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Effects of Land-Use Change on Soil Functionality and Biodiversity: Toward Sustainable Planning of New Vineyards

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Abstract: Sustainable agriculture largely depends on soil biodiversity and requires efficient methods to assess the effectiveness of agronomic planning. Knowledge of the landscape and relative pedosite is enriched by data on the soil microarthropod community, which represent useful bio-indicators for early soil-quality detection in land-use change (LUC). In the hilly Maremma region of Grosseto, Italy, two areas, a >10ys meadow converted into a vineyard and an old biodynamic vineyard (no-LUC), were selected for evaluating the LUC effect. For maintaining soil vitality and ecosystem services by meadow, the vineyard was planted and cultivated using criteria of the patented "Corino method". The aim was to evaluate the LUC impact, within one year, by assessing parameters characterizing soil properties and soil microarthropod communities after the vineyard was planted. The adopted preservative method in the new vineyards did not show a detrimental impact on the biodiversity of soil microarthropods, and in particular, additional mulching contributed to a quick recovery from soil stress due to working the plantation. In the short term, the adopted agricultural context confirmed that the targeted objectives preserved the soil quality and functionality.

Keywords: sustainability; vineyards; best agronomic practices; Collembola; Acari

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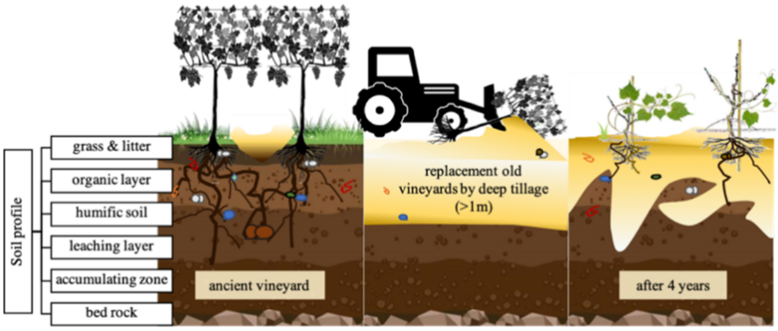
1. Introduction

In terms of soil functionality maintenance, high-quality soils have ensured the integration of soil productivity with other ecosystem services. During the last few years, European policies have enhanced compliance and rules to avoid land degradation [1]. Sustainable development goals for soil management address efforts of rural development and, simultaneously, protection of soil functionality [2]. To support short-term needs and long-term (global) goals, the conventional practices for the new planting of vineyards should be reviewed.

The global agriculture challenge is to increase the output from available land while reducing the negative effects of its use [3]. The traditional agricultural landscape is disappearing due to land-cover changes, and these modifications in vegetation impact regional climate, carbon sequestration, and biodiversity [4]. During the last few years, concern for the environment and sustainability has compelled many governments to adjust land-use policies to balance multiple uses of land resources [4] by increasing expectations that productive agricultural landscapes should be managed by coupling preservation or enhancement of biodiversity [5]. At the various trophic levels in the food chain, the interactions between the communities of soil can be altered according to different strategies of soil management: farming increase and agronomic practices (i.e., land-leveling soil and deep tillage) impact belowground biodiversity [5]. Furthermore, the conversion of natural habitats to agriculture or other intensive human land uses leads to biodiversity loss [6].

Changes in land use have mainly been studied regarding their consequences on productivity and human well-being [7], while their effects on the environment have been poorly investigated [8]. Referring to land-use change (LUC), only a few current European monitoring systems have focused on the status and/or trends recorded in soil functions [9,10]. High activity in physicochemical processes and richness of organisms is recognized in the upper soil layer (from 0 to 20 cm); however, at the same time, this is the layer most vulnerable to erosion and degradation [3]. Usually, the conversion of natural habitat to agricultural land results in the reduction of the edaphic species' richness, along with lower genetic variability and the loss of functional groups/ecosystem functions [11]. Microtopographical changes occurring during and after the planting of vineyards induce soil structural changes, which directly affect ecosystem services and biodiversity for a potentially long time lag [12]. However, little is known about how soil structural changes occur during and after the planting of vineyards and which key factors and processes play a major role in soil degradation due to cultivation works. In viticulture, deep earthworks performed before the plantation of vine plants severely affect the properties of the soil profile, vine phenology, and grape yield by altering the ecosystem functioning for years [13,14]. After deep tillage, soil organism communities are simplified and often need several years to recover [14,15] (Figure 1a). Deep ploughing may not be beneficial for soil types high in clay, as it can simply reseal the clay bank [16]. Conventional ploughing (≥30 cm depth) hinders soil aggregate formation and depletes soil organic matter, thus returning soils to early stages of ecological succession and stimulating soil erosion with the loss of the nutrient-rich upper soil layer [14]. Furthermore, the economic issue must also be considered. In hilly Italian viticultural areas, the cost of a new vineyard, including mechanization and labor, amounts to approximately EUR 20,000/ha [17].

a) conventional floor preparation for new vineyard



b) no-loss of soil structure

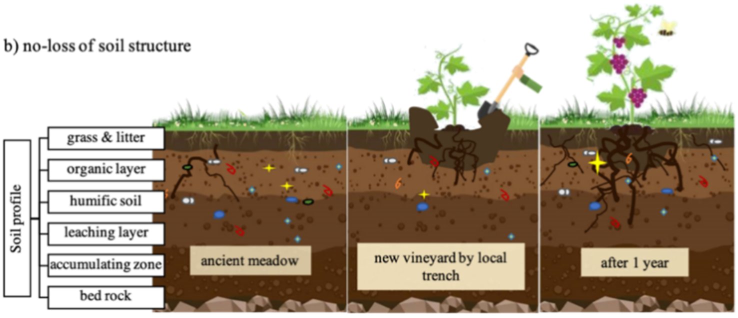


Figure 1. A cross-section of the soil profile in two different examples of management for starting new vineyards in hilly areas: (**a**) no land-use change, deep earthworks, and substitution of an ancient vineyard by implying a recovery time for soil functions and grape production >4 years [10]; (**b**) land-use change with the "Corino method" by maintaining the soil "heritage" using perennial meadows as the biological potential ecosystem service described in this study case (pre- and post-LUC).

The area selection of a new vineyard can be the starting point for a well-prepared soil bed: some sites are suited to low-mowed row middles of native vegetation, while others may require annual planting of winter grasses [16]. Recently, the culture, lifestyle, landscape patrimony, longevity of vineyards, and asset value of the land, as well as farmers' profit margins, were jointly considered in the "Corino method", aiming at increasing the vitality of the soil and the health of the environment, producers, and consumers [18] (Figure 1b). The benefits provided by minimal soil disturbance are multiple: they rely on physical (i.e., erosion reduction, increase of water retention, temperature), chemical (organic carbon storage, nutrient availability, pH), and biological (diversity of organisms, soil quality) properties of soils [19].

Under reduced mechanical disturbance, maintaining the soil profile results in a positive effect on the stability of soil aggregates and mycorrhizal associations. The development of grass cover protects soils from erosion and extreme temperatures [8].

Soils with a good structure allow air, water, and nutrients to move freely through pores within and between the aggregates, thereby influencing the water and nutrient reservoir for vine growth [20]. The content of organic matter and other chemical parameters of soil impact nutrient availability and, indirectly, crop plant growth. Concerning soil organic matter in the soil agro-ecosystems, the more considered living soil components are plant and microorganism contributions [21,22]. Studies focusing on the mesofauna community have not been provided to assess the effects of land use on soil biodiversity. Several ecosystem functions are ascribable to mesofauna and strictly related to soil fertility and agricultural production (i.e., the decomposition of the organic matter and nutrient cycling) [23,24]. A more diverse and abundant soil community provides better soil functions [25], efficiently returning ecosystem processes [26,27]. The biomass and density of the microarthropod population closely reflect the resource availability [25], promoting organic matter breakdown and the recycling of essential nutrients for plant growth [8,28].

Assessments of soil biodiversity can be highly indicative to estimate the impact of human activity and soil biological quality. To quickly assess soil disturbance, the presence of most adapted forms of hypogeal life and assemblage of the edaphic arthropod fauna community can represent a useful tool [2,29,30]. By evaluating the microarthropods' level of adaptation to the soil, the multitaxon indication by the index of Biological Soil Quality (BSQar) can provide efficient information [29]. Several studies have been carried out in vineyards for the evaluation of soil biodiversity and variability among management systems [31], the influence of soil physical and chemical characteristics on the edaphic community [15], and comparison of different ecological indices, e.g., the Shannon diversity index, etc. [30,32,33]. Considering the richness and abundance of soil arthropods as biotic factors, to be incorporated in landscape modeling, their use may implement, at a low cost, the evaluation of short-term conservation in viticulture.

This study aimed to estimate the effects on the short-term change in soil biodiversity for a pluriannual meadow after its conversion into a vineyard, by following rules in the cited Corino method. This purpose was pursued by evaluating if the entire soil-beneficial "inheritance" passes on from the meadow to the vineyard. The approach is based on the possible role, through LUC, of the previous natural habitat (meadow) not as a competitor—i.e., for water availability—but rather as valuable and functional in maintaining ecosystem services, in addition to being a resource involved in assuring natural mulching.

2. Materials and Methods

2.1. Study Area

The study area is in the central part of the Maremma region (Grosseto province, Tuscany, Italy) (Figure 2), and is characterized by hills between 300 and 600 m above sea level, dotted with sulfur-rich sources of water (such as those of nearby the Saturnia-Springs). Soils are shallow but rich in substances useful for the vine plant. The climate is mild, typically Mediterranean, with a constant wind all year round and a dry summer period. Viticulture is the primary activity in the local agricultural economy; its ancestral link with grapes has been strong since the time of the Etruscans, who settled in this area between the sixth and the first century B.C.

Figure 2. Two study areas (satellite image source: Google 2019): the LUC area (5100 m^2, Coord. X: 42.639210, Y: 11.539317) and no-LUC area (8200 m^2; coord. X: 42.619682, Y: 11.537605) delineated by the dotted white circles and 4 different plots (VV area: 4200 m^2; VM area: 4000 m^2; VN area: 3000 m^2; MC area: 2100 m^2) delineated by the red boxes. The schematic representation of the experimental design describes the steps during the conversion process (LUC) from meadows to new vineyards by conservative practices in the upper soil layer (from 0 to 20 cm).

The area extends to approximately 1.8 ha and consists of two areas, distant 2 km, selected as part of a vegetable-based biodynamic farm (La Maliosa Farm, Saturnia, Italy) (Figure 2). The studied vineyards lie on south-/southwest-facing slopes, about 300 m above sea level, in a complex mosaic landscape characterized by multicultivar vineyards surrounded by natural elements such as natural boundaries (i.e., trees and high fences). Farm management was based on the Corino method (IT Patent approved in 2019, IT201700005484A1), a set of agricultural practices developed by the farm owner and focused on soil vitality and environmental health [16]. The method makes use of good protection against erosion and the improvement of self-fertility by exploiting the role of green manure and natural mulching to improve the soil structure. The strengthening of the living organisms, helped by a gas exchange of oxygen/CO_2, will provide sustainable vitality in soil and permanent benefit for grapevines.

Here, vineyards have been rewarded by adopting Tuscan Maremma's historical native vine varieties (mainly Ciliegiolo, Sangiovese, Procanico, and Cannonau grigio). The vine plants were reclaimed from a >50-year-old and semiabandoned vineyard; this choice exploited the wealth of grapevine germplasm, both for the red and white vines selected and retrieved within the farm. For vine disease containment, powdered sulfur of 80 kg/ha and copper metal of less than 3 kg/ha/year were applied. The vine vegetation was arranged on stakes without shoot topping to prolong the foliar activity until late in the season, and pruning mixed with arch, spurred cordon, and sapling.

Considering the soil as a living organism to be preserved in its functions, the vineyard location and grape varieties were chosen to minimize preplanting earthworks and to maintain the natural grassland bed.

The vine rows were not oriented along the maximum gradient of the land, but instead where natural terraces allowed the mitigation of soil erosion, to save the value of the landscape and to maximize the physiological functions of the young plants [16]. In all vineyards, the inter-row spaces were kept under natural grass cover throughout the year. The grass was periodically mowed (two times/year), shredded together with plant residues, and spread on the soil surface as a source of organic matter and to avoid possible plant competition. The contemporary adoption of intercropping with mulches, green manure, and periodic cultivation equipment with manual management (no mould-board plough use) was aimed at enhancing vital soil processes both in the short and long term.

Four vineyards were selected in the two different areas (Figure 2): Vigna Nuova (VN) and Monte Cavallo (MC), in the LUC area, established in March 2014 after land-use conversion from grassland; and Vigna Vecchia (VV) and Vigna Maliosa (VM), in the no-LUC area, with pluridecennial vine plants.

A first soil sampling was carried out in June 2013 to gain information about microarthropod communities and soil texture in all sites. A few months later, in November 2014, two experimental subplots were selected within each area: (1) one managed by straw mulching (mu) between vine plants, in order to reduce soil erosion, control weed development, and improve soil moisture content; and (2) a second one kept as a control plot without any mulching treatment. Different soil-sampling procedures were planned according to the specific analyses to be performed. In each vineyard, three soil cores (7 × 5 cm, 10 cm depth) were collected from the intrarow space, at 20 cm from the vine plant, for zoological analysis. Close to these soil cores, three subsamples were collected by auger to 20 cm depth for chemical (total organic C, total N, total $CaCO_3$, pH, and electrical conductivity) and physical (particle-size distribution) analyses.

2.2. Soil Properties and Microarthropod Communities

Soil texture was determined using the SediGraph method [34] and the USDA classification [35]. The extraction of micro-arthropods was carried out by Berlese-Tullgren selectors for 5 days; specimens were collected in jars with 80% ethanol solution and were counted at a stereomicroscope (10×–60×). Mean microarthropod density was calculated by year (pre- and post-LUC), area (ancient vineyards, grassland, and new vineyards) and plot (VV, VM, NV, and MC). To determine the effects of LUC, differences in the population structure were analyzed among arthropod densities of three main abundant groups: Acari, Collembola, and “other arthropods”. In order to assess the biological soil quality (BSQar), the microarthropods were separated into biological form (BF) morphotypes (see Parisi et al. [29]) according to their degree of morphological adaptation to soil life. Each BF was associated with a score, ranging from 1 (surface-living organisms) to 20 (deep-living organisms). Generally, the soil was considered to have a good “biological quality” when the soil fauna community was abundant and diversified in well-adapted forms to an edaphic environment. For estimating the complexity, stability, and thus general health of soil ecosystem, the following diversity indices were also calculated: taxa richness (S), the Margalef index [36], the Shannon diversity index (H’) [37], Buzas and Gibson’s evenness index (E’) [38], Simpson’s index (1-D) [39], and the Berger–Parker index [40].

2.3. Mulching Effect on Soil

After LUC, each vineyard was split into two subplots: (1) added straw mulch (mu) and (2) control without mulching (no-mulch). The soil chemical parameters in both subplots were subjected to a Pearson’s correlation coefficient. The material for chemical analysis was sampled by 3 topsoil (0–20 cm) cores randomly in each subplot using a hand-auger. The samples were air-dried and sieved through a 2 mm mesh before analysis. For C and N determination, a representative fraction from each sample was ground and homogenized to 0.5 mm. TOC and TN were measured by dry combustion on a Thermo Flash 2000 CN soil analyzer. Then, 70 mg soil was weighed into an Sn-foil capsule to analyze the total C (organic C + mineral C) and N contents. Separately, 20 to 40 mg of soil was weighed into an Ag-foil capsule, pretreated with 10% Cl until complete removal of carbonates, and then analyzed for total C content (corresponding to the TOC content). The total equivalent $CaCO_3$ content was calculated from the difference between the total C measured before and after the HCl treatment [41]. Soil pH was measured potentiometrically in a 1:2.5 soil:water suspension. Electrical conductivity was measured in a 1:2 soil:water extract after 2 h of shaking, overnight standing, and filtration.

2.4. Data Analysis

The effect of LUC on arthropod density was assessed by comparing, within the same year, VV, VM (no-LUC area), MC, and VN (LUC area) by means of one-way ANOVA followed by Tukey's post-hoc test. Richness (S), Shannon (H'), Simpson (1-D), evenness (E), Margalef, and Berger–Parker were calculated and compared by the bootstrap method. The effects of LUC were evaluated by mean BSQ_{ar} values (Mann–Whitney test; $p < 0.05$). The impact of mulching on soil chemical properties was assessed through one-way ANOVAs within each vineyard. The relationships between soil parameters and the abundance of microarthropod groups (Acari, Collembola and other arthropods) were evaluated by correlation analysis (Pearson's "r" coefficient, $p < 0.05$). All analyses were performed using standard methods with PAST software [42].

3. Results

3.1. Soil Properties and Microarthropod Communities

In the no-LUC area, the soil texture was silty-clay (SIC), and in the pre-LUC area it was clay-loam (CL) (Table 1). After LUC, no significant variations in the fine soil-particle distribution were registered, and the textural class was unchanged. In the no-LUC vineyards, in the second year, the sand percentage increased, probably due to light farming interventions to prevent soil compaction.

Table 1. Soil textural classification by individual size-groups (%) of mineral particles.

	2013				2014			
	Sand (%)	**Clay (%)**	**Silt (%)**	**USDA Class**	**Sand (%)**	**Clay (%)**	**Silt (%)**	**USDA Class**
Vigna Vecchia (VV)	15.66	43.79	40.55	silty_clay	21.56	39.19	39.25	clay_loam
Vigna Maliosa (VM)	10.97	43.25	45.78	silty_clay	35.75	37.09	32.15	clay_loam
Monte Cavallo (MC)	28.40	34.90	36.6	clay_loam	27.44	35.42	37.14	clay_loam
Vigna Nuova (VN)	30.88	34.73	34.39	clay_loam	32.68	34.23	33.09	clay_loam

On the whole, 6647 microarthropods were collected. The most abundant group was Acari (61%), followed by Collembola (29%). The other microarthropod group was composed of 21 biological forms (BFs). Araneida and Palpigrada were present only in grasslands; and Coleoptera, Isopoda, and Embioptera disappeared in plots after planting vineyards (post-LUC area). The soil dwellers (i.e., Protura, Diplura, Pseudoscorpiona, Diplopoda, Pauropoda, and Symphyla) were sporadic but present.

Regarding abundance, no substantial difference was registered between LUC (meadow/vineyard) and no-LUC (vineyard) areas, in the two years considered (2013: $F_{1,11} = 2.988$; $P = 0.146$; 2014: $F_{1,11} = 3.097$; $P = 0.109$). Only light differences in total microarthropod density were due to the plot ($F_{3,11} = 9.4$; $P < 0.01$), in 2013, with the lower density in VM; however, this value of abundance was similar to that registered in MC, the long-standing meadow; in 2014, no difference was detected ($F_{3,11} = 1.380$; $P = 0.317$).

The BSQ_{ar} index showed the highest value in meadows (Figure 3). The second-year evaluation (Y2) showed that the vineyard plantation did not affect soil quality despite the soil perturbation, and the BSQ_{ar} values were similar to the ancient vineyards (no-LUC) (Mann–Whitney test, not significant at 5% level) (Figure 3). The decrease of BSQ_{ar} value after LUC was associated with a loss of six arthropod groups, especially euedaphic forms in the no-mulch vineyards (Appendix A Table A1).

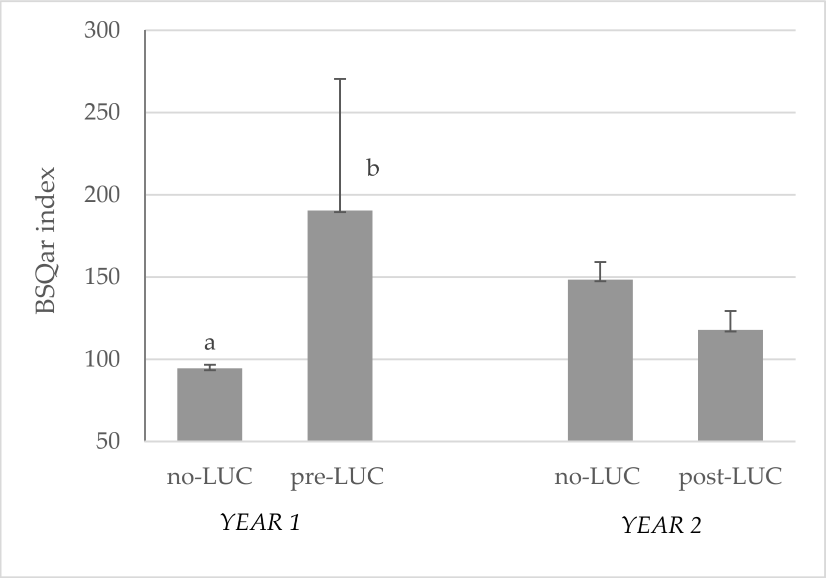


Figure 3. Biological soil quality by BSQar index in the experimental areas. Data were expressed as mean ± SD and 95% confidence interval by different letters. Significance was evaluated within the year (Mann–Whitney test, $p < 0.02$).

By referring to vineyards, after LUC, the diversity richness of soil arthropods became similar between areas (Table 2); the loss of richness in ex-meadow (post-LUC area) affected the Shannon and Simpson's indices, showing a decrease of relative frequencies of soil dominant groups.

Table 2. Biodiversity indices calculated in the no-LUC area and LUC area: S (richness), N (total abundance), H′(Shannon), E (Evenness), 1-D (Simpson's). Significant differences are in bold (Monte Carlo permutation test [42]).

	2013			2014		
Diversity Index	**No-LUC Area**	**Pre-LUC Area**	**p (eq)**	**No-LUC Area**	**Pre-LUC Area**	**p (eq)**
S	11	19		13	12	
N	550	1132		1241	293	
H′	1.05	1.07	0.72	**1.64**	**1.28**	**0.00**
E	**0.26**	**0.15**	**0.00**	**0.40**	**0.30**	**0.04**
1-D	0.47	0.50	0.43	**0.73**	**0.55**	**0.00**
Margalef	**1.60**	**2.60**	**0.00**	1.67	1.98	0.42
Berger- Parker	0.71	0.67	0.16	**0.43**	**0.64**	**0.00**

Concerning biodiversity, the meadow area showed high values of taxa richness of microarthropods; furthermore, different groups were well represented in their natural soil habitat (Figure 4). At the same time, the H′, 1-D, and Berger–Parker indices registered in the old vineyard (no-LUC area) were similar to those of the meadow, probably due to similar habitat conditions (inter-row long-term management within permanent cover grass) (Table 2).

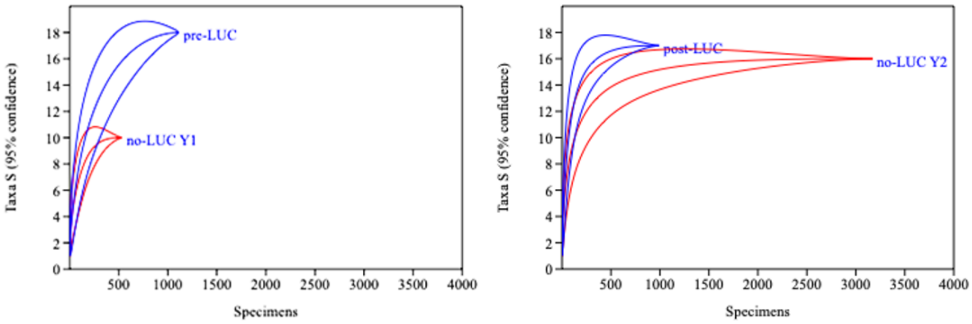
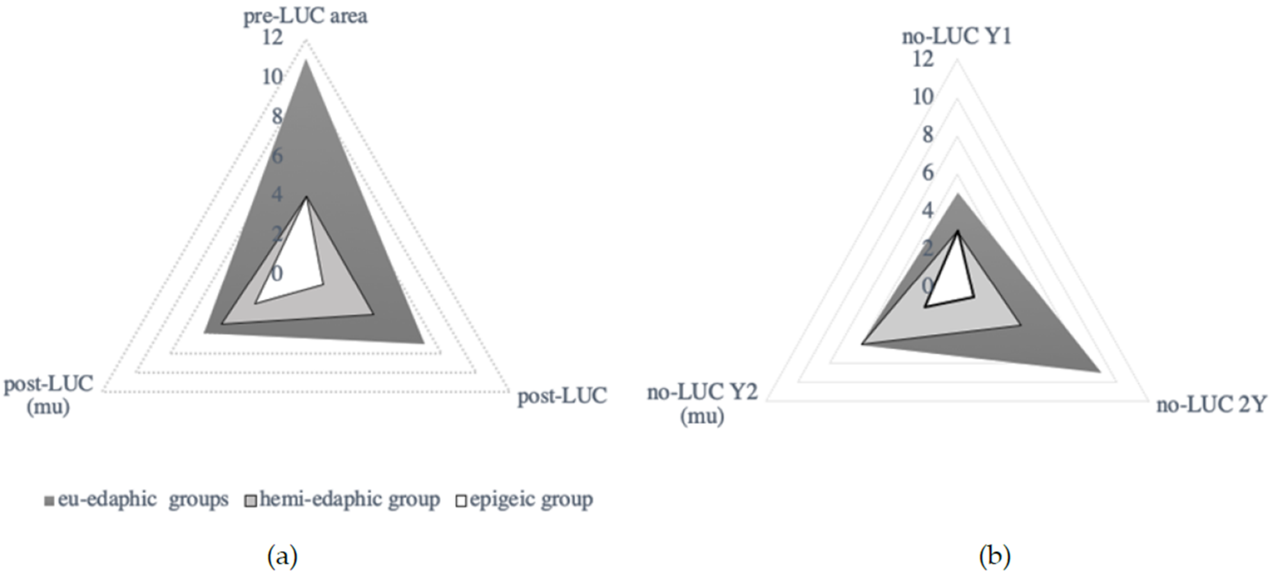


Figure 4. Individual-based taxon rarefaction curves, by year and area, that differentially estimate the relative importance of taxa richness change in composition of the arthropod community. Delimited area around the curves indicates 95% confidence interval.

By including small and rare taxa, the rarefaction curve begins to level off at a new plateau: pre-LUC meadows showed the highest diversity (Figure 4); however, after LUC, the diversity-rarefaction curve denoted changes in taxa richness, independently of the reduction of specimens (Figure 4).

3.2. Post-LUC Mulching Effect on Soil

The BSQ$_{ar}$ values registered in the second year were all ≥110 (Table A1), and no significant decrease was registered between pre- and post-LUC areas (Mann–Whitney test, P = 0.334). High values of biodiversity were obtained where the mulch was added. Nevertheless, the application of a mulch layer closely around the vine plants changed the arthropod assemblages in soils, promoting the presence of epe- and hemiedaphic forms in both areas (Figure 5).



(a) (b)

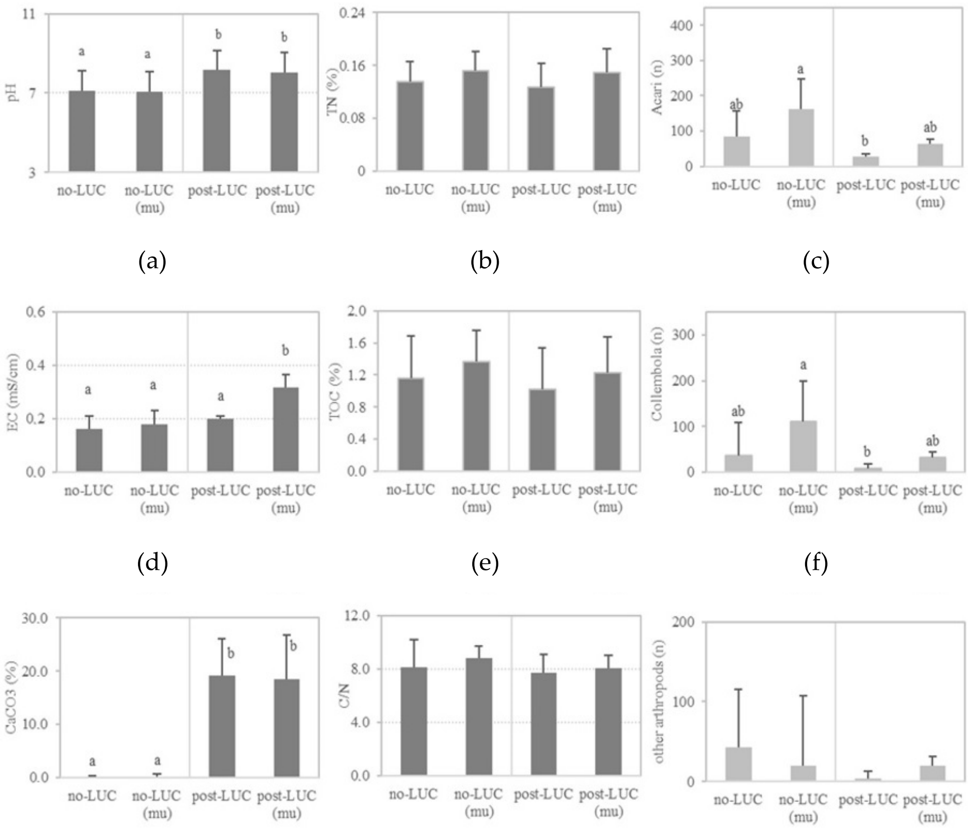
Figure 5. Composition of microarthropod communities by three morpho-functional levels in the different areas: (**a**) LUC area and (**b**) no-LUC area, by mulching (mu) effect.

The effect of mulching was different in two areas (Table 3). In old vineyards, the abundance and richness were similar, independent of the mulching addition; while the other biodiversity indices were higher in plots where straw mulch was not added. A positive effect of mulching on biodiversity was registered in new vineyards by determining differences in S, H′, and 1-D.

Table 3. Diversity indices of soil arthropods between different inter-row managements (mulch; no mulch plots) in 2014 according to richness (S), total abundance of arthropods (N), Shannon (H′), Evenness (E), Simpson's (1-D), and Margalef. Significant differences are in bold (Monte Carlo permutation test [42]).

	Old Vineyard			**New Vineyard**		
Diversity Index	**Mulch**	**No Mulch**	**p (eq)**	**Mulch**	**No Mulch**	**p (eq)**
S	13	13	n.s.	**16**	**12**	**0.0254**
N	1946	1241		709	293	
H′	**1.13**	**1.64**	**0.0001**	**1.51**	**1.28**	**0.0212**
E	**0.23**	**0.40**	**0.0001**	0.28	0.30	0.6038
1-D	**0.58**	**0.73**	**0.0001**	**0.64**	**0.55**	**0.0044**
Margalef	1.58	1.69	0.6725	2.29	1.94	0.2107

Soil electrical conductivity (EC) increased with mulching in the new vineyard ($F_{3,20} = 16.7$; $p < 0.001$), whereas it did not differ in the old vineyard (Figure 6). Soil TOC and TN contents were generally low and did not significantly change related to the floor management, except for a slight increasing trend under mulching (P = 0.68 and P = 0.81, respectively).



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 6. The evaluation of post-LUC mulching effects (mu) by separate ANOVAs on selected soil chemical properties ((**a**) pH, (**b**) TN, (**d**) EC, (**e**) TOC, (**g**) CaCO$_3$ (**h**) C/N) (TOC = total organic carbon; TN = total nitrogen; EC = electrical conductivity; CaCO$_3$ = total equivalent Ca carbonate; C/N = Carbon-to-Nitrogen ratio) and the average of abundance of three main edaphic animal groups, (**c**) Acari, (**f**) Collembola, (**i**) other arthropods in four different management areas (no-LUC; no-LUC (mu); post-LUC; post-LUC (mu)). Error bars indicate the mean standard error and different letters show statistically significant differences between variables (ANOVA; Tukey's test, $p < 0.05$).

The correlation analysis performed on soil properties showed a strong relationship between TOC and TN ($R^2 = 0.97$, $p < 0.01$) (Table 4).

Table 4. Pearson's correlation coefficients (significance level, two-tailed test: $p < 0.05$ *; $p < 0.01$ **) showing interactions among chemical properties of superficial soil samples and mean abundance of arthropod groups in different vineyards.

	pH	**EC**	**TOC**	**TN**	**$CaCO_3$**	**Acari**	**Collembola**	**Other Arthr.**
pH								
EC	0.58 (**)							
TOC	−0.15	0.33						
TN	−0.1	0.39	0.97 (**)					
$CaCO_3$	0.96 (**)	0.56 (**)	−0.3	−0.26				
Acari	−0.39	−0.16	0.16	0.18	−0.44 (*)			
Coll.	−0.24	−0.06	0.34	0.34	−0.28	0.84 (**)		
other arthr.	−0.21	−0.26	−0.21	−0.2	−0.22	0.52 (**)	0.28	

Moreover, the abundance of Collembola and other arthropods were positively related to the Acari ($R^2 = 0.84$ **; $R^2 = 0.52$ ** respectively), while the mites appeared to be negatively affected by $CaCO_3$ ($R^2 = -0.44$ *).

4. Discussion

In the case study, soil arthropod biodiversity was used as an indicator to assess the impact of LUC when planting vineyards in a meadow. In the Mediterranean region, where susceptible land suffers the most degradation because of topographical and climate characteristics [43], the habitat transformation should be carefully chosen according to the soil and environmental specificities [44,45]. Differently from deep soil working [14,45], the Corino method indicates preserving the top layer during a new vineyard planting to protect the soil floor heritage. As soon as LUC was adopted, the complexity of microarthropod communities indicated a short-term restored soil biological diversity [18]. A high number of arthropods, belonging to different taxa, was recorded in the meadow, with Acari and Collembola as dominating groups. Usually, identifying diversity richness is an important indication of the management and preservation of biofunctionality of soil [23].

The entire soil arthropod community was promptly able to react to soil perturbation, probably due to the maintenance of physical and chemical properties in the soil. Furthermore, according to Wong et al. [46], grapevine planting can cause a partial dissolution of soil carbonates, strongly characterizing the mineral phase of the soil and subsequently increasing the soluble salt concentration of the soil solution. It is extremely difficult for most plants to survive in soil whose structure has been destroyed, leading to the clay particles clogging the pore spaces [47,48]; also in vineyards [13]. In this study, the soil textural group did not change post-LUC, remaining moderately fine (clay-loam class texture). Vineyard age and vine age can represent a key issue for soil biota [31]. Among the tested vineyard plots, after LUC, the total abundances of soil microarthropods, independent of the sampling time and arthropod life cycles, were similar to those in the no-LUC areas. The method allowed the preservation of several patterns of euedaphic groups: Acari; Collembola; and some smaller Symphyla, Pauropoda, Diplura, and Hymenoptera Formicidae have been surviving in the soil, and a few months after the planting, they recolonized areas. The spatiotemporal patterns of Acari and Collembola may be due to changes in microclimatic soil properties, adaptive phenological characteristics of the organisms themselves, or pressure from a combination of different anthropogenic environmental change drivers [49,50].

The ANOVA showed only a slight difference in total microarthropod density due to the plot ($F_{3,11} = 9.9$; $P < 0.01$) in 2013, with the lower density in VM; however, this figure was similar to that registered in MC, the long-standing meadow. In 2014, concerning plot or areas, no difference was detected.

An excessive reduction in biological soil components and the loss of microarthropod species with unique functions in nutrient cycles may lead to degradation of soil and loss of agricultural productive capacity [51,52]. This aspect, not even adequately considered, is now assuming importance in providing the basic information required for assessment of sustainable ecosystem services in grape production [53–55]. Studies suggest that organically managed fields contain greater abundance and diversity of arthropods than conventionally managed ones [31,56], but evidence among different strategies in starting new vineyards is not available. This study confirmed, in post-LUC areas, that some groups are very sensitive to recent soil disturbance, such as pseudoscorpions or diplurans, and that their presence is highly associated with environment and soil-specific parameters [57].

Under added mulching, there was a minor increase in the average OC and total N contents. However, overall, the chemical parameters were similar. Only the electrical conductivity (EC) in the new vineyard was significantly higher compared to sites with no-mulching management, supporting soil mineral composition and interactions with soil organic matter and microbial activity [44]. Whereas mulching can provide immediate effects in terms of soil erosion reduction, soil temperature, and moisture control, its contribution to soil organic carbon enrichment also may require longer periods, especially in fine-textured or clayey soils [58]. Field screening performed in experimental sites indicated facilitated growth of new plants, probably favored by easy rooting and availability of rich oligo-elements [59]. In the present study, the scarce accumulation of organic matter in the upper soil layers seemed to have no influence on the abundance of microarthropods and might not necessarily be a limiting factor for the qualitative performance of the vineyard [60].

According to Decaëns et al. [61], the most abundant microarthropod groups were the soil-dwelling organisms: Acari (more than 50%) and Collembola (about 30%). Considering Acari, the highest presence of oribatids, living in dense clusters in the decomposing litter of the upper soil layers, is favored by thick organic horizons, acidic conditions, and recalcitrant litter materials [62].

On the whole, the complexity of the microarthropod population structure did not show significant differences, although the number of euedaphon groups was quite high, as evidenced in all plots by the BSQar values. The soil biological quality index proved to be a good indicator of soil-stress conditions at different levels. Protura, Diplura, and Pauropoda, even if they affect soil processes less compared to soil-dwelling organisms [27], are highly sensitive to soil-stress conditions, and can be relevant for biomonitoring purposes [29,63]. Taxa richness and other ecological indicators, such as the Shannon and Simpson's diversity indexes, confirmed the evidence showed by the BSQ_{ar} index, where the grassland is the habitat with the highest biodiversity [64]. According to Gope and Ray [65], the dynamics of microarthropods were probably dependent on the combined effect of vegetation cover and soil characteristics. Not all groups responded to the same extent: soil microarthropods with a larger body size appeared to be primarily affected by short-term consequences of LUC (disturbance, loss of habitat) [60], and after LUC, some functional groups, as the predators Palpigrada and Araneidae, disappeared. Nevertheless, the application of a mulch layer significantly increased the abundance of different arthropod predators [66], especially predator mites. Overall, a more diverse and abundant soil microarthropod community seems to provide better soil functions by reflecting the resource availability in the soil ecosystem [64].

5. Conclusions

Monitoring soil biodiversity enables the detection of biodiversity hot spots, as well as areas susceptible to changes, and helps to achieve successful implementation of ecosystem management. According to Novara et al. [43], the high eco-mosaic complexity of landscape significantly contributes to the ecosystem resilience. Despite the short time elapsed from LUC, the agronomic strategy employed in planting and managing new vineyards shows a great potential regarding landscape preservation. The strategy provides significant support to address and harmonize changes that are brought about by social, economic, and environmental processes. Based on the FAO input [3], new approaches, inspired by traditional agricultural management, can limit the problems caused by the continuous simplification of agro-ecosystems and the "one-size-fits-all" approach to vineyard management to obtain economic benefits [43]. The economic benefits of adopting a targeted approach rather than a conventional one for vineyard management can improve outputs in crop yield and fruit quality and/or reduced inputs [47].

Our research will continue in the future with the aim of monitoring/determining long-term effects of LUC based on the selected soil biological quality indicators. Monitoring soil quality means improving soil management so that it functions optimally now and is not degraded for future use.

6. Patents

Farming was done according to the Corino method (IT Patent approved in 2019, IT201700005484A1), a completely vegetal-based, closed-cycle agricultural method.

The object of the patent for the Corino method is a process to produce grapes that comprises several phases, such as the use of native vines. As described in the patent, the Corino method represents a humanized system with minimal environmental impact, and constitutes a significant step in technological development, as well as a fascinating return to origins, quality, and excellence.

In addition to the Corino method, the patent covers two products; namely, the grapes and the wine obtained through the Corino method. The main essential characteristics of the wine described in the patent are the absence of added sulfur dioxide, and the absence of additional chemical and microbiological interventions during its production.

Author Contributions: S.S. and L.C. conceived the assessment; S.S., N.V., G.V. and E.G. designed and performed the experiment; E.G., D.G., S.G., F.T., L.C. and S.S. obtained the soil samples; E.G., D.G., S.G., F.T., N.V. performed the lab analysis; E.G., G.V. and S.S. analyzed data; E.G. and S.S. wrote the paper; S.S., D.G. and G.V. revised the paper. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A1. EMI values for biological forms (BF) and BSQar indexes calculated by three morpho-functional levels [29] in the first (Y1) and second (Y2) years, in the different areas (no-LUC, LUC), considering mulching (mu) effect.

	Y1				Y2							
	No-LUC Area		Pre-LUC Area		No-LUC Area				Post-LUC Area			
BF	VV	VM	Pre-VN	Pre-MC	VV (mu)	VV	VM (mu)	VM	VN (mu)	VN	MC (mu)	MC
Acari	20	20	20	20	20	20	20	20	20	20	20	20
Collembola	20	20	20	20	20	20	20	20	20	20	20	20
Diplura	20	20	20		20					20	20	
Pauropoda			20	20	20	20	20	20	20	20	20	
Protura			20			20			20	20		
Pseudoscorpionida			20					20	20			
Embioptera	20		20									
Palpigrada			20									

Table A1. *Cont.*

	Y1				Y2							
	No-LUC Area		Pre-LUC Area		No-LUC Area				Post-LUC Area			
BF	VV	VM	Pre-VN	Pre-MC	VV (mu)	VV	VM (mu)	VM	VN (mu)	VN	MC (mu)	MC
Chilopoda			20		10	10	10	10	10	10	10	10
Coleoptera				6	20	20	20	6	1		6	
Diplopoda			20	20	10	20	20		20		20	20
Symphyla		20	20	20		20			20		20	20
Isopoda			10	10	10	10	10	10			10	
Diptera *larvae*		10	10	10	10	10	10	10	10	10	10	10
Coleoptera *larvae*	10				10	10	10		10		10	10
Hymenoptera	5				5	5	5	5		5		
Araneidae			5	5								
Psocoptera			1	1					1	1		
Hemiptera		1		1	1						1	
Thysanoptera		1	1				1					
Diptera	1	1		1					1			
BSQ$_{ar}$ *	96	93	247	134	156	185	146	141	173	126	167	110

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