Science of the Total Environment 551–552 (2016) 57–65

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Impact of vineyard abandonment and natural recolonization on metal content and availability in Mediterranean soils

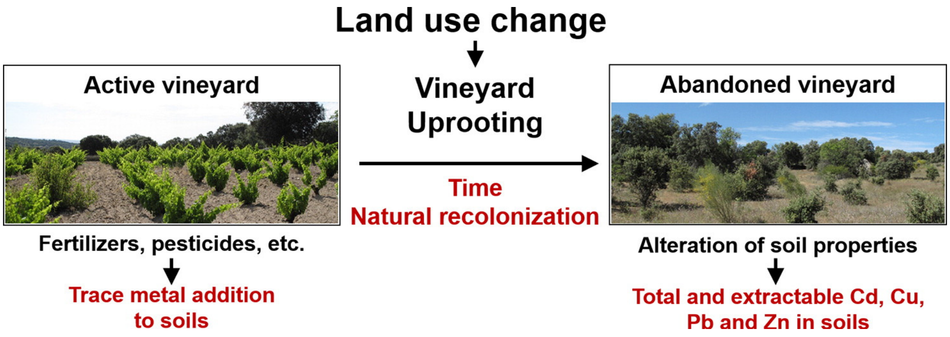
Ana de Santiago-Martín [a,*], Cristina Vaquero-Perea [a], Inmaculada Valverde-Asenjo [a], Jose R. Quintana Nieto [a], Concepción González-Huecas [a], Antonio L. Lafuente [a], Antonio Vázquez de la Cueva [b]

[a] Department of Soil Science, Faculty of Pharmacy, Complutense University of Madrid, 28040, Madrid, Spain
[b] INIA, Forest Research Centre, Carretera de A Coruña km 7.5, 28040, Madrid, Spain

HIGHLIGHTS

- We studied the contribution of vineyard abandonment to metal concentration patterns.
- Age abandonment enhances soil metal total content and extractability.
- The impact of land use change depended on the type of vegetation cover.
- Metal concentration patterns are better explained when considering soil properties.
- Clay and organic fractions are key players in soil extractable metals.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 30 October 2015
Received in revised form 27 January 2016
Accepted 27 January 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Metal concentration patterns
Vine uprooting
Land use change
Vegetation cover
Soil properties

ABSTRACT

Abandonment of vineyards after uprooting has dramatically increased in last decades in Mediterranean countries, often followed by vegetation expansion processes. Inadequate management strategies can have negative consequences on soil quality. We studied how the age and type of vegetation cover and several environmental characteristics (lithology, soil properties, vineyard slope and so on) after vineyard uprooting and abandonment contribute to the variation patterns in total, HAc (acetic acid-method, HAc) and EDTA-extractable (ethylenediaminetetraacetic acid-method) concentrations of Cd, Cu, Pb and Zn in soils. We sampled 141 points from vineyards and abandoned vineyard Mediterranean soils recolonized by natural vegetation in recent decades. The contribution of several environmental variables (e.g. age and type of vegetation cover, lithology, soil properties and vineyard slope) to the total and extractable concentrations of metals was evaluated by canonical ordination based on redundancy analysis, considering the interaction between both environmental and response variables. The ranges of total metal contents were: 0.01–0.15 (Cd), 2.6–34 (Cu), 6.6–30 (Pb), and 29–92 mg kg^{-1} (Zn). Cadmium (11–100%) had the highest relative extractability with both extractants, and Zn and Pb the lowest. The total and EDTA-extractable of Cd, Pb and Zn were positively related to the age of abandonment, to the presence of *Agrostis castellana* and *Retama sphaerocarpa*, and to the contents of Fe-oxides, clay and organic matter (OM). A different pattern was noted for Cu, positively related to vineyard soils. Soil properties

---

Abbreviations: Am-Fe, amorphous Fe-oxides; ANOVA, analysis of variance; CEC, cation exchange capacity; EDTA, ethylenediaminetetraacetic acid; HAc, acetic acid; ICP-MS, inductively coupled plasma mass spectrometry; OM, organic matter; RDA, redundancy analysis; RP, recalcitrant pool organic C; SPSS, Statistical Package for the Social Sciences; TCd, TCu, TPb, and TZn, total Cd, Pb, Cu, and Zn, respectively; TOC, total organic C.

* Corresponding author at: Department of Civil Engineering and Water Engineering, Faculty of Science and Engineering, Laval University, Quebec G1K 7P4, Canada.
E-mail addresses: anasanti@ucm.es, a.de-santiago-martin.1@ulaval.ca (A. de Santiago-Martín), crvaquer@farm.ucm.es (C. Vaquero-Perea), inma.valverde@farm.ucm.es (I. Valverde-Asenjo), jrquinta@farm.ucm.es (J.R. Quintana Nieto), chuecas@farm.ucm.es (C. González-Huecas), lopezlafuente@farm.ucm.es (A.L. Lafuente), vazquez@inia.es (A. Vázquez de la Cueva).

http://dx.doi.org/10.1016/j.scitotenv.2016.01.185

successfully explained HAc-extractable Cd, Cu, Pb and Zn but the age and type of vegetation cover lost significance. Clay content was negatively related to HAc-extractable Cu and Pb; and OM was positively related to HAc-Cd and Zn. In conclusion, the time elapsed after vineyard uprooting, and subsequent land abandonment, affects the soil content and availability of metals, and this impact depended on the colonizing plant species and soil properties.

1. Introduction

Spain is one of the world's largest wine producers, surpassed only by France and Italy (Spanish Wine Market Observatory, 2014). However, in recent decades an overall decrease has been reported in the number of hectares of Spanish vineyards (~10,000 ha per year), and a displacement from European Union countries – which have lost 30,000 ha per year – to other countries (e.g. Chile, Argentina and China), with increases of 10,000 ha per year (Lissarrague García-Gutiérrez and Martínez de Toda Fernández, 2010). The most significant effects have been seen in Spain, France, Italy, Portugal, Bulgaria and Hungary (International Organisation of Vine and Wine, 2013). There are several reasons for this decline: loss of vineyard productivity due to soil depth, slope, parent material, water availability and other factors; population migration to the cities and the lack of generational replacement; and the control of wine production to suit market needs caused by the European Union strategies implemented in the most recent reforms of the organisation of the common market (Martínez-Casasnovas et al., 2010). These consist of i) promoting the restructuring and conversion of vineyards to increase production; ii) regulating the number of cultivated hectares; and – in the case at hand – iii) subsidising the uprooting of vines in non-productive vineyards, thus encouraging abandonment.

The abandonment of agricultural soils is generally followed by one of two trends, with contrasting effects depending on environmental conditions and management: land degradation and desertification due to the spread of overgrazing, steep slopes, climate, and the parent material, which seriously hinders the establishment of natural vegetation (Dunjó et al., 2003); or vegetation expansion processes that facilitate ecosystem recovery if proper management is applied (Escribano-Avila et al., 2014; Pardini et al., 2003). The recovery of the vegetation cover in abandoned agricultural soils often results in the improvement of key soil properties and characteristics such as organic matter – OM – (content and composition), aggregation stability, infiltration, and cation exchange capacity (Kosmas et al., 2000; Lesschen et al., 2008).

However, the alteration of soil properties under land abandonment could affect patterns of total content and availability of trace metals (Fernández-Calviño et al., 2008, 2012) potentially accumulated in agricultural soils through anthropogenic activities, including repeated applications of fertilizers, pesticides, sewage sludge and animal manure (Bai et al., 2010; de Santiago-Martín et al., 2015a). Vegetation colonizing the soils can significantly reduce soil pH through a variety of mechanisms directly related to plant strategies, including rhizodeposition (increasing labile organic fractions), fixation of atmospheric N, etc., which could increase trace metal availability and leaching (Chantigny, 2003; Li et al., 2011; Strobel et al., 2005). In contrast, vegetation cover enhances aggregation stability and prevents erosion processes (Boix-Fayos et al., 2001), contrary to that typically observed in agricultural soils (Fernández-Calviño et al., 2012). This can favour metal retention in soils and should be considered if soils are reused for cultivation, as previously reported (Komárek et al., 2008). Plant cover may also reduce the metal content in surface soils through direct uptake by plants, as observed by Duplay et al. (2014) studying Cu and Zn uptake by grass roots in vineyard soils. The possible scenarios are highly determined by the time elapsed after the land abandonment and the type of subsequent potential vegetation cover (Lesschen et al., 2008). Studies contributing to a better understanding of the effects of different land management strategies after vineyard uprooting and abandonment (reforestation, directed revegetation, semi-natural vegetation, use of amendments, maintenance of certain structures such as terraces, etc.) are essential to minimize negative consequences on soil quality. However, the studies on this subject are scarce (Fernández-Calviño et al., 2008; Michaud et al., 2007).

To ensure proper soil management it is therefore essential to gain greater knowledge of the way in which the type and age of the colonizing vegetation cover and the soil and other environmental characteristics contribute to the concentration patterns in total and available fractions of trace metals in abandoned vineyards. With this aim we selected as our study area a typical Mediterranean scenario that had undergone major changes in land use in recent decades, evolving from a landscape primarily of vineyards with patches of natural vegetation, to its current situation in which most of the area is dominated by sclerophyllous Mediterranean vegetation with occasional vineyards. We sampled 141 points including both vineyard soils and abandoned vineyard soils recolonized by natural vegetation. The contribution of several environmental variables (age and type of vegetation cover, lithology, soil properties, vineyard slope and so on) to the total, HAc and EDTA-extractable concentrations of Cd, Cu, Pb, and Zn in soils was interpreted statistically and discussed.

2. Material and methods

2.1. Study area, sampling design, and soil characteristics

The survey was taken in a 2.5 × 2 km area in the municipality of Navas del Rey located in the Alberche valley (western Madrid region, Spain) at an altitude of 709 m (Fig. 1). The site is typical of a Mediterranean pluviseasonal-oceanic bioclimate in an upper meso-Mediterranean low dry bioclimatic belt (Worldwide Bioclimatic Classification System, 2009). Average annual temperature is 13.2 °C (23.5 °C in the warmest month of the year, July, and 4.6 °C in the coldest month, January) and total annual rainfall is 401 mm year^{-1} (11 mm in the driest month, July, and 48 mm in the month of highest rainfall, May) (Climate-data, 2014). The area is in the contact zone between metamorphic rocks (mainly schist) from the pre-Cambrian period, and igneous rocks (mainly granites). The cultivation of vineyards, along with livestock, has been the main activity in the area, especially from the 19th century. However, in recent decades the area has seen drastic changes in land use, from a landscape of mainly vineyards with scattered areas of natural vegetation to its current situation in which most of the area is dominated by natural vegetation with occasional vineyards. The landscape is composed of Holm oak in mosaic with rain-fed crops (vineyards) and pastures, accompanied by isolated stands of juniper and pine trees, and several species of shrubs such as broom, lavender and others. Soils are characterized by having coarse texture and good drainage, predominantly Lithosols and Regosols according to FAO (Consorcio Sierra Oeste, 2009). Table 1 shows the main soil characteristics. Soil pH values varied from slightly acid to neutral, and reactive soil fractions were in the following range: 2 to 10% (clay), 0.3 to 9.7% (total organic C, TOC), and 83 to 1707 g kg^{-1} (crystalline Fe oxides).

The sampling design consisted of an aggregate survey in 19 plots and a 500-m grid overlaid on the first one. Out of the 141 points sampled in 2010, 102 belong to one of the 19 plots considered, while 39 points belong to the 500 m grid (Fig. 1). Soil samples were taken on each plot under six different types of vegetation cover, selected according to the