A GEOMORPHIC APPROACH FOR THE ECOLOGICAL RESTORATION OF KAOLIN MINES AT THE UPPER TAGUS NATURAL PARK (SPAIN)

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Abstract: The Upper Tagus Natural Park is one of the largest and most valuable protected areas in Spain (Guadalajara Province), and it overlaps with two protected habitats of the Natura 2000 network (a Special Protection Area for Birds and a Site of Community Importance). At the Outlying Protection Zone of the Park, and within the two protected habitats, a series of abandoned kaolin mines affect the aquatic habitats of the area by siltation of the fluvial network, being the main management problem of the protected areas. Active kaolin mines with operations preceding the declaration of the Natural Park (year 2000), although with reclamation plans, have also the potential of affecting the rivers by siltation.

In this work, geomorphic criteria for the eco-hydrological reclamation of both abandoned and active kaolin mines are explained. The proposed landform designs point out that runoff and soil erosion can be reduced to the minimum by building composed concave slopes, whereas the highwalls' geomorphic activity is allowed to be active, although being controlled with drainage systems and retention trenches. It is also recommended that the layout of the reconstructed terrain resembles the local original surficial geomorphology. Finally, the construction of systems of flow control and sediment storage is proposed at the basis of the concave slopes (decanting pools, as small ecologically functional wetlands). For their gauging, the methodology of the International Erosion Control Association (IECA) will be developed. All that is made in a collaborative framework between Universities (UCM-UAH), the Natural Park managers, and one mining company of the area (CAOBAR S.A.) with environmental responsibility.

Keywords: Geomorphology, restoration of water dynamics, identifying appropriate conservation and restoration objectives, change of natural dynamics, extraction of soils and minerals, new techniques for management.

Introduction

The Upper Tagus Natural Park is located in the Eastern Guadalajara province of Spain (Fig. 1). In this area, a spatial coincidence of extraordinary natural resources takes place. On the one hand, exceptional kaolin deposits occur within sediments of the Upper Cretaceous strata (Utrillas Formation). 30% of the kaolin production of Spain comes from this area, being mining the second economic activity here (13.5 % of the local employment). On the other hand, this portion of land supports unique bio and geodiversity in Spain, with distinctive aquatic ecosystems (a Natural Park and two protected habitats of the Natura 2000 network).

The most significant environmental problem arises because the kaolin extractive operations create surfaces with high susceptibility to runoff and water erosion, with high potential of on- and off-site ecological effects. The increase of sediments (siltation) of the nearby fluvial network of the Natural Park causes physical pollution of the water, affecting the aquatic wildlife of the protected area.

The main source of sediments from the surroundings of the Natural is located at the abandoned mines (such as Santa Engracia), by the Peñalen village (Fig. 1). These abandoned mines have not any restoration measurements, As far as active mines are concerned, with reclamation plans, they also have the potential of delivering sediments to the fluvial network, by an incorrect functioning of their decanting pools, dust accumulated in unpaved roads, or erodible spoil heaps draining directly to streams. In any case, it has to be noted that the siltation of the Upper Tagus fluvial network is a very complex issue, since other factors, extrinsic to mining, have had an adverse influence. This is the case of erosion of natural silica sand gullies, or the decrease in flash floods during the last decades (which were able to 'clean' of kaolin the river beds).

The aim of our research in this area is to produce ecological restoration guidelines which tackle this hydrological impact of kaolin mines. For that, a pilot study has ben conducted for El Machorro mine, funded and promoted by a mining company with environmental responsibility, CAOBAR S.A., owner of El Machorro and M. Jose mines.

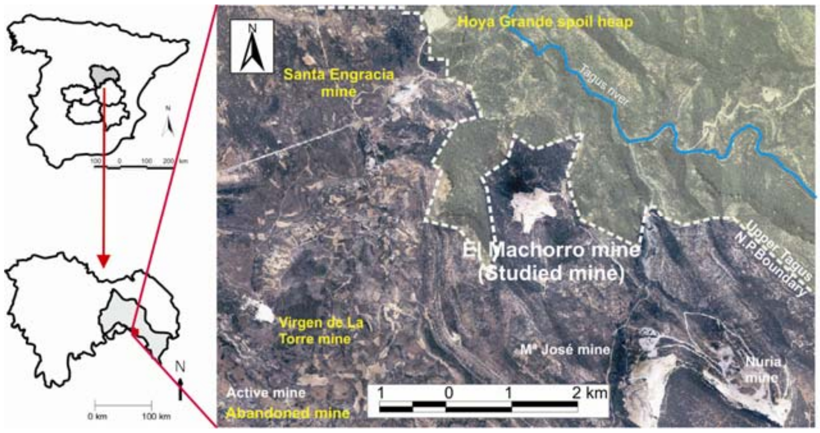

Figure 1. Kaolin mines location at the edge of the Upper Tagus Natural Park (Guadalajara province of Spain).

Materials and methods

Several methodological steps have been followed to pursue the referred aim.

1) Viewshed delineation. In order to assess the significance of the visual impact of El Machorro mine, its viewshed was delineated within the ArcView software, by using the Digital Elevation Model (DEM) and the 2006 ortophoto (0.5 m of pixel size).

2) Sediment sources. In order to identify and quantify sediment sources produced by water erosion, the RUSLE 1.06 *(Rusle for mined lands, constructed sites and reclaimed lands*, Toy & Foster, 1998) was applied to the slope where El Machorro mine is located.

3) Physical and chemical characterization of soil and surficial deposit. Soil and surficial deposits at the surroundings of El Machorro mine were characterized by physical-chemical analysis, in order to obtain as much useful information as possible for their use in future reclamation plans.

4) Critical revision of the reclamation plan wich is currently being applied. The actual reclamation plan of the El Machorro mine has been critically reviewed in the light of the findings from 1), 2) and 3).

5) Revision of applicable case studies. In order to know how geomorphic and hydrologic criteria have been used in similar ecological restoration scenarios, a search of literature and applicable experiences was conducted.

Results and discussion

1) El Machorro mine viewshed shows that the visual impact is conditioned by the local physiography, characterized by a deep fluvial incision, with steep and long slopes. Almost the whole viewshed belongs to a forested area, not being visible from the majority of villages and roads. Therferore, the visual impact of El Machorro mine is not a significant effect, and reclamation plans should not be driven by this factor (Fig. 2A).

2) The application of the RUSLE 1.06 to the slope where El Machorro mine is located evidence that soil erosion by running water is very intense within the mine, with values up to of 210.72 tm ha^{-1} yr^{-1} for the quarry face, in contrast with only 7.83 tm ha^{-1} yr^{-1} of the forested slopes of the surroundings (Fig. 2B). The yielded sediments of the mine are stored in decanting pools, but its functioning has to be checked.

3) Physical-chemical analysis of carbonatic colluvium which support the natural soils of the area show that their textures favour an optimum drainage, nutrient accumulation and make possible the formation of soil´s aggregates. These colluvial deposits have high values of CO_3Ca, which control the pH value, improving the soil structure. The original topsoil has high organic matter content (13.56 % of average) and store native seeds and microorganisms. Thus, both materials are considered to be the most suitable for a hydrological slope protection and for the restoration of the original ecosystems.

4) The current restoration plan propose a 'typical terraced' landform design, addressed to mitigate the visual impact, which is not 'geomorphically' stable in the long term, and which does not fit within the original landscapes. Furthermore, it is planed to use external soil as topsoil, which is considered to be unsuitable, due to its expensiveness and because it introduces external characteristics, exotic to the original ecosystems.

5) Several experiences (Nicolau, 1996; Martín Duque *et al.*, 1998; Hancock *et al.*, 2003) show the long term and self-sustained success of the following practises to analogous reclamation scenarios: the building of concave slopes, instead of the terraced ones; the reconstraction of the original surficial geology and geomorphology; and the correct sizing of decanting pools, designed as small wetlands.

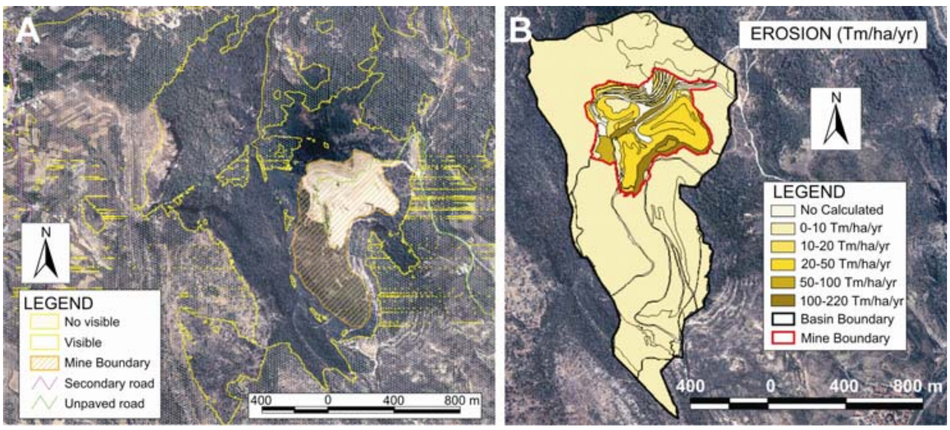

Figure 2. A) Viewshed of El Machorro mine. B) Erosion rates for El Machorro slope with RUSLE 1.06.

Conclusions

The kaolin mining activities of the Upper Tagus Natural Park surroundings expose silica sand and kaolin materials, which are easily eroded by splash erosion and running water. This prevents from the establishment of soils and vegetation, and has the potential of yielding sediments to the fluvial network. This siltation of the Tagus fluvial network, partially 'natural', but accelerated by kaolin mining activities, is the main management problem of this potected area. Therefore, a geomorphic and hydrologic approach is considered to be essential for the reclamation of the kaolin mines of the Upper Tagus Natural Park. The restoration guidelines of this approach are (Fig. 3):

- With the aim of reducing runoff and soil erosion, the building of composed concave slopes is proposed (Fig 3, right), whereas the highwalls' geomorphic activity has to be controlled with drainage systems and retention trenches.
- A new architecture of surficial deposits and topsoil is recommended, based on the layout of the original structure of the surficial geology of the slopes in which the mine is located (Fig. 3, left).
- The construction of systems of flow control and sediment storage (decanting pools, as small ecologically functional wetlands) are proposed at the basis of the concave slopes, gauged by the methodology of the IECA (Fifield, 2004).

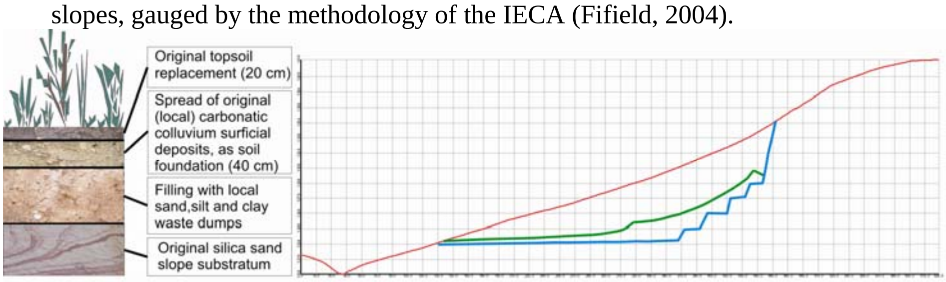

Figure 3. Geomorphic approach for the reclamation of El Machorro mine (see text for explanation). Right: red line, original slope; blue line, exploitation topography; green line, proposed reclamation topography.

Acknowledgements

Two Spanish research projects (CGL2006-07207 and CGL2004-02179) and a research contract 234/2007 between CAOBAR S.A. and the UCM are funding these studies, promoted by the Alto Tajo Natural Park.

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