MAY VINEYARD FLOOR MANAGEMENT AFFECTS INDICATORS OF SOIL QUALITY?

Elena MANIA[1], Nicoletta ALLIANI[2], Matteo GIOVANNOZZI[2], Fabio PETRELLA[2], Luca GANGEMI[1], Silvia GUIDONI[1*]

[1] *DISAFA - Università degli Studi di Torino, Largo Braccini 2, 10095 Grugliasco, Italy*
[2]*IPLA,Corso Casale 476, 10132 Torino, Italy*
**Corresponding author: Guidoni E-mail: silvia.guidoni@unito.it*

Abstract

Soil management techniques may influence soil vulnerability to threat factors such as erosion, compaction, loss of organic matter and biodiversity, contamination and, interacting with pedoclimatic and geo-morphological conditions, they may regulate soil chemical, physical and biological fertility. It has been observed that soil disturbance actions such as tillage, chemical weed, contamination may interact with edaphic communities, but this topic has been very poorly studied in vineyards. The objective of the study was to evaluate some soil quality parameters in vineyards subjected to different soil management practices.

The vineyards were located in Piedmont (North West Italy) in the production area of Barolo wine. The soils were characterized by profile description, chemical-physical analysis, estimation of compaction and erosion. The used floor management techniques were described and amplitude and homogeneity of the natural grass cover were estimated. Biological fertility was assessed evaluating arthropod community (QBS-ar), microbial respiration and microbial biomass.

The vineyards had an average slope of 14°, soils presented fine texture, high limestone content and alkaline pH; these factors determine a generally high erosion vulnerability. Autumn tillage alternating row-interspaces or on each row-interspaces is the most diffused floor management practice. Despite inter-row natural grass cover is becoming increasingly widespread in the this area, its application does not seem related to the prevention of soil vulnerability and to improve soil quality; for that reason no robust evidence of interactions between cultivation practices and soil quality indicators emerged from this first results. Nevertheless, it is clear that major and deeper informations would allowed farmers to be aware in choosing soil management techniques; in addition, more efficient practices in protecting soil from threats need to be widely spread, especially in vulnerable areas.

Keywords: steep slope vineyards, natural grass cover, tillage, soil compaction, soil biological fertility, microbial respiration, microbial biomass, BSQ-ar, soil microarthropods.

1 INTRODUCTION

Soil management techniques have considerable potential to mitigate or increase soil vulnerability to threat factors such as erosion, compaction, loss of organic matter and biodiversity, contamination. Cultural choices, interacting with the pedoclimatic and geo-morphological conditions, can therefore help to regulate many aspects of the soil quality. The grass cover may play a huge role in protecting soil from physical damages (Ferrero et al. 2005) or in increase environment biodiversity (Norris and Kogan 2000; Marshall et al. 2003; Baumgartner et al. 2005) as well as, it is reported that soil disturbance actions such as tillage, chemical weed, fertilization may interact with edaphic communities (Doles et al. 2001; Marinari et al. 2006; Moscatelli et al. 2007; Fließbach et al. 2007; Tabaglio et al. 2009; Sanguankeo and León 2010; López-Piñeiro et al. 2013). Soil quality commonly is indirectly evaluated estimating some biological indicators such as BSQ-ar (Parisi et al. 2005), microbial biomass, basal respiration (Fließbach et al. 2007; Probst et al. 2008); however, this aspect has been very poorly studied in vineyards.

The hilly area of Langhe Piedmont, North-West Italy, has an extension of about 4000 km^2 and has a temperate suboceanic climate. The deep slopes (on average 10-20 %) and their high vulnerability to soil erosion, cause severe limitations to the soil use (AAVV 2007). Erosion effects and landslides are considerably increased in this area as a consequence of intense and frequent meteoric events, more and more diffuse in the recent years. The fragility of the hilly slopes is amplified by the widespread intensive viticulture, by the levelling and excavation works operated for establishing vineyards (Bazzoffi and Chisci 1999; Guidoni et al. 2012) and by the not always convenient cultivation techniques. These reasons make the considered area an ideal environment for developing projects purposing to identify appropriate measures for the protection and the preservation of deep slope land, where, in particular, vineyards are established.

The objective of the present part of the study was to evaluate the impact of soil chemical-physical characteristics and soil management practices on soil biological quality and, secondarily, to spread more and more the use of good practices in order to protect soil from threat factors.

2 MATERIALS AND METHODS

The study took place in 2012-2013 in Piedmont, in an area characterized by steep slopes extensively covered by vineyards, largely used for the Barolo DOCG wine production. 19 vineyard soils were characterized by profile description (IPLA 2003), chemical-physical analysis (MiPAF 2000), estimation of erosion (Wischmeier and Smith 1978). A soil "texture index" was calculated as [(Silt + clay + very fine sand)/fine sand + coarse sand)]. The soil management techniques were identified and the amplitude and homogeneity of the natural grass cover were assessed during summer season, in six plots for each vineyard by measuring the width of grassing and estimating the percentage of the cover. In the same plots, in order to estimate soil compaction, bulk density was assessed by sampling a known volume of soil between 2.5-7.5 cm, on the center of the alleys and on the wheel tracks. In order to assess biological fertility, on the alley center, earth clods were sampled and microbial biomass (Vance et al. 1987), microbial respiration (Sequi et al. 2003), total organic carbon (TOC) (Springer and Klee 1954) and arthropod community (BSQ-ar) (Parisi 2001; D'Avino 2002) were evaluated.

Chemical-physical data were normalized and submitted to the principal component analysis (PCA). To evaluate sampling adequacy and to test the correlations between variables, the Kaiser–Meyer–Olkin (KMO) index and the Bartlett's test of sphericity were applied, respectively.

3 RESULTS AND DISCUSSION

The vineyards were located on slope (in average 14°), at an average elevation between 245 and 480 m above see level; the slope exposure varied from North-East (74°) to North-West (327°). Ten of the studied soils belonged to the order of Entisols, eight to the Inceptisols and one to the Alfisols (AAVV 1999) (Table 1). The lithologic substrate of this area is 'Marne di Sant'Agata Fossili' (marls, composed of gray or gray-whitish silty-clayey marls); these soils present a high amount of carbonates coming from parent material ($CaCO_3$ 21.2 % and pH 8.3 on average) and a loamy texture, whit a high amount of fine silt (Table 1) (Guidoni et at. 2013). The organic carbon (OC) in these soils was often present in low or very low amount, the C/N ratio indicate a general prevalence of the mineralization process and the Cation Exchange Capacity (CEC) variable from 5.3 and 17.5 meq 100g $^{-1}$, well correlated with the organic carbon content (r^2 = 0.64) (Table 1).

Table 1: Vineyards descriptions, physical and chemical indices of soil quality (OC: organic carbon; CEC: Cation Exchange Capacity).

SITES	Altitude (m a.s.l.)	Exposure (°)	Slope (°)	Soil order	Texture	OC (%)	C/N	CEC (meq 100g $^{-1}$)
271	480	250	3	Inceptisol	Loam	1.02	12.8	17.5
272	337	225	5	Entisol	Silty loam	0.40	2.9	6.8
273	390	190	14	Inceptisol	Loam	0.64	6.4	9.8
274	330	235	5	Entisol	Silty loam	0.71	7.9	6.6
283	332	174	13	Inceptisol	Silty loam	1.44	7.6	16.9
284	286	266	13	Inceptisol	Silty loam	0.81	3.5	8.0
285	250	250	16	Entisol	Silty loam	1.76	6.8	18.0
286	330	327	17	Entisol	Silty loam	1.05	6.2	13.8
287	315	340	12	Entisol	Silty loam	1.50	8.8	-
288	320	300	8	Inceptisol	Silty clay loam	0.71	5.1	13.8
289	377	209	12	Entisol	Silty loam	0.42	3.5	8.9
290	420	280	14	Entisol	Silty clay loam	0.54	3.0	7.6
291	360	200	20	Inceptisol	Loam	0.78	4.9	8.7
292	280	146	19	Inceptisol	Loam	1.41	7.4	12.9
293	255	170	10	Inceptisol	Silty clay loam	0.47	4.3	7.5
294	220	135	20	Entisol	Loam	0.52	4.3	5.3
295	373	90	18	Entisol	Clay loam	2.72	11.3	13.5
296	265	74	10	Alfisol	Clay loam	1.21	7.1	16.4
297	285	104	20	Entisol	Silty clay loam	1.19	5.4	11.9

Autumn tillage alternating row-interspaces or on each row-interspaces (T) and inter-row natural covered by grass (CG) were the most diffuse floor management practice in the observed sites; in both situation grass chopping was performed in summer season. When PCA was applied to the best model obtained after application of the KMO test (0.71) and Bartlett's test of sphericity (p-value = 0.013) to the chemical-physical parameters (Figure 1), the sites were ordinated on the base of their composition and bulk density more than on the base of the applied floor management techniques. The used variables were OC, CEC, C/N, Ca/K, texture index, bulk density. PC1, PC2 and PC3 explained, respectively, 46, 18 and 14 % of the model variance; OC, CEC and C/N were highly correlated to the PC1; Texture index, Ca/K to the PC2 and bulk density to the PC3.

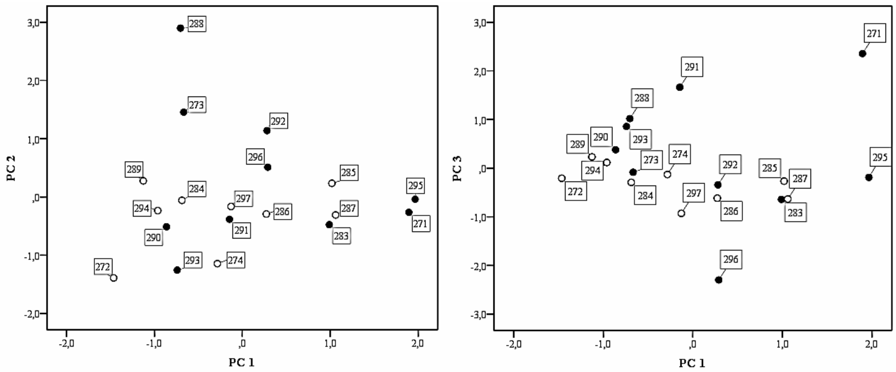

Figure 1: Distribution of the sites as resulting from the submission of the chemical-physical parameters to PCA (PC1 *vs* PC2 on the left, PC1 *vs* PC3 on the right). ● = inter-row permanently covered by grass; ○ = inter-row tilled during autumn season.

Nine of the 19 sites were in the 'high' or 'very high' erosion classes, i.e. the estimated values of annual soil loss were above 15 and 30 t ha-1, respectively (AAVV 2007). Only in five sites, estimated erosion was less than 6 t ha-1 year-1, that is considered a sustainable amount of soil loss (Bazzoffi and Tesi 2011) (Table 2).

Table 2: Floor management techniques, evaluation of soil erosion and bulk density values.

SITES	Floor management*	Soil erosion ($t \cdot ha^{-1} \cdot year^{-1}$)	Erosion class**	Inter-row bulk density ($g\ cm^{-3}$)	Wheel-tracks bulk density ($g\ cm^{-3}$)
271	CG	4	medium	1.47	1.67
273	CG	22	high	1.55	1.42
283	CG	8	medium	1.14	1.45
288	CG	7	medium	1.47	1.35
290	CG	3	medium	1.32	1.60
291	CG	8	medium	1.49	1.49
292	CG	77	very high	1.17	1.49
293	CG	44	very high	1.52	1.64
295	CG	43	very high	1.31	1.56
296	CG	7	medium	1.14	1.44
272	T	46	very high	1.41	1.47
274	T	2	low	1.30	1.40
284	T	27	high	1.32	1.40
285	T	13	medium	1.27	1.35
286	T	2	low	1.36	1.40
287	T	31	high	1.42	1.43
289	T	20	high	1.39	1.32
294	T	2	low	1.20	1.40
297	T	24	high	1.18	1.42
mean ± s.e	CG	22.3 ± 7.76	---	1.36 ± 0.03	1.47 ± 0.03
mean ± s.e	T	18.5 ± 5.17	---	1.31 ± 0.03	1.40 ± 0.02

**CG = inter-row permanently covered by grass; T = inter-row tilled during autumn season.*
***Low < 3 ($t \cdot ha^{-1} \cdot year^{-1}$); medium 3÷15 ($t \cdot ha^{-1} \cdot year^{-1}$); high 16÷35 ($t \cdot ha^{-1} \cdot year^{-1}$); very high > 35 ($t \cdot ha^{-1} \cdot year^{-1}$)*

However, it seems that growers, in choosing the floor management technique, did not take into account the factors increasing soil propensity to erosion, i.e. soil texture and land slope, as demonstrate by the high heterogeneity of the estimated erosion values within the CG or T sites (Table 1 and 2). As expected, in tilled vineyards the bulk density values were lower both on the centre of the alleys and on the wheel tracks; nevertheless, even when no tillage were made, the soil compaction was well under the level that may negatively impact on the root growth (Table 2) (Jones 1983). Thus, these values are not high enough to justify annual tillage in order to loosen and aerate the top layer of soil.

Unlike an ideal situation in which grassing should cover the 80 % of the inter-row distance, i.e. excluding the portion below vines given by the projection of the canopy on the ground, and considering the average values of all the vineyards, the width of grass strips was no more than 57 % of the inter-row surface. The coverage was limited (around 50 %) also in CG vineyards where, instead, a higher homogeneity of coverage was expected if compared to T vineyards. The lack of differences between differently managed floors (Table 3) seems to be attributable to a non-optimal grassing management that did not allow to obtain a homogeneous coverage and an effective action against erosion.

Table 3: Width (as % of inter-row) and coverage (%) of grassed strips in permanently grassed (CG) and autumn tilled (T) vineyards (mean values of 2012 and 2013).

SITE	Width (% of inter-row)	Coverage (%)	SITE	Width (% of inter-row)	Coverage (%)
	Permanently grassed (CG)			Autumn tilled (T)	
271	65	66	272	40	36
273	55	54	274	58	49
283	68	78	284	66	38
288	62	68	285	58	38
290	51	40	286	49	30
291	62	63	287	46	44
292	61	52	289	71	45
293	51	33	294	51	77
295	76	37	297	56	55
296	42	21			
mean ± s.e.	59 ± 2.58	51 ± 5.72	mean ± s.e.	55 ± 3.44	46 ± 4.65

The assessment of soil microbial biomass and soil respiration, the calculation of derived indexes (microbial carbon:TOC ratio and qCO_2) and the evaluation of the SBQ-ar are useful for estimating the soil biological quality (Fließbach et al. 2007; Probst et al. 2008). Floor management technique did not influence the soil quality attributes (Figure 2) but a huge impact of the season was observed on TOC and microbial carbon and, as a consequence, on the derived ratios (Figure 2). As reported (Marinari et al. 2006), the values of microbial carbon:TOC and qCO_2 ratios may be influenced by the soil management strategy (organic *vs* conventional); in particular the ratios were increased and decreased, respectively, when organic strategy was performed in durum wheat, mainly due to organic fertilizations. Since in our study, the higher values were obtained in 2013, that was the rainiest season, it could be assume that also the meteorological conditions may influence the development and activity of the edaphic community.

The increased efficiency of microbial population during 2013 was also described by the low value of qCO_2 index; in other words, the microbial biomass required a lower amount of substrate to obtain an equal amount of energy reducing the mineralization rate of the organic matter. For that reason, the qCO_2 index is inversely related to the energy transforming efficiency; thus it can be an indirect indicator of soil biological quality (Marinari et al. 2006).

The BSQ-ar analysis estimates soil biological quality evaluating the characteristics of the soil microarthropods community (Parisi 2001); microarthropods *taxa* presented in the first layer of soil (20 cm) were identified and a score was attributed to each of them according to the biological forms identified in the sample. Biological forms estimate the level of adaptability to soil conditions of each individual. Among biological forms, the eu-edaphic groups are particularly important being forms adapted to deep soil life (i.e. losing pigmentation and visual apparatus; losing appendages like hairs, antennae, legs, wings). Higher is the number of microarthropods groups well adapted to the soil habitat, higher is the value of BSQ-ar index and higher is soil quality (Parisi 2001).

Three field replicates of each soil were analyzed and, on the base of the BSQ-ar score, were placed in arbitrary BSQ-ar classes and the percentage of samples within each class was calculated (Figure 3). On the contrary to the expected, T soils were insert in higher BSQ-ar classes (Figure 3a) and, if compared to CG soils, a higher percentage of samples included numerous eu-edaphic groups (Figure 3b). Seasonal sample distribution (Figure 3c and 3d), confirmed the findings of the soil biological fertility analysis (Figure 2), namely that vintage (or soil water conditions) may affects the behaviour of the microarthropods community. This hypothesis remains to be verified as no studies on this topic are present in literature.

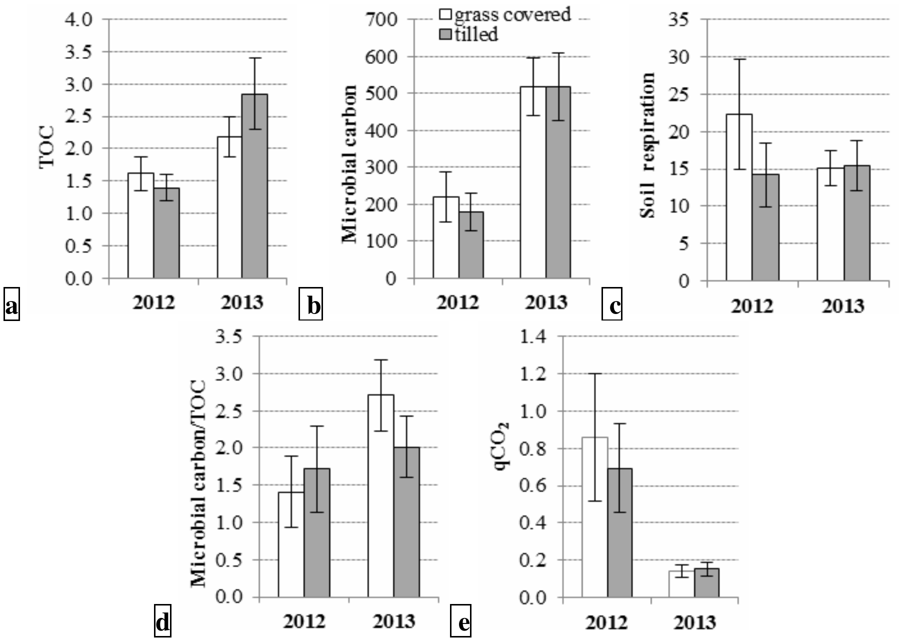

Figure 2: Soil biological fertility indexes for 2012 and 2013; [a: Total organic carbon (TOC) (g C 100 g^{-1}); b: Microbial carbon (mg C kg^{-1}); c: Soil respiration (mg C kg^{-1} day^{-1}); d: Microbial carbon /TOC (%); e: qCO_2 (soil respiration/microbial carbon)].

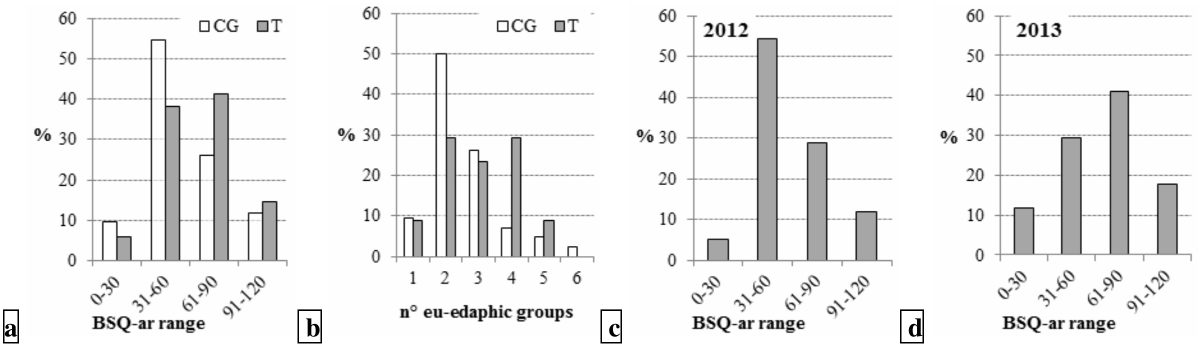

Figure 4: Biological Soil Quality (BSQ-ar) for 2012 and 2013; [a and b: BSQ-ar and percentages of eu-edaphic groups, respectively, of CG and T samples, as mean values of 2012 and 2013; c and d: BSQ-ar in 2012 and 2013, respectively, as mean values of CG and T samples]

4 CONCLUSION

The study aim was to verify the biological quality of soils in steep slope vineyards, tilled in autumn or permanently grass covered, through the evaluation of specific indexes. An important incongruity emerged between the site characteristics and chemical-physical properties of the soils and the applied floor management techniques. It seems that the techniques were not chosen as a function of soil vulnerability to threats such as erosion or loss of fertility (biodiversity), due to a lack of knowledge of the technical issues more than negligence. It follows, in the first instance, the need for a better application of techniques such as grassing, very useful to maintain or improve soil fertility and quality. Therefore, seasonal variability influenced the behaviour of edaphic community much more than used techniques, probably for the imperfect application of grassing and/or to the limited intensity of tillage in this area. The evaluation of soil quality indexes can help to understand the effect of anthropic actions on the conservation of soil biodiversity and to evaluate the potential of edaphic community in maintaining soil fertility. Since this type of assessment has been very little applied to the vineyard, there are no confirmations and deepening in scientific literature, but a certain interest in viticulture is expected where sustainable agricultural strategies are increasingly request. In fact, unlike other crops, vineyards have excellent potential in preserving the agro-ecosystem quality.

Aknowledments: *We would like to thank Syngenta for funding and the wineries participating to this project .*

5 LITERATURE CITED

AAVV. 1999. Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys. Second Ed., Agriculture Handbook, 436. USDA, Natural Resources Conservation Service .

AAVV 2007. Carta dei suoli del Piemonte 1:25.000. Regione Piemonte. S.E.L.C.A. Firenze.

Baumgartner, K., R.F. Smith, and L. Bettiga. 2005. Weed control and cover crop management affect mycorrhizal colonization of grapevine roots and arbuscular mycorrhizal fungal spore population in a California vineyard. Micorrhiza. 15(2):111-119.

Bazzoffi, P., and G. Chisci. 1999. Soil conservation techniques in vineyards and peach orchards of the Cesena hilly area. Riv. Agric. 33:177-184.

Bazzoffi, P., and P.C. Tesi. 2011. Effectiveness of the GAEC standard of cross compliance. Prohibition of performing unauthorized land leveling on soil erosion control. Italian Journal of Agronomy. 6(s1):e4.

D'Avino, L. 2002. Esposizione della qualità biologica del suolo (QBS-ar) e proposta della standardizzazione delle procedure. Depositato presso Museo di Storia Naturale, Dipartimento di Scienze Agrarie, Forestali e Alimentari. Biologia evolutiva e funzionale, Università degli studi di Parma.

Doles, J.L., R.J. Zimmerman, and J.G. Moore. 2001. Effects of broad-spectrum insecticides on epigeal arthropod biodiversity in Pacific Northwest apple orchards. Environ. Entomol. 29:340-348.

Ferrero, A., B. Usowiczb, and J. Lipiec. 2005. Effects of tractor traffic on spatial variability of soil strength and water content in grass covered and cultivated sloping vineyard. Soil & Tillage Research. 84:127–138.

Fließbach, A., H.R. Oberholzer, L. Gunst, and P. Mäder. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems and Environment. 118:273–284.

Guidoni, S. F. Petrella, and M. Giovannozzi. 2013. The lands of Barolo and Barbaresco. The complexity of Piedmont soils. Tong. 16:23-28.

Guidoni, S., L. Gangemi, and E. Mania. 2012. Slope viticulture risk factors impacting on the environment equilibrium. The case of north-west Italy. Proceeding of IXth International Terroirs Congress 2012. 6-37-6-39.

IPLA. 2003. Manuale di campagna per il rilevamento e la descrizione dei suoli. Rev. 03/marzo 2006/DS01P11.

Jones, C.A. 1983. Effect of soil texture on critical bulk density for root growth. Soil Science society of America Journal. 47(6):1208-1211.

López-Piñeiro, A., A.B. Muñoz, C.E. Zamora, and M.B. Ramírez. 2013. Influence of management regime and phenological state of the vines on the physicochemical properties and seasonal fluctuations of the microorganisms in a vineyard soil under semi-arid conditions. Soil & Tillage Research. 126:119-126.

Marinari, S., R. Mancinelli, E. Campiglia, and Stefano Grego. 2006. Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. Ecological Indicators. 6:701–711.

Marshall, E.J.P., B.K. Brown, N.D. Boatman, P.J. Lutman, G.R. Squire, and L.K. Ward. 2003. The rule of weeds in supporting diversity within crop fields. Weed Research. 43:77-89.

MiPAF - Ministero delle Politiche agricole e forestali - Osservatorio Nazionale Pedologico e per la Qualità del Suolo, Metodi di analisi chimica del suolo, FrancoAngeli, 2000.

Moscatelli, M.C., A. Di Tizio, S. Marinari, and S. Grego. 2007. Microbial indicators related to soil carbon in Mediterranean land use systems. Soil & Tillage Research. 97:51–59.

Norris, R.F., and M. Kogan. 2000. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. Weed Science. 48(1):94-158.

Parisi, V. 2001. La qualità biologica del suolo. Un metodo basato sui microartropodi. Acta Naturalia de "L'Ateneo Parmense", 37(3/4):97-106.

Parisi, V., C. Menta, C. Gardi, C. Iacomini, and E. Mozzanica. 2005. Microarthopod communities as a tool to asses soil quality and biodiversity: a new approach in Italy. Agriculture Ecosystem and Environment. 105:323-333.

Probst, B., C. Schüler, and R.G. Joergensen. 2008. Vineyard soils under organic and conventional management - microbial biomass and activity indices and their relation to soil chemical properties. Biol Fertil Soils. 44:443–450.

Sanguankeo, P.P, and R.G. León. 2010. Weed management practices determine plant and arthropod diversity and seed predation in vineyards. Weed Research. 51:404-412.

Sequi, P., A. Benedetti, and M.T. Dell'Abate. 2003. Atlante di indicatori della qualità del suolo ATLAS. Ed. Ministero delle Politiche Agricole e Forestali, Osservatorio Nazionale Pedologico e CRA – Istituto Sperimentale per la Nutrizione delle Piante, Roma.

Springer, U., and J. Klee. 1954. Prüfung der Leistungsfähigkeit von einigen wichtigen Verfahren zur Bestimmung des Kohlenstoffs mittels Chromschwefelsaure sowie Vorschlag einer neuen Schnellmethode. Journal of Plant Nutrition and Soil Science. 64:1-26.

Tabaglio, V., C. Gavazzi, and C. Menta. 2009. Physico-chemical indicators and microarthropod communities as influenced by no-till, conventional tillage and nitrogen fertilization after four years of continuous maize. Soil & Tillage Research. 105:135-142.

Vance, E.D., P.C. Brookes, and D.S. Jenkinson. 1987. An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem. 19:703–707.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting Rainfall Erosion Losses. A Guide to Conservation Planning. USDA Agricultural Handbook, 537, Washington, D.C.