

**SUPPLEMENTARY MATERIAL Forests**

**Natural seed limitation and effectiveness of forest plantations to restore semiarid abandoned metal mining areas in SE Spain**

**Oná MB<sup>1,2</sup>, Goberna M<sup>1</sup> and Navarro-Cano JA<sup>1,\*</sup>**

<sup>1</sup> Department of Environment and Agronomy, Centro Nacional Instituto de Investigación y Tecnología Agraria y Alimentaria, INIA-CSIC, Ctra. de la Coruña, km 7.5, 28040 Madrid, Spain

<sup>2</sup> Facultad de Medio Ambiente, Universidad Nacional de Guinea Ecuatorial (UNGE), Hassan II s/n, 661 Malabo, Guinea Ecuatorial

\*Corresponding author

Table S1. Geographical location (UTM coordinates within the 30S grid zone), area, approximate year of abandonment and current plant cover of the eight studied mine tailings in the Cartagena-La Unión Mining District (Murcia, Spain).

Mine tailing	Coord E	Coord N	Area (ha)	Year of abandonment	Plant cover (%)
1	688312	4162483	2.56	1960-1970	34.6
2	687284	4162590	1.81	1982-1986	25.1
3	685449	4163972	8.81	1970-1980	17.8
4	690862	4164858	1.46	1970-1975	28.3
5	685174	4165582	2.54	1970-1980	10.4
6	690652	4164605	0.62	1970-1975	28.2
7	690922	4164213	1.81	1982-1988	17.0
8	691279	4164234	3.41	1970-1980	11.0

Table S2. Analyses of deviance of the effects of distance to the nearest external adult, soil fertility and metal(oid) contents on natural seedling density. Significant results are indicated in bold type (GLM,  $p < 0.05$ ). Results for *M. senegalensis*, *O. europaea*, *Q. coccifera* and *W. frutescens* are not shown due to the absence of sufficient observations in most tailings.

Species	Analysis of deviance		
<i>T. articulata</i>	Predictor	Deviance	$p(>Chi)$
	Distance	6.0112	0.1610
	Fertility	1.9141	0.4290
	Metal(oid)s	0.5565	0.6698
<i>R. lycioides</i>	Distance	9.8423	<b>&lt;0.001</b>
	Fertility	1.4177	<b>&lt;0.001</b>
	Metal(oid)s	0.0005	0.9493
<i>P. lentiscus</i>	Distance	14.1034	<b>&lt;0.001</b>
	Fertility	0.0033	0.9507
	Metal(oid)s	1.2381	0.2333
<i>P. angustifolia</i>	Distance	21.2395	<b>&lt;0.001</b>
	Fertility	0.2677	0.6407
	Metal(oid)s	0.1002	0.7752
<i>C. humilis</i>	Distance	2.4444	0.2554
	Fertility	2.9503	0.2115
	Metal(oid)s	0.1997	0.7451

Table S3. Seedling survival (%) of planted species 15 months after plantation. Significant differences between control plants and those receiving organic amendments are shown in bold type (GLM, \* $p < 0.05$ ).

Species	Control	Organic amendment	Deviance
<i>Tetraclinis articulata</i> (n=94)	93.2	88.0	0.74
<i>Rhamnus lycioides</i> (n=43)	81.0	90.9	0.90
<i>Pistacia lentiscus</i> (n=42)	90.9	80.0	1.03
<i>Olea europea</i> (n=48)	100.0	91.7	<b>5.21*</b>
<i>Chamaerops humilis</i> (41)	80.0	66.7	0.94
<i>Maytenus senegalensis</i> (n=20)	100.0	100.0	0.00
<i>Periploca angustifolia</i> (n=15)	100.0	60.0	<b>3.94*</b>
<i>Quercus coccifera</i> (n=10)	100.0	66.7	
<i>Withania frutescens</i> (n=6)	67.7	33.3	
Overall (n=319) <sup>1</sup>	93.1	80.5	<b>4.27*</b>

<sup>1</sup>*Q. coccifera* and *W. frutescens* were not included in the analyses due to the low sampling size

Table S4. Mean height and trunk diameter in planted individuals 15 months after plantation. Asterisks indicate significant differences between control plants and those receiving organic amendments (GLM, \* $p < 0.05$ ).

Species	Mean height $\pm$ SE (cm)		Mean trunk diameter $\pm$ SE (mm)	
	Control	Organic amendment	Control	Organic amendment
<i>Tetraclinis articulata</i> (n=20)	33.5 $\pm$ 1.4	<b>40.7<math>\pm</math>2.8*</b>	7.8 $\pm$ 0.6	8 $\pm$ 0.9
<i>Rhamnus lycioides</i> (n=10)	28.0 $\pm$ 9.7	28.5 $\pm$ 7.3	5.9 $\pm$ 0.2	<b>7.6<math>\pm</math>0.7*</b>
<i>Pistacia lentiscus</i> (n=10)	15.8 $\pm$ 2.6	17.2 $\pm$ 3.2	5.3 $\pm$ 1.1	4.5 $\pm$ 0.4
<i>Olea europea</i> (n=10)	36.0 $\pm$ 5.6	43.2 $\pm$ 4.6	5.9 $\pm$ 0.4	7.7 $\pm$ 1.1
<i>Chamaerops humilis</i> (10)	20.8 $\pm$ 1.6	21.0 $\pm$ 3.1		
<i>Maytenus senegalensis</i> (n=10)	25.5 $\pm$ 3.1	26.5 $\pm$ 11.9	3.8 $\pm$ 0.7	6.1 $\pm$ 1.4
<i>Periploca angustifolia</i> (n=10)	24.3 $\pm$ 3.0	23.6 $\pm$ 4.4	3.9 $\pm$ 0.6	6.1 $\pm$ 1.0
<i>Quercus coccifera</i> (n=10)	22.0 $\pm$ 1.5	24.8 $\pm$ 2.5	3.2 $\pm$ 0.3	<b>4.3<math>\pm</math>0.3*</b>
<i>Withania frutescens</i> (n=6) <sup>1</sup>		24.3 $\pm$ 9.2		5.2 $\pm$ 1.7

<sup>1</sup>Control plants were omitted due to labelling loss

Figure S1. Overview and details of the natural colonization in some tailings of the Cartagena-La Unión mining district (SE Spain). (A) Contact line between the *Tetraclinis* mixed forest on natural soils on the left and the emerging one on a mine tailing on the right side in the study area. (B) a Mine tailing with a very low plant cover shaped by a perennial grassland and an incipient patchy shrubland. (C) A detail of two saplings belonging to *P. lentiscus* and *T. articulata* (red arrows). (D) Two adult *M. senegalensis* and *P. angustifolia* (red arrows) on the border of a tailing.

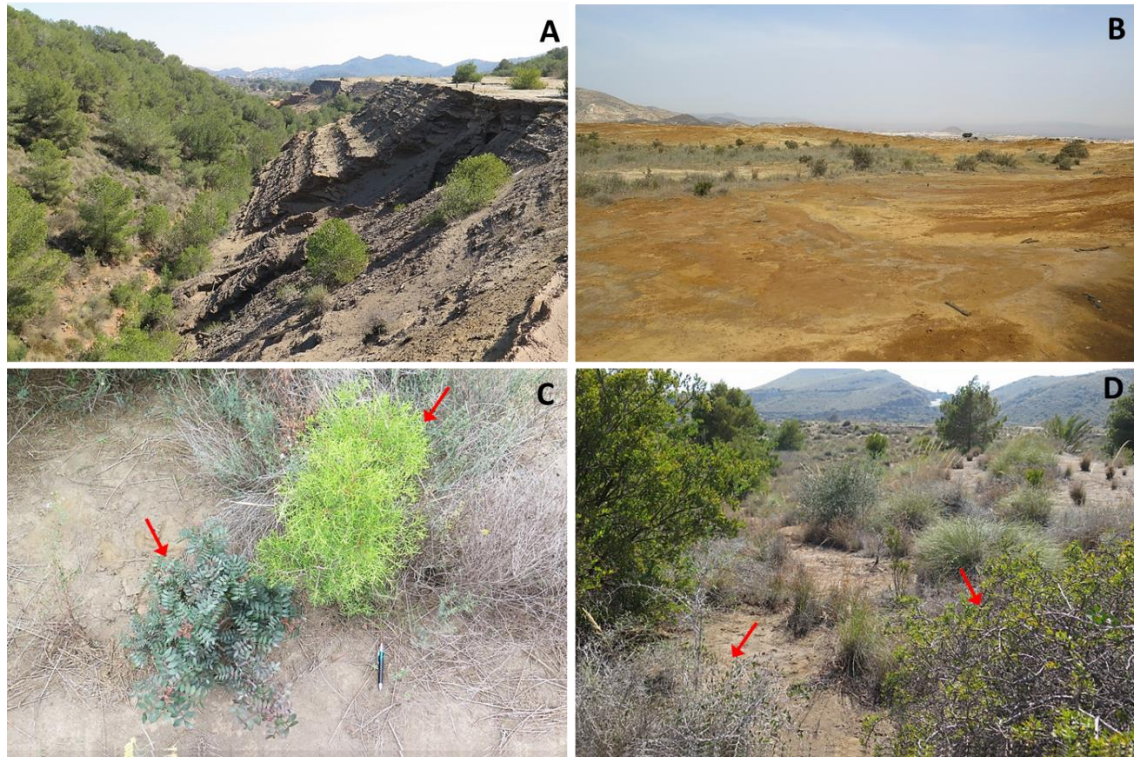


Figure S2. Images of the plantation in the tailing. (A) previous view. (B) detail of the composted waste. (C) an amended hole. (D) subsequent plantation of a *T. articulata*. (E) A sapling of *P. angustifolia* protected with anti-herbivore mesh. Saplings of *M. senegalensis* (F), *W. frutescens* (G) and *O. europaea* (H). General view of the plantation (I).

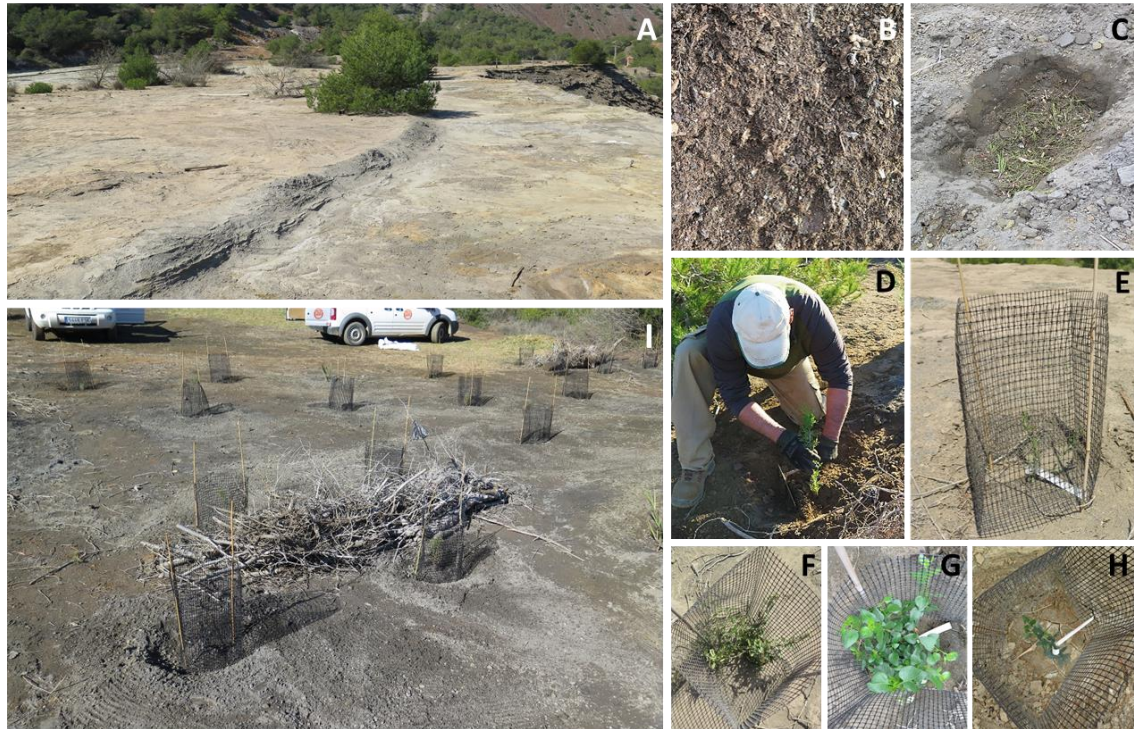


Figure. S3. PCA results for soil fertility (left) and metal(oid) content (right). The plot depicts the first and second principal components and their explained variance are given in parentheses.

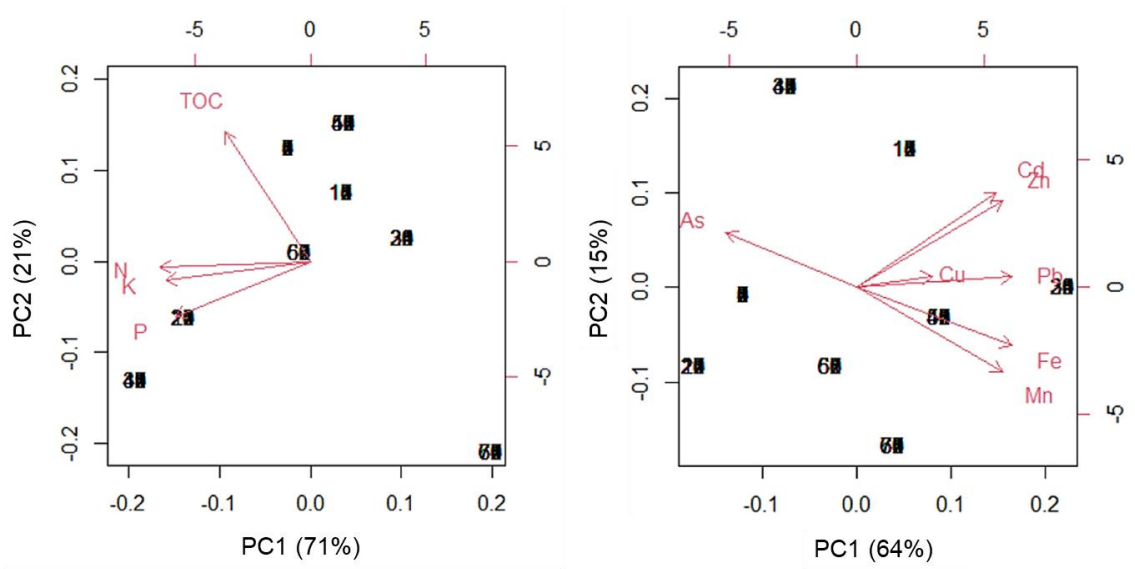




Figure S4. Leaf macronutrient and metal(oid) content 15 months after plantation in control plants (C) and plants receiving organic amendments (OA).

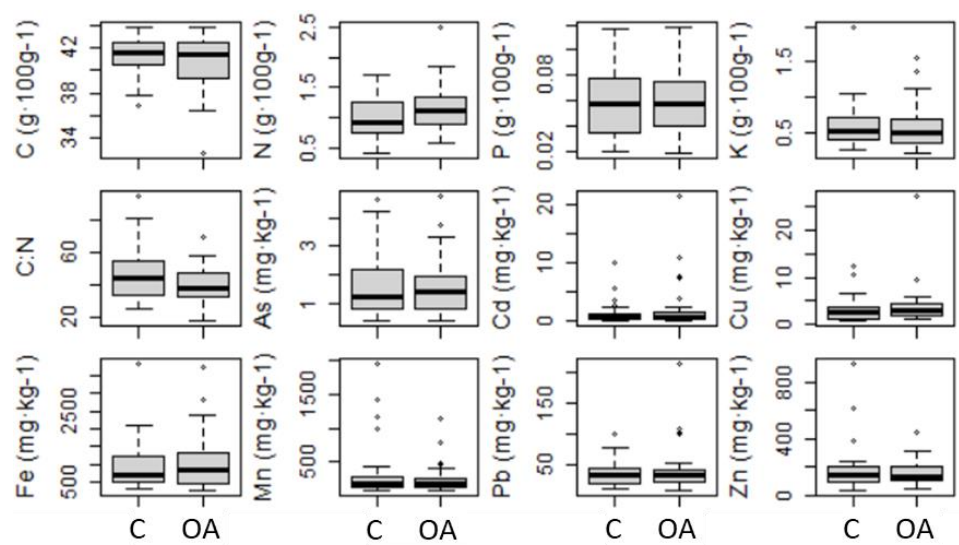


Figure S5. Leaf macronutrient and metal(oid) content in eight species belonging to the *Tetraclinis* mixed forest 15 months after plantation in control plants (C) and plants receiving an organic amendment (OA).

