

USE OF BIOSOLIDS FOR REFORESTATION IN THE REGION OF VALENCIA (E SPAIN). FIRST RESULTS OF A PILOT PROJECT.

Valdecantos A., Cortina J., Fuentes D., Casanova G., Díaz J. M., Llavador F., Vallejo V. R.

1. CEAM., Paterna, Spain.
2. Departament d'Ecologia, Universitat d'Alacant, Spain.
3. TRAGSA, Paterna. (Valencia), Spain.
4. Entitat Pública de Sanejament d'Aigües Residuals de la Comunitat Valenciana, Valencia, Spain.

1. ABSTRACT

Because of the more restrictive legislation dealing with waste water management, the production of biosolids (sewage sludge) in EU countries is expected to increase from 7.2 million tons (dry weight) in 1992 to more than 11 million tons in 2005. In the Region of Valencia (E Spain) the production of non-industrial biosolids was 90.420 tons dry weight in 1993, and increased to more than 300.000 tons in 1999. Most of the biosolids produced in this region are disposed in landfills or used in agriculture. Unlike other regions in Europe, USA, and Australia, in the Region of Valencia the application of biosolids in forests and woodlands has been restricted to research experiments. However, biosolids could help to restore the fertility of soils degraded by long-term uses, and could contribute to the fight against desertification, one of the major environmental threats in this area. Failure to incorporate biosolids as a routine amendment for the restoration of degraded lands is related to complex socio-economical factors. Among them, the perception that it could increase the cost of the already budget-constrained reforestation.

*However, to our knowledge no study has been performed as yet to discuss the technical and economical limitations of this practice. In this study we have assessed the costs and technical limitations to the use of biosolids in reforestation of degraded Mediterranean ecosystems. We selected a degraded area in the inland of Valencia for a pilot-project scale reforestation covering 2 ha. We applied domestic biosolids by using a back-hoe excavator, and planted one-year-old seedlings of *Pinus halepensis* and *Quercus ilex ssp ballota*. We assessed the economic and technical performance of different application types, and monitored survival and growth of introduced seedlings. Application costs (excluding transport) ranged from 23.62 to 41.17 Euro Mg⁻¹ fresh weight, and could easily be reduced to one third of this amount with simple technical improvements. We discuss these, and recommend the best suitable techniques for the use of biosolids in restoration of degraded Mediterranean ecosystems.*

2. INTRODUCTION

The implementation of the European Directive 91/271/CEE will generate large amounts of biosolids. In the European Union the production of biosolids will probably increase from 7.2 million Mg (dry weight) in 1992 to 11 million Mg in 2005 (Hall and Dalimier, 1994). In the Region of Valencia the amount of biosolids produced in 1993 was 90.420 Mg. In 1999 it was more than 350.000 Mg (EPSAR, pers. comm.). In 1995, 60 % of the biosolids produced in the Region of Valencia were used in agriculture, that is somewhat less than the 75 % considered suitable for this purpose. But the application of byproducts of human activity in agriculture is conditioned by the crop surface area available and biosolid characteristics. In the province of Alicante 10.000 ha of crop land have been recently abandoned, specially in the last half of the 20th century (Padilla, 1998). This resulted in an increase in the surface area of forest and shrublands from 16 % in 1957 to 40 % in 1994 (Hernández, 1997). This trend has been promoted by local and regional policies that encourage the forestation of agricultural set-aside lands.

The application of biosolids to agricultural lands is also limited by the heavy metals content of the biosolids (Directive 86/278/CEE). These limits will probably get more restrictive in the next future. These directives could limit the expansion of the agricultural use of biosolids. The application of biosolids in forest lands is less widespread than in agriculture, but it has been gradually increasing in the last decades. In the 80's, biosolid application in forests was a common practice in some areas of the USA (Bastion, 1986; Brockway et al., 1986; Urie, 1986). Australia and New Zealand have a large tradition in using waste water and biosolids in forest plantations (Adams et al., 1991; Barton et al., 1987; Benyon et al., 1991; Constantini et al., 1995; Loch et al., 1995; Stewart et al., 1986). Within the European Union, the application of biosolids at planting and after harvesting was considered a suitable alternative in the UK (Moffat and Bird, 1988; Moffat et al., 1991), and it currently affects close to 1 % of the production of biosolids (Williams, 1999). In France biosolids and waste waters have been applied both at experimental and management levels (Aubert, 1990; Pibot, 1998). In the Region of Valencia results of biosolid application for small-scale research studies have been promising (Ib-Òez et al., 1995; Valdecantos et al., 2000).

The application of organic manures has several potential benefits for soils and plants, including an increase in nutrient availability and organic matter content, an improvement of the physical properties, and an enhancement of the activity of the microbial population. Western Mediterranean soils frequently present low fertility levels (Vallejo et al., 1998) and may be unable to cope with plant nutrient demands (Valdecantos and Cortina, 1999). Several studies showed improved nutrient status and growth of native vegetation after fertilization (Fresquez et al., 1990; Hasselgren, 1998; Labrecque et al., 1995; Loftin and Aguilar, 1994; Rigueiro Rodríguez et al., 1995; Rodgers and Anderson, 1995). The improvement of soil structure and aggregate stability could increase the water holding capacity of these soils, a key factor in dry and semiarid areas. On the other hand, the application of biosolids could also have deleterious effects on the environment due to heavy metal toxicity, salinity and underground water pollution. Finally, social acceptance is a *sine qua non* condition for biosolid application at a management scale.

Some properties of degraded Mediterranean woodlands may affect their capability to incorporate biosolids. This include the abundance of shallow and stony soils, and rugged terrains, the need to preserve existing vegetation and spontaneous recovery processes, and their relative remoteness. Because of this, and because of the above mentioned social acceptance, biosolids should be applied in a single operation by using specifically designed forest machinery, and in a way that may minimize the surface area affected, and the nuisances for neighbouring human communities.

We have evaluated several procedures for the application of biosolids in the afforestation of degraded Mediterranean woodlands. The main objective of this paper is to discuss the economic costs and technical limitations of this practice.

3. MATERIALS AND METHODS

The pilot project is part of a reforestation project undertaken by the Regional Government of Valencia (Conselleria de Medi Ambient, Generalitat Valenciana). The site is a degraded area in the inland of the province of Valencia covering 2.5 ha, and located at 750 m a.s.l. Climate is Dry Mesomediterranean, and soils are highly carbonated and developed from marls. We selected two tree species for the reforestation: *Pinus halepensis* and *Quercus ilex ssp ballota*. These two species are widely used for afforestation in the Region of Valencia, and represent contrasted ecological strategies. We used biosolids from the Waste Water Treatment Plant Pinedo I (Valencia). The application and planting were carried out in February and March 2000, respectively. The main physico-chemical characteristics of the biosolid are described in Table 1.

	Biosolid characteristics	Maximum values
C:N	10.1	
N (%)	2.7	
P (%)	2.1	
K (%)	0.16	
Ca (%)	7.9	
Mg (%)	0.46	
Moisture (%)	78.6	
EC (dS m ⁻¹)	4.18	
pH	7.4	
Fe (ppm)	30264	
Cd (ppm)	3	20 - 40
Cu (ppm)	406	1000 - 1750
Ni (ppm)	47	300 - 400
Pb (ppm)	182	750 - 1200
Zn (ppm)	1036	2500 - 4000
Hg (ppm)	1.79	16 - 25
Cr (ppm)	267	1000 - 1500

Table 1. Biosolid characteristics and maximum levels allowed by the pish legislation (R.D. 1310/1990)

We tested three application rates of the biosolid (0, 6 and 12 Mg d.w. ha⁻¹), and two site preparation techniques (biosolids applied at the base of 60x60x60 cm holes and sludge applied close to the soil surface after topsoil removal) (Table 2). We also tested two different locations for the introduced seedling (in the center or periphery of the biosolid patch). In all cases the biosolid was placed with a backhoe excavator after site preparation, and it was covered with soil. We then planted 50 one-year-old seedlings of *Pinus halepensis* (Aleppo pine) and *Quercus ilex ssp ballota* (Holm oak) per treatment in 20x20x20 cm holes filled with soil. Seedlings were produced by a nearby public nursery (Vivero La Hunde, Conselleria de Medio Ambiente, Generalitat Valenciana).

Survival and growth (seedling height and basal diameter) were monitored after planting and before and after the first summer in the field. Statistical analysis was carried out once selected the best biosolid application treatment (T2 lateral).

Treatment	Dose (Mg d.w. ha ⁻¹)	Site Preparation	Seedling Position
T1	12	Line	Center Lateral
T2	12	Hole	Center Lateral
T3	6	Hole	Center Lateral
T4	0	--	Center

Table 2. Summary of the treatments assayed.

4. RESULTS AND DISCUSSION

The cost of biosolid application ranged from 23.62 (T2) to 41.17 (T3) Euros Mg⁻¹ of biosolid (fresh weight). This represents an increase of 77 - 89 % of the afforestation costs. Economic results could easily be improved by increasing the loading capacity and the stability of the tractor. This type of machinery is barely used for forestry operations in the Region of Valencia but it is widely available for agricultural works. By using improved machinery that is able to carry up to 4 Mg of biosolids, and place it in small doses in the planting hole, we have calculated that costs could be reduced to 30.4 % of the ones obtained in this study (i.e. 8.11 Euros Mg⁻¹). Other machinery (e.g. aerospreader mounted on a Rottne³ chassis) could be much more efficient in spreading the biosolid over the surface of the treated area (application costs down to \$5 Mg⁻¹ fresh weight - Henry and Cole, 1997), but unincorporated biosolids could surely face strong social opposition.

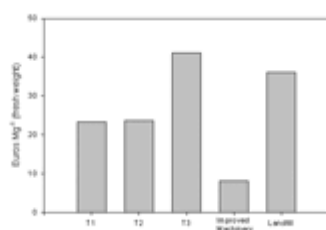


Figure 1. Comparison of unitary costs of biosolid application in afforested areas and landfill disposal. (Source for dumping cost: Entitat PTMblica de Sanejament d'Aigües Residuals de la Comunitat Valenciana).

The improved machinery has higher stability and capacity (two-fold the volume of the assayed machinery). Thus, the frequency of loadings is reduced, and the efficiency of the application increased. With this type of machinery the time needed for the application and loading could be reduced to 4.5 hours ha⁻¹, and 3 hours ha⁻¹, respectively. On the other hand, the time required for the tractor to dig the planting holes and incorporate the biosolid is estimated at 11 hours ha⁻¹. Taking into account machinery costs, the total budget for the afforestation of 1 ha with biosolid application would amount 2082.51 Euros, in contrast with 3013.26 and 2830.96 Euros calculated for treatments T2 and T3, respectively. The unitary costs of the application of 1 Mg of biosolid (excluding plantation costs) is reduced from 23.62 - 41.17 to 8.11 Euros. The unitary price of biosolid landfill disposal is around 36.06 Euros Mg⁻¹ of biosolid (fresh weight) (Entitat PTMblica de Sanejament d'Aigües Residuals de la Comunitat Valenciana), although some authors report lower prices both in Spain (BermTMdez et al., 1999), and in other EU countries (Williams, 1999). With this figure the application of biosolid in afforestation represents a sharp reduction of costs (up to 75 %) for the waste management company.

We observed a high seedling mortality after the first summer in the field. This could be partly due to the scarce rainfall fallen after outplanting. Summer rainfall in 2000 was 17 % of the average summer rainfall. In this context, biosolid application had a negative effect on seedling survival. The negative effect was probably a result of the formation of cracks and hollows as biosolid dried, and later desiccation of the rooting systems. This could be easily avoided by manually digging over after plantation or by using biosolids with higher dry matter content.

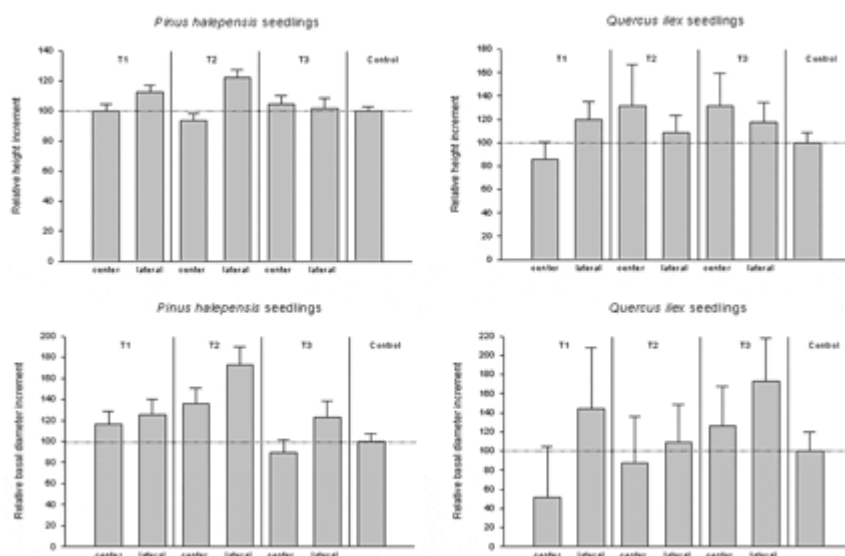


Figure 2. Relative height increment (top) and relative basal diameter increment (bottom) of *Pinus halepensis* (left) and *Quercus ilex* ssp *ballota* (right) seedlings as affected by biosolid dose and placement (mean and standard error). For treatment abbreviations see Table 2.

We found an overall positive effect of biosolid application on seedling size (Figure 2), but this effect was neutralized and even reversed when seedlings were located in the center of the biosolid patch. The best results were obtained with treatment T2 lateral, that is with 12 Mg dry weight of biosolid ha⁻¹ applied at the planting hole, and the seedling placed in a lateral position (Table 3). Pine seedlings responded more clearly to biosolids than holm oak seedlings.

5. CONCLUSIONS

The preliminary results of this pilot-project show that the costs of biosolid application for the restoration of degraded Mediterranean shrublands could be easily affordable with relatively simple technological improvements. Furthermore, the costs of this use of biosolids can be favourable compared with that of landfill disposal. Plantation performance can be improved, although particular care must be taken to avoid short-term direct contact of the seedlings with the biosolid.

6. ACKNOWLEDGEMENTS

We specially thank to D. Rafael Ruano (Conselleria de Medio Ambiente, Generalitat Valenciana) for the facilities in establishing the experimental pilot project and for providing the seedlings (from Vivero La Hundo). We also want to thank TRAGSA and its field staff (specially Octavio) for dealing with the biosolid application and planting. This project is supported by CICYT and Regional Development Funds (Project number 1FD97-1117-C03).

LIST OF REFERENCES

- Adams J. A., Warren J. H., and Cameron, K. C. (1991). Potential nitrogen and phosphorus leaching from a sandy soil under *Pinus radiata* following amendment with municipal sewage sludge. In: 3rd Australian Forest Soils and Nutrition Conf. Pp. 111.
- Aubert G. (1990). Les teneurs en métaux lourds dans les sols naturels et les sols enrichis en résidus d'Épuration urbaine du Sud de la France. *Ecologia Mediterranea*. XVI: 383-393.
- Barton P. G., Dyck W. J., and McFarlane P. N. (1987). Recent developments in irrigating wastewaters into production forests. 56th ANZAAS Congress, Palmerston North.
- Bastion R. K. (1986). Overview on sludge utilization. In: *The Forest Alternative for the Treatment and Utilization of Municipal and Industrial Waste*. D. W. Cole, C. L. Henry, W. L. Nutter (Ed.) Univ. of Washington Press, Seattle. Pp. 7-25.