EQA** – Environmental quality / Qualité de l'Environnement / Qualità ambientale,* ***30 (2018) 1-7

SOIL FUNCTIONS AND EFFECTS OF SOIL EROSION. FIRST EVIDENCES FROM THE RESOLVE PROJECT

Edoardo A.C. Costantini [(1)*], Simone Priori [(1)], Brice Giffard [(2)], Emma Fulchin [(3)], Javier Tardaguila [(4)], Hans-Josef Schroers [(5)], Erhan Akça [(6)], Semih Tangolar [(7)]

[(1)] CREA-AA, Research Centre for Agriculture and Environment, Florence, Italy
[(2)] INRA, UMR 1065 Santé et Agroécologie du Vignoble, ISVV, Université de Bordeaux, Bordeaux Sciences Agro, Villenave d'Ornon Cedex, France
[(3)] Vitinnov-ADERA, France
[(4)] Instituto de Ciencias de la Vid y del Vino, University of La Rioja, CSIC, Spain
[(5)] Agricultural Institute of Slovenia, Ljubljana, Slovenia
[(6)] Adıyaman University School of Technical Sciences, Turkey
[(7)] Çukurova University, Faculty of Agriculture, Department of Horticulture, Turkey.

*Corresponding author: E-mail edoardo.costantini@crea.gov.it

Abstract

The Resolve research project set up a multidisciplinary research work to evaluate the effects of possible errors in soil management during pre-planting and vineyard cultivation, leading to severe soil erosion. Different soil functionalities were considered, namely provision of grape yield and quality, water and nutrient supply, carbon sequestration, organic matter recycling, and soil biodiversity. The project involved 19 experimental organically farmed vineyards situated in Italy, France, Spain and Slovenia (wine grape), and in Turkey (table grape). The aim of the project was to understand the causes of soil malfunctioning and work out a proper strategy to restore soil fertility.

Keywords: *soil quality, soil function, soil degradation, indicators, terroir, grape, wine*.

Soil functions in vineyards

The concept of soil functions emerged during the early 1970's (Glenk et al., 2012) and was adopted for the development of the EU Soil Framework Directive (European Commission, 2006). The concept was also discussed for the Millenium Ecosystem Assessment (MEA, 2005) and by Dominati et al. (2010). Soil functions are sometimes overlapping with the general concept of ecosystem services, that is, the benefits that people obtain from ecosystems, namely, supporting, regulating, provisioning and cultural services (MEA, 2005). Soil ecosystem services have been investigated and mapped at different scales, aiming at land and territorial planning (Egoh et al., 2008, Eigenbrod et al., 2010; Calzolari et al., 2016; Cerretelli et al., 2018). More recently, Keesstra et al. (2016) linked soil functions to ecosystem service and to the UN "Sustainable Development Goals" (http://sustainabledevelopment.un.org/focussdgs.html).

DOI: 10.6092/issn.2281-4485/7905

Although there is not an identical definition of soil functions and related ecosystem services, a common list includes:
1) biomass provision, in form of food and fiber;
2) provisioning of raw materials, such as peat and building materials;
3) regulation of hydrological, sediments, and biogeochemical cycles, including recharge of groundwater, filtering and transformation of nutrients and contaminants;
4) regulation of air quality and climate, including carbon sequestration and greenhouse gases emissions;
5) biodiversity pool, such as habitats, species and genes;
6) regulation of pests and disease populations;
7) support of structures and infrastructures;
8) cultural and aesthetics, such as archive of archaeological heritage and fundamental part of landscapes.
All soil functions of this list apply to the vineyard ecosystem. However, in this agricultural ecosystem, like in the others that are suited to high quality foods, another soil function should be always considered: the quality of food or, better, the expression of terroir. This is the ‘‘peculiar taste’’ provided by soil features, in combination with other natural conditions, agricultural husbandry and grape processing, which forms wine quality and specificity (Vaudour et al., 2015).

Soil degradation in vineyards

In both conventional and organic European vineyards, it is not rare to have delimited areas characterized by problems in vine health, grape production and quality. These problems are very often related to sub-optimal soil functionality. The "degraded areas" can have lost their soil functionality because of errors in soil management occurred in pre-planting and during vineyard cultivation. Most common mistakes are related to an improper land preparation or to a too intense cultivation, leading to an excessive soil water erosion, loss of soil organic matter and nutrients, soil compaction and element accumulation (Vaudour et al., 2015). Land transformation to adapt fields to mechanization, in particular, is a common practice in perennial field crops, which includes land levelling, deep ploughing, stone-breakage and clearing, application of fertilizers and amendments (Costantini, 1992; Bazzoffi et al., 2006). Improper soil manipulation has a specific impact in vineyards, because they are frequently located on marginal and shallow soils, on sloping lands, which are very sensitive to water erosion (Ramos, 2006).
Manipulation of the soil depth and natural profile of soil can disturb the naturally existing soil self-organization and its chemical, physical, biological and hydrological equilibrium (Costantini and Barbetti, 2008; Costantini et al., 2006). The most common effects of the land transformation are mixing of soil horizons, organic matter depletion, enrichment of calcium carbonate content of topsoil, reduction in soil depth and in water retention capacity (Costantini et al., in press). Soil manipulations frequently increase soil spatial variability, therefore, reduced soil functionality and decline of soil ecosystem services may occur in defined areas of the vineyard (Priori et al., 2013). Also the use of heavy machines in inter-rows can increase

soil compaction, reduce soil aeration and biological activity, and then can also lead to an increased susceptibility to soil- and root-borne pathogens, altering root systems and stunting above ground plant development (Hallen et al., 2004, 2006).
Sometimes the impairment of soil functionality in the degraded areas is very high and compromises not only vine performance and crop yield, but also disease resistance of plants and their survival. Moreover, the reduced microbial soil diversity can increase the severity of soil-borne and foliar diseases (Tamm et al., 2010).

Indicators of soil malfunctioning in degraded vineyards

Soil functionality is the degree of soil function extend, which can be quantitatively or qualitatively evaluated by means of different indicators (Costantini et al., 2016). Soil malfunctioning can be indicated by the lack of nutrients, imbalance of some element ratio, pH, water deficiency, soil compaction and/or scarce oxygenation, and Cu-toxicity (Martínez-Casasnovas et al., 2009). The CORE-organic project "Restoring optimal Soil functionality in degraded areas within organic Vineyards - ReSolVe" (http://resolve-organic.eu/) focused on four main soil functions that are deemed to support the delivery of grape yield and its quality, namely, i) water and nutrient supply, ii) carbon sequestration and organic matter recycling, and iii) soil biodiversity. The choice of these functions was made on the research hypothesis that there is a relationship between the different agronomic results, obtained in degraded and non-degraded areas, and the soil features responsible for the different functions. In this short paper, we introduce the issue and show the first results of the project, summarizing the effects of soil erosion on agro-ecosystem services and soil functions.

Experimental setting

The project involved 8 research groups in 6 different countries, and 19 experimental vineyards situated in Italy (Tuscany), France (Sant Emillion and Languedoc), Spain (La Rioja) and Slovenia (Primorska) and in Turkey (Adana and Mersin). Vineyards were cultivated to produce wine grape (cultivar: Sangiovese in Italy, Cabernet franc and Syrah in France, Tempranillo in Spain and Refošk in Slovenia) and table grape in Turkey (cultivar Early Cardinal and Yalova Incisi). All the vineyards were organically farmed and in full production stage (more than 10 years from planting). Organic management limited the use of pesticides and that of fertilizers to organic, possibly integrated with other fresh or matured organic substances, like compost made in farm from crop residues, green manure, dry mulch, permanent grass cover.
Soil erosion was mainly due to truncation provoked by back hoeing and surface levelling, apart from France sites, where it was attributed to rill erosion. Annual soil cultivation was variable, either natural grass cover in Italy and Slovenia, alternate natural grass cover / tilled rows in France, or tillage in Spain and Turkey.
The materials and methods used to assess the considered aspects of soil functionality regarded different indicators of water supply, such as rooting depth, available water capacity, soil aridity index (Costantini et al., 2009); nutrient availability, in particular, total nitrogen, pH, cation exchange capacity, exchangeable bases, elec-

DOI: 10.6092/issn.2281-4485/7905

trical conductivity, lime content; carbon sequestration capacity (carbon density and stock); organic matter recycling, namely, carbon nitrogen ratio, enzymatic activities, decomposition rate measured with teabags (Keuskamp et al., 2013). Biodiversity and functionality was appreciated studying the mesofauna composition, in particular, Acari and Collembola, and through genetic fingerprinting of microbial communities from bulk and rhizosphere soil, and grapevine roots. For a detailed explanation of the materials and methods used, we refer to the specific publications.

First results from the Resolve project

Aim of this short paper is to introduce and report the first outcomes of the Resolve project, therefore it is not possible to show the results obtained by the different analyses. A more comprehensive treatment is reported in several thematic articles, also presented in this special issue. The effects of soil erosion on agro-ecosystem services and soil functionalities in the studied vineyards are briefly summarized in figure 1.

Country	Farm	Years of organic management	Irrigation	Grape yield	Grape quality	Water supply	Nutrient supply	Carbon sequestration	Organic matter recycling	Biodiversity
ITALY	Fontodi	15 years	no	↓	↑ ↓	↓	↓	↓	↓	=
	San Disdagio	2 years	no	↓	↑ ↓	↓	↓	↓	↓	=
FRANCE	Château Maison Blanche	11 years	no	↓	↑ ↓	↓	↓	=	↓	↓
	Château Pech Redon	> 15 years	no	↓	N.D.	↓	↓	↓	↓	N.D.
SPAIN	Bodegas Puelles	> 10 years	no	↓	↑ ↓	↓	↓	=	↓	N.D.
SLOVENIA	Bonini	10 years	no	↓	↑ ↓	↓	↓	↓	↓	↓
	Prade	10 years	no	↓	↑ ↓	↓	↓	↓	↑	↓
TURKEY	Çelebi	1 year	yes	=	N.D.	↓	N.D.	=	↑	N.D.
	Evran	1 year	yes	=	N.D.	↓	N.D.	↓	↓	N.D.

Figure 1. *Effects of soil erosion on agro-ecosystem services and soil functions in 19 European and Turkish vineyards (upward and downward arrows indicate positive and negative effects, respectively; the equal sign stands for not significant differences, N.D. for not determined).*

Degraded areas with severely eroded soils showed a marked decrease in wine grape yield, except for Turkey, where table grape was harvested very soon in summertime and irrigation was also possible. Wine grape quality was often characterized by an excess of sugar and polyphenols accumulation, related to the very low yield, which was considered negatively for the production of an equilibrated wine.

Among the considered indicators of soil functionality, those related to the regulation of water and nitrogen supply highlighted the most striking differences between degraded and non-degraded area. Carbon sequestration was also reduced in most vineyards, apart where it was already very low, as well as the soil ability to recycle organic matter, especially the most hardly decomposable fractions.

The different aspects of biodiversity measurements indicated that, as a whole, biodiversity and the specific composition of microbiota was affected by degradation. However, where organic farming was long since carried on, it resulted in increasing biodiversity and recovering it to values not significantly different from the non-degraded soil.

Conclusions and further perspectives

The first results of the trial indicate that the lower soil functionality in degraded areas actually lowered grape production, both in terms of yield and grape quality. The most affected soil functions were those related to the regulation of water and nutrient supply related to the entire soil profile, not only the topsoil. No significant effect of different forms of annual soil cultivation was found. Irrigation could counterbalance natural low water supply, but not the other soil functions. Long lasting organic management instead was somehow able to restore biodiversity of topsoil.

We may conclude that more intense and specific organic treatments are needed to restore soil ecosystem services in severely eroded areas in vineyards. These treatments might consider an extra-input of organic matter through green manure, grass cover, compost, manure spreading. However, it must be taken into account that degraded soils have a reduced ability to recycle organic matter, then the quality of the input is very important, and the distribution should privilege the more decomposable forms.

Further research perspectives may consider the restoration of soil fertility also in depth, by forms of cultivation able to increase water availability and the penetration of nutrients and biological activity throughout the rooting depth, mainly facilitating soil self-organization, macroporosity and aggregate formation.

Acknowledgements

The research work was carried out in the framework of the EU project RESOLVE (Restoring optimal Soil functionality in degraded areas within organic vineyards), supported by transnational funding bodies, being partners of the FP7 ERA-net project, CORE Organic Plus, and the cofound from the European Commission. Authors express their gratitude to the farms that hosted the field trials and thank all the RESOLVE people who helped during field-work and laboratory analysis.

References

BAZZOFFI P, ABBATTISTA F, VANINO S, PELLEGRINI S. (2006) Impact of land levelling for vineyard plantation on soil degradation in Italy. Bollettino della Società Geologica Italiana, 6:191–199.

DOI: 10.6092/issn.2281-4485/7905

CALZOLARI C., UNGARO,F., FILIPPI N., GUERMANDI M., MALUCELLI F., MARCHI N., TAROCCO P. (2016) A methodological framework to assess the multiple contributions of soils to ecosystem services delivery at regional scale. Geoderma, 261:190-203.

CERRETELLI S., POGGIO L., GIMONA A., YAKOB G., BOKE S., HABTE M., BLACK H. (2018) Spatial assessment of land degradation through key ecosystem services: The role of globally available data. Science of The Total Environment, 628:539-555.

COSTANTINI E.A.C. (1992) Study of the relationships between soil suitability for vine cultivation, wine quality and soil erosion through a territorial approach. Geoöko-Verlag, Geoökoplus, 3: 1–14.

COSTANTINI E.A.C., PELLEGRINI S, VIGNOZZI N, BARBETTI R. (2006) Micromorphological characterization and monitoring of internal drainage in soils of vineyards and olive groves in Central Italy. Geoderma, 131:388–403.

COSTANTINI E.A.C., BARBETTI R. (2008) Environmental and Visual Impact Analysis of Viticulture and Olive Tree Cultivation in the Province of Siena (Italy). European Journal of Agronomy, 28:412–426.

COSTANTINI E.A.C., URBANO F, ARAMINI G, BARBETTI R, BELLINO F, BOCCI M, BONATI G, FAIS A, L'ABATE G, LOJ G, MAGINI S, NAPOLI R, NINO P, PAOLANTI M, PERCIABOSCO M, TASCONE F. (2009) Rationale and methods for compiling an atlas of desertification in Italy. Land Degradation and Development, 20:261–276.

COSTANTINI E.A.C., BRANQUINHO C., NUNES A., SCHWILCH G., STAVI I., VALDECANTOS A., ZUCCA C. (2016) Soil indicators to assess the effectiveness of restoration strategies in dryland ecosystems. Solid Earth, 7:397–414.

COSTANTINI E.A.C., PRIORI S., GIFFARD B., FULCHIN E., TARDAGUILA J., SCHROERS H-J, PELENGIĆ R., AKÇAH E., TANGOLAR S., VALBOA G. (2018) Causes of soil malfunctioning in degraded areas of European and Turkish vineyards. EQA - International Journal of Environmental Quality (in press)

DOMINATI E., PATTERSON M., MACKAY A. (2010) A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecol. Econ., 69:1858–1868.

EIGENBROD F., ARMSWORTH P. R., ANDERSON B. J., HEINEMEYER A., GILLINGS S., ROY D. B., GASTON K. J. (2010) The impact of proxy-based methods on mapping the distribution of ecosystem services. Journal of Applied Ecology, 47(2):377-385.

EGOH B., REYERS B., ROUGET M., RICHARDSON D. M., LE MAITRE D. C., VAN JAARSVELD A. S. (2008) Mapping ecosystem services for planning and management. Agriculture, Ecosystems & Environment, 127(1-2):135-140.

EUROPEAN COMMISSION, COM 231 (2006) Communication from the Commision to the Council, the European Parliament, the European Economic and Social Committee and the Committee of Regions Thematic Strategy for Soil Protection. Commission of the European Communities. Brussels.

GLENK K., MCVITTIE A., MORAN D., DELIVERABLE D. (2012) Soil and Soil Organic Carbon within an Ecosystem Service Approach Linking Biophysical and Economic Data. SmartSOIL Report.

HALLEN F., SCHROERS H.J., GROENEWALD J.Z., CROUS P.W. (2004) Novel species of Cylindrocarpon (Neonectria) and Campylocarpon gen. nov. associated with black foot disease of grapevines (Vitis spp.). Studies in mycology, 50:431-455.

HALLEN F., SCHROERS H.J., GROENEWALD J.Z., REGO C., OLIVEIRA H., CROUS P.W. (2006) Neonectria liriodendri sp. nov., the main causal agent of black foot disease of grapevines. Studies in mycology, 55:227-234.

KEESSTRA S. D., QUINTON J. N., VAN DER PUTTEN W. H., BARDGETT R. D., FRESCO L.O. (2016) The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals. Soil, 2(2):111.
KEUSKAMP J A, DINGEMANS BJJ, LEHTINEN T, SARNEEL J M, HEFTING MM. Tea Bag Index, a novel approach to collect uniform decomposition data across ecosystems. Methods in Ecology and Evolution, 4, 1070–1075 (2013).
MARTÍNEZ-CASASNOVAS J. A., CONCEPCIÓN RAMOS M. (2009) Soil alteration due to erosion, ploughing and levelling of vineyards in north east Spain. Soil use and management, 25(2):183-192.
MILLENIUM ECOSYSTEM ASSESSMENT (MEA) (2005) Current state and trends: findings of the conditions and trends working group. In: Hassan, R., Scholes, R., Ash, N. (Eds.), Ecosystems and Human Well-being. Island Press, Washington DC, USA.
PRIORI S., MARTINI E., ANDRENELLI M.C., MAGINI S., AGNELLI A.E., BUCELLI P., BIAGI M., PELLEGRINI S., COSTANTINI E.A.C. (2013) Improving wine quality through harvest zoning and combined use of remote and soil proximal sensing. Soil Science Society of American Journal, 77(4), 1338-1348.
RAMOS, M. C. (2006) Soil water content and yield variability in vineyards of Mediterranean northeastern Spain affected by mechanization and climate variability. Hydrological processes, 20(11):2271-2283.
TAMM L., THUERIG B., BRUNS B., FUCHS J.G., KÖPKE U., LAUSTELA M., LEIFERT C., MAHLBERG N., NIETLISPACH B., SCHMIDT C., WEBER F., FLIEßBACH A. (2010) Soil type, management history, and soil amendments influence the development of soil-borne (Rhizoctonia solani, Pythium ultimum) and air-borne (Phytophthora infestans, Hyaloperonospora parasitica) diseases. European Journal of Plant Pathology, 127:465-481.
VAUDOUR E., COSTANTINI E.A.C., JONES G. V., MOCALI S. (2015) An overview of the recent approaches to terroir functional modelling, footprinting and zoning. Soil, 1:287–312.

DOI: 10.6092/issn.2281-4485/7905