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Deliverable "Report on Soil threats across Europe"

Sub-action A1.2 "Soil threats in Europe"

LIFE+ PROJECT Soil4Wine

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Abstract

Aim of this Deliverable is the identification of main soil threats in vineyards in Europe through a systematic literature review of more than one hundred scientific papers and institutional documents and reports (Annex A) and a wider survey of stakeholders soil threats perception.
At first the definition of meaning and typologies of soil threats was done, according to European legislation that define 8 main soil threats (COM(2002)179 final). Literature analyzed were classified according to European definition.
Research on erosion, flood and landslides, decline in organic matter, soil contamination and compaction and decline in biodiversity are presented located mainly in Spain, France and Italy with also a considerable numbers of contributions in Central-East Europe viticultural zones. Erosion was defined as the main cited and forced soil threats from researchers but several different methods can be used to assess problem magnitude and outcomes are not easly comparable.
Survey on soil threats aimed at a better understanding of the stakeholders perception about this matter; though, it has to be recognized the low number of fillers have devoted just few minutes to give opinions and suggestion for the project. This can be indirectly inferred as a sign of low level of interest to soil problems from wine chain actors. Responses disclose that sustainable management techniques are mostly known albeit at a quite general level and that their potential efficacy is still hidden to many fillers.

1. Introduction: Project overview

Soil4Wine project "*Innovative approach to soil management in viticultural landscape*" aims to achieve a better soil management in the whole vineyard ecosystem developing and testing an innovative Decision tool and management solutions tested in several farms located in the Project area and in Europe.
This report presents the structure and main outcomes of sub-action A1.2 related to Soil4Wine project Action A.1 "Study on the soil threats and constitution of the stakeholder groups" from M1 (01.01.2017) until M6 (30.06.2017). UCSC is the main responsible for this action, while other partners involved are HORTA, EGPB, VINIDEA and ERVET.

Main aim of this sub-action was to define and quantify extent of the main soil threats across Europe. Outcomes derives from two different survey methodologies:
- systematic literature review (please see chapter 9 "*List of case studies references*")
-questionnaire about soil threats perception from different stakeholders (researcher, growers, wine associations...) prepared by UCSC and VINIDEA.

2. Soil threats according to European Union legislation

European Union considers soil as a non-renewable resource subjected to increasing threats from a wide range of human activities.
Documents at different government and administrative levels were produced such as Rio declaration (UN, 1992) on Environment and Development, United Nations Convention to Combat Desertification (UN, 1994), Declaration of Rio+20 Summit (UN, 2013b) and Resolution on World Soil Day and International Year of Soil (UN, 2013a).
In particular, in 2002, the European Union proposed to promote measures and policies committed to enhance soil quality in Member States (COM(2002) 179 final) (EC, 2002). Moreover, the communication defines and identifies the main soil's threats and soil functions. This communication prompted the European Thematic Strategy for Soil Protection. (COM(2006)231 final; COM(2012)/046 final) (EC, 2006, 2012)

COM(2002)179 estimated that, in EU, 52 million of hectares are affected by some kind of degradation process. Soil erosion by water has the higher impact in Europe (Panagos *et al.*, 2015) and in 2006 EU assessed that 12% of emerged lands were subjected to water erosion (CEC, 2006)
Main arable soil loss rates (% of t ha^{-1} y^{-1}) were recorded in Malta (15.93%) and Italy (8.38%). Italy has the highest mean overall annual soil loss rate (8.46 t ha^{-1}), yet analyzing the contribute to total soil loss in EU the top value is still retained by Malta (24.13%) followed by Spain (19.61%) and France (11.85%) (Panagos *et al.*, 2015). Lower values were recorded in Scandinavian and Baltic countries (mean annual soil loss rates less than 0.52 t ha^{-1} y^{-1}). It is important to underline that soil degradation processes are not confined to EU but constitute a worldwide problem.

3. Soil threats affecting European vineyards

	Harvested area (km^2)	**Production (Mt)**
Europe	34.986	26.6
Eastern Europe	5.508	3
Northern Europe	3	0.004
Southern Europe	20.281	15.8
Western Europe	9.193	7.8

Table 1: data on grapes production in Europe (FAO, 2014)

In Europe about 35.000 km^2 are covered by grapevine and total yield (2014) was about 27 Mt (FAO, 2014, *Table 1*) and wine production in 2015/2016 was about 163.000.000 hl (EUROSTAT, 2017)

Many researches have been carried out on soil threats in Europe, but few of them were focused on vineyards.

In some part of Mediterranean areas vineyards represent the largest agro-ecosystem and most important crop in terms of income, employment and environmental impact (Raclot *et al.*, 2009).Vineyards are generally planted in hilly lands more susceptible to erosion and other limitations.

Vineyard soil management practices in Europe are many but it is possible to group them into three main categories:
- tillage
- no tillage with chemical weeding
- natural or permanent sowed grass in the inter-rows.

4. Statistics and information about searched papers

Main soil threats affecting vineyards in Europe were collected from research papers and European Project reports and classified according to COM(2002)179 final (EU, 2002) in 8 classes (*Table 2*).

Soil threats CODE	Soil threats (ST)
ST1	Erosion
ST2	Decline in organic matter
ST3	Soil contamination
ST4	Soil sealing
ST5	Soil compaction
ST6	Decline in biodiversity
ST7	Salinization
ST8	Floods and landslides

Table 2: Soil threats according to COM(2002)179 final

Literature search was performed using common scientific databases such as Science Direct (www.sciencedirect.com), Scopus (www.scopus.com) and Google Scholar (scholar.google.it) and 90 case studies were analyzed.
Collected papers were published in 48 different Journals with *Catena* (www.journals.elsevier.com/catena) and *Soil and Tillage Research* (www.journals.elsevier.com/soil-and-tillage-research) having the higher numbers of published works (14 and 10 respectively). Year of publishing ranges from 1986 to 2017, with a publication peak in 2016.
Papers were classified according to European classification of Soil Threats (*Table 2* and *Figure 1*)

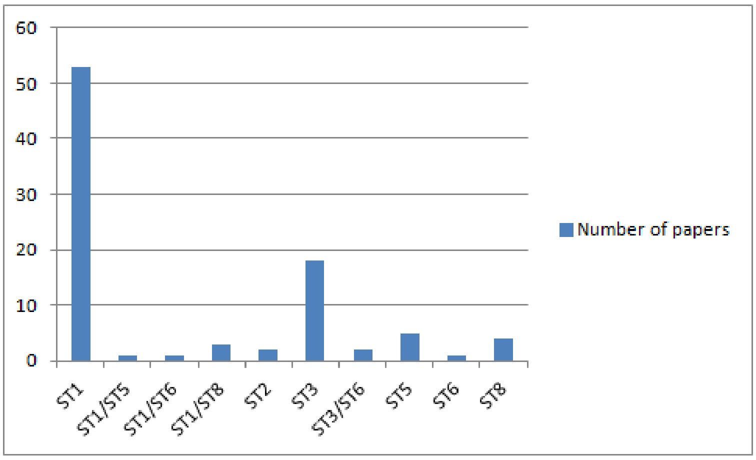

Figure 1: distribution of paper in ST classes

Geographical distribution of case studies in collected works is reported in *Figure 2*.
Main case studies are located in Spain (27), France (20) and Italy (14) but a considerable numbers of contributions also refer to Central-East Europe viticultural zones.

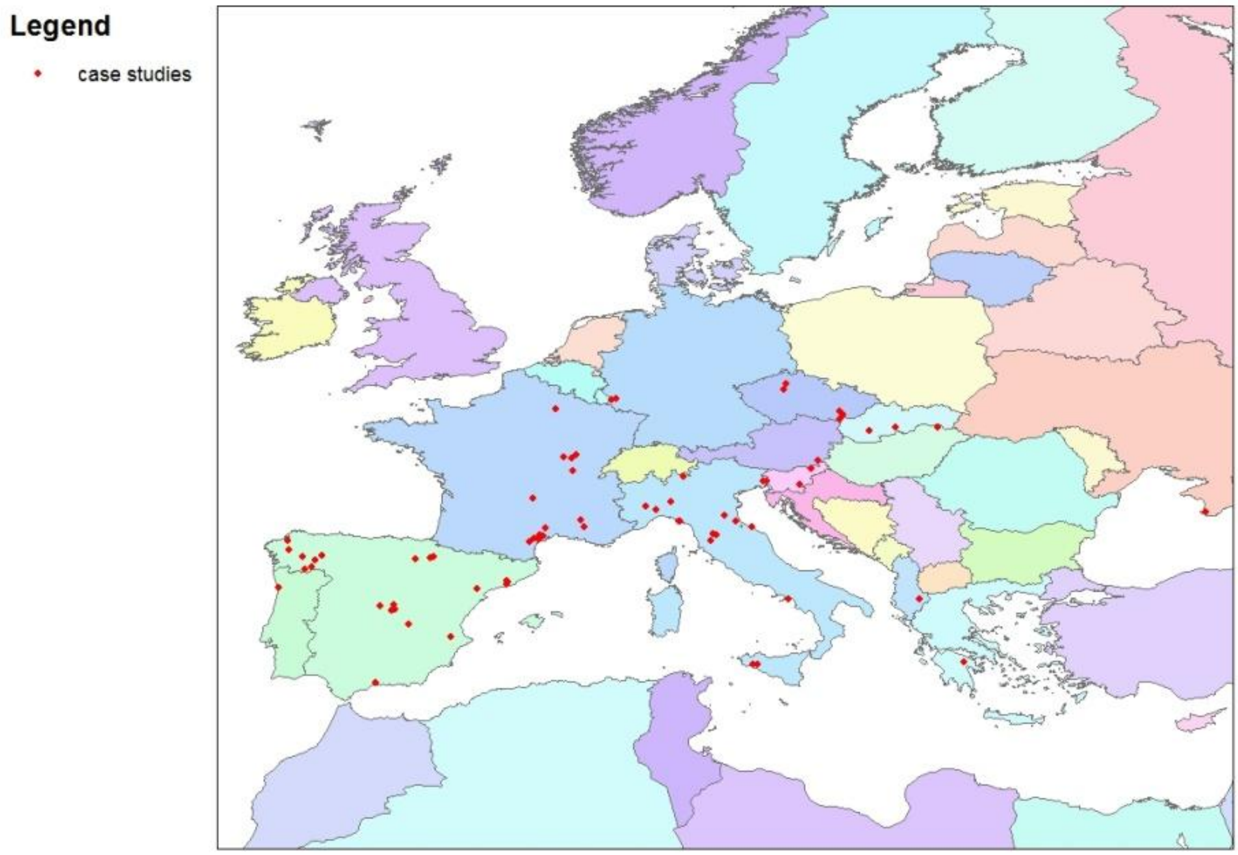

Figure 2: Geographical distribution of surveyed literature

ST1/ST8: "Erosion" and "Flood and landslides"

General considerations

Erosion can be assessed and also tolerate up to a certain limit but there is no agreement about this threshold.. Verheijen *et al.* (2009) proposed a definition of acceptable soil erosion as "*any actual erosion rate at which a deterioration or lost of one or more soil functions does not occur*". For Europe this threshold is equal to soil formation rate, between 0.3 to 1.4 t ha^{-1} y^{-1}. Other Authors (van der Knijff *et al.*, 2000) report a maximum acceptable erosion rate of about 1 t ha^{-1} y^{-1}, while others indicate maximum acceptable rates of 12 t ha^{-1} y^{-1} (López-Bermudez and García-Ruiz, 2007).According to all the analysis provided by these Authors, actual average soil loss in Europe for cultivated land is 3 to 40 times grater than the upper erosion limit.

Many models were used by the European Union Agency to estimate the rates and risks of erosion in Europe, in particular related to water erosion, with models such as CORINE EROSION, RIVM and GLASOD (Oldeman *et al*, 1991). More recent analyses use the Universal Soil Loss Equation USLE (Wischmeier and Smith, 1978) and its revised versions as well as data contained in the the PESERA (Pan European Soil Erosion Risk Assessment) project (Kirby *et al.*, 2004)

Wind erosion also plays an important role in soil threats analysis and EU applied the RWEW model on arable land of its 28 Member States. The model was designed to evaluate the potential daily soil loss at about 1 km^2 spatial resolution. In EU average annual soil loss obtained from model application is about 0.53t ha^{-1}

y^{-1} (Borrelli *et al*., 2016). Literature shows the lack of a standardized procedure to assess soil erosion but it can be possible to categorized research studies into three groups:

1. experimental plot station and simulated rainfall
2. erosion models
3. erosion makers

1. Experimental plot station and simulated rainfall

In order to investigate the processes of runoff and erosion under different soil management techniques many authors had used experimental station that consiste in a portion of vineyard in which soil sediments, precipitation, velocity of water on surface and other parameters are monitored.
Analysis on plot sediments amount were mostly performed using **Gerlach through** (Gerlach, 1967) consisting in a sediment collector that is used to indicate relative amounts of soil losses (g m^{-1}) during a given period. Sediments concentration (g L^{-1}) and overland flow (L m^{-1}) is measured after each rainfall events.
Cerdan *et al*. (2010) estimated the average erosion rates for European countries based on literature review, erosion plot and modeling of the relationship between morphological and soil properties. Maximum erosion rates (for all land uses) was estimated in San Marino (5 t ha^{-1} y^{-1}) and Slovakia (3.2 t ha^{-1} y^{-1}), minimum rates were in Russian Federation, Bosnia and Herzegovina, Finland, Moldova, Norway, Andorra (all with 0.2 t ha^{-1} y^{-1}) and Monaco and Gibraltar (0.1 t ha^{-1} y^{-1}).

2. erosion models

1. **(Revised) Universal Soil Loss Equation USLE/RUSLE/RUSLE2015** (Wischmeier and Smith, 1978; Renard *et al*., 1997): represent the empirical model most frequently used for erosion evaluation:

$$E = R \times K \times C \times LS \times P$$

E: annual average soil loss (t ha^{-1} y^{-1})
R: rainfall erosivity factor (Mj mm ha^{-1} y^{-1})
K: soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1})
C: cover management factor
LS: slope length and slope steepness factor
P: support practice factor

The European Commission used USLE model to create maps of Actual and Potential Soil Erosion risk in Europe (van der Knijff *et al*, 2000) and more recently applied the revised model RUSLE2015 (Panagos *et al*., 2015) to estimate soil losses by water erosion at 100 m resolution (*Figure* 3). Mean soil loss rate in EU is estimated to 2.46 t ha^{-1} corresponding to a total soil loss of about 970 Mt annually and 12.7% of European arable lands have soil loss higher than 5 t ha^{-1} (Panagos *et al*., 2015). An interesting benefit of the revised RUSLE2015 is that it can take into consideration the effects of policies in the definition of erosion scenarios.

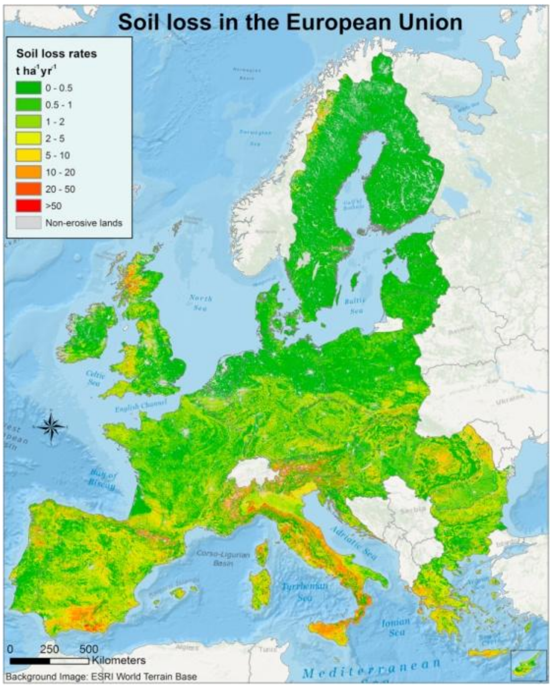

Figure 3: Map of soil loss rate in EU based on RUSLE2015 (Panagos *et al*. 2015)

2. **G2 erosion model (**Panagos *et al.*, 2012)**:** G2 erosion model was conceived on the same principles of empirical equation of the USLE and estimates soil losses caused by raindrop detachment and rainfall runoff on a month-time step on local scale. G2 put emphasis to the dynamic erosion factor such as vegetation cover and it was design to run in a GIS environment:

$$E = \left(\frac{R}{V}\right) \times K \times \left(\frac{T}{l}\right)$$

E: annual average soil loss (t ha^{-1} y^{-1})
R: rainfall erosivity factor (Mj mm ha^{-1} y^{-1})
V: vegetation retention
K: soil erodibility factor (t ha h^{-1} ha^{-1} MJ^{-1} mm^{-1})
T: topographic influence
l: slope intercept

3. **WaTEM/SEDEM** (van Oost *et al*., 2000): this model is a revised RUSLE model focused on spatial distribution of erosion.

4. **surface elevation change-based methods** (Casalì *et al.*, 2009; van der Knijff *et al*, 2000)**:** this method, using DEMs (Digital Elevation Models) assesses soil loss comparing topographic information derived by morphological models.

3. Erosion makers

1. **radionuclides** (such as Cesium-137) (Fornes *et al*., 2005): this method is based on the evaluation of soil erosion rates on a decadal scale but it is costly in terms of money and time and results have large uncertainly because model does not consider the time-independent nature of ^{137}Cs fallout;
2. **plant markers** (Pérez-Rodríguez *et al.*, 2007): the method is based on the analysis of growth rings of trees affected by different phenomena. This method is not widely used in crops due to lifetime of biomarkers;
3. **Stock Unearthing Measurement (SUM)** (Brenot *et al.*, 2008)**:** this method consist in the measurement of erosion-deposition rates based on stock unearthing measurement.

SUM method is based on the assumption that the stock exposure reflects the dynamics of soil surface considering the scion-graft limit to be a marker of the initial morphology. (*Figure 4)*

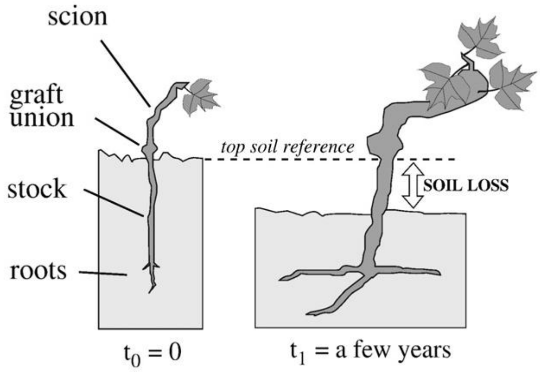

Figure 4: SUM method assumption (from Brenot et al., 2008)

Vineyards, among cultivated land, represent the most vulnerable land cover in Mediterranean area because of the interaction between natural and anthropogenic factors (Prosdocimi *et al.*,2016). Several Authors (Kosmas, 1997, Cerdan *et al*., 2010, Rodrigo Comino *et al*., 2016a,b, Maetens *et al*., 2012) recorded highest value of sediment losses (1.42 t ha^{-1} y^{-1}) compared to others Mediterranean crops and vegetation cover such as wheat (0.2 t ha^{-1} y^{-1}), eucalyptus (0.2 t ha^{-1} y^{-1}), scrublands (0.07 t ha^{-1} y^{-1}) and olives (0.008 t ha^{-1} y^{-1}) (Kosmas, 1997). Maetens *et al*. (2012) reported that in Mediterranean region runoff rates higher that 9% are related to vineyard land use.

A systematic literature survey regarding soil erosion based on plot data in Europe was proposed by Cerdan *et al.* (2010). Erosion rates were collected and calculated based on land use reporting mean erosion value (t ha^{-1} y^{-1}) for different land usage. Vineyards resulted in 12.22 t ha^{-1} y^{-1}, that is 40 times greater than grass (0.3 t ha^{-1} y^{-1}) and similar to orchard (11.75 t ha^{-1} y^{-1}) and bare soil (15.1 t ha^{-1} y^{-1}). Prosdocimi *et al.* (2016) made an in-depth review of soil erosion in Mediterranean vineyards analyzing and discussing effects of topographic and management variables showing high variability in erosion rates.

Topography, soil type, climate and agricultural practices are generally recognized as the most significant factors affecting soil erosion in vineyards; moreover, cultivation requires, in traditional agronomical practices, frequent removal of weeds and repeated tillage with heavy machinery that affect soil stability, organic matter content and porosity. (Kosmas *et al*., 1997; Arnaez *et al*, 2007, Prosdocimi *et al*., 2016)
Soil erosion, especially under Mediterranean climate, is naturally related to the seasonal changes which are mostly affecting rainfall erosivity (van der Knijff *et al*, 2000).Moreover, abandoned lands and changes in land use greatly accelerate the erosion processes (Park, 2001).

Erosion rates in different countries

- **Germany**

Vineyards in Germany are located close to the northern European limit for grapevine cultivation and cover an area of about 1000 km^2 with a total production of 1,2 Mt (FAO, 2014). They are affected by erosion especially under steep slopes (15 - 50°) and terraced areas due to topsoil compaction and decrease of porosity under heavy machinery traffic, disturbance of soil during vines planting and tillage practice in the inter-rows (Rodrigo Comino *et al.*, 2016a). In Germany, which is not characterised by a Mediterranean climate that strongly influences the erosion processes, an important factor in the erosion phenomena is human management of vineyards and in general of cultivated lands (Rodrigo Comino *et al.*, 2016a). According to Cerdan *et al*. (2010) the German mean average erosion rate is 1.9 t ha^{-1} y^{-1}.
Auerswald *et al.* (2009) estimated an average soil loss of 5.2 t ha^{-1} y^{-1} for German vineyards using the RUSLE equation, whereas Hacisalihoglu (2007) estimated losses of 6.47 t ha^{-1} y^{-1} using an adaptation of RUSLE model for Germany (ABAG).

In particular in the Ruwer-Mosel region a range of 0.2-6.6 t ha^{-1} y^{-1} was recorded by Ritcher (1980) using sediment trap. In the Ruwel-Mosel valley Rodrigo Comino *et al.*, 2016c obtained different results with the SUM method over 2013-2015: in 2013 for older vineyards soil loss was 3.4 t ha^{-1} y^{-1} while for 3 year old vines losses reached 62.5 t ha^{-1} y^{-1} indicating that vineyard establishment induces strong soil disturbance (similar values were registered for 2014 and 2015). The RUSLE model also reported that the younger vineyard was mostly affected by erosion (19.46 t ha^{-1} y^{-1} vs 11.28 t ha^{-1} y^{-1}). Results from rainfall simulation in the Ruwer-Mosey Valley about conventional and grass covered vineyards reported a suspended sediment load of 3.74 g m^{-2} for old vineyards (35-40 years) to 53.56 g m^{-2} for young ones (4 year old) (Rodrigo Comino *et al.*, 2016b)

In the Saar-Mosel Valley, the erosion was assessed also comparing conventional and organic vineyards using “Gerlach troughs” during 33 natural rainfall events (for a total of 979.4 mm) (Kirchhoff *et al*., 2017). Considering events that produce runoff, for each trap traditional practices caused an average soil loss of 4909.2 g m^{-1} while organic practices registered less average sediment losses (402.1 g m^{-1}), in addition average sediment concentration is quite different between conventional (34.6 g L^{-1}) and organic soil management (11.62 g L^{-1}) showing comparable values with other countries such as Spain (Rodrigo Comino *et al*., 2016b, Ramos and Martínez-Casasnovas, 2007) .

- ## Central-East Europe

Analyses on erosion threat in vineyard were reported in Albania, Hungary, Slovenia and Slovakia for Central-East Europe. Details about grapes production and interested areas are shown in Table 3 (FAO, 2014).
In literature there are few studies about soil threats, and in particular erosion, out of Mediterranean Region.

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	Harvested area (km^2)	***Production (t)***
Albania	96.25	203.700
Hungary	707.2	406.020
Slovenia	160.1	93.976
Slovakia	87.6	38.450

Table 3: Harvested areas, grapevine production and average soil erosion for the four Countries considered in the Central-East Europe

1. *Albania*

Zdruli *et al.* (2016) analyzed vineyards in Korçe region that cover about 2.45 km^2 (it must be noted that this value is underestimated because Corine Land Cover data have a resolution of 25 ha and many Albanian vineyards are really small and could be missed from the evaluation). Monthly and annual analysis of erosion (t ha^{-1}) were obtained using G2 model and results have shown an annual average of 28.3 t ha^{-1} with November as the most critical month (6.01 t ha^{-1}). Zdruli *et al.* (2016) compared erosion rates under different land covers and the highest annual average value was recorded for the class 332 of Corine Land Cover Classification (bare rocks ; 91.21 t ha^{-1} y^{-1}).

2. *Hungary*

A famous wine region in Central-East Europe is Tokaj-Hegyalja in Hungary characterized by terraced landscape (declared by UNESCO World Heritage in 2002) that facilitates cultivation on very steep slopes. In last years terracing is being increasingly abandoned due to the high labour and cost for maintenance and, as Tarolli *et al.* (2014) argued, terraced landscapes are now one of the most endangered landscape in whole Europe and the absence of an appropriate management should increase erosion and slope failure processes.
In Tokay-Hegvalja region terraces cover about 11.3% of total vineyards area (corresponding to 590 ha) and an analysis main causes of land abandonment and correlated threats from 1784 and 2010 was carried out (Incze *et al*., 2016) showing that abandonment were caused, probably, by mechanisation of agriculture during post-socialism and today only 2.4% of terraced areas are still under cultivation with no signs of degradation processes.

3. *Slovakia*

In Slovakia analysis on erosion in vineyards is limited but a general study on erosion was made using GIS in recent years based on USLE model and CORINE land cover data with the aim of identification of potential and actual soil erosion rate (Šuri *et al,* 2002). According to this study, vineyards were classified as land cover having the highest cover managerment factor (C- factor) (0.350-0.550) and in whole Slovakia main areas were classified with none or very low actual soil erosion (38.9% ranging from 0 to 0.7 t ha^{-1} y^{-1}). However, analysing potential erosion this percentage decrease to 24.9% but with very high erosion characteristics (soil loss higher than 75 t ha^{-1} y^{-1}) increased from 0.8 to 52%.
Detailed analyses on vineyards were made by Lieskovsy and Kenderessy (2014) in the Vráble region strongly subject to abandonment through comparison of different floor management systems. Stanfard benchmarking was used to evaluate erosion magnitude and the WATER/SEDEM model employed to assess the impact of various vegetation covers.
Observed erosion values on selected transects ranged from 3.89±3.46 t ha^{-1} y^{-1}for hoed vineyards to 24.08±2.39 for ploughed ones; predicted values, instead, ranged from 8.52 t ha^{-1} y^{-1}for ploughed vineyards to 10.07 t ha^{-1} y^{-1}in rotovated ones. Huge differences in erosion between grass cover management (18.95 t y^{-1}) and ploughing (808.80 t y^{-1}) were ascertained.

4. *Slovenia*

Interesting is the case of Slovenia in which, in recent years, the erodibility of soil has been reduced due to the decreasing in tillage to the benefit of grassing, mulching and sowing reducing erosion by more than a third (Komac *et al.,* 2005). Erosion remains, however, a severe threat and analysis on erosion in Slovenia were carried out in several vineyard regions modelling the phenomena with RUSLE method or with direct measuring. Results have reported values ranging from 51 t ha^{-1} y^{-1} in Rokava with RUSLE method to 22 t ha^{-1} y^{-1} in Straža , 10.76 in Limbuš (Vršič *et al*., 2000) and 1.89 t ha^{-1} y^{-1} under traditional practices and 0.09 t ha^{-1} y^{-1} with grass cover in Meranovo (Vršič et al., 2011). In Slovenia, annually cultivated land loss was estimated at 0.92-2.45 million m^3 of soil, for vineyards it was 0.27-0.29 million m^3 (Komac *et al*., 2005).
Moreover, in 2006 a map map of susceptibility of Slovenia' soil (Komac and Ribičič, 2006) considering lithological/geological characteristics, slope and land cover type on erosion was produced and and vineyards land cover proved having a direct influence on landslide occurrence.

- ## France

According to FAO statistics (FAO, 2014) in France vineyards cover an area of 7580 km^2 with a total grapes production of about 6.2 Mt. During last decades French wine-growing regions were subjected to deep changes in land uses and farming techniques that have made vineyards more susceptible to water erosion (Blavet *et al*., 2009)

Many studies were focused on the comparison of erosion rates between different soil management techniques. For instance, Ballif and Herre (1986) found no differences in runoff and topsoil loss under no tillage (300 g m^{-2} y^{-1}) as compared with tillage (250 g m^{-2} y^{-1}) in a three year experiment in Champagne vineyards. Following, Raclot *et al*. (2009) compared vineyards in the Roujan catchment e with different weed control practices (herbicides sprayed on the whole field with no tillage, herbicides sprayed along vine rows and tillage between rows). Run-off sediments were recorded using gauging stations. Results of this work showed that, in presence of exceptional events (more than 100 mm of rain in few hours) superficial tillage using rotary hoe significantly reduced total soil losses compared with no-tillage practices associated with herbicides leading to bare soil. Registered data for the most erosive event are 1049.6 g m^{-2} for no tillage and 516.4 for tillage associated with weed control practices. Comparing analyses on field and catchment scale authors underlined and confirmed that a catchment cannot be considered as a sum of single fields and, rather, it follows a more complex erosion model.

Paroissien *et al*. (2010) using vine-stock unearthing method in 49 fields in Hérault region assessed deposition and erosion rates finding an average soil loss of 10.5 t ha^{-1} y^{-1} (ranging from -27.5 to 66.7 t ha^{-1} y^{-1} for deposition and erosion, respectively). This value is about 10 times greater than the acceptable threshold although it is important to underline that the used method might underestimate the impact on vineyard of soil erosion between rows and headlands.

In general in France vineyards soil erosion is a strong limitation and the complexity of interaction between anthropogenic and natural elements makes not easy to find a solution (Blavet *et al*, 2009). In Burgundy area, Chevigny *et al.* (2014) analysed maps data from 1972 to 2012 to evaluate erosion rates and investigated the impact of geomorphological and anthropogenic factors that control this phenomenon. Methodology used to evaluate soil loss by erosion was SUM (Brenot *et al*., 2006, 2008) performed in 2004 and 2012 having as reference the age of planting (1972). Soil loss ranged from 1.1±0.3 mm y^{-1} and 2.8±1.3 mm y^{-1} for 1972-2004 and 2004-2012, respectively, registering a significant increase over time. These results enlightened the crucial role of historical and anthropogenic actions on vineyards land from the point of view of landscape morphology and characteristics.

Analysis of erosion/deposition of soil are made also with sediment boxes put in the end of rows. From 1991 to 2002 Quinquerez *et al.* (2008) recorded and analysed storm events in Burgundy pointing out that event characterised by rainfall intensity lower than 20 mm h^{-1} were slightly erosive so it was clear that rills were due to intense events that had a lower frequency (2 events for the case study area with intensity higher than 40 mm/day). Analysis of morphological features of resulting rills and of sediments collected in sediment boxes at the end of rows, helped to understand the dynamic of erosion/deposition processes. Main soil loss during a single storm events was about 24 t ha^{-1} y^{-1} that compared with mean soil production rates (0.01- 0.1 t ha^{-1} y^{-1}) underlines a strong disequilibrium in vineyards.

Usually farmers apply techniques to reduce erosion effects in vineyards such as movement of eroded soil from the bottom to the top of the slopes with the aims of maintaining soils on hill slopes and fill rills created during rainstorm (Quinquerez *et al*., 2008). This practice is used also in Burgundy (France) and the application of mathematical models (Quinquerez *et al.*, 2008) permitted to understand and simulate the interactions between natural soil and anthropogenic supply confirming that this is not a sustainable technique in vineyards.

Also vineyard configuration can affect erosion magnitude and literature reports data in Champagne region aiming to assess optimal rows lengths to reduce erosion (Gaubesville, 1997) or to assess runoff and erosion (Rodrigo Comino *et al*, 2016d). Using a modelling approach based on rainfall/runoff relationship over 10 years tested on 30% sloping plot authors identify the best and more sustainable row lengths in 70 m (soil loss 5.3 m^3 ha^{-1} y^{-1}), i.e. shorter than the standard length of 100-150 m (8.6 m^3 ha^{-1} y^{-1}) with a reduction of sediments losses of about 40% (Gaubesville, 1997).

- **Italy**

Mean Italian erosion rate was setdefined of 2.3 t ha^{-1} y^{-1} corresponding to 12.5% of total European erosion. (Cerdan *et al*., 2010)

Piedmont is one of the most specialized and well-known wine region in Italy with about 7.3% of total Italian wine production. Many researches were carried out on vineyards (vine and soils). Regarding erosion threat analysis on vineyards in Alto Monferrato wine region managed differently (tillage and grass covering) in the period 2000-2013, reported maximum value of soil loss of 47.5 (2002), 74.6 (2010) and 4.7 (2002) t ha^{-1} y^{-1} for conventional tillage, conventional tillage with grass strips and grass covering, respectively, although higher seasonal and annual variability was registered with the sediment trap method (Bidoccu *et al*., 2016, Corti *et al.*, 2011).

RUSLE equation validated with benchmarking was used in Tuscany, in Chianti wine region, to produce soil loss maps (in GIS environment) suitable to define territorial and agricultural development policies. Average measured soil losses were 42.01 t ha^{-1} y^{-1}. In general, results of this study indicated that (considering all the cultivated land of region comprising vineyards, orchards and olive trees) more than 29% of the whole Chianti region was affected by very high soil losses and over 13% of the total area registered soil losses higher than 22 t ha^{-1} y^{-1} (Napoli *et al.*, 2016).

In Sicily analyses on erosion rates comparing conventional tillage and alternate tillage using cover crops were made using benchmarking during 9 years. Mean erosion rate was 102.2 t ha^{-1} y^{-1} (more than 40 time greater than average Italian rate) but comparing results of different vineyards management it was clear that cover crops greatly helped to reduce soil losses (until a reduction of 76% for *Trifolium subterraneum, Festuca rubra* and *Festuca ovina*) (Novara *et al*, 2011).

Erosion was also analyzed in vineyards located in Marche region in which almost 3% of the land is covered by vineyards. In vineyards near Ancona, Corti *et al.* (2011) tested different soil management techniques (tillage and natural grass cover) aimed at reducing erosion risk on sloping vineyards. Results showed that where the slope was about 15% grass cover can reduce water run-off and soil losses but in presence of more gentle slopes (about 5-6%) grass cover can reduce run-off facilitating the infiltration in soil but soil erosion is not reduced.

Agronomical practices on vineyard soils have usually a huge impact on soil properties and resilience to erosion and other threats. One of the usual practices used before planting is land leveling after deep ploughing up to 1 meter. These operations cause heavy disturbance to soil profile and performances.
In Cesena, Emilia-Romagna region, a value of soil water erosion higher than 180 t ha^{-1} (Bazzoffi *et al*., 2006). was recorded after leveling

Erosion threat is strongly related to landslides risk (ST8) and the assessment of the mechanical contribution that vine roots give to slope stability was assess by Bordoni *et al*. (2016) in Oltrepò pavese wine region (Lombardy), an area highly susceptible to landslides. It was concluded that grapevine roots can provide a good reinforcement in the first 0.6 meters from the ground were root density is higher but it also depends on soil properties that affect root penetration and development.

Italian landscape is also characterized by terraced landscapes that, over years, were used to facilitate cultivation on steep slopes and controlling erosion processes. Terraces also represent a European and World cultural heritage. Nowadays cultivation on terraces is expensive due to low susceptibility to mechanization so some terraced areas are progressively abandonee. Abandonment causes increasingly erosion and landslides. In Italy there are many example of terraces cultivated with vineyards affected by erosion: Cinque Terre (Liguria), Chianti classico wine region (Tuscany) Amalfi Coast (Campania), Pesaro (Marche), Valtellina (Lombardy) and remote sensing techniques were used to recognize the topographic signs of abandoned terraces or evaluate damage in elements and architecture aims to restore and maintain them to reduce erosion phenomena and its consequence (such as landslides) (Crosta *et al*., 2003, Tarolli *et al.*, 2014, 2015; Cevasco *et al.*, 2013)

- ## Spain

Viticulture in Spain is one of the most important economic sector: in 2014, 9310.7 km^2 were covered by vineyards with a total grapes production of more than 6 Mt (FAO, 2014). Spain is characterized by a semi-arid Mediterranean climate with low frequency, high intensity rainstorms having high erosive impact.
Intensification of agriculture in last decades had a strong impact on soil and in particular on its susceptibility to erosion.

In NE Spain (Penedès-Anoia vineyard region) analysis on land use change in 1957-1992 were carried out (Martínez-Casasnovas and Sánchez-Bosch, 2005). Most soil protective practices (such as terraces and tillage perpendicular to maximum slope gradient) were replaced by modern plantations suitable for mechanization. RUSLE application showed an increase in agricultural areas with soil losses over 100 t ha^{-1} y^{-1} (from 10.8 to 25%) and one of the most impacting actions was the removal of terraces.
Another point of view in the analysis of erosion is the assessment of economical implication of this phenomenon, even though this aspect is fundamental in the definition of mitigation actions and policies. From analysis on Penedés-Anoia, the highest costs deriving from erosion in vineyards are related to nutrients losses, maintenance of drainage channels and filling of gullies for a total cost of about 7-8% of the income derived from the sale of grapes production (Martínez-Casasnovas and Ramos, 2006). Again, in Penedès region analysis on land level impacting on soil properties and erosion rates was carried out by Ramos and Martínez-Casasnovas (2006, 2007). Sediment concentration in runoff ranged up to 0.2 to 27 g L^{-1} .
Scenarios of future erosion due to climate changes were developed in Anoia region (Ramos, 2016) using the WEPP (Water Erosion Prediction Project) model with two slope management hypothesis (with and without terraces). Models showed a greater negative trend in precipitation until 2050 with modification also in the distribution over years and erosivity of single events; moreover, simulation presented changes in runoff which were affected by less precipitation so erosion will be less but erosion rates may increase due to the effects of extreme events. Terracing had a positive effect on erosion in Anoia region, reducing soil losses by about 45%. Terracing reduced soil erosion reducing slope length and retaining sediments inside the fields.

In la Rioja wine region, Arnaez *et al*. (2007) applied a rainfall simulation and USLE-M modeling to evaluate changes in soil due to erosion processes. Considering three different rainfall intensity (high: 92.5-117.5 mm h^{-1}; intermediate: 51-70 mm h^{-1} and low: 30-46 mm h^{-1}) authors calculated the total average value of soil losses at, respectively, 66.8, 17.9 and 23 g m^{-2} h^{-1}; moreover, it was analyzed the relationship between recurrence period and strength of erosion showing that highest soil losses were related to 200 years and 127 mm h^{-1} rainfalls; though shorter recurrence period (5 years) caused a soil loss of 11.3 g m^{-2} h^{-1}.

Different impacts of water erosion in vineyards with diverse soil management (*Secale cereale, Brachypodium distachyon* and traditional tillage) have been enlightened in Henares River basin (Ruiz-Colmenero et al., 2013). Erosion was estimated through erosion plots with Gerlach trough taking into account only rainfall events intensity > 1 mm. Average annual rates of erosion under tillage was about 6 t ha^{-1} y^{-1} compared with cover crops treatments where erosion rates were 5 times smaller (0.8 t ha^{-1} y^{-1} with *Brachypodium distachyon* and 1.3 t ha^{-1} y^{-1} with *Secale cereale)* with a value of organic matter 1.4 times higher. In the same area, comparison between conventional tillage, two spontaneous grass (*Secale cereale L., Hordeum vulgare L.)* and a seeded strip *(Lens culinaris* Medik) was performed (Ruiz-Colmenero *et al*., 2011) measuring soil losses using a Gerlach trough. Maximum sediments amount after two years were, for conventional tillage, 357 g m^{-2} while the coverage with permanent grass had reduced soil losses by 86% at Villaconejos and by 58% at Belmonte..

In Axarcuia region, characterized by high temperature and extreme rainfalls in autumn and winter and vineyards located on high steep slopes, land degradation is a severe problem that impacts on vine productivity. Rainfall simulations carried out in this area show that total average soil losses during experiments at upper, middle and foot slope were respectively 11.4 g m^{-2}, 3.97 g m^{-2}, 11.9 g m^{-2} (Rodrigo Comino *et al*., 2016c,d).

One of the most important and famous wine region in Spain is Navarre and many studies were carried out to assess soil and ecosystem vulnerability in this area (Casalì *et al*., 2009, De Santisteban *et al*., 2006, Lorenzo *et al*., 2002).A long-time assessment of soil erosion in Navarre region was made using exposed tree roots under vine canopy as benchmarks and GIS analysis of obtained DEM (Casalì *et al.*, 2009). Outcome reported an average soil loss rate of about 3 kg m^{-2} y^{-1}, observing highest rates near planting (5 kg m^{-2} y^{-1}) according to what was registered in Germany using the same methodology (Rodrigo Comino *et al*, 2016a)
Literature (Martinez-Casasnovas *et al.*, 2005) reported soil loss of 282 t ha^{-1} during a single storm with an intensity of 187 mm h^{-1} in the north-east Spain (Catalonia). Erosion rate registered in literature are higher than soil formation rates indicated by Verjeijen *et al*. (2009)

In *Table 4* erosion rates found in searched literature are summarized. It is clear that is not easy to find common element in published data, as methodology, vineyard features and management techniques and results are various. It is quite complicated to compare obtained result from above cited methodologies (SUM; models, sediment analyses etc) and it is hard to better understand the magnitude of erosion in each european country.

Country	Area	t ha^{-1} y^{-1}	g m^{-2}	g m^{2} h^{-1}	Data source	References
Germany	Whole country	6.5			ABAG	Hacisalihoglu, 2007
	Whole country	5.2			RUSLE	Auerwald *et al.*, 2009
	Whole country	1.9			USLE	Cerdan *et al.* 2010
	Ruwer-Mosel	0.2-6.6			Experimental plot station	Ricther, 1980
	Ruwer-Mosel	3.4[a]-62.5[b]			erosion makers	Rodrigo Comino *et al.*, 2016a
	Ruwer-Mosel	11.28[a]-19.46[b]			RUSLE	Rodrigo Comino *et al.*, 2016a
	Ruwer-Mosel		3.7[a]-53.6[b]		Rainfall simulation	Rodrigo Comino *et al.*, 2016b
	Saar-Mosel		402.1[c]-4909.2[d]		Experimental plot station	Kirchhoff *et al*, 2017
Albania	Whole country	0.4			USLE	Cerdan *et al.* 2010
	Whole country	28.3			G2 model	Zdruli *et al.*, 2016
Hungary	Whole country	1			USLE	Cerdan *et al.* 2010
Slovakia	Whole country	3.2			USLE	Cerdan *et al.* 2010
	Vráble	8.52[c]-10.07[e]			WATER/SEDEM	Lieskovsky and Kenderessy, 2016
	Vráble	18.95[f]-808.80[c]			WATER/SEDEM	Lieskovsky and Kenderessy, 2016
Slovenia	Whole country	1			USLE	Cerdan et al. 2010
	Rokava	51			RUSLE	Vršič *et al.*, 2000
	Straža	22			RUSLE	Vršič *et al.*, 2000
	Limbuš	10.76			RUSLE	Vršič *et al.*, 2000
	Meranovo	0.09[f]-1.89[c]			RUSLE	Vršič *et al.*, 2011
France	Whole country	1.5			USLE	Cerdan *et al.* 2010
	Champagne	2.5[c]-3[j]				Ballif and Herre, 1986
	Roujan		516.4[h]-1049.6[i]		Experimental plot station	Raclot *et al.*, 2009
	Burgundy	24[g]			Experimental plot station	Quinquerez *et al.*, 2008
	Hérault	10.5			erosion makers	Parossien *et al.*, 2010
Italy	Whole country	2.3			RUSLE	Cerdan *et al.*, 2010
	Emilia-Romagna	180			surface elevation change-based methods	Bazzoffi *et al.*, 2006
	Sicily	102.2[c]			erosion makers	Novara *et al.*, 2011
	Piedmont	4.7[f]-47.5[j]-74.6[c]			Experimental plot station	Bidoccu *et al.*, 2016; Corti *et al.*, 2016
	Tuscany	42			RUSLE	Napoli *et al.*, 2016
Spain	Av Whole country	1			USLE	Cerdan *et al.* 2010
	La Rioja			23-66.8	USLE-M	Arnez *et al.*, 2007
	Catalonia	282[g]			surface elevation change-based methods	Martinez-Casasnovas *et al.*, 2005
	Navarre	30			surface elevation change-based methods	Casalì *et al.*, 2009
	Villacoejos		55.15[j]-63.71[k] -		Experimental plot	Ruiz-Colmenero *et al.*, 2011

			357[e]		station	
	Henares River basin	0.8[k]-1.3[m]-6[c]			Experimental plot station	Ruiz-Colmenero *et al.*, 2013
	Axarcuia		3.97-11.9		Rainfall simulation	Rodrigo and Comino *et al.*, 2016 c,d

[a,]35 years old vineyard; [b,] 3 years old vineyard; [c,] conventional tillage/ploughed vineyard; [d,] organic practices; [e,] rotovated vineyards; [f,]grass cover management; [g,] registered during a single storm event; [h,] herbicides along rows and tillage between rows; [i,] herbicides sprayed in whole field and with no tillage; [j,] reduced tillage/no tillage; [k,] grass cover with *Brachypodium distachylon;* [l,] grass cover with *Hordeum vulgare*; [m,] grass cover with *Secale cereale*

Table 4: Comparative table of erosion rate data in citied literature

- ### Consequences of soil erosion: *Nutrients losses*

In literature there are only few researches regarding derived impact of soil erosion such as nutrient losses, especially in vineyards. Nutrient loss cause on-site and off-site effects, the former causing the loss of soil fertility, the latter generating pollution of rivers and groundwater. The majority of work has focused on nitrates because many European agricultural areas are classified as Nitrate Vulnerable Zones by Nitrate Directive (EC, 1991). Ramos and Martínez-Casasnovas (2006) measured a loss of 0.01-4.20 kg of nitrogen/ha in one single storm in Penedès region (Spain). Rainfall simulation is useful to measure nutrients loss in water and sediments and using this technique García-Díaz *et al*. (2017) compared nutrient losses under three different soil management practices in Spanish vineyards: 1. conventional tillage, 2. cover crop (*Brachipodium distichyon)* and 3. spontaneous vegetation. Spontaneous grass generated 6 time less nitrates and 5 time less total mineral nitrogen in the runoff than conventional tillage; seeded grass was less effective although the best at reducing soil erosion, runoff and NO_3 losses.
Another important nutrient affected by erosion is phosphorous (P). Ramos and Martínez-Casasnovas (2006) in vineyards of Penedès region registered losses of 0.012-4.23 kg ha^{-1} during a single storm. Climate change increased the numbers of extreme storms and literature reports losses during a single extreme event in Spain up to 9.66 kg ha^{-1} of N and 11.46 kg ha^{-1} of P (Ramos and Martínez-Casasnovas, 2004), i.e. higher than data collected in Spain for other crops.
Nutrient losses have also economical implications on farmers' income in terms of direct cost and long-term loss of productivity. On-site cost of soil erosion can be estimated using the replacement cost method (Martínez-Casasnovas and Ramos, 2006) as it was done in wine-region of Penedès-Anoia (Spain). Regarding cost related to nutrient losses, analysis was performed using Gerlach collectors indicating that total N loss was 14.9 kg ha^{-1} and losses of P set at 11.5 kg ha^{-1} that, in the investigated vineyards, corresponded to 6% and 26.1% of the annual N and P intake or, in monetary terms, they represented the 2.4% (for N) and 1.2% (for P) of the annual income from the sale of grapes.

Country	***Nutrient***	***kg ha^{-1}*** *(in individual storm)*	***mg***	***Reference***
Spain	**N**	0.01-4.2		Ramos and Martinez-Casasnovas, 2006
			6.11[a]-16.05[b]-36.27[c] (Rainfall simulation)	García-Diaz *et al.*, 2017
		9.66		Ramos and Martinez-Casasnovas, 2004
		14.9		Martinez-Casasnovas and Ramos, 2006
	P	0.012-4.23		Ramos and Martinez-Casasnovas, 2006
		11.46		Ramos and Martinez-Casasnovas, 2004
		11.5		Martinez-Casasnovas and Ramos, 2006

[a],spontaneous vegetation; [b], *Brachypodium distachyon;* [c],35 conventional tillage

Table 5: Comparative table of nutrient losses rate data in citied literature

ST2: "Decline in organic matter"

European Union has estimated the Pan-European Soil Organic Carbon (SOC) stock in agricultural soil in 17.63 Gt and the effect of soil erosion to this stock (Lugato *et al.*, 2016). According to this assessment in Europe 143 M ha C erosion rates < 0.05 Mg C ha^{-1} y^{-1} with the presence of hot-spot areas in which erosion is > 0.45 MgC ha^{-1} y^{-1}.
In *Figure 5* the European Map of Topsoil Soil Organic Carbon for EU25 based on LUCAS2009 data. Topsoil carbon content (g C kg^{-1}) (de Brogniez *et al.*, 2014)

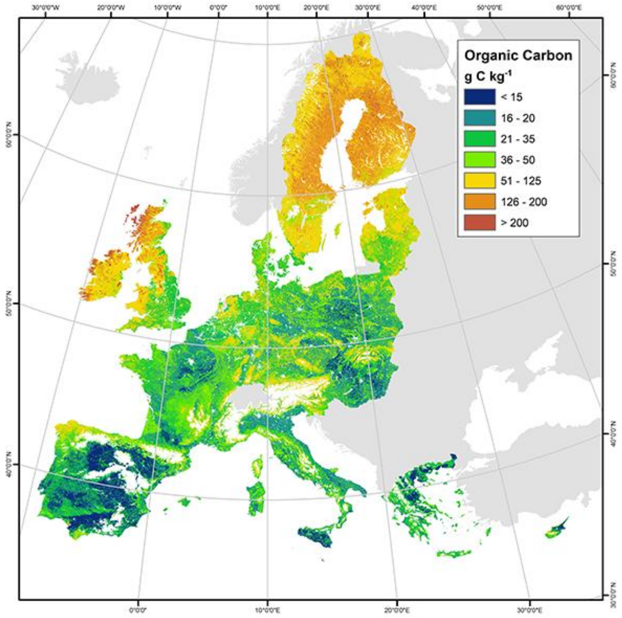

Figure 5: Map of Topsoil Organic Carbon content (g of C /kg of soil) for EU25 (de Brogniez *et al.*, 2014)

Decline in organic matter is usually due to soil erosion that causes severe problems in vineyards, reducing fertility and stability of aggregates, causes floods and landslides and affects the ecosystems functions.
One of the recognized soil functions is the Carbon dioxide (CO_2) stock capacity and the adoption of correct and sustainable conservation practices can both prevent erosion and enhance this function (García-Díaz *et al.*, 2016). Erosion causes both soil and organic matter losses: the average erosion-induced loss rates range from 6 to 52 gC m^{-2} y^{-1} (Jacinthe and Lal, 2001) where the amount depends on the C content of the soil. Starr *et al.* (2000) described the relationship between the loss of C in soil sediment, the content of organic C in soil (%) and the enrichment ratio of eroded sediments relative to the original soil; according to this relation C loss increases with the erosion rate and SOC content.

Due to erosion processes Carbon loss can happen along three pathways:
1. C contained into soil is transported and deposited elsewhere;
2. C is dissolved into run-off water during extreme events;
3. CO_2 emissions.

In Sicilian vineyards a compared analysis on conventional vineyard management and alternative soil management (use of cover crops such as *Vicia faba* and *Vicia sativa*) was carried out from November 2005 to April 2007 (Novara *et al*., 2011). Aim of the work was to evaluate how alternative management techniques affect C inputs, organic matter mineralization, soil erosion and soil structure. It is important to underline that enrichment in soil Carbon with cover crops management could lead to higher C losses as compared to conventional techniques. So García-Díaz *et al.* (2016) introduced the concept of SOC threshold as the level of SOC in alternative regime that results in a C loss that is equal to C loss using conventional management.
In the Sicilian case study soil erosion was lower under alternative management and the use of cover crops increase SOC that entailed a higher OC loss with this management than with conventional management. The risk of higher losses with cover crops can increase after few years so in the definition of alternative management it will be fundamental considering many factor such as cover crops species, pedoclimates etc...
In Spain, analysis on the degree in which cover crops (*Brachipodium distachylon*) and cereal crops (*Secale cereale)* reduce runoff and loss of SOC were performed in vineyards (Ruiz-Colmenero *et al*. 2013). Even though experimental period was limited (only 3 years) and aggregate stability due to the increase of SOC needs more time, the aggregate stability index decreased by about 30% in tilled vineyard and the SOC was, in this treatment, less than the amount found in cover crops plots, Total SOC loss under tillage was 0.06 t ha^{-1} y^{-1} while in cover crops treatment was 0.02 t ha^{-1} y^{-1} (Ruiz-Colmenero *et al*. 2013).

Also abandonment of cultivated land traditionally tilled, such as vineyards, causes an increasingly loss of organic carbon in topsoil layer and more of 4 years are necessary to recover part of organic matter after cessation of tillage (Acin-Carrera *et al.*, 2013).

ST3: "Soil contamination"

Many problems of soil contamination are related to copper (Cu) accumulation caused by the disease control strategies against downy mildew (caused by the Oomicete *Plasmopara viticola*); this is especially true under the organic production where only copper based products are allowed and 12-14 applications are performed per season.
Due to the worldwide spread use of fungicides in viticultural areas, especially in Europe, average values above 100 mg kg-1 of total Cu have been reported in literature and these values needs to be compared with UE thresholds (50-140 mg kg^{-1}) (EC, 1986). The European Union has also established a maximum annual dose of applied Cu (6 kg ha^{-1}) corresponding to an annual accumulation of metal in topsoil (10 cm) of 5 mg kg^{-1} (with no losses) (EC, 2002). In unpolluted soil Cu concentration is influenced by parental material and average value reach 30 mg kg^{-1}.
Using synthetic organic fungicides also has negative effects on soil health and residues in vineyard ecosystems are related to their solubility in water and adsorption coefficients (Komarek *et al.*, 2010).

Cu mobility is low and it is mostly mobilized by organic matter and Fe-Mn oxides in upper layers of soil, near plant roots (Komarek *et al.*, 2008); this part of soil has high susceptibility to water erosion and leaching so Cu can be subject to mobilization due to soil depletation.
In respect ot others crops in vineyards effects of Cu toxicity for plants can be less thanks to the high depth root system; but it is in any case important to limit the contamination of vineyard soils because the increase of Cu concentration might affect vine phenology, growth,reproduction, microbial soil communities balance and groundwater quality causing indirectly negative effects to vine (Komarek *et al.*, 2008).

Soil contamination by Cu is related to some factors:
- physico-chemical properties of soil (pH, texture -especially clay content-, soil organic matter...);
- tillage;
- erosion.

As stated before France has severe problems of Cu contamination reaching concentrations from 100 to 1500 mg kg^{-1}. (Bordeaux: 800 mg kg^{-1}; Alsace, Burgundy and Champagne: 400-500 mg kg^{-1}) (Brun *et al.*, 1998, 2001). Values show high variability due to different agricultural practices that affect distributed Cu quantities (Parat *et al.*, 2002).
Cu contamination may pose problem of Cu toxicity to plants (vine, grass and replacing crops), animals and humans; though, evaluating effects and eco-toxicological risk requires prediction of the bioavailability of metals. In such a context total Cu content in soil is not a good predictor of Cu effects on plant and microbial communities since Cu is often associated with soil components (organic matter, oxides, silicates..termed "fractionation of soil Cu") that will influence the mobility and bioavailability of the metal.
Bioavailability can be evaluated through chemical extraction (this method has received a lot of criticism due to analytical limitations) or through bioassay for accumulation in roots and shoots (Chaignon *et al.*, 2003, Navel and Martins, 2014). The latter method was used in a large study in Roujan region (France) using tomatoes as bioassay for vineyards soils. Values of extractable soil Cu ranged from 22 mg kg^{-1} to 398 mg kg^{-1}However, bioassay showed values of Cu in upper parts of plants setting below critical values, whereas but contamination was visible in roots. Other authors have confirmed that aerial parts of plants would not be the best indicators for Cu plant uptake (Brun *et al.*, 2001).
Phyto-toxicity was also reported as a problem in case of land use change. In France, Michaud *et al.* (2007) - analyzed growth and disease (especially chlorosis) in durum wheat grown in a Cu contaminated (30 to 1000 mg kg^{-1}) calcareous soil previously cultivated with vineyards and found linear relationships between root Cu concentration, soil Cu-content and Fe-deficiency.
Negative effects on microbial communities and earthworms (Paoletti *et al.*, 1998) and biochemical activity were observed in vineyards with high Cu-concentration, with evidence in the downturn of phosphatase, dehydrogenase and β-glucosidase activity above the Cu-total concentration threshold of 200-250 mg kg^{-1} (Fernández-Calviño *et al.*, 2010, Diaz-Ravina *et al.*, 2007)

In order to evaluate management techniques able to to reduce Cu-impact on soil, in Burgundy Navel and Martins (2014) assessed the effect of several long-term applications of organic amendments (conifer compost, straw) and cover crops (Fescue and Clover) on the biogeochemistry of copper. Straw and conifer amendments protect soil microorganism reducing Cu bioavailability, while clover reduces Cu-bioavailability for vines but not for bacterial communities.
Soil properties mostly influence Cu concentration and especially pH (higher concentration in acidic soils than in calcareous ones) (Fernández-Calviño *et al.*, 2009). In particular Cu can migrate along soil profile reaching water ground and mobility increases at pH values above 7.5 due to solubilization of SOM and formation of Cu complexes. Analysis of correlation between soil properties and soil fraction showed, for example, that Cu inhibits organic matter mineralization (Parat *et al.*, 2002)
Moreover, soil Cu accumulation does notshow a linear increase with vines age because along years vines show some devigoration with a subsequent lower disease impact of downy mildew; thus, fungicides are usually distributed in lower quantities and older vineyards (more than 20 years) show a reduction of total copper content (mg kg^{-1}) at all the analyzed depths (Rusjan *et al.*, 2007). Landforms also affect soil Cu concentration due to different slopes and water movement. Meso-climate also affects the number of fungicide sprays and, in turn, Cu accumulation in soils.
Erosion has an high impact on Cu soil content and ecosystem contamination; some reports argued that there is an high loss of Cu due to runoff and an enrichment of Cu from erosion sediments in Spain and Portugal (Fernández-Calviño *et al.*, 2008, 2009) and in France (Besnard *et al.*, 2001).

Also vineyards in Central-East and Sub-Mediterranean Europe have a long tradition of intense use of Cu-based fungicides due to climate conditions that favored fungi diseases. In Slovenia, vineyards are mainly planted in terraced areas on slopes over 30%. They are subjected to erosion phenomena and average total Cu concentration often exceedse 60 mg kg^{-1} decreasing along soil profile. Terracing affect Cu concentration that reaches 160 mg kg-1, higher than EU limit (Rusjan *et al.*, 2007).

In Czech Republic limit varies between 60 mg kg-1 (coarse-texture soil with less than 20% clay) to 100 mg kg^{-1} for high clay soil contents. (Ministry of Environment of Czech Republic 13/1994).
Komarek *et al.*, (2008) evaluated the range of metal (Cu, Pb and Cd) contamination (vertical and horizontal) in Czech vineyards of Boemia and Moravian regions representing several soils, climatic and management features. Regarding Cu, only one of the 6 studied vineyards respected the Czech and EU limits while the others reached concentrations of about 114 mg kg^{-1} (data are comparable with other countries contaminated vineyards soils). Interestingly, the highest copper concentrations were found in abandoned vineyards indicating that soil contaminant should be investigated before conversion. Also cadmium (Cd) concentration in all studied vineyards exceeded national limit (0.4 mg kg^{-1} that is more restrictive compared to the EU threshold set at 1 mg kg^{-1}). Conversely, lead (Pb) content di not exceed limits (50 mg kg^{-1} for Europe and 100 mg Kg^{-1}) for Czech Republic.

In Ukraine a wide analysis on metal concentration in vineyards, vines and wines of the Crimea Region was performed by Vystravna *et al.* (2014). Topsoil registered high values of Zn (54 mg kg^{-1} considering pseudo-total concentration) and Pb (4.61 mg kg^{-1}); Zn enrichment was probably due to fungicides (Mancozeb). In the aerial parts of the vine higher values of Cu were found in grapes and Zn in leaves.

In the Galicia region (North Western Spain) high content of Cu was assessed in topsoil characterized by steep slopes and high erosion threats, with values ranging from 25 to 730 mg kg^{-1} (Fernández-Calviño *et al.*, 2009, Gómez-Armesto *et al.*, 2015). In the Castilla-León region average value of 115 mg kg^{-1} of total Cu concentration in soil has been reported (Fernández-Calviño *et al.*, 2009). Moreover, in Spain Ramos (2005) pointed out also the impact, in terms of enrichment, of application of organic waste/compost on heavy metals (Cu, Zn, and Mn) soil concentration after land levellinf with Zn concentration to be the mostly affected
Marín *et al.* (2016) analyzed in La Roja spanish region the accumulation of Pb and Cd, elements that are also naturally released in soil by the degradation of rocks or present in soil due to anthropogenic activities. Pb and Cd are not required in soil so their accumulation has negative impacts on plants and food chains. Mean soil concentration of Pb and Cd was similar to concentration of undisturbed soils and lower than European Union upper limits; yet the creation of risk maps of contamination represents a useful instrument for policies. Besides contamination by metals, in Spain (La Roja) an overall analysis of persistent organic pollutants (POP) (herbicides, insecticides, fungicides) was performed (Pose-Juan *et al.*, 2015). It is well-known that

during treatment only a given fraction of pesticides targets the canopy, with the remaining part to be deposited in soils. The persistance of these substances depends on processes of adsorption, degradation and mobility that change during year according to operations and season. Highest concentration were found for *metalaxil* as a fungicide, *terbuthylazine* and *fluometuron* as herbicides and *methoxyfenozide* as insecticide. All compounds detected in soil were found also in water (pesticides or degradation products), sometimes in concentration higher than law threshold.

Also in Portugal analysis on soil Cu concentration were carried out and values up to 190 mg kg^{-1} were found (Fernández-Calviño *et al.*, 2009)
Analysis of soil Cu contamination in Greece in different crops were carried out on 54 samples (cereals, vegetables, vine, olive, fallow, orchard and citrus) (Vavoulidou *et al.*, 2005). Mean value of total Cu for the grapevine was 35.4 mg kg^{-1} but in several samples from the Nemea region average values reached Cu concentration of 130 mg kg^{-1}.

Country	***Element***	***Area***	***mg kg^{-1}*** *(EU limit 50-140 mg kg-1)*	***Reference***
France	**Total Cu**	Bordeaux	800	Brun *et al.*, 1998,2001
		Alsace, Burgundy, Champagne	400-500	
	Extractable **Cu**	Roujan	22-398	Brun *et al.*, 2001
Slovenia	**Total Cu**		60-160	Rujan *et al., 2007*
Czech Republic	**Total Cu**		114	Komarek *et al.*, 2008
	Cd		>0.4	
Ukraine	**Zn**	Crimea	54	Vistravna *et al.*, 2014
	Pb (acid soluble fraction)	Crimea	4.6	Vistravna *et al.*, 2014
Spain	**Total Cu**	Galicia	25-730	Fernández-Calviño *et al.*, 2009 Gomez-Arnesto *et al.*, 2015
	Total Cu	Castilla-León	115	Fernández-Calviño *et al.*, 2009
Portugal	**Total Cu**		190	Fernández-Calviño *et al.*, 2009
Greece	**Total Cu**		35.4-130	Vavoulidou *et al.*, 2005

Table 6: Comparative table of contaminant rate in citied literature

ST5: Soil compaction

Soil texture and porosity affect its natural susceptibility to compaction (*Figure 6).* However, in Mediterranean areas vineyards are also subjected to human activities such as high traffic due to repeated tillage and chemical or agronomical operations that deteriorate aggregates structure. Soil compacted by repeated passage of heavy agricultural machinery have a decreasing surface porosity and infiltration rates causing increasing erosion and runoff (Beslic *et al.*, 2015).Moreover soil compaction is one of the principal obstacles to root development and cause withering to vineyards, especially if compaction reaches deep soil layers. So compaction affects, indirectly, vineyard production (quality and quantity).
Compaction is caused both by superficial tillage and tractor traffic and, also, by deep tillage before planting.
Effects of deep tillage on soil structure depend mostly on soil moisture, soil and tillage typologies (Couolouma *et al.*, 2006). Effects of soil compaction on surface run-off and infiltration in loamy soils were studied in Southern France (van Dijck *et al.*, 2002). Analyses usually performed to evaluate soil compaction are assessment of bulk density, penetration resistance, and water retention and infiltration properties. Rainfall simulators are useful to measure water behaviour of soils (Rodrigo Comino *et al.*, 2016d). Also geostatistical analyses are useful in the field of "precision agriculture" in order to understand and explain better the spatio-temporal patterns of soil characteristics (Ferrero *et al.*, 2005). Lagacherie *et al.* (2006) applied visual assessment and morphological description of compacted soil features in order to produce a regional-scale analysis of phenomenon in the Hérault region.

Compaction effects are not uniformly distributed along the inter-row space. Main limitations occur under wheel track compacted strips and such a kind of compaction can be solved in 5 years of no-tillage regime. Used tractors in vineyards are usually 1.15-1.40 meters wide so load is concentrated in space near vine rows.
Soil management in vineyard can affect and reduce load impacts and consequent compaction processes. Grassing of inter-row spaces is also subject to tractors load for mowing and chopping operations but there is minimal direct impact on soil. In Piedmont Ferrero *et al.* (2005) compared conventional and permanent grass soil management in sloping vineyards and in Central Italy assessment of different soil management techniques was carried by Lipiec *et al.* (2007) who analysed effects on thermal soil properties, erosion and run-off and changes in vine vigour.

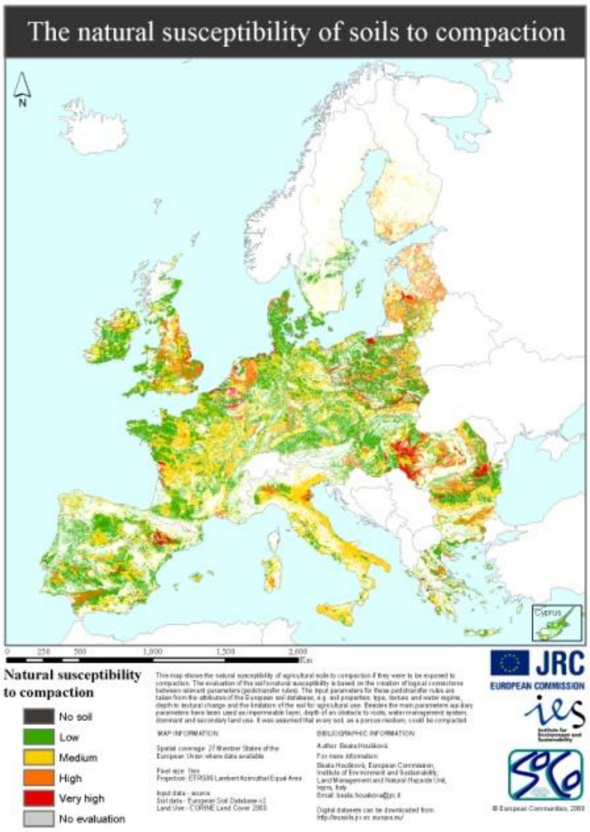

Figure 6: The natural susceptibility of soil to compaction (EC, 2008)

ST6: "Decline in soil biodiversity"

Soil Biodiversity in Europe is affected by many stresses and a wide analysis on potential risk was developed for EU-27 countries using expert knowledge and GIS (Orgiazzi *et al.*, 2016) taking into account threats at three levels (Soil microorganism, Soil fauna and Soil biological Functions) (*Figure 7*). Moreover, threats levels were classified according to land cover typologies and results showed that permanent crops (such as grapevine) are mainly subjected to high/moderate-high risk for each of the three components of soil biodiversity.

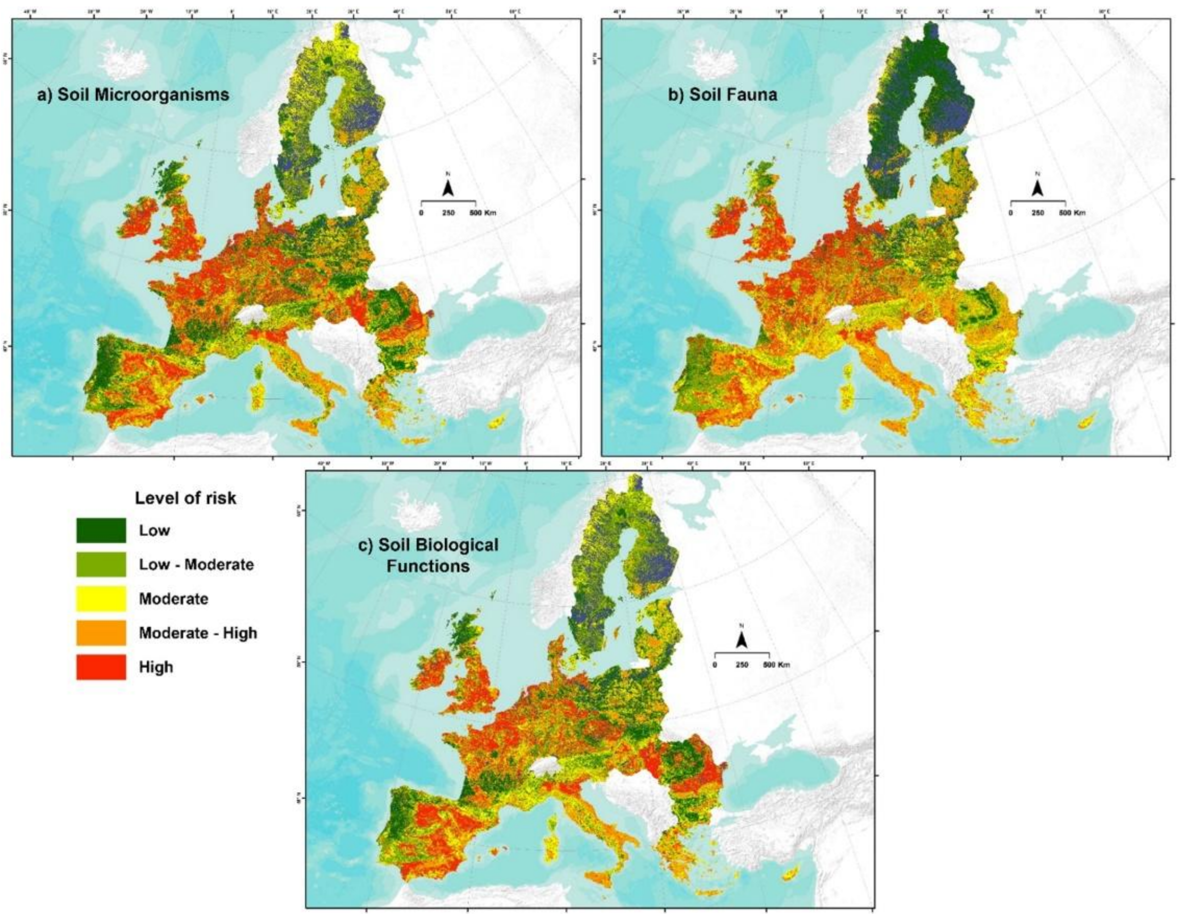

Figure 7: potential risk to soil biodiversity classified as risk to soil microorganisms (a), soil fauna (b) and soil biological functions (c) (Orgiazzi *et al*., 2016)

5. Vineyards soil threats solution applied across Europe

Many solutions have been applied in order to reduce effects of soil threats affecting soil and vine health. In literature there are many works aiming at analyzing effects of different soil management techniques that can be grouped into the three following classes:

- cover crops;
- terracing;
- mulching.

Some of these solutions have been already discussed in paragraph 3.

- **Cover Crops**

Cover crops are defined as *"temporary vegetative cover that is grown to provide protection for the soil and the establishment of plants [...]"* (OECD, 2001). Cover crops in vineyards are mainly used against erosion in slopes (*Table 7*)

.

In Italy grass covering was encouraged also by Rural Development Programme such as in Piedmont in 2007-2013 period. Here Bidoccu *et al.* (2017) tested the effects of different soil management in vineyards managed with conventional tillage (CT) and spontaneous grass cover (GC) in which residues were left on the soil surface. Results showed that GC increases the topsoil water content and grass covering reduced the run off rate (GC was 2-3.6 times higher in CGT than in CG). Erosion was reduced by covering and no tillage management with a decrease of sediments yield of about 80%. Grass covering was a mixture of *Lolium perenne* (20%), *Festuca rubra* (60%), *Poa nemoralis* (15%), *Poa trivialis* (5%).
In Southern Italy, analysis on erosion rates were performed in Sicily (Novara *et al*., 2011) comparing conventional tillage and alternative tillage using cover crops (*Vicia faba*, *Vicia faba* + *Vicia sativum;*

Trifolium subterraneum + Festuca rubra + Lolium perenne, Trifolium subterraneum + Festuca rubra + Festuca ovina, Triticum datum, Triticum darum + Vicia sativa). Most effective cover crops in reducing soil losses was *Trifolium subterraneum + Festuca rubra + Festuca ovina* (-76%) while the least effective was *Vicia faba* (only - 39.6%). Effects of covering with *Vicia faba* and *Vicia sativa* were tested in Sicily also by García-Díaz *et al*. (2016).

Analysis on the effects of different vineyard floor management were carried out also in Serbia vineyard region (Beslic *et al*., 2015) where the usual practice is the mechanical cultivation between the rows. Cover crops tested were grasses mixture of *Lolium perenne, Poa pratensis, Festuca rubra* and *Festuca ovina.* Tillage has led to soil depletion and the use of cover crops has been introduced with good results; in particular a decrease in grape yield associated with an increase in grape composition (i.e. phenols and , anthocyaninis) was demonstrated.

In Spain effects of cover crops on organic carbon and erosion rate were analyzed (Ruiz-Colmenero *et al*., 2011, 2013) comparing different types of covering species: *Secale cereale* and *Brachipodium distachylon. Brachipodium* enhanced soil organic content but needed to be managed correctly to avoid water competition against vines. Cover crops can reduce also negative effects of erosion in sloping vineyards. In Central Spain García-Díaz *et al*. (2017) compared different ground cover treatment: *Brachipodium distachyon* and spontaneous vegetation proved effective at reducing losses of nitrogen and runoff.

Species	References
Festuca ovina, Festuca rubra, Festuca spp.	Italy (Novara et al., 2011), Serbia (Beslic *et al.*, 2015), France (Navel *et al.*, 2014)
Lolium perenne	Italy (Novara et al., 2011), Serbia (Beslic *et al.*, 2015)
Poa pratensis	Serbia (Beslic *et al.*, 2015)
Poa nemoralis	Italy (Bidoccu *et al*, 2016)
Poa trivialis	Italy (Bidoccu *et al*, 2016)
Trifolium subterranum, Trifolium spp.	Italy (Novara et al., 2011), France (Navel *et al.*, 2014)
Triticum datum	Italy (Novara et al., 2011)
Vicia faba	Italy (García-Díaz *et al.*, 2016; Novara *et al.*, 2011)
Vicia sativum	Italy (García-Díaz *et al.*, 2016; Novara *et al.*, 2011)
Secale cereale	Serbia (Beslic *et al.*, 2015), Spain (Ruiz-Colmenero *et al.*,2013)
Brachipodium distachylon	Spain (García-Díaz *et al.*, 2017; Ruiz-Colmenero *et al.*, 2011, 2013)
Lolium italicum	Italy (Ferrero *et al*, 2015)
Trifolium repens	Italy (Ferrero *et al*, 2015)

Table 7: Species using in cover crops management

6. Survey on European stakeholders soil threats perception

In order to understand the impact of soil threats in Europe it was necessary to make a survey to assess the sensibility of stakeholders about how soil threats are perceived as a limiting factor.
A questionnaire was prepared from UCSC, VINIDEA and ERVET and it was sent to stakeholders (SHs) such as winegrowers, researchers, actors of the wine market chain and it was also published on websites and Facebook pages of the project and partners. Questionnaire was prepared in Italian, English, Spanish and French.

6.1 Structure of questionnaire

The questionnaire was structured in different sections (https://it.surveymonkey.com/r/5328NGQ for English version) and questions were referred to the wine region in which stakeholders work.

The first part was devoted to understand the incidence and impact on vineyards, with regards to their different areas (between rows, along the rows and in headlands), of each threat as defined by European Commission (EC, 2002 and 2006). Following sections were focused to each threat with questions aiming to assess the impact of each threat on the production factors as water efficiency, costs, quality and to determine the impact of different soil cover management techniques in each part of the vineyard. Moreover SHs had to

give indication regarding effectiveness of agricultural practices to reduce negative effects of that specific threat.
Last part of the questionnaire was about the assessment of the sensibility of stakeholders to policies aimed to support sustainable vineyard soil management and to evaluate which factors contributes more to the determination of vineyard economic benefits for the community that are not remunerated by market.

6.2 Results of survey

Questionnaire was sent to about 11.000 stakeholders between May and July. Only 157 responses were received. *Figure 8* shows the provenience of respondents.

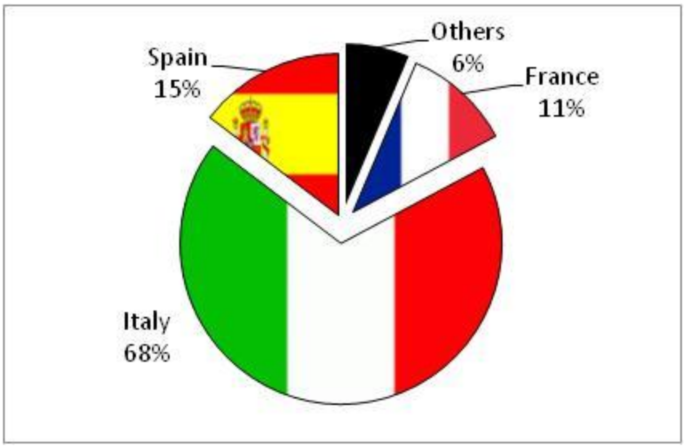

Figure 8: Countries of the 157 respondents to the questionnaire (update on 30/08/2017)

Stakeholders had to indicate how much they agreed with this sentence *"The quality of the soil has an effect on the quality of the vineyard ecosystem and on the quality of wine";* 93% of the responses was between "*definitely yes"* and only 7% was "*probably yes"* indicating that SH recognized the relationship between soil and quality.

In *Figure 9* the incidence of each threat classified in 5 classes (from none to high impact) is reported. *Salinization and flood and landslides* are not generally perceived as problems affecting vineyard soils and also *soil contamination* registered high percentage in low impact classes (78.7%).

Considering only *high impact* class *decline in organic matter* is the main perceived threat (23.9%). From the *Figure 9* it is clear that *erosion, decline in organic matter and soil sealing* are perceived as main threats (percentage of responses above 50% considering high and medium high classes).

Responses about localization of threats in vineyard spaces are so distributed: *between rows* main perceived threats are *soil sealing* (20.8%) and *soil compaction* (16.1%); *along the row* main reported threats are *decline in organic matter* (21.6%), *soil contamination* (16.6%) and *decline in soil biodiversity* (16.2%), in *headlands* main perceived threats are *flood and landslides (*28%) and *erosion* and *soil contamination* (16.5%). Analyzing responses according to each threats (*Figure 10*), in particular which was mainly perceived (as indicated in *Question 2*), *erosion* and *decline in organic matter* was mainly localized between rows while soil sealing in the headlands.

Soil cover management (*Question 5, Figure 11*) reveal that *spontaneous grass cover* is *common* (41%), *artificial grass cover* is areas in which SH works (considering without provenience distinction) is *uncommon* (47,4%), *cover crops/green manure* is reported as *uncommon* (49.6%) and finally *bare soil* is uniformly distributed in all classes of frequency.

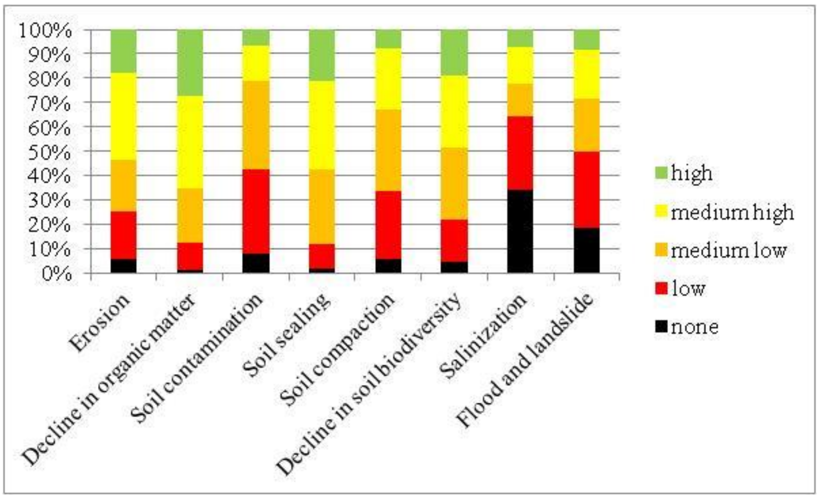

Figure 9: response to question 2 "*With reference to the winegrowing area in which you operate and according to your perception, what is the incidence of the following threats on the soil in vineyards?*"

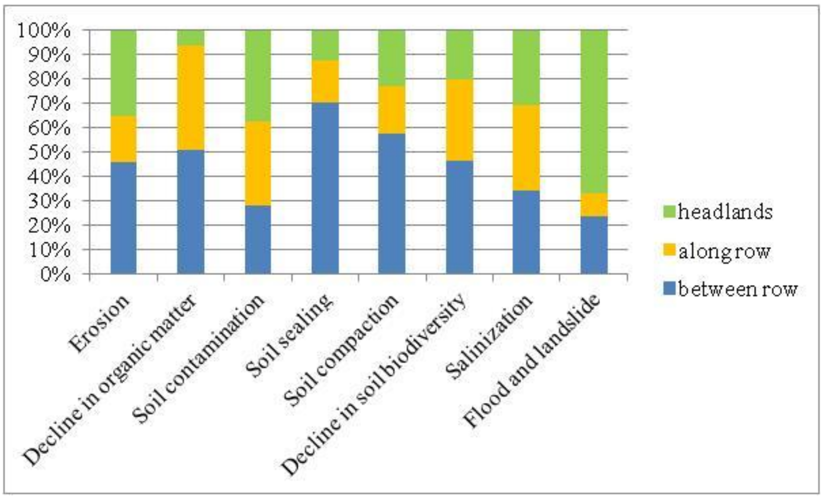

Figure 10: responses to question 3 " *What are the vineyard areas most at risk for each of the previous threats?*"

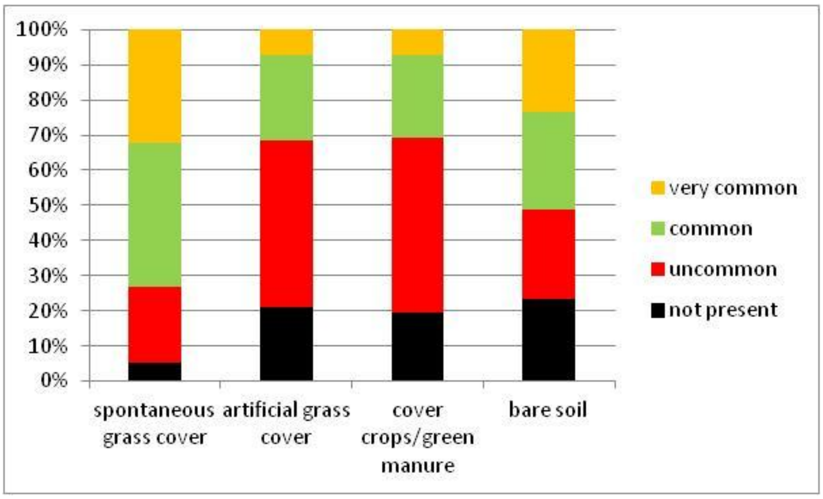

Figure 11: response to question 5 *" What is the soil cover in the vineyards of your territory (interface / row / in adjacent areas)"*

- **Erosion**

Stakeholders perceived the *water efficiency of the vineyard* as a major factor affected by erosion, but also high impacts are on *cost of tillage operations* and grape *quality. Other* impacts reported by SHs are related to loss of soil structure that affects soil management.

Responses to open questions regarding the main effective agronomical practices aiming at reducing erosion impact can be summarized in few actions:

  - grass cover (artificial or natural) under the row, between rows and in the headlands.
  - planting of cover crops such as legumes
  - drainage
  - good practices in tillage operations or minimum tillage.

- **Decline in organic matter**

Outcomes from the impact of a decline in organic matter show that this threat affects all proposed factors (grape *quality, fertility, water use efficiency of the vineyard and soil structure)* with *medium high/high* strength.

In the considered areas SHs reported that organic ammendants are commonly used (63.8%) and typologies are various (compost, manure, pelletted manure, microbiological amendments with *Bacilluss spp.*, marcs and pruning materials and green manure).

Agronomical practices to reduce decline in soil organic matter indicated by SH are also various but can be grouped in:

  - organic fertilization;
  - green manure using cover crops;
  - limitation of tillage;
  - burying of pruning materials;
  - grass cover.

- **Soil contamination**

Main affected factor by soil contamination reported by Stakeholders is grape *quality (*63% of responses in *medium high/high* classes). About the 57% of interviewed SHs reported that chemical fertilizers are commonly used and more frequent ones are N-P-K and micro-elements products.

Agronomical practices used to reduce soil contamination risk can be grouped in:

  - integrated and organic agriculture;
  - cover crops and green manure;
  - reduction of organic fertilization (sustainable distributions instead of "planned" ones);
  - reduction of chemical products such as copper based;
  - periodical analysis to verify irrigation water quality;
  - reduction of herbicide quantities;
  - higher use of manure.

- **Soil compaction**

From SHs the most affected factors by *soil compaction* are *water efficiency* and *soil structure* and common agricultural practices used to reduce soil compaction in vineyards are:

- grass cover (on the whole vineyard or in alternate inter-rows);
- cover crops with deep root system;
- use of caterpillar;
- passage only with dry soil;
- use of ripper;
- minimum-no tillage;
- organic ammendants.

- **Soil sealing, flooding and landslides**

According to SHs perception and opinion, *soil sealing* affects mainly *water regime regulation* soil function and ragarding the magnitude of soil sealing affecting vineyards land use, in general they are unaware with vineyards that in recent years were converted to urban use (77.8%).

Open question regarding opinion about most effective agronomic practices to limit the incidence of floods and landslides in vineyards generated various answers that were grouped into few categories:

- environmental engineering to protect soil and slopes;
- precipitation water management;
- management of channels and trenches;
- management of natural vegetation in headlands;
- terracing and good practices for vineyard planting and tillage;
- natural covering of vineyards soil.

- **Decline in soil biodiversity**

Outcomes show that SH perceived that the *decline in soil biodiversity medium/highly* affected all the proposed factors (grape quality*, water use efficiency, quality of organic matter and soil structure)* and good agricultural practices to reduce negative effects due to this threat are:

- organic agriculture;
- soil covering (grass or cover crops);
- reduce or eliminate herbicides;
- no tillage;
- enhancing of organic matter in soil (with manure, organic amendments....);
- enhancing biodiversity in headlands.

- **Salinization**

Outcomes show that SH perceived that *salinization medium/highly* affected all the proposed factors (*grape quality, water use efficiency, quality of organic matter and soil structure).* Main water source used are groundwater and water from natural and artificial lakes, channels and springs.

- **Socio-economical concerns**

Soil produces a series of benefits for the ecosystem and their magnitude is related to vineyard management and winegrowers approaches and decisions. This kind of benefits is not directly remunerated but some typologies of indirect funding have been identified, although still widely used and regulated. Stakeholders perceived *"Voluntary payments by consumers (duly informed)"* and *"Development of payment / compensation systems with marketing and distribution companies" as less effective tools while* gaving importance to the creation of a *specific trademarks and public contribution for organic farming.* This clearly shows that, from SHs point of view, remuneration of ecosystem services (ESS) has to be a public issue.
Going more in depth about main soil ecosystem services that impact on economical remuneration outcomes SHs feel that all the proposed ESS have *medium high/high* impact and in particular *cultural and landscape value*, that are strongly joined, are considered as primary ones.

7. Conclusions

Analysis of literature regarding soil threats in viticultural areas of Europe has revealed some interesting aspects. 90 case studies were analyzed and reported in Chapter 9 for each one indication of Journal, Author(s), keywords, main soil threats analyzed (according to European classification) and case study area were reported.
Regarding geographical distribution of papers they are concentrated in main European viticultural areas. Considering applied classification, not all the eight soil threats defined by the European Union are considered in the same way from researchers. In particular "erosion" is the most cited one (58 publications out of total, mainly located in Italy, France and whole Europe). Several methods for assessing degree and effects due to soil erosion are presented and discussed.
Figure 12 shows a word cloud indicating the distribution of keywords listed in papers classified as ST1 (erosion), size text being correlated to citation frequency.
Ecosystem functions of vineyards soils such as carbon stocks, heritage protection, habitat and source of biodiversity are less considered and few papers have focused on vineyard soil biodiversity decline or effects of contamination.
Regarding erosion, that is the main relevant threat with case studies in all of the principal vine-growing countries, methods for assessing its magnitude are various and also units are different (i.e. g m^2 for single event or t ha^{-1} y^{-1} for general vineyard measurements). This makes uneasy comparing data and results.

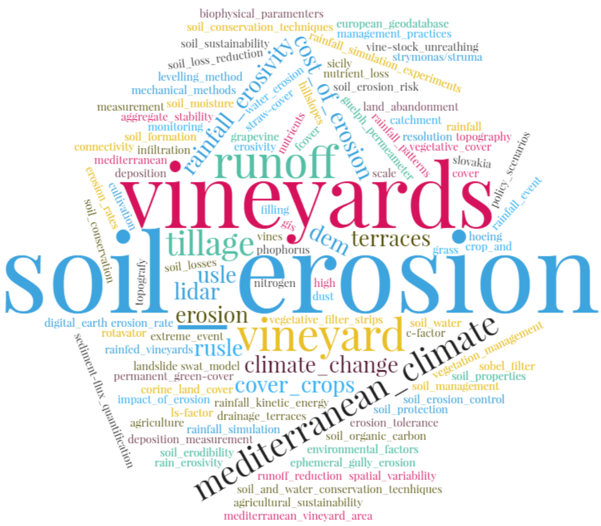

Figure 12: word cloud of ST1 papers keywords

Unfortunately, literature also reveals significant differences in outcomes (*Table 4*) and measured values considering the same country and it is difficult to summarize and compare results. This is clear in studies performed in East Europe where Cerdan *et al.*, 2010 reported estimated average values of 1.45 t ha^{-1} y^{-1} for Albania, Hungary, Slovenia and Slovakia that are several times smaller than the 28.3 t ha^{-1} y^{-1} in Albania (Zdruli *et al.*, 2016) Scale of analysis higly affect the obtained results but in general magnitude of this phenomenon is not sustainable and largely exceeds the defined tolerable thresholds. (0.3-12 t ha^{-1} y^{-1}) For example, considering application of RUSLE methods in traditionally tilled vineyards, erosion rate (t ha^{-1} y^{-1}) ranges between 5.2 in Germany (Auerswad *et al.*, 2009) to 66.8 in Spain (Arnaez *et al.*, 2007).
Main works compared different soil management techniques (tillage/no tillage/cover crops) but those comparisons need several years to obtain significant results, especially when one of the analyzed parameters is organic matter and many of them were carried out only for 2-3 years.
Few works have dealt with the decline of organic matter even if this is an important factor in the prevention of others threats such as erosion, water logging and depletion in soil biodiversity.

Contamination threats is focused on heavy metals content in vineyard soil due to fungicide applications; very little work has been done on the issues related to soil contamination (such as underground water contamination, effects on microorganism etc). Survey on soil threats aimed at a better understanding of the stakeholders perception about this matter; though, it has to be recognized the low number of fillers have devoted just few minutes to give opinions and suggestion for the project. This can be indirectly inferred as a sign of low level of interest to soil problems from wine chain actors. Responses disclose that sustainable management techniques are mostly known albeit at a quite general level and that their potential efficacy is still hidden to many fillers. Perception of economical value of soil ecosystem services is well perceived.

8. List of case studies references

Journal	*Year*	*Authors*	*keywords*	*ST code (EC, 2002,2006)*	*Title*	*Case study area*
Acta geographica Slovenica	2005	*Komac et al*	geomorphology, erosion, soil erosion, Besnica, Slovenia	ST1	***Soil erosion on agricultural land in Slovenia, measurement of rill erosion in the Besnica Valley***	Slovenia
Agriculture, Ecosystem and Environment	2017	*Garcia-Diaz et al*	Runoff simulation, nutrient loss, vineyards, soil management, groundcover	ST1	***Nitrogen losses in vineyards under different types of soil groundcover. A field runoff simulator approach in Central Spain***	Spain
Agriculture, Ecosystem and Environment	2009	*Raclot et al*	Erosion, Scale, Tillage, Mediterranean vineyard area, catchment	ST1	***Soil tillage and scale effects on erosion from fields to catchment in a Mediterranean vineyard area***	France
Agriculture, Ecosystem and Environment	2015	*Ramos et al*	Erosion rate, mediterranean climate, Rainfall patterns, Runoff, SWAT model, vegetative filter strips, vines	ST1	***Simulating soil conservation measures to control soil and nutrient losses in a small, vineyard dominated, basin.***	Spain
Agriculture, Ecosystem and Environment	2006	*Ramos et al*	Nitrogen, Phophorus, Soil losses, Vineyards, Runoff, Rainfall erosivity, Rainfall kinetic energy, Mediterranean climate	ST1	***Nutrient losses by runoff in vineyards of the Mediterranean Alt Penedès region (NE Spain)***	Spain
AIMS Agriculture e food	2016	*Ramos*	climate change, drainage terraces, rainfed vineyards, soil erosion, soil water	ST1	***Soil losses in rainfed Mediterranean vineyard under clumate change scenario. The effects of drainage terraces***	Spain
Bollettino Società Geologica Italiana	2006	*Bazzoffi et al*	land levelling, bulldozer, water erosion, vineyard, Italy	ST1	***Impact of land levelling for vineyard plantation on soil degradation in Italy***	Italy
Bollettino Società Geologica Italiana	2006	*Brenot et al*	erosion rate, vineyards, Burgundy	ST1	***Soil erosion rates in Burgandian vineyards***	France
Catena	2009	*Casalì et al*	Grafting callus, Paleosurface, soil erosion, sedimentation, vineyard.	ST1	***Determination of long-term erosion rates in vineyard of Navarre (Spain) using botanical benchmarks***	Spain
Catena	2014	*Chevigny et al*	Erosion pattern, 1 m-scale resolution, Historical landscape	ST1	***Lithology, landscape and management practice change: key factors patterning vineyard soil***	France

			structure, Land use changes, Vineyards, Dendrogeomorphology		***erosion at metre-scale spatial resolution***	
Catena	2008	*Corbane et al*	Soil surface characteristics, Spatial variability, Sampling design, vineyard, mediterranean climate	ST1	***Assessing the variability of soil surface characteristic in row-cropped fields: The case of Mediterranean vineyards in Southern France***	France
Catena	1997	*Kosmas et al*	land use, erosion, Mediterranean	ST1	***The effect of land use on runoff and soil erosion rate under Mediterranean conditions***	Spain and Portugal
Catena	2005	*Martinez-Casasnovas et al*	Ephemeral gully erosion, Filling, Cost of erosion, Vineyards, DEMs	ST1	***On site effects of concentrated flow erosion in vineyard fields: some economic implication***	Spain
Catena	2006	*Martinez-Casasnovas et al*	Soil erosion, Impact of erosion, Nutrient loss, Cost of erosion, vineyards	ST1	***The cost of soil erosion in vineyard fields in the Penedès-Anoia Region (NE Spain)***	Spain
Catena	2016	*Napoli et al*	Soil erosion, rainfall erosivity, RUSLE, C-factor, LS-factor, soil conservation	ST1	***Simulation of field-measured soil loss in Mediterranean hilly areas (Chianti, Italy) with RUSLE***	Italy
Catena	2010	*Paroissien et al*	Soil erosion, vineyard, vine-stock unreathing, spatial variability, connectivity	ST1	***A regional-scale study of multi-decennial erosion of vineyards field using vine-stock unearthing-burying measurements***	France
Catena	2016	*Prosdocimi et al*	Agriculture, erosion rates, topography, soil properties, rainfall, soil conservation techniques	ST1	***Soil water erosion on Mediterranean vineyards: A review***	Mediterranean regions
Catena	2004	*Ramos et al*	extreme event, erosivity, soil erosion, nutrients, DEM (Digital elevation model), vineyard, Mediterranean climate	ST1	***Nutrient losses from a vineyard soil in Norteastern Spain caused by an extraordinary rainfall event***	Spain
Catena	2016	*Rodrigo Comino et al*	Vineyards, Soil erosion, Runoff, Guelph permeameter, Rainfall simulation	ST1	***High variability of soil erosion and hydrological process in Mediterranean hillslope vineyards (Monte de Malaga, Spain)***	Spain

Catena	2013	*Ruiz-Colmenero et al*	Aggregate stability, Soil Organic Carbon, Vineyard, Vegetative cover, Water erosion	ST1	***Vegetation cover reduces erosion and ehances soil organic carbon in a vineyard in the Central Spain***	Spain
Catena	2008	*Quiquerez et al*	Sediment-flux quantification, Rainfall event, Hillslopes, Soil sustainability, vineyards.	ST1	***Soil degradation caused by a high-intensity rainfall event: Implication for medium-term soil sustainability in Burgandian vineyards***	France
Cuadernos de Investigacion Geografica	2017	*Kirchhoff et al*	soil erosion, organic vineyards, conventional vineyards, rainfall simulation, Gerlach trough	ST1	***Soil erosion in sloping vineyards under conventional and organic land use management (Saar-Mosel Valley - Germany)***	Germany
Earth Science Informatics	2016	*Zdruli et al*	G2, USLE, Gravilovic, Fcover, CORINE LC	ST1	***HigH resolution spatiotemporal analysis of erosion risk per land cover category in Korce region, Albania.***	Albania
Earth Science Review	2009	*Verheijen et al*	erosion tolerance, soil formation, climate change, soil protection, monitoring, dust deposition	ST1	***Tolerable versus actual soil erosion rates in Europe***	Europe
Earth Surface Processes and Landforms	2006	*De Santisteban et al.*	assessment of erosion, rill erosion, ephmeral gully erosion, Spain, Navarre	ST1	***Assessing soil erosion rates in cultivated areas of Navarre (Spain)***	Spain
Earth-Science Reviews	2012	*Maetens et al*	Soil and water conservation tecnhiques, runoff reduction, soil loss reduction, crop and vegetation management, soil management, mechanical methods	ST1	***How effective are soil conservation techniques in reducing plot runoff and soil loss in Europe and the Mediterranean?***	Europe
Ecology	2002	Š*uri et al*	soil erosion, USLE, GIS	ST1	***Erosion assessment of Slovakia at regional scale using GIS***	Slovakia
Environmental Science and Policy	2015	*Panagos et al*	Soil erodibility, RUSLE, Rain erosivity, Management practices, Agricultural sustainability, Policy	ST1	***The new assessment of soil loss by water erosion in Europe***	Europe

			scenarios.			
EUROPEAN COMMISSION	2004	*Kirkby et al*		ST1	***European Soil Bureau Reseach Report No. 16, EUR 21176***	Europe
EUROPEAN COMMISSION	2000	*van der Knijff et al*		ST1	***Soil Erosion risk Assessment in Europe***	Europe
Geoderma	2016	*Garcia-Diaz et al*	Agro-environmental measures, soil erosion, degradation, organic carbon	ST1	***Carbon input threshold for soil carbon budget optimization in eroding vineyards***	Italy
Geomorphology	2009	*Auerswald et al*	soil erosion, landuse, slope gradient, erosivity, Germany	ST1	***Rates of sheet and rill erosion in Germany - a meta analysis***	Germany
Geomorphology	2010	*Cerdan et al*	Erosion plot, Europe, Land use, slope gradient, soil texture, stoniness	ST1	***Rates and spatial variations of soil erosion in Europe: A study based on erosion plot.***	Europe
International Journal of Appplied Earth Observation and Geoinformation	2012	*Corbane et al*	Hydrological soil surface characteristic, Mediterranean vineyards, Expert knowledge, H-SSC evolution, Multitemporal classification, Aerial photos	ST1	***Multitemporal analysis of hydrological soil surface characteristics using aerial photos: A case study on a Mediterranean vineyard***	France
International Journal of Digital Earth	2012	*Panagos et al*	soil erosion, biophysical paramenters, digital earth, European geodatabase, Strymonas/Struma, Sobel filter	ST1	***Monthly soil erosion monitoring based on remotely sensed biophysical parameters: a case study in Strymonas river basin toward a functional pan European service***	Bulgary/Greece
Journal of Environmental Biology	2007	*Hacisalihoglu*	Soil erosion, Land use, Vineyard, ABAG, USLE	ST1	***Determination of soil erosion in steep slope with different land-use types: A case study in Mertesdorf (Ruwertal/Germany)***	Germany
Land Degradation & Development	2016	*Borrelli et al*	soil degradation, GIS-RWEQ, Soil Thematic Strategy, European Union, wind erosion modelling	ST1	***A new assessment of soil loss due to wind erosion in european agricultural soils using a quantitative spatially distributed modellind approach***	Europe
Land degradation and	2014	*Lieskovsky et al*	erosion modelling,	ST1	***Modelling the effect of vegetation***	Slovakia

development			erosion measurement, deposition measurement, levelling method, hoeing, rotavator, cultivation, grass cover, slovakia		***cover and different tillage practices on soil erosion in vineyards: a case study in Vrable (Slovakia)***	
Le vigneron Champenois	1986	*Ballif and Herre*		ST1	***Ruissellement et erosion dans le vignoble champenois. Synthese des mesures effectuees entre 1981 et 1984***	France
Plant soil and Environment	2011	*Vršič*	grapevine, tillage, straw-cover, permanent green-cover	ST1	***Soil erosion and earthworm population response to soil management system in steep-slope vineyards***	Slovenia
Proceeding of Rabat Symposium	1997	*Goubesville*		ST1	***Soil erosion in the vineyards of Champagne***	France
Science of Total Environment	2016	*Rodrigo Comino et al*	Soil erosion, Runoff, Infiltration, vineyards, Rainfall simulation experiments, Environmental factors.	ST1	***Quantitative comparison of initial soil erosion processes and runoff generation in Spanish and German vineyards***	Spain and German
Scientia Horticulturae	2015	*Beslic et al*	Floor management, Soil water content, Stem water potential, Xigour, Yeld, Fruit composition	ST1	***Effect of vineyard floor management on water regime, growth response, yeld and fruit quality in Cabernet Sauvignon***	Serbia
Soil and Tillage Research	2007	*Arnaez et al*	Erosion, vineyards, Rainfall simulation, USLE-M, La Riojam, Spain	ST1	***Factors affecting runoff and erosion under simulatedrainfall in Mediterranean vineyards***	Spain
Soil and Tillage Research	2017	*Biddoccu et al*	soil management, vineyards, soil hydrological properties	ST1	***Temporal varibility od soil management effects on soil hydrological properties, runoff and erosion at fiel scale in a hillslope vineyard, North-West Italy.***	Italy
Soil and Tillage Research	2009	*Blavet et al*	Erosion, Mediterranean region, vineyards, soil cover, aggregate stability, calcic luvisols, rainfall simulation	ST1	***Effect of land use and management on the early stage of soil water erosion in French Mediterranean vineyards***	France
Soil and Tillage Research	2000	*Martinez-Casasnovas et al*		ST1	***Impact assessment of changes in land***	Spain

					use/conservation practices on coil erosion in the Penedès-Anoia vineyard region (NE Spain)	
Soil and Tillage Research	2011	*Novara et al*	Cover crops, Mediterranean, Soil erosion control, vineyard, sicily	ST1	***Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyards***	Italy
Soil and Tillage Research	2011	*Ruiz-Colmenero et al*	Erosion, Vineyards, Soil moisture, Cover crops, Tillage	ST1	***Soil and water conservation dilemmas associated with the use of green cover in steep vineyards.***	Spain
Soil erosion issues in agriculture	2011	*Corti et al*		ST1	***evaluation of erosion intensity and some of its consequences in vineyards from two hilly environments under mediterranean type of climate, Italy***	Italy
	2007	*Lopez-Bermudez et al*		ST1	***La degradacion del suelo por erosion hidrica en Espana***	Spain
Hydrology	2016	*Rodrigo Comino et al*		ST1	***Soil Erosion Processes in European Vineyards: A qualitative Comparision of Rainfall simulation Measurement in Germany, Spain and France***	Spain, Germany and France
Catena	2007	*Ramos et al*	Soil erosion, Runoff, Soil moisture, Land levelling, Mediterranean rainfall, vineyards	ST1/(ST4)	***Soil loss and soil water content affected by land levelling in Penedès vineyards, NE Spain***	Spain
Agriculture, Ecosystem and Environment	2016	*Rodrigo Comino et al*	vineyard, Ruwel-Mosel valley, soil erosion, Gerlach trough, Stock unearthingh method, RUSLE	ST1/ST5	***Soil erosion in sloping vineyards under conventional and organic land use management (Saar-Mosel Valley - Germany)***	Germany
Journal of Environmental Biology	2011	*Vršič et al*	viticulture, Soil management, Erosion, Climatic changes, Soil macro-organism	ST1/ST6	***Effect of soil management systems on erosion and nutrition loss in vineyards on steep slopes***	Slovenia
Anthropocene	2014	*Tarolli et al*	Terraces, Land abandonment, Soil Erosion risk, Landslide, Lidar	ST1/ST8	***Terraced landscape: From an old best practice to a potential hazard for soil degradation due a land abandonment***	Italy
Journal of Map	2016	*Incze et al*		ST1/ST8	***Identification of extent, topographic characteristics and land***	Hungary

					abandonment process of vineyard terraces ub Tokay-Hegyalja wine region between 1784 and 2010	
Land degradation and development	2015	*Tarolli et al*	vineyards, terraces, lidar, high resolution topografy, soil erosion	ST1/ST8	***Vineyards in terraced landscapes: new opportunities from LIDAR data.***	Italy
European Journal of Soil Science	2015	*de Brogniez et al*		ST2	***A map of the topsoil organic carbon content of Europe generated by a generalized additive model***	Europe
Soil Use and Management	2013	*Acin-Carrera et al*	Livestock routes, abandoned lands, vineyards, soil organic carbon, soil structure, agricultural policies	ST2	***Impact of land-use intensity on soil organic carbon content, soil structure and water-holding capacity***	Spain
Communication in Soil Science and Plant Analysis	2005	*Vavolidou et al*		ST3	***Copper content in Agricultural soils related to cropping system in different region of Greece***	Greece
Environmental Pollution	2001	*Besnard et al*		ST3	***Influence of organic amendments on copper distribution among particle-size and density fractions in Champagne vineyard soils***	France
Environmental Pollution	2001	*Brun et al*	Copper, contamination, bioavaiability, vineyard, bordeaux mixture	ST3	***Evaluation of copper avaiability to plants in copper-contaminated vineyard soils***	France
Environmental Pollution	2003	*Chaignon et al*	Copper, Bioavaiability, Extractability, Soil properties, Tomato	ST3	***Copper biovaialability and extractability as related to chemical properties of contamined soils from a vine-growing area***	France
European Journal of Soil Science	2008	*Fernandez-Calvino et al*		ST3	***Copper distribution and acid-base mobilization in ineyard soils and sediments from Galicia (NW Spain)***	Spain
European Journal of Soil Science	2002	*Parat et al*		ST3	***The relationship between copper accumulated in vineyard calcareous soil and soil organic matter and iron***	France
Geoderma	2008	*Komarek et al*	Copper, metal, vineyard, soil contamination, pesticide	ST3	***Copper contamination of vineyard soils from a small wine producers: A case study from Czech Republic***	Checz Republic
Geoderma	2007	*Rusjan et al*	Accumulation, Copper, Pesticied, Soil, Vineyard	ST3	***Copper accumulation regarding the soil characteristic in Sub-***	Slovenia

					mediterranen vineyard of Slovenia	
Journal of Environamental Quality	2007	*Diaz-Raviña et al*		ST3	***Tolerance (PICT) of the bacterial communities to copper in vineyard soils from spain***	Spain
Journal of Environmental Management	2006	*Ramos*	vineyard, compost, total metal, extractable fraction, Cu, Zn, Mn	ST3	***Metals in vineyard soils of the Penedès area (NE Spain) after compost application***	Spain
Land degradation Development	2016	*Marin et al*	lead and cadmium, vineyard soils, guideline levels, spatial variability, La Rioja D.O.Ca.	ST3	***Lead and Cadmium in soils of La Rioja vineyards, Spain***	Spain
Plant soil	2007	*Michaud et al*	Copper, Iron, pH, Phytotoxicity, Rhizosphere, *Triticum turgidum durum L.*	ST3	***Copper uptake and phytotoxycity as assessed in situ for durum wheat (Triticum turgidum durum L.) cultivated in Cu-contaminated, former vineyard soils.***	France
Science of the Total environment	2015	*Pose-Juan et al*	Pesticide residues, vineyard soils, spatial and temporal distributions, soil characteristics	ST3	***Pesticide residues in vineyard soil from Spain: Spatial and temporal distribution***	Europe
Soil Biology & Biochemistry	2010	*Fernandez-Calvino et al*	vineyards, Copper fractionation, Wnyme activities, Soil degradation	ST3	***Enzyme activities in vineyard soils long-term trated with copper-based fungicides***	Spain
Spanish journal of soil science	2015	*Gomez-Armesto et al*	Fractionation, organic matter, contamination, heavy metals, Iberian Peninsula.	ST3	***Copper content and distribution in vineyard soils from Betanzos***	Spain
Environmental International	2010	*Komarek et al*	Pesticide, Viticulture, Copper, Toxicity, Environmental risk	ST3	***Contamination of vineyard soils with fungicides: A review of environmental and toxicological aspects.***	World
Food Chemistry	2014	*Vystravna et al*	Vineyard, Muscat white, Chardonnay, Trace metals, Crimea	ST3	***Trace metal in wine and vineyard environment in southern Ukraine***	Ukraine
Geoderma	2009	*Fernandez-Calvino et al*	vineyards, Cu fractionation, Soil properties, multivariate	ST3	***Copper accumulation and fractionation in vineyard soils from temperate humid zone (NW Iberian***	Spain

			analysis		***Peninsula)***	
Applied Soil Ecology	1998	*Paoletti et al*	Aptorectodea caliginosa, Agroecosystems, Octodrilus lissaensis	ST3/ST6	***Earthworms as useful bioindicators of agroecosystem sustainability in orchards and vineyards with different inputs.***	Italy
Science of the Total environment	2014	*Navel and Martins*	Vineyard soil, Physical fractionation, Copper speciation, Amendant and vegetation, soil micro-aggregates, biovaiability to plants and bacteria	ST3/ST6	***Effect of long term organic amendments and vegetation of vineyard soils on the microscale distribution and biogeochemistry of copper.***	France
Geoderma	2006	*Lagacherie et al*	vine, compaction, soil structure, regional diagnosis, soil tillage, deep ploughing, wheeling, languedoc	ST5	***Spatial variability of soil compaction over a vineyard region in relation with soil and cultivation operations***	France
International Journal of Heat and Mass transfer	2007	*Lipiec et al*	Thermal conductivity, Heat capacity, Thermal diffusivity, Soil compaction, Water content	ST5	***Impact of soil compaction and wetness on thermal properties of sloping vineyard soil***	Italy
Soil and Tillage Research	2006	*Coulouma et al*	Deep tillage, Soil structure, Morphological analysis, Bulk density, Saturated hydraulic conductivity	ST5	***Effect of deep tillage for vineyard establishment on soil structure: A case study in Southern France***	France
Soil and Tillage Research	2005	*Ferrero et al*	Penetration resistance, Bulk density, Water content, Sloping vineyard, Management, Spatial effects	ST5	***Effects of tractor traffic on spatial variability of soil strength and water content in grass covered and cultivated sloping vineyard***	Italy
Soil and Tillage Research	2002	*van Dijck*	Tractor traffic, Soil compaction, Infiltration, Vineyards, Southern France	ST5	***Compaction of loamy soils due to tractor traffic in vineyards and orchards and its effect on infiltration in southern France***	France
Science of Total Environment	2016	*Orgiazzi et al.*	Soil biodiversity, Risk assessment, Land-use planning, Soil biota	ST6	***A knowledge-based approach to estimating the magnitude and spatial patterns of potential threats to soil***	Europe

			conservation		***biodiversity***	
Bullettin of Engineering Geology and the Envionment	2013	*Cevasco et al*	Shallow landslides, Terraced slopes, Heavy rainfall, Land management, Cinque Terre, Liguria	ST8	***The influence of geological and land use setting on shallow landslide trigged by an intensive rainfall event in a coastal terraced environment***	Italy
Geologia	2006	*Komac et al*	landslides, susceptibility, influence factors, model, Slovenia	ST8	***Landslide susceptibility map of Slovenia at Scale 1:250000***	Slovenia
Natural Hazard and Hearth System Sciences	2003	*Crosta et al*		ST8	***Soil slips and debris flows on terraced slopes.***	Italy
Soil and Tillage Research	2016	*Bordoni et al*	Grapevine, Roots, Soil mechanical reinforcement	ST8	***Quantifying the contribution of grapevine roots to soil mechanical reinforcement in an area susceptible to shallow landslide.***	Italy

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