Technosols of Mining and Quarrying Areas: Toward Multifunctionality

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Abstract. The soils of mining and quarrying areas, characterised as Technosols, are deeply modified soils. The intense degradation they are subject to has altered their capacity to support ecosystem services. However rehabilitation issues are now considering the multi-functionality of mining and quarrying Technosols, i.e. their capacity to provide altogether several ecosystem services. Integrated rehabilitation techniques encompassing physical, chemical and ecological aspects are now being designed to ensure sustainable multifunctional soils in mining and quarrying areas. The aim of this position paper is to assess the multifunctional potential of Technosols of those areas and, thus, to determine its implications for the establishment of rehabilitation schemes.

Keywords. Ecosystem services, SUITMAs, rehabilitation.

1 Introduction

With the rising of anthropogenic pressures on the Earth system, many natural resources are going toward shortage and planetary boundaries are being threatened or even transgressed (Rockström et al. 2009). Soil is one key natural capital which supports critical ecosystem services but has often been overlooked (Breure et al 2012, Dominati et al. 2010). Today, sustainable soil management is needed to meet the environmental challenges of our era (Lal 2009).

Soils of Urban, Industrial, Traffic, Mining and Military Areas or SUITMAs are among the essential soils to manage as they represent increasing land surfaces (EEA 2010) and are expected to support a wide variety of ecosystem services like regulating, provisioning and cultural services (Morel et al. 2014). SUITMAs are mainly "*soils dominated or strongly influenced by human-made material*" called Technosols (IUSS 2014).

As for agricultural soils (Kibblewhite et al. 2008), sustainable management of Technosols should integrate their potential multi-functionality, *i.e.* their capacity to provide altogether several ecosystem services. Steps toward the integration of multi-functionality for the management of urban Technosols have been made (Morel et al. 2014). However such a work is still needed for Technosols of mining and quarrying areas whereas they represent large areas and are subject of major environmental disturbances (Echevarria et al. 2015).

Thus, the aim of this position paper is to assess the multifunctional potential of Technosols of the mining and quarrying areas and, thus, to determine its implications in rehabilitation schemes.

2 Technosols of mining and quarrying areas: from degradation to rehabilitation

2.1 Characteristics of Technosols right after mining and quarrying

In this paper, we first examine the characteristics of Technosols left after the mining and the quarrying activities. In a detailled litterature review, briefly summarised here, we identify the various mining and quarrying processes, their consequences on soil chemical, physical, and biological properties, and, lastly, their impact on supported ecosystem services.

Mining and quarrying can be the source of large-scale ecosystem degradation. For example, mining for strategic metals often implies contamination of surface environments with hazardous trace metals or metalloids. Mining of sulphide minerals induces soil acidification as well as trace metal transfers. Opencast coal mining and aggregate quarries do not have such an acute geochemical impact on the environment, but they strongly modify the geochemical cycles, the agro-ecosystems, the geomorpholgy and the landscapes. Deep mining also produces larges quantities of spoils and tailings, which cover huge surfaces.

In consequence, mining and quarrying activities generally generates degraded Technosols with low carbon content, very low pH, very high bulk densities, coarse or fine textures, and low nutrient contents in comparison with initial soils. Such changes induce a dramatic alteration of the supported ecosystem services and rehabilitation is needed to enhance the multi-functionality of the soils of those areas.

2.2 Rehabilitation issues

Concerns about the rehabilitation of mining and quarrying sites have emerged as early as the begin of the 20th century (Plass, 2000). The rehabilitation efforts first focused on a return of the minesoils to a productive use (*e.g.* wood, agriculture) and then on environmental quality (*e.g.* spoil toxicity, water quality). Issues were pointed by the public, the politicians, the scientists and the mining industry. Now, regulations have emerged worldwide to limit adverse effects of mining activities and to define rehabilitation strategies and goals. Thus,

according to changing regulations and emerging social demand, the way degraded land and mine wastes were handled has changed with time (Plass 2000, Schulz 1996). Some mining companies are now implementing real sustainable strategies for mined land reclamation (Toy and Griffith 2001).

An increasing number of ecosystem services are now considered when establishing a rehabilitation scheme. At first, mine Technosols are engineered to render local ecosystem services, which include: food and non-food biomass production, geotechnical stability, soil erosion and runoff control, groundwater level and quality, landscape and cultural services. Furthermore, they must ensure that no geochemical contamination of adjacent environments occurs: air (dust emissions), water (particulate and soluble contaminant transfer) and biota (soil-plant or soil-animal transfer). Finally, more global goals, such as carbon sequestration or the preservation of endemic species can even be set for rehabilitated mined Technosols.

Multi-functionality is thus today a common goal for soil rehabilitation in mining and quarrying areas.

2.2 Rehabilitation techniques

One of the most important steps of land reclamation is landscaping the site by implementing new vegetation covers and create a surface water flow network. Technosols are therefore created at large scales in post-mining sites. The first purpose of landscaping mined areas was to properly handle geotechnical risks. Sloping spoil heaps and dumps is basically intended to avoid dump collapse, to provide stability over time and to avoid excess water runoff. For this purpose, rock stability, porosity, density, hardness, rainfall are among the main criteria taken into account for designing landscapes, sloping spoil or tailing dumps.

Designing new soil covers for landscape issues has emerged in the last decades. As an example, it became a legal standard and requirement for coal mining in the Ruhr area (Germany) in 1985 or in 1982 in Spain. A holistic approach started to be needed and land reclamation plans for ecological and landscape purposes became a requisite for post-mining rehabilitation. Consideration of the integration of the geomorphology of dumps with surrounding landscapes, the composition of the vegetation, the future land use (secondary natural sites, forests, agricultural areas, urbanised or industrial areas), and the need for infrastructures became of high importance in the landscaping process.

Soil construction and amendment are more often used to ensure a sustainable rehabilitated ecosystems. As for other engineered soils, the construction of Technosols follows some basic rules in order to make them fulfil essential ecological and environmental functions (Séré et al. 2008). Basically, as the raw materials (spoils, stripped soils, tailings) are the main geochemical driving forces of the system a careful characterisation, including physical, chemical and biological properties, is required prior to soil construction. Assessment of the re-colonisation of soil biota is also a critical feature to assess in order to design sustainable rehabilitated system (Frouz 2013).

Numerous techniques have been developed and tested over the years to integrate a wider variety of ecosystem services in the rehabilitation of mining and quarrying Technosols. Mid-term surveys point the importance of integrating the rehabilitation goals and techniques right at the beginning of the mining or quarrying operations in order to preserve the physical, chemical and ecological properties of the raw materials that are used for soil reclamation.

3 Conclusion

From degraded soils, Technosols of mining and quarrying areas are now more often expected to be multifunctional and support a wide range of ecosystem services. Relevant rehabilitation techniques have been designed to enable this multi-functionality but they have to be integrated right at the beginning of the mining or quarrying operations to be successful.

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