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Dynamics and patterns of plant development in restored mining areas. Practical examples

Carolina Martínez-Ruiz[1,2]
[1]Sustainable Forest Management Research Institute, University of Valladolid & INIA, E.T.S.II.AA., 34071 Palencia, Spain (caromar@agro.uva.es)
[2]Area of Ecology, Dept. of Agroforestry Sciences, University of Valladolid, E.T.S.II.AA, Avda. Madrid 50, 34071 Palencia, Spain

Opencast mining has altered large areas in many countries, generating major environmental impacts, whose restoration is an urgent need. The effective restoration of opencast mines is a complex process, hampered primarily by the total elimination of vegetation and soil. In the absence of plant cover, these areas may be subject to wind and water erosion, or leaching, polluting rivers, streams, aquifers, and arable lands, as well as being unsightly. Although revegetation of mine wastes can occur naturally, if given time, the process could be extremely slow due to the toxicity, and physical and nutritional shortcomings that wastes often present. Several revegetation approaches have been undertaken worldwide to promote faster vegetation development. However, the results have often been discouraging by a lack of knowledge of the ecological principles involved; the soil is one of the most important limiting factors for vegetation establishment in mine lands.

Topsoil addition over coal-mine wastes in northern Spain favours the establishment of native vegetation by improving physico-chemical and biological soil properties. Without topsoil, vegetation establishment is extremely slow resulting in very unstable plant communities even 40 years after the stop of mining. The addition of herbaceous plant seeds by hydroseeding is frequently used to compensate for the seeds scarcity in the added topsoil. However, hydroseeding is not always successful because of the use of commercial mixtures of non-native seeds. In any case, the installed grassland is being colonized by woody species from the surrounding forest. The structure of the new plant community varies not only in time (succession) but also in space (distance to the seed source), and the process is strongly determined by interactions between the forest edge and the initial grassland patch. The colonization pattern of woody species is affected by fine-scale variations in abiotic factors, including soil properties, which change from the forest to the mine. The native shrubs that colonize the mines (*Genista florida* and *Cytisus scoparius*) facilitate the establishment of native oaks (*Quercus pyrenaica* and *Q. petraea*) and thus the natural forest expansion. One of the mechanisms driving this facilitation shrub-tree process is the soil improvement mediated by native shrubs. Also, hillside topography, common in mines located in the mountains, has certain peculiarities regarding revegetation in flat areas since there is a segregation of vegetation along the slope with grasslands occupying the upper parts and shrublands of legumes the lower parts.

In order to improve the decision-making during restoration management, it is necessary to be based on the knowledge of the mechanisms that condition the establishment of vegetation and the underlying succession processes. The long-term monitoring of existing experimental devices and their extension to other areas and restoration objectives are essential to establish a protocol of performance to adjust decisions to the particular circumstances of each area to be restored and thus reconcile environmental restoration with the economic activity of the area.