2001). Curiously, gypsum production only reaches 50 kt per year (USGS, 2016).

Yemen. This country holds large gypsum deposits, as gypsum soils summ up to 2,931 km^2, being 8.8 % of the territory (FAO, 1990), although its production is only of 100 kt per year (USGS, 2016). This republic is a biogeographical crossroad, also in the case of gypsum environments, as gypsophytes linked to the Saharo-arabic and Mediterranean flora – e.g. *Diplotaxis harra* subsp. *harra* – and other tropical elements linked to the Africa Horn – e.g. *Commicarpus reniformis* (Chiov.) Cuf.– (Al Khulaidi, 2013) can be recognized here.

Countries without gypsophytes but with presence of gypsoclines

Angola. Gypsocline plant *Stipagrostis subacaulis* (Ness) De Winter (Fish *et al*., 2015) has been cited in the southwest of the country, in the northernmost of Namib dessert biome although the largest deposits are located more to the north of the country, in the Dombe Grande deposit (Van Straaten, 2002).

Austria. This country presents gypsum deposits tha could be exploited (USGS, 2016). Furthermore, it is possible to find comunities of *Astragalus exscapus* L. subsp. *exscapus* and *Crambe tatarica* L. that are included in the habitat 6250 Pannonic loess steppic grassland (sensu Habitat Directive) (Anon, 2013). Some of the characteristic *taxa* of this habitat show a gypsocline behaviour in other countries, therefore, it would be necessary to evaluate if they are present on gypsum in addition to loess.

Chile. This country holds important gypsum deposits and produce 129,000 kt per year of such mineral (USGS, 2016). However, there are no references of flora linked to gypsum deposits, plant communities of Eriosyce (that are detailed in Peru section) could be an exception to this, whose peripherical distribution reaches the northernmost part of the country in Arica Region (Cáceres *et al*., 2013).

Czech Republic. The Badenian Basin deposits are peripherically present in this country (Peryt *et al*. 1998). The presence of gypsocline steppe *taxa* such as *Astragalus exscapus*. subsp. *exscapus* and *Crambe tatarica* (Euro+Med, 2006-2015) have also been reported.

Djibouti. This small country posseses diferent endorheric basins, such as lake Assal, where different kinds of salts are present, including gypsum (Van Straaten, 2002). These environments are inhabited by halogypsophyte *taxa* such as *Dracaena ombet* Heuglin ex Kotschy & Peyr. (African Plant Database, 2015).

Dominican Republic. From a floristic point of view, it is important to emphasize the Enriquillo Valley basin (“the Caribbean Dead Sea”). In Enriquillo Basin some halopgypsophytes have been cited, such as the *Cactaceae* species *Leptocereus paniculatus* (Lam.) D.R. Hunt and *Consolea moniliformis* (L.) A. Berger (Oldfield, 1997).

Eritrea. In the Danakil basin, there are deposits of late Tertiary to Pleistocene evaporites including halites, gypsum and potassium salts. This is an area located mainly in Ethiopia with a small portion reaching into Eritrea, along with the coastal area of eastern. Gypsoclines such as *Dracaena ombet* Heuglin ex Kotschy & Peyr. have been cited in this country (African Plant Database, 2015).

France. There are not very numerous gypsum outcrops here. From a floristic point of view, deposits of the alpine area are remarkable (some of them reach noteworthy heights). There, the gypsopcline *Onosma alpina* (A. DC.) Boiss. can be found, as well as *Festuca rupicola* Heuff. (Aeschimann *et al*., 2004). These Alpine gypsum outcrops (and neighbouring Swizertland) serve as shelter for missing or scarce xerophtermophilic elements in the surrounding vegetation (Gensac, 1968; Biedermann *et al*., 2014).

Germany. There are large gypsum outcrops here, specially in Thuringia and Saxony Anhalt. The presence of gypsum is linked to thermophile communities, such as beech woods (Schmid & Leuschner, 1998). However, it is not possible to find gypsocline flora, with the significant excepcion of *Astragalus exscapus* subsp. *exscapus* (Becker T. & Voß., 2003; Brekke & Hansson, 1990; Podlech, 1988).

Greece. In Crete, the mining prospection of the Altsi deposits in the eastern portion of the island (USGS, 2016) has been mentioned. There, the gypsocline *Viola scorpiuroides* Coss. grows, in addition, it is presented on dolomite and, perhaps, phyllites at the western end of the island (Turland *et al*., 1993).

Haiti. As in the case of Dominican Republic, it is possible to find gypsum outcrops in the Enriquillo lake basin, and a halogypsicolous behaviour has been observed in *Leptocereus paniculatus* and C*onsolea moniliformis* (Oldfield, 1997).

Hungary. In this country there are no important gypsum outcrops; in fact, there has been no production of gypsum since 2010 (USGS, 2016). By way of compensation, steppe gypsoclines have been cited such as *Astragalus exscapus* subsp. *exscapus*, *Krascheninnikovia ceratoides* (L.) Gueldenst, etc.; but surely these species growon loess or alkali soils, not on gypsum (Euro+Med, 2006-2015).

India. In the Thar desert there are gypsum deposits; however, there is no confirmation of clearly defined gypsophilous flora (cf. Rawat, 2008), even though halogypsophytes such as *Haloxylon salicornicum* (Hooker, 1872-1897) have been cited. Additionally, there is information about vegetation dynamics, in the case of abandoned quarries that are colonized by xenophytes such as *Prosopis juliflora* (Sw.) DC. (Sharma *et al*., 2001). It would be of interest to research further into the edaphic behaviour of the autocton flora of the Thar desert.

Kenya. There are important gypsum outcrops here, in the Garissa area and on the Somalian border (Van Straaten, 2002). There is no distinguishable gypsophyte flora, although gypsocline elements have been described, which are also shared with Somalia and Ethiopia, such as *Microcharis gyrata* (Thulin) Schrire, *Gossypium bricchettii* (Ulbr.) Vollesen, etc. (African Plant Database, 2015).

MALI. Its main outcrops are located in the north of this country, in the heart of the Sahara, in the Tessalit and Taoudenni areas (Van Straaten, 2002). Therefore, it shares gypsoclines of the Saharan floristic catalogue such as *Cornulaca monacantha* Delile or *Stipagrostis pungens* (Le Houérou, 1995; African Plant Database, 2015).

PERU. In the southern coast of the country it is possible to find the communities of the Garua desert with gypsum soils colonized by beds of spherical cacti of genus *Eriosyce* (subgen. *Islaya*), such as *E. islayensis* Backeb (Devillers & Devillers-Terschuren, 1996; Cáceres *et al*., 2013). However, it would be advisable to carry out newer botanical prospections.

SLOVAKIA. This country presents some small gypsum deposits where steppe gypsocline have been cited, such as *Astragalus exscapus* subsp. *exscapus*, Krascheninnikovia ceratoides, etc.; but probably these populations are growing on other types of substrates (Euro+Med, 2006-2015).

SWITZERLAND. This country shares the gypso-alpine floristic entourage with France (see above in section dedicated to France).

Countries without presence of gypsophytes or gypsoplines, although there are distinguishable traces in flora and vegetation.

Those countries where a clear influence of gypsum on vegetation has been documented are included here, although there is no statement of presence of special flora linked to gypsum.

BRAZIL. Gypsum material can be found in numerous areas of the country, although it is important to mention the northeast of the country, with a semiarid climate, where it is possible to find a type of vegetation called caatinga. In this area, in the municipality of Araripina (state of Pernambuco), there are large gypsum outcrops from which most of the Brasilian gypsum is obtained. There are no clear mentions of flora linked to gypsum outcrops; but there are studies of micoflora that conform mycorrhiza (Mergulhão, 2010). These studies have described the presence on gypsiferous substrate of stenocorous vascular plants such as *Spondias tuberosa* Arruda, *Aspidosperma pyrifolium* Mart. and *Parapiptadenia zehntneri* (Harms) M.P. Lima), even with the possibility to colonize abandoned gypsum quarries (*Ruellia paniculata* L., *Alternanthera tenella* Colla and *Ziziphus joazeiro* Mart.). On these *taxa* and communities, it would be interesting to continue researching.

CANADA. It is possible to find gypsum deposits in the Atlantic area of the country, in Ontario and Western Canada (Kogel *et al*., 2006). However, gypsophile flora has not been described, although there are some rare and uncommon local plant species associated with gypsum. Among these *taxa Anemone parviflora* Michx. or *Viola canadensis* L., among others (Mazerolle *et al*., 2015) can be cited.

POLAND. Badenian Basin materials can be found in the southernmost area of the country, which are shared with Ukraine and Czech Republic (Peryt *et al*., 1998). Outcrops can be locally relevant, being reflected in the place names (e.g. Mount Gipsowa) and yielding a gypsum production of 1,085 kt per year (USGS, 2016). There are references that gypsum outcrops can act as refuge for xerothermic elements like *Campanula bononiensis* L. or *Verbascum phoeniceum* L. (Keilholz, 1927).

Countries with gypsum deposits but without floristic or vegetation data linked to gypsum.

Those countries where there are references on the existence of gypsum deposits, but not on the existence of a flora associated to gypsum soils, or the existence of biases on flora and vegetation belong to this list. This question is open to oncoming studies.

ALBANIA; BELARUS; BHUTAN; BOSNIA AND HERZEGOVINA; BULGARIA; CAPE VERDE (with deposits in Maiao island); COLOMBIA (there are deposits in the Cordillera Oriental, coast of Guajira peninsule and part of the Cordillera Central [Ponce & Torres Dunggan, 2006]); CROATIA; CUBA (deposits belong to the upper Jurasic, and are exploited in three populations: Canasí, Punta Alegre and Baitiquirí [Ponce & Torres Dunggan, 2006]); ECUADOR (Ponce & Torres Dunggan [2006] cite gypsum exploitation in the south, province of Loja, in Malacatos and Bramaderos); GHANA (small amounts of gypsum and gypsiferous clays were reported from near Accra and localities in the Western Region, and from the Keta region [Van Straaten, 2002]); GREENLAND (gypsum materials have been located outside the ice sheet, especially on the east coast of the island, where there is a geological formation called Gipsdalen, "gypsum valley" in Danish [Clemenns *et al*., 1985; Kent & Clemenns, 1996]); INDONESIA; IRELAND (in two sites in southern County Monaghan); JAMAICA; KOREA (Republic of); LAOS; LATVIA; MACEDONIA; MAGADASCAR (exploited deposits are present mainly in Antsahampano); MALAWI (small gypsum occurrences are known in several seasonally flooded shallow valleys (dambos) in the northern part of the country and the Kasangadzi Dambo. Malawi imports most of its gypsum needs); MOZAMBIQUE. There are several gypsum and anhydrite occurrences in oil and gas exploration boreholes in the coastal zone of Mozambique.

The most extensive gypsum and anhydrite deposits are date back to the Oligocene/Miocene age and occur in the evaporite sequence of the Temane Formation [Van Straaten, 2002]); Nicaragua (deposits were originated in tertiary age, and are located in the Central Province [Ponce & Torres Dunggan, 2006]); Nigeria; Paraguay; Portugal; Puerto Rico (despite the fact that there is no mining production, gypsum outcrops have been cited, especially in Isla Mona (Kaye, 1959); Serbia; Taiwan; Tanzania (the major rock gypsum and anhydrite resource is located in a remote area, at Pindiro and Mandawa in southeastern Tanzania [Van Strasten, 2002]); Thailand (the fourth worldwide producer, and recently, with the highest increase in production (from 0.86 kt in 2008 to 12,500 in 2015 [Crangle, 2016; USGS, 2016]); Uganda (The best known source of natural gypsum is at Kibuku, in the southwestern area of Lake Albert in Bundibugyo District); United Kindogn; Uruguay (known deposits are associated with Santa Lucía and La Laguna Merín basins in lands from cretacean age [Ponce & Torres Dunggan, 2006]); Venezuela (presents deposits in the Cordillera de la Costa which is the main gypsum district of the country, located in Paira Peninsule. Also, northern sedimentary formations contain gypsum deposits [Ponce & Torres Dunggan, 2006]); Vietnam; Zambia (gypsum clays occur in surfacial environments of the Kafue Rats and the Siloana Plain, close to hot springs. Furthermore, there are gypsiferous clays of Lochinvar, on the edges of the alluvial plain of the Kafue River. Gypsum content in these clays reaches 40% with crystals up to 4 cm in size [Van Straaten, 2002]).

To conclude, it is important to mention that perhaps the Antarctic territories should be included among the contries of the previous paragraph, as gypsum outcrops have been found in the areas that are not covered by ice. This is the case of Seymur Island (Tartur *et al*., 1993) or the Dry Valleys in McMurdo region (Keys, 1979). Studies of biota present on these deposits are of interest as they are analogues of Mars (Losiak, 2016). The main objective of their citation here is to encourage the study of gypsophily, or at least, gypsophyte flora in these territories.

Conclusions

Gypsum outcrops are widely distributed worldwide, being present in 112 countries. The phenomenon of Gypsophily is widespread in 71 countries, in which there are unquestionable references to gypsophyte *taxa*; while in 53 countries *taxa* with a certain preference for gypsum are mentioned. These data contrast with previous works that directly allude to gypsophily, which is only circumscribed to ten countries. This indicates very clearly the need to undertake further research in additional geographical areas. The main objective of those citations of countries here is to encourage the study of gypsophily, or at least, gypsophyte flora in these territories.

The existence of gypsophyte *taxa* mainly occurs in dry climates. Nevertheless, in higher humidity conditions the presence of gypsum still has a visible effect on flora and vegetation, since the outcrops serve as a refuge for xerothermophilic *taxa* absent (or almost) on the surrounding vegetation of the outcrop.

The vegetation on gypsum is more sparse and scattered than that existing on other sorts of substrates adjacent to gypsum outcrops, although depending on the climate, some forests might thrive on this material.

Due to the great mismatch between countries with gypsum outcrops and the available information about them, uniting the scientific community in the effort to characterize the edaphism of gypsum phenomenon around the planet would be worthwhile.

Acknowledgements

This research was supported by the Plan Andaluz de Investigación, Desarrollo e Innovación (Junta de Andalucía) and by ECORESGYP proyect, funded by Explotaciones Rio de Aguas S.L.E.S.S has been awarded with a postdoctoral grants (Contrato Puente, Plan Propio 2016), sponsored by the University of Almeria, Spain.

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