Factors affecting tree growth in bauxite mining wastes

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**Restoration**

- Restoration of bauxite mining areas constitutes a difficult issue to address due to the destruction of the vegetation and soil decay of the excavated area. The traditional approach to reclamation has been to sow grass and legumes and plant trees to minimize financial and human resource expenditures. In general, the establishment of woody species on degraded lands is highly variable due to the many soil conditions factors that affect vegetation’s success.
Common used Herbaceous species for restoration

- **griminaceous plants**
  - *Agropyrum cristatum*
  - *Lolium rigidum*
  - *Dactylis glomerata*
  - *Phalaris aquatica*

- **leguminous plants**
  - *Medicago sativa*
  - *Medicago lupulina*
  - *Onobrychis sativa*

- **broad-leaved herb**
  - *Sanguisorba minor*
  - *Phacelia tanacetifolia*
Commonly used Woody species for restoration

Indigenous species
- Pinus brutia
- Pinus nigra
- Cupressus sempervirens
- Medicago arborea
- Spartium junceum
- Nerium oleander
- Pyracantha coccinea
- Cercis siliquastrum

Non-Indigenous species
- Cupressus arizonica
- Robinia pseudoacacia
- Ailanthus altissima
New Legislation Framework


- Directive applies to waste resulting from the extraction, treatment and storage of mineral resources and the working of quarries. Waste covered by this Directive no longer falls within the scope of Directive 1999/31/EC on the landfill of waste.
Bauxite

Bauxite is:
- the principal raw material used in the production of aluminium,
- the world’s second most used metal, after iron.

All around the world, aluminium is in increasing demand with a world annual production of 141 Mt. The aggregate output from the five largest mines worldwide was nearly 70 Mt in 2002. More than 98% of the total reported bauxite is mined by open-cast/open cut methods.
Greece is the leading bauxite producer in the EU having production outputs of 1.99 Mt for 2001, compared to 1.82 Mt in 1998 and 3.1 Mt in 1980, while for 2005 the production was 3.315 Mt. The major bauxite deposits in Greece are located within the Parnassos-Ghiona geotectonic zone that includes Giona, Elikonas, Parnassos, and the Oeti mountain site. The reserves are of diasporic and boehmitic type.
The project

Project duration: 26 months
Start up: November 2005
Partners:
- Department of Forestry (Lead partner)
- Department of Mechanical Engineering (LHTEE)

Project objective: Study of ecological and aesthetical restoration of mines and quarries through herbaceous and woody vegetation overlying mining and quarrying waste.
This research was implemented on Mount Ghiona and Parnassos of the Fokida Prefecture in Central Greece, in an area covered with piles of calcareous spoils derived from bauxite mining.

These sites were located in three different elevations and the restoration took place in two phases, namely in 2001 and 1996.
Experimental area

- Varios:
  - Elevation: 420 m
  - Restoration year: 1996

- Agia Anna:
  - Elevation: 500 m
  - Restoration year: 2001

- Keounklias:
  - Elevation: 420 m
  - Restoration year: 1996

- Crias (Ilorali):
  - Elevation: 550 m
  - Restoration year: 1996

- Palio (Horio):
  - Elevation: 1200 m
  - Restoration year: 1996
Tree species

The common tree species that were planted in these sites were:

- *Robinia pseudoacacia*,
- *Pinus brutia*
- *Cupressus sempervirens*.

During June 2006, the height of these species was measured for twenty individuals of every species randomly selected in every experimental site. The tree height was measured by using Bitterlich’s relaskop.
Materials and Methods

- Mechanical texture analysis was performed according to the Bouyoucos hydrometer method.
- Total content of Ni, Cu, Zn, Cd, Cr and Pb in soil samples were determined on filtered extracts obtained from 2g of grated samples, which were digested by 12.5 ml 4M HNO₃, at 80ºC overnight. Following samples’ preparation, the total concentration of heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) was measured via atomic absorption spectrophotometry.
Tree height (m) of species in the experimental sites

restoration year: 1996

restoration year: 2001

- **Kounouklias**
  - **Robinia pseudoacacia**: a
  - **Pinus brutia**: ab
  - **Cupressus sempervirens**: b

- **Palio Horio**
  - **Robinia pseudoacacia**: a
  - **Pinus brutia**: a
  - **Cupressus sempervirens**: b

- **Grias Horafi**
  - **Robinia pseudoacacia**: c
  - **Pinus brutia**: b
  - **Cupressus sempervirens**: c

- **Agia Anna**
  - **Robinia pseudoacacia**: a
  - **Pinus brutia**: a
  - **Cupressus sempervirens**: a

- **Vartos**
  - **Robinia pseudoacacia**: a
  - **Pinus brutia**: a
  - **Cupressus sempervirens**: a
# Mechanical Texture

## Table

<table>
<thead>
<tr>
<th>Site</th>
<th>Clay [%]</th>
<th>Silt [%]</th>
<th>Sand [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kounouklias</td>
<td>38</td>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>Palio Horio</td>
<td>14</td>
<td>16</td>
<td>70</td>
</tr>
<tr>
<td>Grias Horafi</td>
<td>39</td>
<td>21</td>
<td>40</td>
</tr>
<tr>
<td>Agia Anna</td>
<td>7</td>
<td>9</td>
<td>84</td>
</tr>
<tr>
<td>Vartos</td>
<td>28</td>
<td>17</td>
<td>55</td>
</tr>
</tbody>
</table>

1. Kounouklias  
2. Palio Horio  
3. Grias Horafi  
4. Agia Anna    
5. Vartos
Heavy metals in the soil (mining waste)

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th>mg/kg</th>
<th>Heavy metal</th>
<th>mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>3</td>
<td>Ni</td>
<td>75</td>
</tr>
<tr>
<td>Cr (total)</td>
<td>-</td>
<td>Pb</td>
<td>300</td>
</tr>
<tr>
<td>Cu</td>
<td>140</td>
<td>Zn</td>
<td>300</td>
</tr>
</tbody>
</table>

![Graph showing heavy metal concentrations in soil samples from different locations.](image-url)
This study indicated that the current replanting of the examined bauxite mine area is yielding desirable results in the sustainable restoration process. Probably the altitude affected negatively the establishment of the three tree species. Perhaps, other species should be tested in such an environment.
Conclusions (2)

- It was concluded that the altitude probably act as a growth setback. The planted species prefer the thermo- and meso-Mediterranean vegetation belt and probably are not appropriate for revegetation of high altitude sites.
Conclusions (3)

- *Robinia pseudoacacia* and *Cupressus sempervirens*, could be considered as proper species for restoration of degraded bauxite mining areas with increased heavy metal concentration, due to their adaptability to poor sites.
Current situation of bauxite mine
Current situation of bauxite mine
Current situation of bauxite mine

[Image of a landscape with mountains and a barren area with some greenery and pipes running through it.]
Acknowledgements


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Thank you for your attention