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Research Article

Herbaceous Plant Cover Establishment in a Barren Materials Quarry

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Abstract: The ability to establish cover using grass and legume species without any soil preparation was studied in a barren materials quarry. The biodiversity indexes (Simpson) during the growing season as well as the vegetation cover and composition were measured. The results showed that the established species had a satisfactory cover (up to 87.5%). This means that we can achieve significant soil rehabilitation after mining using herbaceous plant cover and reduce the cost of rehabilitation by cutting the expenses of soil preparation.

Key Words: Biodiversity, soil analyses, soil rehabilitation, mining

Introduction

Mining is an important economic activity, but the re-establishment of the disturbed habitats constitutes a serious problem. Results of research worldwide show that 120 plant species (trees, shrubs, and grasses) are appropriate for plant cover establishment after mining (Fox, 1984). One of the most common plant mixtures used in rehabilitation comprises grasses and legumes. Grasses are regarded as the most appropriate plants for protection from soil erosion, while legumes grow rapidly, particularly in soils with a low concentration of nitrogen. Grasses and legumes contribute to the region's biodiversity and help the new ecosystem to evolve to more stable vegetation stages (growth of shrubs and trees) (Brook & Bates, 1960).

The cost of rehabilitation concerns 2 things: soil preparation and plant culture. Soil preparation (ploughing, fertilization, watering etc.) is the most expensive procedure (Burke, 2008). Tacey (1980) reports that 90% of the total cost of rehabilitation concerns soil preparation, while only 1.4%-3.5% concerns the plants culture. Consequently, if we can reduce the work involved in soil preparation we can reduce the total cost of rehabilitation.

The aim of this work was the establishment of a grass and legume species plant cover in a barren materials quarry, without any soil preparation.

Materials and Methods

Area description

The experiments were conducted in the quarries of the factory Titan (Thessaloniki, northern Greece). The region belongs to the Serbo-Macedonian massif. The rocks are transformed with very little sedimentary rocks. The main rock is limestone. The soil is clayish and alkaline, with Ca^{2+}, Mg^{2+}, and K^{+}. The method of exploitation applied is equitable rungs. The mean annual rainfall of the region is 477 mm (maximums in December and May). The dry period lasts 3 months. The mean daily temperature is 16 °C with the minimum in January (5.9 °C) and the maximum in August (26.5 °C). The mean annual relative humidity is 68%. The region's vegetation is kermes oak shrubs (*Quercus coccifera* L.) and grasses.

Material studied

The following plant species were selected, based on their ecological characteristics (area of spread, needs for soil nutrients, and tolerance in extreme temperatures).

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Plant species have different seed weights. In order to get equal numbers of seeds, we took different weights for each plant species. The plants selected were proven to be appropriate (biocenotic, protective, soil-creative) for land reclamation (Hubbard, 1972; Chatain & Payany, 1994; Richards et al., 1998; Halofsky & McCormick, 2005):

Grasses (Poaceae or Gramineae family)	
1. Arrhenatherum elatius (L.) P.Beauv. ex J.Presl & C.Presl	200 g
2. Stipa bromoides (L.) Dörfler	40 g
3. Agropyron cristatum (L.) Gaertner	670 g
4. Phalaris aquatica L.	200 g
5. Festuca ovina L.	200 g
6. Bromus inermis Leyss.	200 g
7. Dactylis glomerata L.	600 g
Legumes (Fabaceae or Papilionaceae family)	
1. Lotus corniculatus L.	200 g
2. Trifolium repens L.	50 g
3. Trifolium subterraneum L.	600 g
4. Trifolium alexandrinum L.	125 g
5. Melilotus alba Desr.	200 g
6. Medicago sativa L.	200 g
7. Onobrychis sativa Lam.	200 g
Roses (*Rosaceae* family)	
1. Sanguisorba minor Scop.	200 g

Two soil types were selected, based on their concentration in gravel (stones with diameter greater than 4 mm) (soil A had less gravel than soil B). We applied 3 cultures: 1 with a mixture of seeds of all plant species (culture A), 1 with a mixture of seeds of grasses (plants from the family Poaceae) (culture B), and 1 with a mixture of seeds of legumes (plants from the family Fabaceae) and roses (family Rosaceae) (culture C). Each culture occupied an area of 30 m^2. The density of the plants was measured (number of individuals per surface of frame) with frames 10 × 10 cm (parcels) that were placed in fixed positions on all the experimental surfaces. The measurements of the plants density refer to well expanded plants only (very weak or dead plants were not measured). Self-sown species were not included in the experiment. The results were converted into number of individuals per square metre. There were 3 parcels of each of the 6 combinations of treatments (2 soils × 3 cultures) that were measured in 5 time periods (March, April, May, June, and July 1997), in order to cover the entire growing season.

In October 1996 all the surfaces were sown. There was no other intervention (ploughing, fertilisation, watering etc.).

Techniques

The composition of the barren materials stones (soil density and concentration in stones >4 mm) was determined from 2 soil samples (1 from each soil type), by digging 2 holes of 660 cm^3 volume. The soil samples were dried in air for 3 days. After that we smashed the lumps in a mortar and we riddled the soil samples in fractions of >4, 2-4, and <2 mm. In order to determine the concentration in stones >4 mm, we converted the volume of the >4 mm fraction to a percentage of the total sample volume (660 cm^3).

In order to determine the soil specific weight (soil density), we dried the soil fractions in an oven at 100 °C and after that we weighed them (results in grams). We determined the fractions volume by plunging the soil fractions into a volumetric cylinder containing 500 ml of water (results in cubic centimetres).

For the pH determination, we used the soil fractions <2 mm. We determined the pH electrically by using a solution of 1 part soil and 2 parts water. For the determination of the organic matter the humid oxidation method was used (Allison, 1965), for nutrient elements (Ca^{2+}, Mg^{2+}, K^+, Na^+) the disorganisation method with H_2SO_4, HNO_3, and $HClO_4$ was used (Richards, 1954), for phosphorus the $NaHCO_3$ method was used (Olsen et al., 1954), and for the particle size distribution of barren materials the Bouyoucos method (Bouyoucos, 1952) was used.

Cover and Composition

The composition and the cover of the vegetation were measured with the method of line and point (Cook & Stubbendiek, 1986) at the end of the growing season as follows: a measurement tape (length 25 m) and a needle of wire, with a ring at the end in order to be held (length 1 m) were used. We walked along the length of the measurement tape and we registered every observation taken by letting down the needle every 25 cm. Depending

on what the needle came into contact with, the registration was either a plant or bald soil. The procedure was repeated 4 times on each experimental surface and the mean of the observations was converted into a percentage (percentage of cover). Finally, percentage of cover was converted into percentage of composition.

Biodiversity

The density of the plants was measured (number of individuals per surface of frame) with frames 10 × 10 cm that were placed in fixed positions on all the experimental surfaces. The results were converted into number of individuals per square metre. In each time period, 3 frames from each experimental surface (that is 18 frames in each time period) were measured. The measurements were taken in 5 time periods (March, April, May, June, and July 1997). We used Simpson's Diversity Index *D* in order to measure the biodiversity of the plant cover establishment (Simpson, 1949). The diversity indexes (Simpson's indexes) were calculated by

$$D = \sum \left(\frac{\text{number of individuals for the i}^{th}\ \text{plant/m}^2}{\text{total number of individuals/m}^2} \right).$$

Results and Discussion

The results from the soil analysis showed that the 2 soil types do differ in their concentration in big stones; soil type A has a percentage of 27.84 in stones with diameter >4 mm and soil type B 75 (Table 1). As for the pH, the concentrations in mineral elements, organic matter, and phosphorus, and the particle size distribution, there are no significant differences between the 2 soil types (Tables 2-3).

Table 1. Means of barren materials composition.

Fractions	Weight (g)		Volume (cm^3)		Soil specific weight (g/cm^3)		Concentration in >4 mm (%)	
	Soil type A	Soil type B	Soil type A	Soil type B	Soil type A	Soil type B	Soil type A	Soil type B
>4 mm	459.34	1306.29	183.75	495.00	2.50	2.64		
2-4 mm	197.14	164.49	87.50	65.00	2.25	2.53	27.84	75
<2 mm	483.50	335.29	388.75	100.00	1.24	3.35		
Mean specific weight (soil density)					2.00	2.84		

Table 2. Concentrations in mineral elements and organic matter of barren materials.

	pH	Organic matter (%)	Ca^{2+} (me/100 g)	Mg^{2+} (me/100 g)	K^+ (me/100 g)	Na^+ (me/100 g)	P (ppm)
Soil type A	7.73	1.15	18.63	4.71	0.60	0.20	0.94
Soil type B	7.73	0.18	22.22	1.22	0.24	0.16	0.69

Table 3. Particle size distribution of barren materials.

	Clay (%)	Silt (%)	Sand (%)
Soil type A	19.5	19.5	61
Soil type B	10	16	74

Table 4 shows that in soil type A (small concentration in stones >4 mm) we had a satisfactory cover (70.1%) from grasses and legumes, while in soil type B (big concentration in stones >4 mm) the percentage of cover was significantly smaller (58.5%). The species *Agropyron* sp., *Festuca ovina*, *Bromus inermis*, *Dactylis glomerata*, *Medicago sativa*, *Onobrychis sativa*, and *Sanguisorba minor* remained in the plant cover at the end of the growing season in both soil types.

Table 5 shows that in soil type B we had a better cover from grasses (87.5%) than in soil type A (66.7%). The species *Agropyron* sp., *Phalaris aquatica*, *Festuca ovina*, *Bromus inermis* and *Dactylis glomerata* remained in the plant cover at the end of the growing season in both soil types.

Table 4. Cover and composition in culture A (mixture).

	Soil type A		Soil type B	
	Cover %	Composition %	Cover %	Composition %
Grasses (Poaceae or Gramineae family)				
Arrhenatherum elatius	0.000	0.000	0.000	0.000
Stipa bromoides	0.000	0.000	0.000	0.000
Agropyron sp.	9.178	13.090	2.981	5.093
Phalaris aquatica	0.000	0.000	2.875	4.913
Festuca ovina	8.539	12.179	3.715	6.348
Bromus inermis	4.693	6.693	1.429	2.441
Dactylis glomerata	12.486	17.808	5.899	10.080
Total percentage of grasses	34.895	49.770	16.897	28.875
Number of grass species	4	4	5	5
Legumes (Fabaceae or Papilionaceae and Rosaceae families)				
Lotus corniculatus	0.000	0.000	2.062	3.523
Trifolium repens	0.000	0.000	0.000	0.000
Trifolium subterraneum	0.373	0.532	1.143	1.953
Trifolium alexandrinum	0.000	0.000	0.000	0.000
Melilotus alba	0.000	0.000	0.000	0.000
Medicago sativa	13.081	18.657	8.431	14.407
Onobrychis sativa	9.235	13.172	4.369	7.466
Sanguisorba minor	9.809	13.990	11.696	19.987
Total percentage of legumes	32.498	46.351	27.700	47.336
Number of legume species	4	4	5	5
Self-sown species	2.720	3.879	13.921	23.789
Total percentage of species	**70.113**	100.000	**58.518**	100.000
Bald soil	29.887		41.482	
TOTAL	100.000	100.000	100.000	100.000

Table 5. Cover and composition in culture B (grasses).

	Soil type A		Soil type B	
	Cover %	Composition %	Cover %	Composition %
Arrhenatherum elatius	0.000	0.000	0.000	0.000
Stipa bromoides	0.000	0.000	0.000	0.000
Agropyron sp.	12.121	18.182	7.500	8.571
Phalaris aquatica	4.545	6.818	25.000	28.571
Festuca ovina	10.606	15.909	5.000	5.714
Bromus inermis	6.061	9.091	7.500	8.571
Dactylis glomerata	33.333	50.000	32.500	37.143
Total percentage of grasses	66.667	100.000	77.500	88.571
Number of grass species	5	5	5	5
Self-sown species	0.000	0.000	10.000	11.429
Total percentage of species	**66.667**	100.000	**87.500**	100.000
Bald soil	33.333		12.500	
TOTAL	100.000	100.000	100.000	100.000

Table 6. Cover and composition in culture C (legumes).

	Soil type A		Soil type B	
	Cover %	Composition %	Cover %	Composition %
Lotus corniculatus	6.154	8.333	0.000	0.000
Trifolium repens	0.000	0.000	0.000	0.000
Trifolium subterraneum	0.000	0.000	0.000	0.000
Trifolium alexandrinum	0.000	0.000	0.000	0.000
Melilotus alba	0.000	0.000	0.000	0.000
Medicago sativa	10.769	14.583	9.302	13.793
Onobrychis sativa	18.462	25.000	18.605	27.586
Sanguisorba minor	24.615	33.333	34.884	51.724
Total percentage of legumes	60	81.249	62.791	93.103
Number of legume species	4	4	3	3
Self-sown species	13.846	18.750	4.651	6.897
Total percentage of species	73.846	100.000	67.442	100.000
Bald soil	26.154		32.558	
TOTAL	100.000	100.000	100.000	100.000

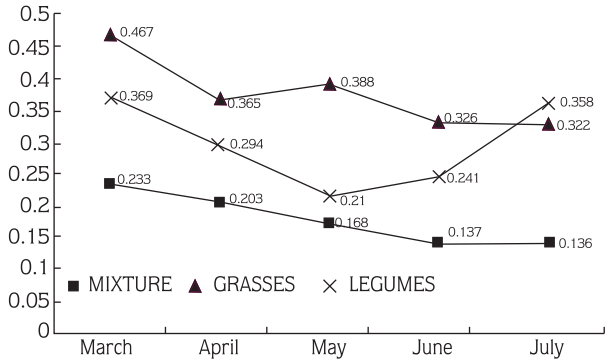

Figure 1. Simpson's Diversity Indexes (D) in soil type A.

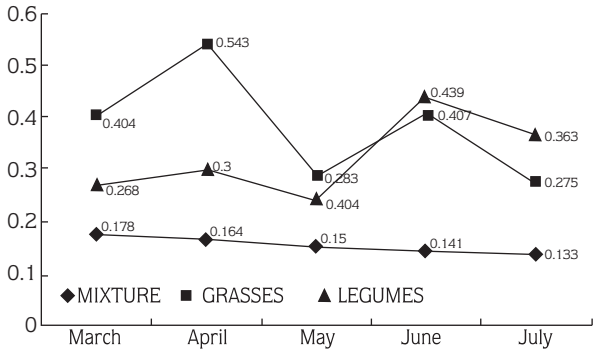

Figure 2. Simpson's Diversity Indexes (D) in soil type B.

Table 6 shows that in soil type A we had a better cover from legumes (73.8%) than in soil type B (67.4%). The species *Medicago sativa*, *Onobrychis sativa*, and *Sanguisorba minor* remained in the plant cover at the end of the growing season.

Figures 1 and 2 show that in both soil types culture B (grasses) has the biggest biodiversity (Simpson's index maximum value is equal to 0.467 and 0.543 for soil types A and B respectively) and culture A (mixture of grasses and legumes) has the smallest biodiversity (Simpson's index maximum value is equal to 0.136 and 0.133 for soil types A and B respectively). We observe that, in both soil types, culture A (mixture) has a more stable biodiversity during the growing season than the other 2 cultures.

Conclusion

The plant cover establishment in a barren materials quarry, without any soil preparation, was successful in all cultures (mixture of grasses and legumes, or grasses or legumes) (58.5%-87.5%). Consequently, we can achieve significant rehabilitation after mining activities with grasses and legumes and decrease the cost by reducing the work involved in soil preparation. In contrast, other

studies (Teixeira et al., 2007) showed that grasses and legumes were not sufficient for the rehabilitation of a degraded study area.

We can recommend a mixture of the species *Agropyron* sp., *Festuca ovina*, *Bromus inermis*, *Dactylis glomerata*, *Medicago sativa*, *Onobrychis sativa*, and *Sanguisorba minor*, which had stable biodiversity during the growing season (creating a stable plant cover), either in soil with small concentration either in soil with big concentration in big stones.

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