Restoration criteria on dolomite quarries on “Sierra de Mijas” mountain range

Alberto Jiménez Gómez
Master´s Project 20p
25-05-2007

Supervisors:

Marie Mattson   Halmstad University
J. M. Nieto Caldera   Universidad de Málaga

Summary

There are many dolomitic outcrops at Rondean sector (into the biogeographical Betic Province). Most of them, involve floral richness and vegetal endemic species due to its calcareous origin. These diverse organisms build peculiar plant communities. They can survive in extreme conditions as drought and high levels of Mg^{2+} cation. Many studies pronounce that these communities are unique, so they have to be conserved, and some of these plant communities are in the Habitats Directive 92/43 EC.

38% of the dolomitic outcrops can be affected by mining processes. Those particularly affected are dolomitic outcrops located in the mountains range of “Sierra Blanca” and “Sierra de Mijas”. Nowadays, there are 21 quarries in these mountains and they occupy more than 409 Ha. We have studied 11 dolomite quarries and surroundings on “Sierra de Mijas”. There is one vegetation serie on these areas (*Rhamno oleoidis-Querco rotundifoliae sigmetum. Dolomitic section*), knowing the plant communities we could draw with a Geographical Information System (GIS) the polygons where they are. And using the modified Botanic Value Index equation (Nieto *et al.,* 1999) we could calculate the botanical value of these polygons. After that, we could establish a classification of the study area from the point of view of conservation interest, and we could set up new restoration criteria on these lands.

We have found that approximately the 53 % of the studied area has a high botanic value. There are many endemic taxa in the studied area and 4 species exclusive of the “Sierra de Mijas” mountain range. 90 % of the present communities are included in the Habitats Directive 92/43 CE, and three of the communities are exclusive of the studied area. This is the reason why these quarries have to be restored with a sustainable criteria.

Current restoration plans try to reforest with the climax vegetation (*Quercus rotundifolia*) or different species of pines (used in several previous reforestations). However, to restore a quarry these plans should include, in addition, other factors such as soil depth, structure of vegetal communities, botanic value, etc. And the Reforest Models of Valle (2004) propose sustainable restoration that could be usefull in the dolomite quarries of “Sierra de Mijas” mountain range.

Keywords: Dolomitic outcrops, quarry restoration, botanic value, vegetation serie.

Introduction

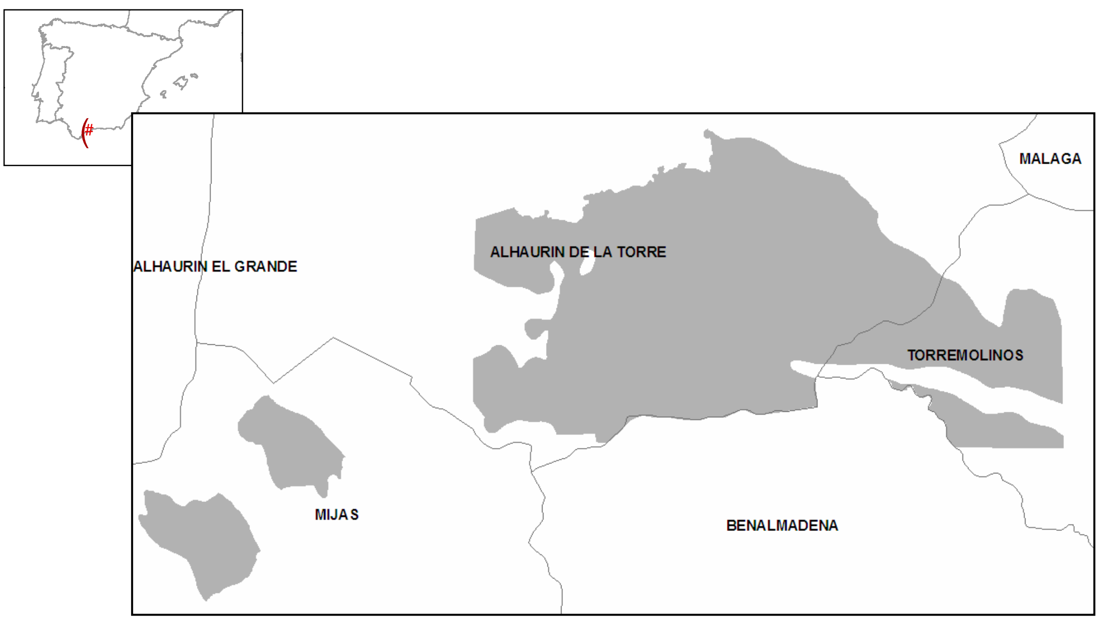
Mining is necessary to get raw materials for the development and growth of a region. Crystalline dolomite is a precious material with several industrial applications such as building materials, chemistry industry, ornamental stones, glass, ceramic, etc. Mining industry is very interested in this kind of outcrops, because they are easy to explorate, and this material is very easy to operate. Total production of dolomite in Spain is around 10.7 Millions of tons. More than 79% of them are destined to be construction material (Instituto Geológico y Minero de España, 2002).

Dolomitic areas involve floral richness, extremely peculiar plant communities and they are diverse and especially rich in endemic species. (Rivas Goday, S. & Mayor, M., 1965; Rivas Goday, S. & Rivas Martínez, S., 1967; Rivas Goday, S. & Esteve, F., 1972; Rivas Goday, S., 1973; Rivas Goday, S. & López González, G., 1979; Salvo, A.E. *et al.* 1983; Salvo, A.E. & Cabezudo, B., 1984; Sainz Ollero, H. & Hernández Bermejo, J.E., 1985; Nieto Caldera *et al*, 1987; Asensi A. & Diez Garretas B., 1988; Rivas Martínez, S., 1991; Medina Cazorla, J.M. *et al*. 2005). There are few dolomitic outcrops in the whole of Spain and most of the outcrops are under concessions of mining rights.

Criteria for use and restoration must be settled down due to the high ecological value of the plant communities, due to the few outcrops we can find and, of course, due to the fact that most of the outcrops are under concessions of mining rights.

Study area can be classified according to the bioclimatology classification into the Holarctic Kingdom, Mediterranean Region, Betic Province, Rondean sector. The present vegetation series that can be found are *Rhamno oleoidis-Querco rotundifoliae sigmetum, Smilaco mauritanicae-Querceto rotundifoliae S. and Paeonio coriaceae-Querceto rotundifoliae S.* (Rivas-Martínez *et al*., 2002, Rivas-Martínez, 2007, http://www.globalbioclimatics.org).
"Sierra de Mijas" mountain range constitutes a dolomitic bulk, at the west of Malaga, southern Spain. It is a steep relief, more than 1000 m height, 5-10 km from the Mediterranean Sea. It is so important because of its hydrogeologic characteristics (Andreo & Sanz de Galdeano, 1994; Andreo *et al.,,* 1996; Andreo, 1997) and there is an aquifer inside that supplies water to several municipalities as Benalmádena, Mijas or Torremolinos. These municipalities increase their population to the double in the summer time (when there is less water).

Fig.1 Location of "Sierra de Mijas" and the study area.



85% of dolomitic outcrops of the "Sierra de Mijas" mountain range are under concessions of mining rights. It is already known that the ecological effects of exploitation are extreme, resulting in the complete removal of overlying ecosystem The habitat reconstruction phase is very important, mainly, when self-sustaining system capacity is exceeded In addition, the common method of quarry exploitation in terraces increases drainage and the physical and chemical erosion of the substrate, hindering natural germination and establishment of young plants, thus delaying recolonization (Sort & Alcañiz 1996). We need to consider the nutrient, water, succession stage and the characteristics of the communities in our study zone in order to restore the ecosystem. It is important to include realistic goals and to establish a scale and strategy to restore an area.

The time scales involved in the creation of species-rich communities (possibly hundreds of years) are not considered acceptable as a reclamation or restoration strategy (Wheater & Cullen, 1997) and current law does not allow this restoration (Real Decreto 2994/1982). Traditionally there are not many restorations of sites after mining activities in Spain. From 1982, the law establishes that we need to attach a mandatory Restoration Plan whenever we want to open a mining project in Spain. So, mining companies do not need to attach any document to restore a quarry opened before 1982. Reason why Spanish regional authorities have launched projects to rehabilitate the old quarries now closed. There is not a single strategy to follow in the restoration of quarries, and many authors have made studies using fertilizers and sludge to increase the plant growing (Sort & Alcañiz, 1996). These studies always affect biodiversity negatively, because they increase the biomass of the plants but not the diversity of wild plants (Moreno Peñaranda *et al*., 2004; Michley, J. *et al*., 1996). However, some authors establish geomorphological designs (Martín Duque, J.F. *et al.,* 1998) and our criteria must maintain floral richness and the diversity of the plant communities (Valle, *et al.,* 2004) in zones of crystalline dolomite. We can do that sowing desirable species or introducing post-growing plants (Dutoit & Alard, 1995; Hutohings & Booth, 1996a; Davies & Waite, 1998). Other studies have evaluated the vegetation for the creation of new conservation areas (Alonso, 2000) or to evaluate the conservation degree of protected areas (Esteve & Ramírez, 1989).

<u>Objetives</u>
The present study tries to demarcate the total area of dolomitic outcrops in Rondean biogeographical sector. We will demarcate vegetation series and their structure (Rivas Martinez, 2007), especially on “Sierra de Mijas” mountain range (where the crystalline dolomite and its plant communities could be more affected by quarrying) to elaborate a Botanic Value Map, and establish land-use criteria on dolomite quarries. Finally, we will elaborate restoration criteria on quarries trying to sustain mining and biodiversity conservation actions.

We will focus our quarries study on dolomitic outcrops under concession of mining rights at “Sierra de Mijas” mountain range. We will especially focus on two quarries at the northeast of “Mijas” municipalities and another area that include eight quarries in “Alhaurín de la Torre” municipality, and one in “Torremolinos” (see Fig. 1).

Material and Methods

Photo-interpretation
A first steep was to work with the digital orto-photo of the area (Ortofoto Digital de Andalucía, 2002). We identified homogeneous surfaces. We could separate urban areas, crop areas, natural vegetation areas... with the Photo-interpretation. We drew polygons in which we could apply the same characteristics, arboreal cover, presence/absence of scrubs and bare soil. These polygons are the base unit to manage the field work.
We worked with a Geographical Information System (GIS) ArcGIS 9.1, distributed by ESRI (USA; http://www.esri.com).

We identified the homogeneous polygons at scale 1:5000. But we drew the polygons at 1:2500; because we reduced the errors at this scale.

Field Work

The second step was to verify and assign the content of the drawn polygons. Sometimes we united polygons that seemed to be different in the orto-photo and the opposite. Once we had the final polygons, we sampled each one to get information of floral composition (qualitatively and quantitatively), vegetaion and structural characteristics.

Field Sampling

We established the sample points thinking about vegetal environmental factors (orientation, height, litology, vegetation series map, ombroclime [average annual precipitatons], biogeography, time and accessibility)

We used a GPS model "Garmin 72" by Garmin (USA, http://www.garmin.com/) for the positioning *in situ* in the sample points (there is an error range of 3-15 meters).

We used the European Reference System ED50, UTM Huso 30 with Hayford reference ellipsoid (International 1909) and Postdam European Datum as projection system.

We sampled with three different field methods:

Characterization of the cartographic units - Following the methods of the Zürich-Montpellier Sigmatist School (Braun-Blanquet, 1979; Gehú & Rivas-Martínez, 1981) we took the following data for the phytosociologic inventories: area sampled height, inclination, orientation, mean cover and vegetal height. We used the Braun-Blanquet abundance-cover index (Mueller-Dombois & Ellenberg, 1974) to obtain the structure and vegetal composition.

Plant species' field notes were written down to get information about the polygons in which we could not elaborate the phytosociologic inventories (there were not ecological and floral repetitive characters). Then, we listed the species and noted the vegetal layer of redlisted species.

Plant communities' field notes are the list of communities of the sampled polygons. There is some additional information about cover degree, naturalness and vegetal layer to which vegetal communities belong to.

Flora

According to the Flora, we followed the Stebbins System as in "*Flora Ibérica*" (Flowering plants – Evolution above the species level, 1974). For gymnosperms the system was Melchior & Werdermann, A (*Engler´s Syllabus der Pflanzenfamilien,* ed. 12, 1954) also as in "*Flora Ibérica*".

We used "*Flora de Andalucía Occidental*" (Valdés et al., 1987), "*Flora Europea*" (Tutin et al., 1972), "*Atlas Clasificatorio de la flora de España Peninsular y Balear*" (García Rollán, M., 1999-2001) and the edited volumes of "*Flora Ibérica*" (different authors), to determinate the vegetal taxa.

Plant communities
We used the nomenclature and classification system followed by Zürich-Montpellier Phytosociologic Sigmatist School (Braun-Blanquet, 1979; Gehú & Rivas-Martínez, 1981, Rivas-Martínez, 2007) to determinate and to name the vegetal communities. We have always tried to identify until association range. However, in some degraded areas, we identified until higher ranges, alliances or orders sometimes.

Vegetation series
They are the base unit in dynamic landscape Phytosociology or Sinphytosociology. The methodology has been used according to Gehú & Rivas-Martínez (1981) and Rivas-Martínez (2007).

Botanic Evaluation
We have used a modified Botanic Value Index Equation (Nieto Caldera *et al*., 1999); it is the sum of intrinsic and extrinsic factors for each vegetal community adjusted by its respective cover. We considered also if the community is prioritized in the Council Directive 97/62/EC of 27th October 1997 adapting to technical and scientific progress Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

We get a polygon value *k*, known as *Vp* like this:

$$\mathrm{Vp}_K = \sum_{j=1}^{n}\left[P_j * H_j * \left(\sum_{i=1}^{k} V_{ij} + N_j * A_j \right) + \mathrm{Ep} \right]$$

Where, Vp_k is the Quality Botanic Value of the unit *k*, *Pj* is the cover value of the community *j* in the unit *k*, *Hj* is the "habitat" index for that *j* community, *Vij* is the value of the intrinsic factors of the community *j* (endemicity, rarity, fragility, vulnerability and relictism), *Nj* is the phytosociologic naturality, *Aj* is the antrophism of the community *j*, *Ep* is refereed just in case there are species under environmental laws; we sum 15 points whenever there is some "Endangered" specie, 10 points in case there is some "Vulnerable or Sensible to the alteration of its habitat", and 5 points whenever there is some species classified as "Special interest". The different attributes are explained in Appendix I.

Codification and storage of the information
We have stored the information in a database with alphanumeric codes into an interface designed in MS Access XP (Microsoft Office; USA; http://www.microsoft.com/).

Cartographic Restitution
At this moment we wanted the final cartography to be elaborated. We have corrected the polygons shapes (modified at the field). We identified similar polygons to get "homogeneous cartographic units" represented as polygons with the same bioclimatic belts, vegetation series, land-use, main vegetal community, the following succession step on each community, relative information about the different vegetal layers and bare soil, etc.

Analyse of the information
This was the last step. We could elaborate synthetic information and a thematic cartography from the analysis of the information. We generated a filtrate of information

relating the alphanumeric database (MsAccess) with the georeferenced graphic information (polygons) within geodatabase (ArcView).

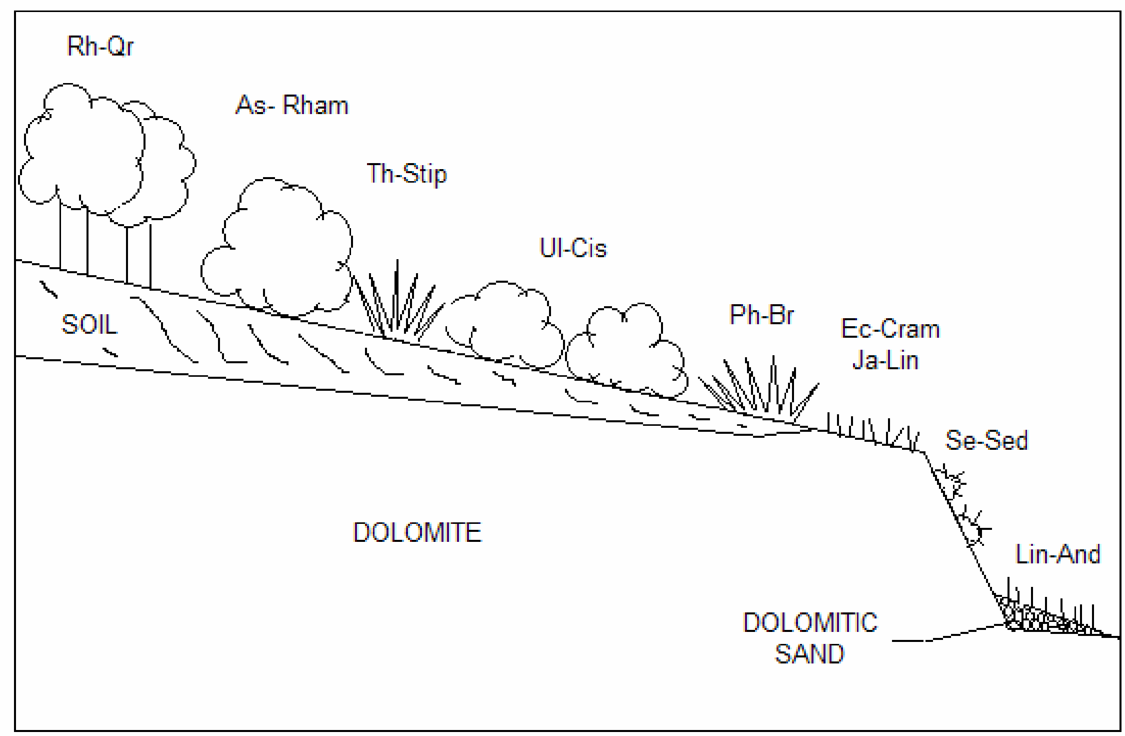
Results

The Rondean sector occupies approximately 474021 Ha; 37678 Ha is composed by dolomitic outcrops (aprox. a 7.9%). 38% of the dolomitic outcrops are under concessions of mining rights, these are 14319 Hm^2. But it is important to say that approximately the 55% of the areas under concessions of mining rights, on dolomitic outcrops, are in the "Sierra de Mijas" mountain range.

We have found the next vegetation serie in the study area: *Rhamno oleoidis-Querco rotundifoliae sigmetum*. *Dolomitic section.*

The phytosociology of the vegetation serie is like this:

Fig. 2. The phytosociology of the vegetation serie is concerned with plant communities, their relationships with the environment and the temporary processes modifying them. Here we can see the different states of succession and the landscape of the studied area.



Rh-Qr: *Rhamno oleoidis-Quercetum rotundifoliae*.	Forest
As-Rham: *Asparago albi-Rhamnetum oleoidis.*	High shrubs
Th-Stip: *Thymo gracilis-Stipetum tenacissimae.*	Medium shrubs
Ul-Cis: *Ulici baetici-Cistetum clusii* and *teucrietosum chrysotrici.*	Low shrubs
Ph-Br: *Phlomido-Brachypodietum ramose.*	High grassland
Ec-Cram: *Echio-Crambetum filiformis.*	Grassland
Ja-Lin: *Jasiono-Linatietum saturejoidis linarietosum huteri.*	Grassland
Se-Sed: *Sedetum micrantho-sediformis.*	Cliff vegetation
Lin-And: *Linario clementei-Andryaletum ramosissimae.*	Grassland

Table 1. Valoration of the communities in the study area.

COMMUNITY	Vij	E	Ra	F	Re	V	A	H
Asparago albi-Rhamnetum oleoidis	**4**	0	0	2	0	2	1	1,25
Echio-Crambetum filiformis	**10**	3	3	2	0	2	1	1,25
Jasiono-Linarietum saturejoidis linarietosum huteri	**11**	3	3	2	0	3	1	2,5
Linario clementei-Andryaletum ramosissimae	**10**	3	3	2	0	2	1	1,25
Phlomido -Brachypodietum ramosi	**5**	1	0	1	2	1	1	2,5
Rhamno oleoidis-Quercetum rotundifoliae	**5**	0	0	2	0	3	1	1,25
Sedetum micrantho-sediformis	**4**	0	0	2	0	2	1	2,5
Thymo gracilis-Stipetum tenacissimae	**5**	0	2	2	0	1	1	1
Ulici baetici-Cistetum clusii	**13**	3	4	2	0	4	1	1,25
Ulici baetici-Cistetum clusii teucrietosum chrysotrici	**13**	3	4	2	0	4	1	1,25

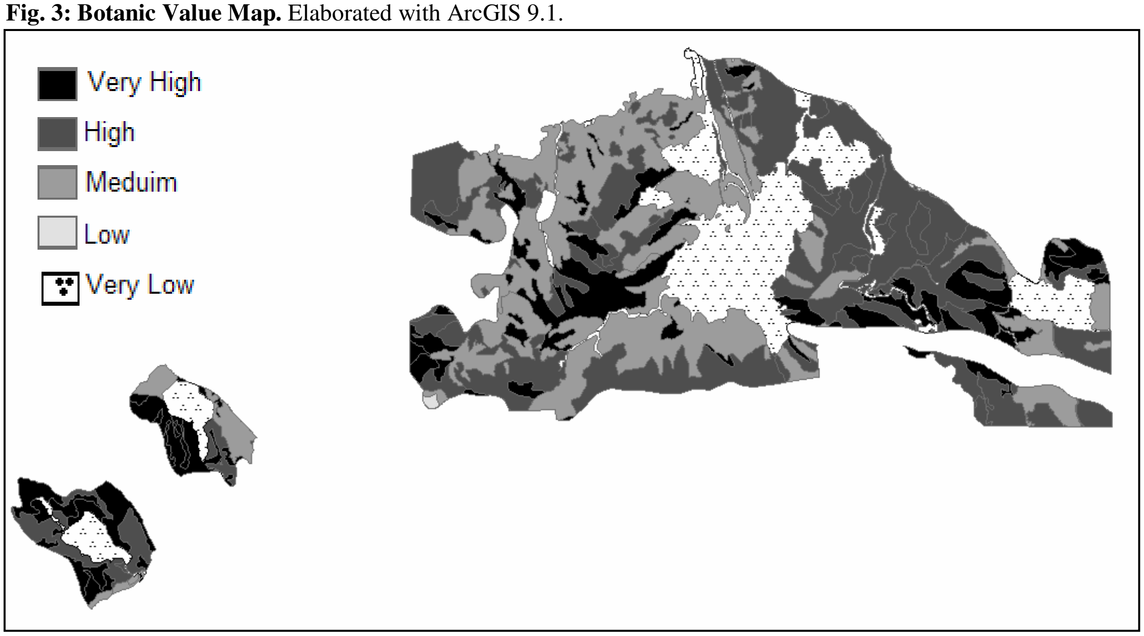
V_{ij} is the value of the intrinsic factors of the community *j.* Communities as *Ulici-Cistetum, Jasiono-Linarietum* , *Echio-Crambetum* and *Linario-Andryaletum* have a high value of V_{ij}. They will obtain high values in the Quality Botanic Value (Vp_k).

Table 2. Value of the different polygons in the Botanic Value Map of the study area.

Botanic Value	Area (Ha)	%
Very High	1551	16.80
High	261	36.49
Medium	560	29,06
Low	2	0.16
Very Low	276	17.98

We can see that aproxmitately 53% of the area has a High or very High Botanic Value. These results emphasize that is important to conserve and restore these areas.

Fig. 3: Botanic Value Map. Elaborated with ArcGIS 9.1.



The very high value is a 16 % of the studied area (Table 2). The main vegetation is covered with shrubs. There is high habitat diversity within these zones, we can find zones with vegetations and rock outcrops that make microhabitats in the same polygons. We can enphasize typical vegetation of cliff faces (*Sedetum micrantho-sediformis*). We only can find within these zones vegetation of kakirites dolomitic outcrops; they are endemic communities as *Ulici-Cistetum clusii* (dolomitic down shrubs), *Linario-Andryaletum* (slope vegetation) and *Jasiono-Linarietum* (annual grassland).

The high value is 36 % of the studied area. This value occupied the longest area. Poligons have this value because of similar causes of areas with a very high value; the difference is the vegetation cover, in these polygons the habitats are occupied of *Pinus halepensis* reforestations.

The medium value (29 % of the studied surface) is located over reforest zones with dense cover. They are pines; they have this value because of their landscape homogeneity. There is a low development of other vegetation cover under the pines cover. This value is also in the eucaliptus near to Mijas village.

The low value (0.16 %) is located on areas with a low vegetation cover.

The very low value (17 % of the studied surface) is occupied by zones without any natural vegetation or no vegetation. On these polygons there are quarries, roads and urban zones.

We have found, in the study area, the next taxa that can grow in areas with high levels of magneium:

- *Alyssum serpyllifolium* subsp. *malacitanum* Rivas Goday
- *Andryala ramosissima* Boiss.
- *Crambe filiformis* Jacq
- *Echium albicans* Lag. & Rodr.
- *Iberis nazar*ita Moreno.
- *Linaria huteri* lange
- *Linaria saturejoides* Boiss
- *Linum suffruticosum* L.
- *Teucrium chrysotrichum*

Endemic Flora

In the Appendix VI there is the table 1, referred to endemic taxa in Andalusia (Rivas-Martínez, Asensi, Molero Mesa & Valle, 1991). From the analyses of the table we can conclude that:

1. There are 104 andalussian endemic species in the Rodean sector and 29 of them are in the study area. This is a **27.9 %.**
2. There are 13 endemism of the 55 Rondean endemic species in the study area. This is a **23.6 %.**
3. There are 29 endemic species in the “Sierra de Mijas” mountain range and 13 of them, are exclusively from the “Mijense sector”. This is a **44.8 %.**

We can recalculate, knowing that there are 4 endemic species (*Arenaria retusa* subsp. *retusa, Linaria clementei* subsp. *clementei, Linaria clementei* subsp. *reverchonii, Linaria huteri*) exclusively from the "Sierra de Mijas, Ojén y Yunquera" mountain ranges:

1. There are 4 endemic species of the 104 andalussian endemism in the Rondean sector. This is a **3.8 %.**
2. There are 4 endemic species of the 55 Rondean endemism. This is a **7.3 %**.
3. There are 4 of the 29 endemic species of the "Sierra de Mijas" mountain range. This is a **13.8 %**.

There are 583 taxa in "Sierra de Mijas" mountain range (see Appendix VII), 49 of them are under a protected law figure (Real Decreto 439/1990; Decreto 104/1994), and this is an **8.4 %.**

Plant communities

There are 10 communities that compound the sintaxonomic catalogue in the studied area. Three communities, *Linario clementei-Andryaletum ramosissimae, Jasiono penicillatae-Linarietum saturejoidis* and *Ulici baetici-Cistetum clusii*, are endemic from the Rondean sector.
Nine of the communities are included in the Habitats Directive (Council Decision 82/72/EEC). This is a **90 %** of the present communities. And, 3 communities have an especial status as Priorized Conservation in the Habitats Directive: *Jasiono penicillatae-Linarietum saturejoidis, Sedetum micrantho-sediformis* and *Phlomido lychnitidis-Brachypodietum ramosi.*

Discussion

The exploited surface has destroyed more than 266 Ha. of mountains. The existing vegetation has been eliminated and we need to establish the restoration criteria to return the ecosystem to a close approximation of its condition prior to disturbance.

We have followed the advices given by the "Handbook of Ecological Restoration" (Perrow *et al.,* 2002), "Recuperación de espacios degradados" (Gómez-Orea, 2004) and "Modelos de restauración forestal" (Valle *et al.* 2004) to elaborate the restoration criteria on dolomitic quarries on "Sierra de Mijas" mountain range. Our aims are to priorize actions to increase vegetal biodiversity reconstructing natural communities (which have a high botanic value):

Restoration of soil environments: Soil can be added from adjacent undisturbed areas during the dry season (Jian-Gang *et al.,* 2006) or we can save the soil before the mining procces to add it afterwards.
Use of soil seed banks: In this way, seed that cannot be purchased commercially can be collected. And a better restoration can be achieved with material collected locally. There are several methods to collect seeds, but James D. Riley (2004) has optimized the time for seed collection by vacuum harvesting of magnesian limestone grassland for restoration.

Establishment of vegetative plants: We will select local species because they are adapted to the environment (humidity, temperature, slope, soil characteristics…), we can get seeds and plants in a relatively easy way (it is important to know where they come from) and we will restore natural communities with natural plants (according to our aim). The logistic aspect (budget, transport) is another characteristic we need to know when we are choosing species to restore.
“Modelos de restauración forestal” recommend us, for a right species selection, to prefer quality than quantity, to use the maximun number of different species as possible and do not follow a regular pattern because they seem artifical.

According to the vegetation serie we have to select the species to sow, we will priorize the establishment of priorized communities (*Jasiono penicillatae-Linarietum saturejoidis, Sedetum micrantho-sediformis* and *Phlomido lychnitidis-Brachypodietum ramosi*) and the endemic ones (*Linario clementei-Andryaletum ramosissimae* and *Ulici baetici-Cistetum clusii*). They are shrubs, grasslands and cliff face communities. It is better to restore with non arboreal species. And the quarry geomorphology has to conserve some cliffs. These cliffs will be colonised by species from *Sedetum micrantho-sediformis* community.

Studies with *Pistacia lentiscus, Olea europea* and *Ceratonia siliqua* (presented in the vegetation serie) in a limestone quarry restoration (Clemente *et al.,* 2004) recommend to plant these three species for revegetation programs in the Mediterraean, with other native species, because increasing the number of plant species would create an array of microsite conditions available for colonization by other species and also mimic the natural vegetation, accelerating secondary succession.

Conclusions

The results show us the importance of the plant communities in the study area. We can extrapolate the results to other dolomitic areas. These areas would have a high Botanic Value Index, depending on their naturality. We have to plan in the conservation of dolomitic outcrops, especially on “Sierra de Mijas” mountain range (Medina-Cazorla *et al.,* 2005). The plant communities included in the Habitats Directive are established in poor-developed soils, so we have to consider the conservation of areas with poor-developed soils (Now these areas are under conccesion of mining rights).

This value based methodology could be applied in Environmental Impact Assessments, in the establishment of new limits of a Protected Area, in land-use studies, etc. It is useful working with the Administration (to discuss or justify new plans). In this way; it is easier to discuss a future restoration projects, land-use, etc.

Finally, this value based methodology is a phase in the land-management, which tries to adapt the management of natural resources and the activities with environment preservation.

References

ALONSO, R. (2000): *Valoración del estado de conservación de la vegetación y propuestas de ordenación y uso del territorio de la margen izquierda de la cuenca alta del río Esla (León).* Universidad de León, Serie Tesis Doctorales 2000. Volumen 2.

ANDREO, B. (1997): *Hidrogeología de acuíferos carbonatados en las Sierras Blanca y Mijas (Cordillera Bética, Sur de España).* SPUMACHS, Málaga. 489 p.

ANDREO, B.; CARRASCO, F., VADILLO, I. y LIÑÁN, C. (1996): Características hidrogeológicas de las Sierras Blanca y Mijas (provincia de Málaga, Cordillera Bética). *Geogaceta,* 20(6), 1267-1270.

ANDREO, B. y SANZ DE GALDEANO, C. (1994): Stratigraphy and structure of Sierra Mijas (Alpujarride complex, Betic Cordillera). *Annales Tectonicae,* 8(1), 23-35.

ANONIMOUS. Real Decreto 2994/1982, de 15 de octubre, sobre restauración de espacio natural afectado por actividades mineras.

ANONIMOUS. Real Decreto 439/1990, de 30 de marzo, por el que se regula el catálogo nacional de especies amenazadas.

ANONIMOUS. Decreto 104/1994, de 10 mayo, por el que se establece el Catálogo Andaluz de Especies de la Flora Silvestre Amenazada.

ANONIMOUS. Council Decision 82/72/EEC, of 3 December 1981, concerning the conclusión of the Convention on the consercation of European wildlife an natural habitats.

ASENSI, A. y B. DIEZ GARRETAS -1988- Matorrales y jarales del sector Rondeño. *Documents Phytosociologiques*, 11: 263-274.

BAILEY, D. E., GUNN, J., HANDLEY, J. and SHAW, S. (1991). The construction of limestone ecosystems on quarried rock slopes. *Proceedings of the Environmental Workshop 1991, Australian Mining Industry Council,* Perth pp. 13-25.

EHRENFELD, J. G. (2000): Defining the limits of restoration: The need for realistic goals. *Restoration Ecology Vol.8 No.1, pp.2-9.*

EHRENFELD, J. G., TOTH, L. A. (1997): Restoration Ecology and the Ecosystem Perspective. *Restoration Ecology Vol.5 No. 4, pp. 307-317.*

GÓMEZ-OREA, D., (2004): Recuperación de Espacios Degradados. *Ed. Mundi-Prensa.*

JIAN-GANG YUAN, WEI, F., LING, F., YAN, C., DONG-QING, W., ZHONG-YI, Y. (2006): Soil Formation and Vegetation Establishment on the Cliff Face of Abandoned Quarries in the Early Stages of Natural Colonization. *Restoration Ecology 14 (3), pp. 349-356 0*

KLEMOW, K.M. (1984). Plant community development in an abandoned limestone quarry: a demographic study. In *The Biosphere*, ed. T. N. Veziroglu, pp. 195-210. Elsevier, Amsterdam.

MARTÍN DUQUE, J. F., PEDRAZA, J., DÍEZ, A., SANZ, M. A., CARRASCO R.M. (1998):
Geomorphological desing for the rehabilitation of an abandoned sand quarry in central Spain.

MEDINA CAZORLA, J.M., PÉREZ GARCÍA, F.J., GARRIDO-BECERRA, J.A., MARTÍNEZ-HERNÁNDEZ, F., MENDOZA, A., PÉREZ DE LA TORRE, A.V., MOTA, J.F. (2005). Riqueza y rareza florística en los afloramientos dolomíticos de las cordilleras béticas (Sur de España): Ensayo preliminar. *Acta Botánica Malacitana* 30: 111-126.

MORENO-PEÑARANDA, R, LLORET, F., ALCAÑIZ, J.M. (2004): Effects of sewage sludge on plant community composition in restored limestone quarries. *Restoration Ecology 12 (2), pp. 290-296*

NIETO CALDERA, J.M., S. PEREZ SANZ y B. CABEZUDO -1987- Datos sobre la vegetación dolomitícola del Sector Rondeño. Lazaroa, 10: 35-46.

NIETO, J.M., CONDE, R., VELASCO, C., SANTILLANA, N., ARREBOLA, M.A., COMINO, O. (1999): Cartografía y evaluación de la vegetación de la Reserva Natural de la Laguna de Fuente de Piedra (Málaga). *Libro de resúmenes de las XVII jornadas de Fitosociología, Jaén.*

PERROW, M. R., DAVY, A. J., (2002): Handbook of Ecological Restoration. *Cambridge University Press. Vol. 1-2.*

RIETKERK, M., KOPPEL, J. van de (1997). Alternate stable states and threshold effects in semi-arid grazing systems. O*ikos,* 79(1): 69-76.

RILEY, J.D., CRAFT, I.W., RIMMER, D.L., SMITH, R.S. (2004): Restoration of magnesian limestone grassland: Optimizing the time for seed collection by vacuum harvesting. *Restoration Ecology 12 (3), pp. 311-317.*

RIVAS GODAY, S. -1973- Plantas serpentinícolas y dolomitícolas del sur de España. Bol Soc Brot. (2ª ser.), 47(2): 161-178.

RIVAS GODAY, S. y ESTEVE, F. -1972- Flora serpentinícola española. Anales Real Acad. Farmacia, 38(3): 409-462.

RIVAS GODAY, S. y MAYOR, M. -1965- Aspectos de la vegetación y flora orófilas del Reino de Granada. Anales Real Acad. Farmacia, 31(6): 345-400.

RIVAS-GODAY, S. & RIVAS-MARTÍNEZ, S. -1967- Matorrales y tomillares de la Península Ibérica comprendidos en la clase Ononido-Rosmarinetea Br.-Bl. -1947- *Anal. Inst. Bot. A. J. Cavanilles* 25: 7-180.

RIVAS GODAY, S. y G. LOPEZ GONZALEZ -1979- Nuevos edafismos hispanos de sustratos ultrabásicos y dolomíticos. *Anales Real Acad. Farmacia*, 45: 95-112.

RIVAS-MARTINEZ, S. (2007): Itinera Geobotanica Nº 17. Universidad de León, Secretariado de Publicaciones.

RIVAS-MARTINEZ, S. *et al*. -1991- Endemismos vasculares de Andalucía. *Rivasgodaya* 6: 5-76. Madrid.

RIVAS-MARTÍNEZ, S., E. DÍAZ, T., FERNÁNDEZ-GONZÁLEZ, F., IZCO, J., LOIDI, J., LOUSÃ, M. & PENAS, A. (2002). Itinera Geobotanica Nº 15 (1).Universidad de León, Secretariado de Publicaciones.

SAINZ OLLERO, H. y J.E. HERNÁNDEZ BERMEJO -1985- Sectorización fitogeográfica de la Península Ibérica e Islas Baleares: la contribución de su endemoflora como criterio de semejanza. *Candollea*, 40: 485-508.

SALVO, A.E.; J.M. NIETO CALDERA; F. CONDE; J. GUERRA y B. CABEZUDO -1983- Especies vegetales endémicas y amenazadas de la provincia de Málaga. *Jábega*, 44: 66-76.

SALVO, A.E. y B. CABEZUDO -1984- Bases para la utilización de los pteridófitos en el establecimiento de unidades corológicas. I, Andalucía. *Anales de Biología*, 1: 309-316.

SORT, X., ALCAÑIZ, J.M. (1996): Contribution of sewage sludge to erosion control in the rehabilitation of limestone quarries. *Land Degradation & Rehabilitation 7:69-76.*

VALLE, F., NAVARRO, F. B., JIMENEZ, M.N. (2004): Modelos de restauración Forestal. Modelos de gestión de la vegetación. *Junta de Andalucía.*

WHEATER, C.P., CULLEN, W.R. (1997). The flora and invertebrate fauna of abandoned limestone quarries in Derbyshire, United kingdom. *Restoration Ecology* 5, 77-84.

Web pages:

Instituto Geológico y Minero de España:	http://www.igme.es/internet/default.asp
Bioclimatolgy, Universidad Complutense Madrid:	http://www.globalbioclimatics.org
ESRI, ArcGIS:	http://www.esri.com
GARMIN, GPS:	http://www.garmin.com
Microsof Office:	http://www.microsoft.com

Sistema de Información Geológico y Minero de Andalucía:
http://www.juntadeandalucia.es/empleoydesarrollotecnologico/w08/sigma

Shapes used with ArcGIS:

Ortofotografía Digital de Andalucía. Provincia de Málaga vuelo del 2002. *Junta de Andalucía. Consejería de Medio Ambiente.*

Mapa de series de vegetación de Andalucía. Francisco Valle, 2003. *Editorial Rueda, Consejería de Medio Ambiente.*

Mapa Digital de Andalucía. FICA, escala 1:10000.

Mapa Topográfico de Andalucía. Escala 1:10000.

Geologic Digital Map of Málaga. Elaborated with ArcGIS based on Málaga Geologic Map (IGME, 2004).

Conccesions of Minning rights. Elaborated with ArcGIS based on Minning rights of SIGMA, 2007.