ECOLOGICAL RESTORATION OF GYPSUM QUARRIES IN SOUTHEAST SPAIN

Marta ALBERT [1] – Sara ABAD [1] – Jose M. CASTILLEJO [1] – Ana G. SAN CRISTOBAL [1] – Ricardo CASTELLÓ [1]

[1] Center of Environmental Sciences, Spanish Center for Scientific Research, Serrano 115 bis, 28006 Madrid, Spain, e-mail: marta.albert@ccma.csic.es

Abstract: Recent studies have highlighted the gypsum outcrops of Spain as the most outstanding for the conservation of gypsiferous flora. Open cast gypsum mining rehabilitation is made difficult because the original soil resource is not retained and local substitute materials, that is, soil-forming materials (SFMs), have to be used as growing media. One severe limitation of SFMs is their poor inherent structure and nutrient content, mainly derived from their low organic matter (OM) content. Concerning this case, the restoration strategy carried out in open cast gypsum quarry on Southeast Spain was mainly based on geomorphological reconstruction, subsuperficial organic amendment (Municipal solid waste compost) and topsoil replacement. A 5-year field study has been carried out in 2 landfill materials (gypsum fines and sterile material) to evaluate the effect of these materials on the evolution of soil chemical properties and to consider amendment addition. The influence of chemical and physical soil properties on plant community has been studied since rehabilitation success could be conditioned by landfill materials. The results showed that there is a clear difference between the 2 landfill materials. Sterile material is characterized by a higher nutrient and carbonate content and more heterogeneous texture than gypsum fines. Therefore, landfill materials would benefit different life forms hence plant community is dominated by annual species in gypsum fines while shrubs are clearly dominant in sterile material. All this leads us to establish that amendment addition could be considered an efficient tool to enhance ecological restoration.

Keywords: Iberian gypsum vegetation, quarry, life forms, soil rehabilitation, organic amendment

Introduction

Gypsum outcrops are widely distributed around the world and generally appear in areas subjected to dry or semiarid climate (Parsons 1976). By the rarity and richness of their flora, gypsum soils of Almería Province (SE Spain) are the most valuable from a conservation viewpoint, whereas at the same time the territory is being intensively exploited by quarrying the most important production of gypsum rocks in Europe (Mota et al. 2003). Surface mining includes removal of vegetation, disturbance of soil profile and compaction resulting in environmental degradation of the site (Rao 1998). The reconstitution and management of a suitable soil layer to support vegetation in the long run is a crucial phase of landscape rehabilitation (Roberts & Roberts 1986).

The gypsum quarry studied is located in Sorbas (Almería, SE Spain), which is considered the most desertified locality in Europe. The restoration strategy carried out was mainly based on geomorphological reconstruction, subsuperficial organic amendment of the landfill material with Municipal solid waste compost and topsoil replacement.

The current study focused on making a physico-chemical characterization of the SFMs to evaluate the effect of these materials on soil evolution and plant community success to consider amendment addition.

Materials and methods

It has been worked with two different landfill substrates, gypsum fines and sterile substrate, being these SFMs covered with topsoil. It was designed a monitoring model consisted on 6 experimental plots (3+3), each measuring 40m^2 (8x5m). In each plot it has been recollected 3 soil samples. The field sampling was carried out during 2002 and 2006, fitting each year basically with the optimal phenological state of most plant species.

Soil samples were collected on a yearly basis from the surface and subsurface layers of each plot. Since the specific target of this work was to analyze landfill material effects (i.e. effects on the subsurface layer), and the topsoil layer was as thin as 5–10 cm, the analytical results for the topsoil layer were discarded. Soils were mainly analyzed following the official Spanish methods (M.A.P.A. 1993). Total organic N was determined by the Kjeldahl nitrogen method. Total organic carbon (TOC) was determined by oxidation with potassium dichromate and concentrated sulfuric acid. The P was determined colorimetrically (1:100 extraction). The Ca, K, Mg (assimilable macronutrients) and Na were determined by flame photometry. Sulfate ions were quantified by ion chromatography. Carbonates were estimated with a 1:1 HCl – calcic carbonate reagent using a standard calcimeter. pH was determined in a 1:2.5 soil–water extract. Electrical conductivity (EC) was measured in a 1:5 soil–water extract. Available water-holding capacity (AWC) was computed as the difference between field capacity (FC) and permanent wilting point (PWP) (Cassel and Nielsen 1986).

Physical and chemical properties of SFMs comprise many repercussions on plant-growth potential in order to rehabilitate the lands disturbed by surface mining (Chichester & Hauser 1991). As a consequence, every monitoring year the vegetation was sampled in both landfills for percent canopy cover, which was estimated according to Folk (1951). It was measured total canopy cover and canopy cover for the 2 main plant life-forms (woody perennials and herbaceous annuals). The results were compared with 3 meteorological factors of the phenological year: average maximum temperature, average minimum temperature and annual average rainfall.

Analysis of variance (*ANOVA*) was carried out with the data collection. Data were interpreted using the least significant difference values throughout a *Tukey's test*. The changes produced in the content of chemicals throughout time were evaluated using a multivariate statistic tool (discriminant analysis). This evolution was compared with autochthonous gypsum soil profiles (*Gypsic regosol*).

Results and discussion

Physico-chemical characterization of gypsum landfills and sterile landfills was made at the starting point of the study (Table 1 and 2). It has been demonstrated that there are significant differences between both landfills. From a chemical viewpoint, gypsum landfills have an elevated content of sulfates and calcium (derived from the chemical composition of gypsum [$Ca_2SO_4 * 2H_2O$]), whereas sterile landfills present a major content in carbonates and general nutrients (mainly TOC, N and K). On the other hand, sterile landfills are characterized by higher water content (AWC). All the above leads to conclude that landfill substrate can be more biologically active in sterile materials than in gypsum fines.

Table 1. Main chemical composition (mg kg^{-1}) of both landfills (gypsum fines and sterile material)[$p < 0.05$]

	SO_4	CO_3	Ca	TOC	N	P_2O_5	K	Na	Mg
Gypsum fines	384,519	68,500	28,630	677.5	0.0	45.0	15.0	15.0	16.2
Sterile material	31,700 *	726,750 *	24,780 *	4,312.5*	135.0*	22.5 *	65.0 *	41.2 *	22.5

Table 2. Main physico – chemical properties of both landfills (gypsum fines and sterile material) [$p < 0.05$]

	EC (dS m^{-1})	pH	AWC (%)
Gypsum fines	2.09	8.07	10.9
Sterile material	2.10	7.70	13.7*

It has been shown that landfill material seriously determines the type of plant communities that can be developed (figure 1). As a result, grasslands are preferentially found in gypsum fine landfills, while plant communities dominated by shrubs are better favored in sterile landfills. Therefore, total plant cover associated to gypsum fine landfills is highly controlled by meteorological conditions of the phenological year, being considered rainfall as the main factor (no correlation for thermal parameters). Although this fact also can be observed in sterile landfills during the initial years, its significance decreases in time as shrub cover raises. These results comprise important implications relating to rehabilitation management since restorer can not expect similar behaviour from different landfill materials.

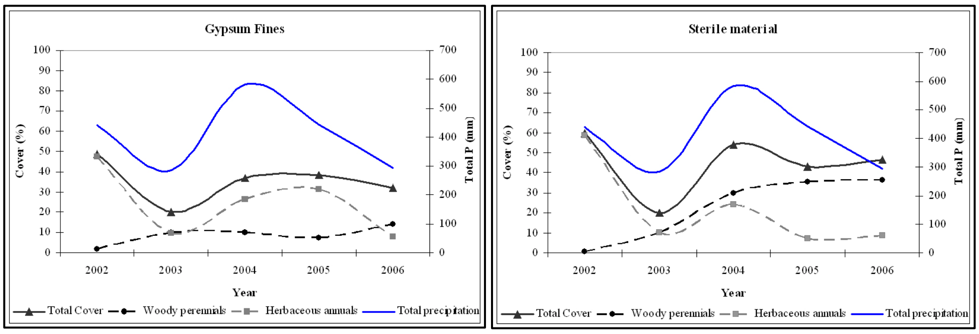

Figure 1. Plant cover monitoring in both landfills (gypsum fines and sterile material)

The discriminant analysis (figure 2) has also shown several important conclusions from a restoration perspective. Function 1 (explaining most of the variance of this data set) establishes firstly a remarkable separation between landfill materials and autochthonous gipsiferous soils (*Gypsic regosol*). Nevertheless, it seems that the restoration strategy of using topsoil allows plant growth even from the initial stages of rehabilitation and consequently soil profile development. Thus, as gypsum landfill as sterile material (each with their own path) undergo an evolution towards natural soil throughout time from sampling 1 to sampling 4. However, the original lack of soil nutrient in these stripped substrates (less marked in sterile materials) force the system to go back in this progress as time increases (sampling 5). As a consequence, it can be deduced the need of nutrient outside supply in terms of landfill recuperation. Relating to this fact, it has been proved that soil development is accelerated by using organic amendments (Gregory and Vickers 2003). This can be observed graphically in figure 2, which shows the theoretical position of the analytical results coming from landfill materials amended with municipal solid waste compost as a method to boost rehabilitation.

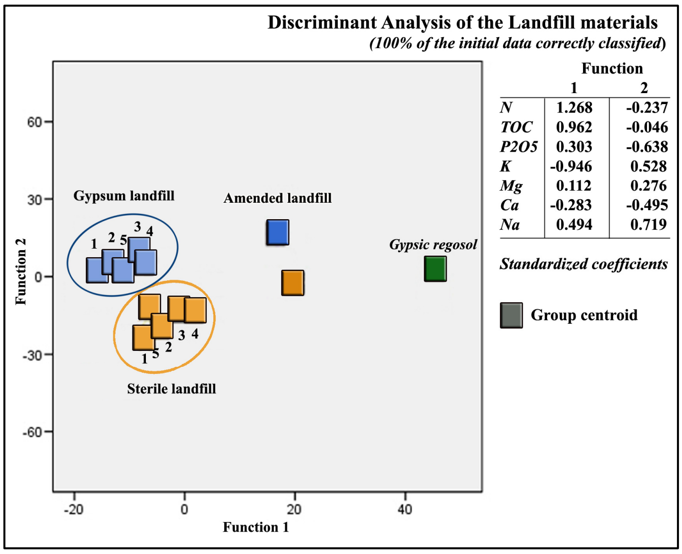

Figure 2. Discriminant analysis of landfill soil chemical evolution

Conclusions

It has been demonstrated that landfill materials generated from gypsum quarrying (gypsum fines and sterile substrates) present significant different properties, which extremely affect plant community on development. Edaphically, organic amendment seems to represent a suitable approach to rehabilitate these stripped landfill materials.

Acknowledgements

This study was funded by Saint – Gobain Placo Ibérica (Sorbas, Almería, Spain).

References

Bradshaw, A. (1997). Restoration of mined lands - using natural processes. Ecological Engineering 8(4): 255-269.

Gregory, A. S. and A. W. Vickers. (2003). Effects of amendments on soil structural development in a clay soil-forming material used as a cap for landfill restoration. Soil Use and Management 19(3): 273-276.

Rao, A. V., J. C. Tarafdar and B. K. Sjarma. (1996). Characteristics of gypsum mine spoils. Journal of the Indian Society of Soil Science 44(3): 544 - 546.