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# DVINE – THE DOURO VINEYARDS, WORLD HERITAGE PATRIMONY: ASSESSING THE IMPACT OF AN ANCIENT ACTIVITY IN THE QUALITY OF SEDIMENT AND WATER IN THE DOURO

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## Resumo

As vinhas do Vinho do Porto localizadas ao longo das margens do rio Douro são importantes em termos sócio-culturais uma vez que aquele tipo de vinho é um produto agrícola de classe mundial. A tradição da vindima e os benefícios económicos são aspectos consideráveis, mas a utilização de fertilizantes, fungicidas e pesticidas para controlo de pragas das vinhas estão actualmente a causar uma preocupação junto do público. O objectivo principal deste projecto é avaliar os efeitos que a viticultura intensiva tem na composição dos sedimentos do rio Douro, na qualidade da água e na comunidade microbial dos solos e sedimentos. Pretende-se estabelecer padrões de poluição orgânica e inorgânica, investigar a relação entre os solos das vinhas e as concentrações de elementos nos sedimentos, estudar a especiação dos metais nos sedimentos, avaliar o impacto da contaminação na qualidade da água e avaliar também o risco existente para os biota proveniente destas matrizes naturais. A evolução temporal verificada em cores de sedimentos permitirá a avaliação do impacto no rio da utilização histórica dos solos, sendo importante no desenvolvimento de futuras estratégias ambientais para a área em estudo. Estudar-se-á em particular o registo deixado pela cultura de vinhas ao longo do tempo.

Palavras chave: contaminação dos sedimentos, erosão do solo, qualidade da água, solo das vinhas

## Abstract

Port wine vineyards along the margins of the Douro River are socio-culturally important, as Port wine is a world class agricultural product. While the tradition and economic benefits of the crop are considerable, the intensive use of fertilizers, fungicides and pesticides to diseasecontrol in the vineyards is currently raising public concern. The principal aim of this project is to assess the effect of intense vine cultivation in the composition of sediments of the Douro River and its effect in water quality, and the changes in soil and sediment microbial community. We intend establishing patterns of inorganic and organic pollution, investigating the relationship between vineyard soils and element concentrations in sediments, studying metals speciation in sediments, assessing the impact of contamination in water quality, and assessing the risk posed by these natural matrices to the biota. Comparison of the present situation with the record of the past as registred in sediment cores will allow assessing the impact of past and current land use on the river that may assist in developing future environmental strategies for the catchment. We will seek in particular the record of changes related to vine cultivation over time.

Keywords: contamination of sediments, soil erosion, vineyard soil, water quality

## Introduction

The Demarcated Region of Douro (Portugal) runs along both margins of Douro River from its midcourse in the East up to the border with Spain in the West. The vineyards of this wine producing region are located on steep slopes of narrow valleys, planted on very stony soils that show a large degree of anthropogenic disturbance.

Very intensive cultivation systems have been developed in the region formore than two centuries. This has resulted in large accumulation of pesticides and fertilizers and associated heavy metals and nutrients in surface layers of vineyard soils. Some phosphate fertilizers contain potentially toxic elements (PTE), including As, Cd, Cr, Pd, Hg, Ni, and V) and some pesticides had Cu and As in their composition. Once in the soil, heavy metals are strongly adsorbed onto organic matter and other charged material. As heavy metals bond strongly to soil colloids and organic matter, they should also be moved with fine soil particles and soil carbon, eventually trapped and deposited in dam reservoirs. Soil microbial communities are also adversely affected by heavy metals. Erosion processes in the Douro vineyards lead metals and nutrients accumulated in soils to be transferred spatially by runoff, functioning as a diffuse pollution source for the stream in the catchment area.

The principal aim of this project (PTDC/CTE-GIX/112821/2009) is to assess the effect of intense vine cultivation in the composition of sediments of the Douro River and its effect in water quality, and the changes in the soil and sediment microbial community. To achieve this objective the approach proposed consists of: 1 - Geochemistry of vineyards soil to assess its contribution in the input of pollutants into the drainage system; 2 - Mineralogy of the particulate and chemistry of the particulate/dissolved phases of surface waters to assess its quality, to determine metal mobility, dispersion and fate, in order to establish the distribution of excess nutrients in the watershed and to identify potential sources of particulate matter; 3- Lateral and vertical variation of stream sediment properties to assess the impact of wine growing practices in the drainage system, through the study of sediment cores collected in representative sites of the reservoirs; we may be able to assess the evolution of the sedimentary conditions and the chemical fluctuations of PTE retained in the sediments, and correlate them with varying land uses and agricultural practices.

Besides its intrinsic value for the Port wine region and industry, this project will be formatted, in terms of approach and strategy, to be of more general interest to other regions of Europe (and the world) where intensive cultivation is also generating environmental stresses.

## Plan and methods

The first step of this project will be create erosion probable risk maps of the Demarcated Douro Region since the vineyards have been particularly valued in the literature as a land-use context highly susceptible to erosion with substantial soil losses, as compared to other types of agricultural land. This task will contribute with relevant information about the deposition rates. After this task the team will select the vineyards that have higher deposition rates, and decide on the study area.

Several environmental media will be sampled: vineyard soils, surface waters, stream sediments, sediment and porewater. The selected vineyard soils will be classified into three categories according to their land use history, namely young, old and abandoned, as the age of the vineyard controls the geochemistry of the soil. For instance, since the end of the 19th century, the mixture of copper sulphate and lime has been extensively applied and it is still in use. Because of its worldwide use, the accumulation of copper has already been established in some viticulture soils, where influences plant growth, micro organisms and soil properties. Pietrzak and McPhail (2004) mentioned that the conversion between copper fractions is slow, indicating that Cu can stay active in soils for long periods of time, greater than tens of years, and may result in leaching and transport to deeper soil layers.

Before a vineyard can be planted on the very steep slopes of Douro region, the land has to be shaped to form terraces, which implies soil removal from higher gradients to lower gradients. Therefore the vineyard soils are very mixed and revolve soils. The strategy to sample the vineyard soils is a composite sample of 5 sub-samples, one from each terrace. In order to access lateral variations and as each terrace has gentle slopes, one sub-sample is collected at the higher gradient and another at lower gradient of the same terrace. In this way each vineyard is sample with a composite vineyard (5 sub-samples) and a lateral sample (5 sub-samples).

Channel sediments will be sampled in tributary stream to access the lateral geochemistry variations. The vertical variations will be access through vertical profiles done at the nearest Douro river dam. Acumulated sediment contains a repository of valuable historical information on the temporal trend of pollutants input into aquatic ecosystems (Goldberg et al., 1977; Palanques et al., 1998). We aim to assess the temporal changes in nutrient inputs reflected in the sedimentary record of carbon, phosphorus and nitrogen in sediments of by using $^{210}Pb$ chronology in association with $^{137}Cs$; to assess the relationship between runoff and soil organic carbon release during soil erosion; investigate the occurrence of several vineyard pesticides and heavy metals in sediment profile. To measure vertical spatial resolutions in sediments

we use the DGT (diffusive gradients in thin films) technique. These measurements reflect pore-water labile concentrations of metals and their rates of resupply from the local solid phase of a very small volume of sediment. The relationship between the data achieved in the sediments and pore water, will improve (1) the knowledge of the adsorption/desorption capacity of the mineral and organic particles in relation to pollutant elements, (2) the influence of their mineralogical and geochemical characteristics on the routing, transport and fate of pollutant elements in the environment and (3) the specific chemical conditions liable to the release of these elements from sediments to the aqueous phase, with the subsequent increase of its availability in the environment.

Stream water samples will be collected at the same sites of those of at sediments. We will determine organic and inorganic contents in suspended particulate matter (SPM) and dissolved phases in stream waters; 1) to relate these two phases with the distribution of excess nutrients in the watershed, 2) to identify, when possible, potential sources of SPM (via clay mineralogy) in the watershed; 3) to assess the water quality of the tributaries of Douro and the influence of vineyard soils.

The geochemical characteristics of vineyard soils will be determined by analysis of total concentration of trace metals, nutrients and pesticides. We intend to determine the fate of fertilizers and pestecides and associated heavy metals and nutrients applied to vineyards grown on raised beds. We will determine the pH ($H_2O$), pH ($CaCl_2$), cation exchange capacity, and organic matter content. Finer particles show higher concentration of heavy metals due to large surface area, higher clay minerals and organic content, high binding capacity of clay particles and the presence of Fe-Mn oxide phases (Marengo et al., 2006; Qian et al., 1996). Therefore the size fractions distributions will be accessed. The sequential (Tessier et al., 1979; Ure et al., 1993) extraction procedure is commonly used in the literature to identify trace element mobility. Soil trace element partitioning is determined by submitting soil samples to successive extractants using the sequential extraction. We intend with metal fractionating investigate the mobility and distribution mechanisms of heavy metals in vineyard soils and to assess the risk of release into surface water.

The water, sediment and soil bacterial and fungal communities will be characterized by culture independent approaches, in order to describe the community size and diversity. This will allow the construction of vertical profiles of abundance of microorganisms in water, sediment and soil as well as the characterization of the structure of the prevailing communities at different sites and at different sediment depths. The abundance, diversity and activity of microbial communities obtained at different sitesand different sediment horizons will be related to the observed levels of contamination in order to interpret the spatial and vertical profiles of contamination.

## Results

The final result of this project is to build a database to manage the project geographic information. Building a geographic database or geodatabase for this particular basin or watershed (Douro Region) means storing geospatial and temporal data about soil, land use, topography, geology, sampling locations and other resources into a GIS database. This database also includes the final spatial models obtained.

The project will contribute to raise awareness among winegrowers to the importance of sustainable winegrowing practices which have potential benefits, namely economic (long-term viability of land or minimize environment pollution), environmental (conservation of natural resources, long-term viability of land) and social equity (enhance relations with consumers and tourists, enhance relations with regulators and public policy institutions). Our major aim is to develop a tool that is useful in the implementation of sustainable wine-growing practices to the potential end users.

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