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The use of native pasture species in the rehabilitation of a limestone quarry

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Abstract. In high environmental value areas, the rehabilitation of quarries requires the use of native well-adapted plant material. The use of forage species could perform the dual function of rehabilitation and production, where livestock breeding is a key aspect. With the aim of evaluating the establishment and persistence of a mixture of native pasture species selected by CNR-ISPAAM from Sardinian populations, a trial for the rehabilitation of a limestone quarry located in a Site of Community Importance (SCI) was carried out. The mixture components were: *Medicago polymorpha* L., *Psoralea bituminosa* L., *Psoralea morisiana* (Pignatti & Metlesics) Greuter, *Melilotus indica* (L.) All., *Lolium rigidum* Gaudin and *Plantago lanceolata* L.. Moreover, an amount of commercial seeds of Mediterranean origin of *Trifolium subterraneum* L. and *Dactylis glomerata* L. was added. The mixture was distributed by hydro seeding in autumn 2011. Two sowing rate, 12 and 21 g m⁻² seeds, were compared. The mixture showed an excellent establishment with the dominance of native annual species and a high soil cover rate from spring of the establishment year. The autumn re-establishment of self-reseeding annual species in the second year was excellent and then it has gradually reduced. Perennial species showed a slow establishment, reaching a satisfactory presence only from third year. Similar results in terms of soil covering and persistence for the two seeding treatments were observed.

Keywords. Rehabilitation – Native species – Mixtures – High environmental value areas.

L'utilisation d'espèces indigènes de pâturage dans la réhabilitation d'une carrière de calcaire

Résumé. La réhabilitation des carrières situées dans des zones de haute valeur environnementale nécessite l'utilisation de matériel végétal natif bien adapté. L'utilisation d'espèces fourragères là où l'élevage est un aspect important, pourrait avoir le double objectif à la fois de la réhabilitation et de la production. Dans un essai en Sardaigne, certaines espèces indigènes annuelles et vivaces de pâturages, choisies parmi les populations locales par le CNR-ISPAAM, ont été utilisées dans un mélange, dans le but d'évaluer leur mise en place et la persistance dans la réhabilitation d'une carrière de calcaire située dans une zone spéciale de conservation (ZSC). Les composants du mélange étaient : *Medicago polymorpha* L., *Psoralea bituminosa* L., *Psoralea morisiana* (Pignatti & Metlesics) Greuter, *Melilotus indica* (L.) All., *Lolium rigidum* Gaudin et *Plantago lanceolata* L. En outre, une quantité de semences commerciales d'origine méditerranéenne, de *Trifolium subterraneum* L. et *Dactylis glomerata* L. a été ajoutée. Le mélange a été distribué à l'automne 2011 par hydro-ensemencement. Deux densités de semis ont été comparées. Le mélange a montré une excellente mise en place avec la dominance des espèces indigènes annuelles et un taux de couverture élevé du sol au printemps. Le rétablissement des espèces annuelles à auto-ensemencement dans la deuxième année a été excellent, diminuant ensuite progressivement. Les espèces vivaces ont montré une lente mise en place, pour n'atteindre une présence satisfaisante que dans la deuxième année. Les deux taux de semis ont montré des résultats satisfaisants.

Mots clés. Réhabilitation – Espèces indigènes – Mélanges – Haute valeur environnementale.

I – Introduction

The disused areas exploited for raw material extraction are usually recovered from decay with environmental engineering practices, aimed at achieving the main objectives to preserve the soil from erosion and to include these areas in the surrounding landscape. Conrad and Tischew

(2011) strongly recommended avoiding the use of standardized commercial non-local seed mixtures for grasslands restorations. The use of native species offers a greater probability of adaptation and, in the case of native forage species, it could perform the dual function of rehabilitation and production (Porqueddu *et al.*, 2013).

As a general rule, the rehabilitation of degraded sites should be always made according to the environmental characteristics of the area (i.e. potential vegetation). Nonetheless, in the Sites of Community Importance (SCI) the application of this principle is compulsory, since the European environmental policy imposes strict guidelines especially concerning the plant material suitable to be employed for the rehabilitation. Unfortunately, the application of the European rules is often difficult, as the correct realization of re-vegetation plans requires the market availability of adequate seed amounts of well adapted species to the target substrates and to the local conditions. Our research concerned the environmental quarry rehabilitation program provided by Italian law for the mining sector. The aim of the present study was to evaluate a native-based pasture mixture, including species of different functional groups, for the rehabilitation of a limestone quarry located in Sardinia (Italy).

II – Materials and methods

Study Site. The study was carried out over four years (2011–2015) at the quarry “Sas Funtanas”, located in North East Sardinia (latitude 40° 33' N, longitude 9° 39' E) at an altitude of 560 m a.s.l.. The quarry has been exploited for limestone extraction from 1977 and in 1995 it was included in the perimeter of a Site of Community Importance (SCI - ITB021107 – Monte Albo) defined by the ‘Habitat’ Directive 1992/43/EU. The extraction method currently used was a subvertical steps. The area is characterized by a typical Mediterranean climate, with an average annual rainfall of 900 mm concentrated in autumn and spring, with mild winters and severe drought from late May to early October. The vegetation surrounding the quarry consisted of a degraded garrigue, Sheep, cattle, goats and wild animals (such as wild boars) grazed the surrounding area during the year.

Plant materials. Six native species (selected by CNR-ISPAAM) and two commercial varieties of annual and perennial species belonging to the botanical families Fabaceae, Poaceae and Plantaginaceae were sown in mixture (Table 1). The mixture components were chosen on the basis of their functional features: (i) fast or slow establishing species, namely annual and perennial species, (ii) N-fixing or no N-fixing species, namely legumes, grasses and forbs. According to the SCI management plan, all species used were native and present in the surrounding environment. Restoration activities have also included the planting of autochthonous woody species such as *Quercus ilex*, *Juniperus sp.*, *Arbutus unedo*, *Phyllirea sp.* (planting distance 1,5 x 1,5 m).

Table 1. List of species and sowing rate. Life form: T = therophyte; H = hemicryptophyte; SR = seed rate in the mixture (in weight)

Plant materials	Provenance	Common name	Family	Life form	SR (%)
<i>Medicago polymorpha</i> L.	Sardinia	Burr medic	Fabaceae	T	40.0
<i>Lolium rigidum</i> Gaudin	Sardinia	Annual ryegrass	Poaceae	T	26.4
<i>Psoralea bituminosa</i> L.	Sardinia	Arabian pea	Fabaceae	H	2.1
<i>Psoralea morisiana</i> (Pignatti & Metlesics) Greuter	Sardinia	Arabian pea	Fabaceae	H	0.4
<i>Melilotus indica</i> L.	Sardinia	Sweet clover	Fabaceae	T	0.6
<i>Plantago lanceolata</i> L.	Sardinia	Narrowleaf plantain	Plantaginaceae	H	4.7
<i>Trifolium subterraneum</i> L.	Commercial	Subterranean clover	Fabaceae	T	13.4
<i>Dactylis glomerata</i> L.	Commercial	Orchardgrass	Poaceae	H	12.4

Plot Management. The trial was carried out in a slope (average slope = 85%). A layer (12 cm) of soil added with compost (14%) was distributed on the slope surface. The soil was sandy-clay-loam (53.6% sand, 22.8% silt and 23.6% clay), sub-alkaline with pH 7.8 (in water), containing 3.5‰ N (Kjeldhal method), 9.77 ppm P₂O₅ (Olsen) and 5.0% organic matter. The slope area was divided into two plots: (i) A1, equivalent to 900 m²; and (ii) A2, equivalent to 1800 m². Two different sowing rates of the mixture were used in the plots: 12 and 21 g m⁻² viable seeds, respectively in A1 and A2. Mixtures were sown in November 2011 by hydro-seeding. The hydro-seeding contained a blend of water, green-dyed short fiber, soil improvers and fertilizers appropriately selected. The mixtures were sown after the plantation of native woody species.

Measurements. In the first year, forty days from sowing, plant establishment was assessed by counting the seedlings on eight and twenty-two sample areas of 1/16 m⁻² in A1 and A2, respectively. Sampling areas were chosen randomly. In spring and winter, vegetation data were collected by applying a point intercept method (Daget & Poissonet, 1969) on 50 m line intersect transects (total counts per transect = 200) to evaluate the species contribution to soil cover.

III – Results and discussion

A satisfactory establishment of seedlings was found in both plots. No statistical differences between the two seeding rates for the establishment (2810 ± 568 SD and 3593 ± 1027 SD seedlings m⁻² in A1 and A2, respectively) were observed. In the different seasons and years, no remarkable variations were recorded for total soil covering (Fig. 1).

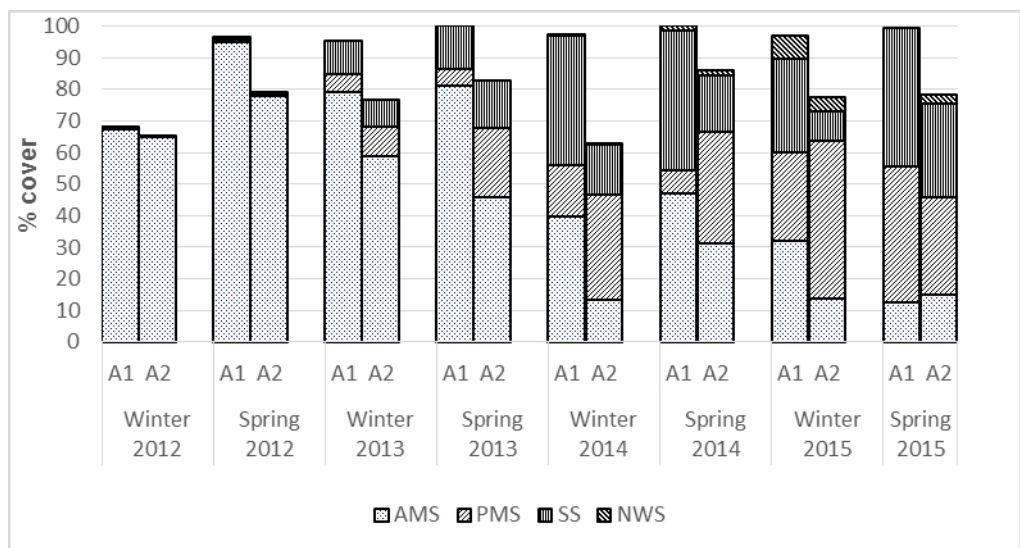


Fig. 1. Soil covering (%) of natural and introduced species during the 4 years for the two seeding rates A1 (12 g m⁻²) and A2 (21 g m⁻²). AMS: Annual Mixture Species, PMS: Perennial Mixture Species, SS: Spontaneous Species, NWS: Native Woody Species (planted).

Its level always exceeded 65%, the minimum level registered in the winter of the establishing year. This soil covering rate is the minimum cover level below which increases the risk of erosion (Thornes, 1988). The soil covering rate was slightly higher in A1 than A2. In spring 2015, at the end of the observation period, soil covering was high both in A1 (98%) and A2 (78%). As expected, the annual species of the mixture provided the higher contribution to soil

covering in the first two years, especially in A2. The perennial species contribution was initially negligible but tended to increase their importance gradually, reaching rates of 30-40% and more in the last years. In spring 2015, *Psoralea* spp. contributed to soil covering for 14% in A2 and 28% in A1, while the contribution of *P. lanceolata* and *D. glomerata* was similar in both plots (around 10%). Along the years, the spontaneous species also showed an increasing contribution, ensuring a higher plant biodiversity and a better inclusion of these areas in the surrounding landscape. *Onopordum illyricum* L., *Helminthotheca echioides* (L.) Holub, *Sonchus asper* (L.) Hill, *Convolvus* spp. and *Chrysanthemum coronarium* L., were the most abundant species among spontaneous one, accounting for 7% the first three and 5% and 4% the last ones. The growth of woody native species was very slow and their contribution to soil covering was always below 5% in the different years and treatments.

IV – Conclusions

The study highlighted the good performances of the mixture based on native species of different functional groups, even at low sowing rates. The main objective of the rehabilitation was to control soil erosion and the excellent soil coverages recorded in the 4-year trial allowed to meet it. The good performance of species employed, in particular the native ones, encourages the research aimed at promoting the use of local germplasm for the re-naturalization, especially when the seed market does not offer well adapted plant materials. The mixture shown to be not too aggressive, allowing for the spontaneous species growth. Moreover, in degraded areas where slope is not a limiting factor, the introduced forage species ensure, over the years, a high quality pasture for potential pastoral activities. In this case, the creation of areas with high forage production, especially in high natural value areas, could reduce the pressure from grazing areas more susceptible to degradation. Finally, the rehabilitation of abandoned areas by extraction processes generates environmental and landscape benefit, playing an important role for the socio-economic subsistence of rural populations.

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