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ABSTRACT

In the Mediterranean area many organic farms oriented toward the marketing of fresh products or toward agro-food processing have been interested in the conversion of at least a part of their horticultural production to natural cultivation systems in order to supply "natural" food to satisfy a particular market demand. In this study, the role of natural agriculture has been investigated in order to evaluate its effects in environmental safeguarding and organic farm production, contrasting soil erosion and soil organic matter decline, maintaining general soil fertility on hilly farms and supporting income in the context of climate change. This study is a field trial on a hilly farm, which compared a natural plot to an organic one. It showed that in the plot conducted with natural farming, total soil organic C increased significantly compared to the organic plot, from 1.97% to 4.16%. In organic farming system a significant increase of Total Organic Carbon (TOC) at the lower part of plot was observed as a consequence of soil loss (+ 25%). An economic analysis of the two farming systems on four farms, carried out considering the average costs and the average revenues, highlighted for the first time the greater profitability of natural cultivation compared to organic farming (+43%). The balance between safe food production, natural resources management and economic performance, obtained by substituting the organic farming with natural techniques, provides new and effective resilient agricultural practices to the organic farm sector.

KEYWORDS

Natural farming; resilient agriculture; soil conservation; organic farm economics

Introduction

The aim of natural farming is to transform current short-term monoculture rotations to long-term biodiverse rotations with the consequent environmental benefits. The main concept of this cultivation method is the self-enforcing

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of undisturbed soil fertility, by increasing humus genesis, and excluding tilling, fertilizing, chemical spraying and weeding (Cappello 2019; Shyam et al. 2019). Unlike organic farming, tillage is not carried out, except for the preparation of the cultivation beds at the beginning of conversion. Natural horticulture requires the construction of specific beds, raised or not. In the first case, the bed is prepared by taking the topsoil from permanent walkways. Organic farms in central Italy have soils with a high clay content. For this reason, farmers that do not practice natural farming carry out tillage to prepare the soil for sowing or transplanting and to control weeds. In these farms mulching is rarely practiced because a further cultivation operation would reduce the profitability of the crops.

In natural farming also the use of chemicals allowed in organic farming, both synthetic and mineral, is not practiced. The only application carried out regards self-produced technical means, such as composted green material, integrated into the mulch in order to accelerate the creation of a permanent humigenous topsoil layer, or plant aqueous extracts used as basic substances to support the crops' defense.

The methods of natural farming, e.g. synergistic gardening, "hügelkultur" or elementary cultivation, activate biodiversity and latent fertility of soil (Fiebrig et al. 2020; Mancin et al. 2012). Natural horticulture requires the highest possible biodiversity through the mixed planting of vegetable and fruit crops, herbs, flowers, green manures, cover crops and companion plants to increase and preserve diverse micro-organisms and meso- and macrofauna of soil. Beneficial companion plants must be chosen among perennials or self-seeding species to promote the maximum synergic effect or to exploit the allelopathic effects (Hazelip 2014; Rezendes et al. 2020).

Permanent mulching is a widely used technique in natural farming due to its positive effects such as improved crop growth and root elongation, mitigation of soil temperature, water availability increase, maintenance of soil aggregate structure and porosity and reduction of water and wind soil erosion (Rakow 1998). In particular, organic mulches (e.g., chipped wood, grain straw, hay and composted materials) have positive effects on soil functional qualities and increase soil moisture, total organic carbon and mineral nutrient availability while they decrease soil bulk density (Fini, Degl'Innocenti, and Ferrini 2016; Pinamonti 1998).

Widespread soil degradation, leading to a decline in the ability of soil to carry out its ecosystem services, is caused largely by non-sustainable use of the land. This has also marked local, regional, European and global impacts. Some recent studies suggest that soil organic carbon (SOC) in European agricultural land is decreasing. Soil organic matter (SOM) decline is also of particular concern in the Mediterranean region where high temperatures and droughts can accelerate its decomposition. Several factors are responsible for a decline in SOM and many of them relate to human activity: conversion of grassland, forests and natural vegetation to arable land; deep plowing of arable soils; drainage and fertilizer use; tillage of peat soils; crop rotations with a reduced proportion of grasses, and wildfires (Boix-Fayos et al. 2009). The above factors, combined with typical pedoclimatic Mediterranean conditions with long dry periods followed by heavy bursts of intense rainfall on steep slopes and fragile soils, make this area particularly prone to water erosion. (Jones et al. 2010)

During the past decade, the problem of soil erosion has become part of the environmental agenda in the European Union (EU). The Soil Thematic Strategy, adopted by the European Commission in September 2006, indicated accelerated soil erosion as a major threat to European soils. The EU Common Agricultural Policy (CAP) recognizes the importance of protecting our soils and has addressed the issue of reducing soil erosion on agricultural lands (Panagos et al. 2015). The necessity to contrast soil degradation phenomena and to define soil sustainable management practices motivated many researchers to study soil quality in terms of suitability for its use and functions within the agroecosystems (Cosentino et al. 2015).

Many authors have pointed out the role of plants in the remediation of some heavy metal contamination in the soil. In natural farming, due to the increase in vegetal diversity, this role can take on relevance (Chiwetalu, Mbajiorgu, and Ogbuagu 2020; Tariq and Ashraf 2016)

Italy is the main European producer of organic vegetables, with an area of 38,000 ha in 2018 (Rete Rurale Nazionale (RRN) 2019). In the last two decades, surfaces intended for natural horticulture have largely been increased. On social networks there are several forums dedicated to this production system which include over 14,000 producers (Agricoltura Naturale Community 2020; Orto Sinergico Community 2020). These are mainly families, schools, communities or small farms interested in the self-consumption of the products. However, in many organic farms oriented to the market of fresh products or to agro-food processing, the conversion of at least a part of the horticultural production to natural cultivation is being observed. This is in order to supply "natural" food to satisfy a particular market demand due to consumers' requirement of healthy and high quality products (Agricoltura Naturale Sinergica 2020). Initially, these farms produced with natural methods only for self-consumption, but at the request of consumers intrigued by this production technique, they began a partial conversion of production (Beni et al. 2018a).

In this study four farms were chosen for their representativeness of the national and regional agricultural sector, in particular for the organic farming (ISTAT 2016). These farms have a Utilized Agricultural Area close to the national average (5.3 ha) and they are located in mountainous or hilly areas, like most farms in Italy (76%). Furthermore, they have a mixed productive orientation typical of central Italy (at least 1 ha of arboretums with prevalent olive groves, arable land, vegetable garden, small animal husbandry or beekeeping), agriculture is the main or secondary activity of the entrepreneur and they have only seasonal workers (as in the 61% of national farms). Finally, farms are market oriented, with the possibility of direct sales of products (35%).

On one of these four farms, located in the Sabina territory of Lazio region (latitude 42°28′46"52 N, longitude 12°67′51"50 E), a sloping plot of approximately 2,000 m^2 was divided in two halves in 2016, allocating one of the two to natural cultivation of vegetables and leaving the other half to organic management. The soil characterization of the two plots, based on a sampling pattern along transects traced along the lines of maximum slope, carried out in December 2019, allowed the evaluation of the initial effects on soil of this conversion (Beni et al. 2018a). In addition, on the set of four organic farms chosen in the same area, which have converted part of their production toward the natural system, the production costs, quantities and prices of products harvested over the last three years have been recorded.

Resilient agricultural practices aim to balance producing safe food, managing natural resources, dealing with uncertainty and providing a farm management extension for the rural population (Sawicka 2019). The aim of this study is to evaluate the role of natural agriculture in order to evaluate its effects in safeguarding the environment and organic farmer's production, contrasting soil erosion and SOM decline, maintaining general soil fertility on hilly farms and maintaining income in the context of climate change.

Materials and methods

Description of the field trial site

The certified organic farm, located in the Lazio region in a territory called Sabina 60 km north of Rome, carried out the conversion to natural agriculture on half of a plot of almost 2,000 m^2 intended for the cultivation of vegetables. The whole farm has been managed with organic farming since 1995, while the above mentioned conversion began in summer 2016. Soil is characterized by a clayey loamy texture, sub-alkaline reaction, an average content of organic matter and macronutrients, high Cation Exchange Capacity (CEC) and exchangeable Ca content (Table. 1).

Sample taken from the whole plot: * before conversion; ** after conversion

M.U.: measurement unit

The plot has a slope of about 12%, with a rectangular shape (30 x 65 m) positioned with the longer sides parallel to the contour lines and oriented North-South. In the summer of 2016, it was divided into two areas (about 30 × 32.5 m). On one half management was converted to natural, based on the synergistic method, and on the other the management remained organic (Figure 1). The cultivation of vegetables was carried out with the random

Table 1. Soil physical-chemical characteristics.

Parameter	M.U.	2010*	2015*	2020**
Sand	%	24.82	24.92	25.24
Loam	%	41.14	42.74	42.91
Clay	%	34.11	32.44	31.92
pH		7.83	7.81	7.72
C	%	2.23	1.98	3.06
N	%	0.16	0.14	0.19
K_20	mg kg^{-1}	454.63	411.18	435.12
P_20_5	mg kg^{-1}	43.24	41.87	43.21
CEC	meq 100 g^{-1}	33.15	32.86	35.78
exchangeable Ca	meq 100 g^{-1}	27.89	27.92	29.87
exchangeable Mg	meq 100 g^{-1}	3.87	3.70	4.12
exchangeable K	meq 100 g^{-1}	0.97	0.88	0.94
exchangeable Na	meq 100 g^{-1}	0.42	0.36	0.34
assimilable Fe	mg kg^{-1}	22.15	21.24	24.87
assimilable Cu	mg kg^{-1}	27.33	31.11	33.83
assimilable Zn	mg kg^{-1}	5.25	5.13	5.12
assimilable Mn	mg kg^{-1}	18.22	18.92	19.03
assimilable B	mg kg^{-1}	1.13	1.19	1.15

Figure 1. Map of the field study site. Map data © 2019 Google

consociating method on raised beds in natural farming and with specialized rows on trunk shape soil in organic farming.

In December 2019, after a period characterized by high rainfall (Figure 2) with two events of high intensity, soil samples were collected along three transects traced along the lines of maximum slope (3 samples replicated at the top, center and bottom of the plots) along every transect.

Data source: ARSIAL Station 101- Lazio Region Agrometeorological Network

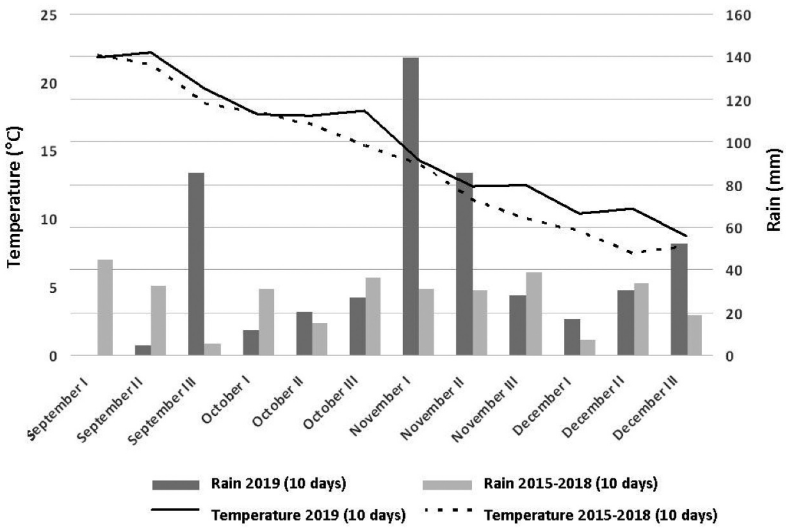

Figure 2. Climate data of the investigated period and comparison with 2015–2018.

Soil characterization at the end of the experience

The following parameters were determined on the samples:

- Total organic carbon (TOC) with the wet oxidation method (Nelson and Sommers 1982).

- Clay content was measured with hydrometer after sample dispersion with sodium hexametaphosphate (Gee and Bauder 1986).

- Dry bulk density was measured by collecting samples of soil with a corer (100-cm3 sample ring; internal diameter 5 cm, length 5.1 cm, and wall thickness of 0.15 cm) at a depth of 0.05–0.10 m. These samples were dried until they reached a constant weight (Blake and Hartge 1986.).

- Counts of bacterial communities were determined using viable plate counts of the colony forming units (Cfus) from bacteria and propagules. The bacteria count was determined using the serial dilution and spread plate techniques in nutrient agar (Gram 1984).

- Counts of fungal colonies were determined using the serial dilution and spread plate technique on potato dextrose agar, after a 4-days inoculation (Monica 2001).

All the solvents and reagents used were of a quality standard grade. The analyzes relating to the microbial count were carried out in a certified laboratory, in accordance with the ISO/IEC 17025: 2005 standard.

In addition, tests were performed in the field to assess the drainage capacity of the soil, detecting the rate of infiltration of the water through a single ring Müntz-Faure-Lainé infiltrometer, for two hours, until soil saturation was achieved (Beni et al. 2012).

The survey of economic and productive performances

In the four farms investigated, the areas intended for natural production are still low, as in these farms the sowing, transplanting and harvesting operations are still carried out manually, considering the natural character of this production technique. Areas intended for natural farming per farm vary from 1.0 to 1.4 ha, depending on the available personnel. The farms employ on average four operators twice a week for the management of the crop operations, mainly for the harvest, according to the ripening calendar from early May to the end of September for spring-summer vegetables and from the first days of October to the end of March for autumn-winter productions.

The conversion from organic to natural method affects in particular the following two production phases:

- Soil management: in contrast to organic farming, the soil is not worked. The management purpose is the creation of a permanent humigenous topsoil layer, at least 7–8 cm, in order to simulate what happens in natural ecosystems (e.g. in forests or stable meadows) and guarantee the self-fertility of the soil itself. This occurs through the addition to the soil of undecomposed organic matter of different types (straw, wood chips, hay, farm vegetable waste), mixed in adequate proportions, or self-produced green compost.
- Crop protection: this phase is essentially entrusted to the biodiversity of the system, guaranteed by the simultaneous presence of plants of at least 3–4 different botanical families distributed randomly on the surface to be cultivated, to reduce the spread of pests and predators among plants of the same family. In addition, vegetable species are associated with plants of medicinal or aromatic species, often having a repellent effect on parasitic insects, which can also be carriers of diseases of different types (virosis, bacteriosis, etc.). In this way, the self-defense of the agro-ecosystem is guaranteed. Furthermore, to replace the chemicals allowed in organic agriculture, the use of plant extracts to spray vegetable plants is increasing. These are products obtained from medicinal or aromatic plants, classifiable as basic substances, having phyto-stimulating effects on vegetables, due to the nutritional and antioxidant properties that allow the plant resistance to disease agents to increase.

On the farms examined, mechanical weeding is not carried out. Weed control is carried out through increasing sowing or plantation density (+25%) in both cultivation systems to obtain the maximum soil coverage. Furthermore, in order to diminish weed competition, in organic farming self-seeding prostrate cover crops are sown every 3–4 years while, in natural farming, mulching with vegetal biomass is regularly adopted.

The survey of information relating to production costs, quantities and prices of the product marketed was carried out using the method of interviews in four farms in the Sabina territory of Lazio, including the farm where the field trial is being carried out. As regards the production costs of the two farming systems, differences have been observed mainly in two phases: 1) soil management; 2) crops defense.

1) In organic farming, the soil management is carried out by means of a mechanized preparatory tillage, generally a plowing or a dig, followed by two secondary tillages which can be carried out with harrows of different types. The series of preparatory operations is repeated twice a year, before the spring-summer and autumn-winter cultivation cycles. Shortly before spring plowing, organic fertilization with mature manure or other biomasses is carried out, using quantities of about 30–40 t ha□1, depending on their nitrogen content.

In natural farming, the application of organic matter onto the soil's surface is carried out in order to constitute a mulch layer and is repeated twice a year before each production cycle. This operation could be carried out with the aid of mechanical equipment exclusively for the transport and unloading of the biomasses. These are constituted by shredded wood, straw, hay or compost self-produced by the farm, and are manually distributed onto the cultivation beds, while cutting down the wild plants along the walkways (Beni et al. 2018a).

2) in organic farming, interventions for crops' defense are mechanized, using the permitted plant protection products (PPP). In the case of consociated vegetable crops on small surfaces, treatment planning is carried out considering the crops with the longest cycle which occupy the largest surface having greater planting distances and which are more sensitive to pest attacks (e.g. tomato or courgette in the spring-summer period).

The phytosanitary treatments carried out can be summarized in Table 6: the treatments refer to the use of an 80 HP tractor with a 1,000 L sprayer, calibrated to distribute 150 L ha^{-1} of solution. The PPP used for the defense of the consociated vegetables are the following:

- Copper oxychloride, used in doses of 300–500 g hL^{-1} per treatment. The cost of a 10 kg pack varies between € 55 and € 65.

- Copper sulfate, in doses of 500–700 g hL^{-1} per treatment. Cost for packs of 10 kg equal to € 45–55.
- Elemental sulfur, distributed with 300–400 g hL^{-1} per treatment, the cost for the 10 kg package is € 30–35.
- Neem oil (azadirachtin), diluted in water to 1–2%. The 1 L pack costs € 30–40; for each intervention it must be mixed with 200 g of potassium soap, having a cost of € 4–5.

- Bacillus spp, generally sold in packs of 500 g, having an average price of € 27, which corresponds to the dose for one treatment with 150 L ha^{-1} of aqueous solution.

In natural farming, the self-defense of the agro-ecosystem is promoted, which can be:

- Indirect, through the consociation among vegetables and with flowers and medicinal or aromatic plants that increases the system's biodiversity. In this case, the cost is limited to the planting of perennial flowers, officinal and aromatic plants in the first year: for one hectare, the average planting density is 500 plants.
- Direct, through the use of plant extracts considered as basic or phytostimulant substances. In this method, the costs of self-production of the extracts can be estimated.

The calculation of the production parameters was carried out in four organic farms with a surface area intended for natural horticulture equal to at least 1 ha. In these farms, cultivation is carried out on beds, about 1 m wide and 5 m to 10 m long, depending on the consociation chosen. Walkways for the carrying out of the cultivation operations surround all these areas, so as not to step on the cultivation beds. Compared to organic management, the productive tares are greater in the natural system, corresponding to about 30–35%, compared to 10% that is observed in the soils conducted according to the organic method. However, the planting density of the two vegetable cropping systems per hectare can be considered similar, since in natural systems the sowing or transplanting distances are increased by 15–20% compared to the organic ones (Beni et al. 2018a).

The vegetables grown in the spring-summer period were fresh tomatoes, chicory, savoy cabbage, courgettes, beetroot and lettuce, while in the autumn-winter cycle cabbage, endive, chard, fennel, red onions and potatoes were cultivated. The latter species in the synergistic system was cultivated in raised boxes containing sand-enriched soil, interspersed with the raised beds that hosted the other crops.

Statistical analysis

All soil data collected, including counts of bacterial and fungal communities, were preliminarily submitted to descriptive statistics and graphic analysis (box plot) to evaluate variability with respect to central indexes and to identify any outliers. Homoscedasticity of data were checked using Levene's test. Univariate analysis of variance (ANOVA) was performed and comparisons of treatments were done when test F of ANOVA was significant (α level = 0,05) using Tukey's HSD test. An additional factor analysis was carried out to understand the role played by the two systems studied in the variability of the observed soil parameters. Principal component (PC) criteria was used for factors extraction. Only PC with Eigenvalues higher than 1 were considered useful to the factor solution.

We used average per hectare yields and selling prices of the last three years to assess the gross revenues of the two farming systems. For each crop we used the average gross revenue (yield times price) over the last three years. Total average revenues resulting from the unweighted mean of all crops revenues over the three years were considered (2017–18-19). We graphically compared the variability of average revenues in the two farming systems using box plot, where values were normalized on a 0–100 scale. Then we used a t-test (α level = 0,05) to test the difference in means.

Results

Field trial

The univariate ANOVA (Tab. 2) showed that the effect of the cultivation system (System) was significant for all soil and microbiology parameters studied (*P* values <.01), while the position of sampling sites (Position) in the sloping plot was significant only in TOC and Clay (*P* values <.01). Interaction of System*Position resulted significant in Clay (*P* value <.001). In the plot conducted by natural farming, TOC increased significantly compared to the organic plot and in this last cultivation system we observed a significant increase of TOC at the bottom position (Tab. 3).

In the organic plot, the clay content shows a decreasing trend to the top toward the bottom, with significant difference between the bottom and top and medium positions. This result is in line with the significant effect of interaction System*Position and together with the TOC trend, suggesting erosive phenomena in this plot with loss of fertile soil from the top of the plot. This result is in accordance with multiple experiments at the plot and field scales that showed selective erosion of fine particles and enrichment of SOC in sediments, compared to the original soils (Boix-Fayos et al. 2017; Martínez-Mena et al. 2012; Starr et al. 2000).

In the naturally managed field, the clay and TOC concentrations remained stable throughout the plot (Table 3). Dry bulk density was lower in natural cultivation, denoting the best degree of soil structure in this system compared to organic management. In this last system, the bulk density values have significant increased downwards, highlighting the loss of soil structure due to the slope and erosion (Table 3). The drainage capability was doubled in the natural system, showing a greater stability of soil structure compared to the organic one. Furthermore, in this last plot, drainage has become significantly

Table 2. Test F ANOVA results.

	TOC (%)		**Clay (%)**		**Bulk density ($t\ m^{-3}$)**		**Drainage capability ($L\ m^{-2}$)**		**Bacterial colonies ($CF\ g^{-1}$ soil)**		**Fungal colonies ($CF\ g^{-1}$ soil)**	
Source	F	P value	F	P value	F	P value	F	P value	F	P value	F	P value
System	610.25	0.000	7.24	0.010	120.67	0.000	866.12	0.000	1642.00	0.000	361.60	.000
Position	7.47	0.001	29.95	0.000	3.37	0.043	2.32	0.109	1.25	.319	.34	.716
System * Position	3.12	0.053	17.01	0.000	1.75	0.184	3.17	0.051	2.73	.105	1.11	.360

Table 3. Soil and microbiology parameters.

	TOC (%)		Clay (%)		Bulk density (t m^{-3})		Drainage capability (L m^{-2})		Bacterial colonies (CF g^{-1} soil)		Fungal colonies (CF g^{-1} soil)	
	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural
Top	1.74 a	4.24 a	28.32 a	29.14 a	1.19 a	1.04 a	60.44 a	113.89 a	46.00 a	296.33 a	15.33 a	42.33 a
Medium	1.84 a	3.96 a	29.60 a	29.87 a	1.22 ab	1.05 a	54.78 ab	111.56 a	49.33 a	302.00 a	16.67 a	41.33 a
Bottom	2.32 b	4.28 a	34.43b	30.18 a	1.28 b	1.06 a	49.56 b	114.89 a	71.67 a	293.67 a	19.00 a	42.33 a
Mean	1.97 **A**	4.16 **B**	30.78 **A**	29.73 **B**	1.23 **A**	1.05 **B**	54.93 **A**	113.44 **B**	55.67 **A**	297.33**B**	17.00 **A**	42.00 **B**

much slower in the bottom sector due to the presence of heavily destructured soil (Table 3).

The number of bacterial colonies has increased by about five times in natural cultivation, while in organic farming this value increases downwards, due to erosion. Bacterial colonies are generally linked to the presence of organic carbon (Table 3). The number of fungal colonies has increased in the natural system compared to the organic one. Also in this case, despite a not significant effect of Position, in the organic plot the colonies have increased downwards, as observed for bacterial colonies (Table 3).

Means followed by different lowercase letters within a column are statistically different to Tukey HSD test (*P* value < .05).

Mean of System followed by different uppercase bold letters in the row are statistically different (test F ANOVA significant; *P* value < .05).

The multivariate Factor analysis was adopted to resume variability of soil parameters in a few factors that might represent the causes of co-variation of data set. The PC criterion was adopted as extraction factors method and results are reported in Table 4 which shows eigenvalues and the portion of the total variance explained by all the components extracted. The first two components, with eigenvalues higher than 1, explained 81.09 and 17.16% of the total variance respectively, reaching a cumulative 98,25% of the total variance. The first component is strongly associated with the variability of TOC, Bulk density, Drainage capability, Bacterial and Fungal colonies, while the second component is associated only with the Clay variability (factor loadings higher than 0,9) as showed in the component plot (Figure 3).

Factor score Plot, (Figure 4), is a graphic tool useful in identifying the clustering of all sampling sites by the two factors, suggesting natural or anthropic causes that could influence the variables studied. The first factor shows a strong discriminant capacity between natural and organic systems because of general improvement of parameters of soil fertility (TOC, Bulk density, Drainage capability, Bacterial and Fungal colonies) in natural plot. The second factor, linked to the clay variability, gathers the low position sites within the organic system. This suggests that the second factor probably represents the erosive events, accentuated in the organic plot and not detected in the natural plot. In fact, we have not carried out erosion measurement or

Table 4. Extraction Method: Principal Component Analysis.

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.866	81.093	81.093	4.866	81.093	81.093
2	1.030	17.164	98.258	1.030	17.164	98.258
3	.044	.731	98.989			
4	.033	.549	99.538			
5	.017	.281	99.819			
6	.011	.181	100.000			

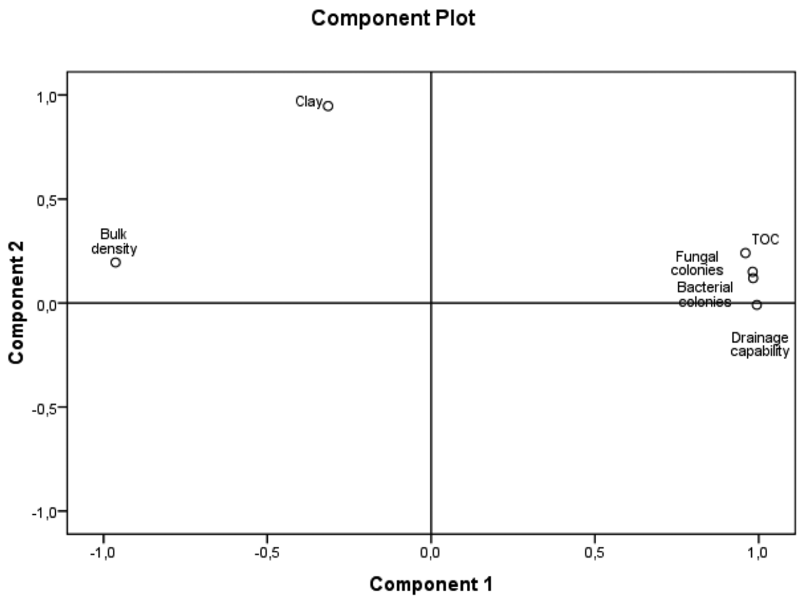

Figure 3. Factor loadings plot.

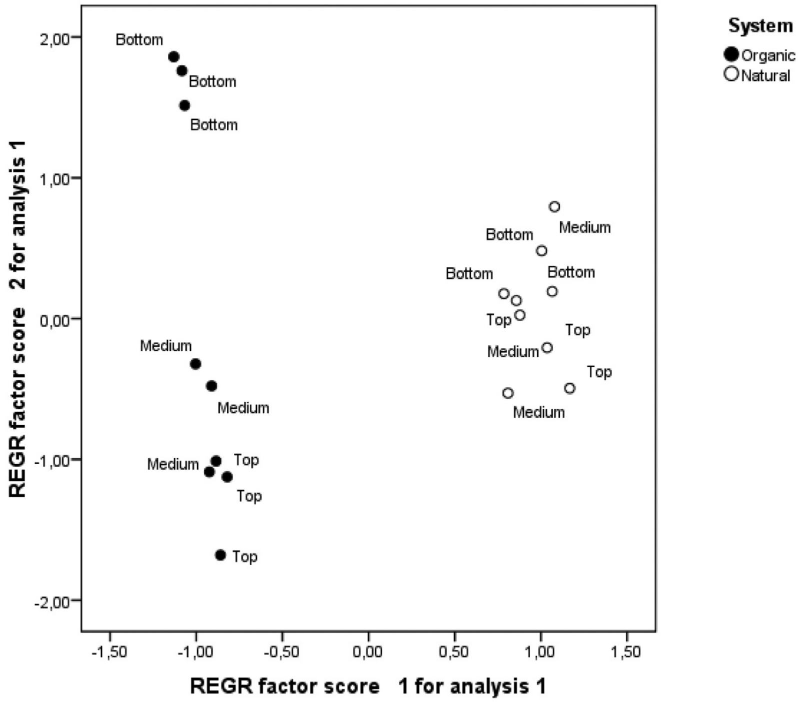

Figure 4. Factor score plot.

estimates with canonical methods (empirical models, UAV-GIS applications, radionuclides etc.) but we have hypothesized and represented erosive phenomena on the basis of experimental data and statistical processing. We adopted factor analysis to find non-measurable causes/factors that influenced data collected by associating to the second factor extracted the erosive effect in the organic farm as a result of the deposition of clay particles and enrichment of SOC in topsoil on the plot bottom. This result is in line with the significant test F of the interaction "System*Position" of clay obtained by the univariate ANOVA (P value<.001) (Table 2) and Tukey HSD post hoc test in organic System (Table 3).

Production costs

As regards the production costs of the two farming systems, differences have been observed mainly in two phases: soil management and crops defense.

Table 5 shows the survey of the costs for soil management in which it was observed that in organic farming the cost of the operations performed before

Table 5. Soil management costs in the two production systems examined referred to 1 ha.

Organic farming			
Agricultural operations/working	Agricultural machines	Number of operators	Cost* (€)
Organic fertilization treatments	80 HP tractor manure spreader 6 m^3	1	300.00
Plowing	80 HP tractor Two-furrow plow	1	120.00
Harrowing	80 HP tractor Disc harrow	1	80.00
Harrowing	80 HP tractor Tine harrow	1	50.00
Synergistic agriculture			
Organic matter handling, transport and unloading	80 HP tractor 6 m^3 trailer	1	160.00
Organic matter distribution.		3	360.00

Table 6. Average annual treatment plan applied in the farms investigated.

Crop treatment (n.)	Active ingredient	Average cost (€)	Duration (Years)	Total cost (€)
3	copper oxychloride	20.00	3	60.00
3	copper sulfate	17.00	3	50.00
2	elemental sulfur	11.00	3	33.00
2	azadirachtin +	17.00	2	35.00
	potassium soft soap			10.00
3	Bacillus spp.	27.00	3	81.00

**Treatments carried out with an 80 HP tractor and 1,000 L sprayer, distributing 150 L ha^{-1}; cost per treatment equal to 40 Euro ha^{-1}

Table 7. Average costs of production.

	Natural		Organic
	Indirect defense	**Direct defense**	
Soil management	520.00 €	520.00 €	550.00 €
Crop defense	127.41 €	880.00 €	698.70 €
Total cost	**647.41 €**	**1,400.00 €**	**1,248.70 €**
Average revenue	**14,673.60 €**	**14,673.60 €**	**8,320.93 €**
Average profit	**14,026.19 €**	**13,273.60 €**	**7,072.23 €**

each cultivation cycle amounts to 550 € ha^{-1} while that relating to the natural agriculture is slightly lower, equal to 520 € ha^{-1}. For a whole production cycle, a series of treatments can be assumed on average as listed in Table 6, in which it is observed that the total cost of the defense of 1 ha of summer vegetables in organic management is equal to € 698.70.

In natural farming, the self-defense of the agro-ecosystem is promoted, which can be:

- Indirect; the average cost of plants in pots of 12–14 cm in diameter is variable from € 1.5 to € 2.5 each one. Assuming a proportion of 1/3 of the plants to € 1.5 and 2/3 to € 2.5, the total cost of indirect defense is € 1,083, amortizable in 7–10 years (plant life cycle).
- Direct; assuming the distribution of 150 L ha^{-1} per treatment of solution prepared with 1% dry material (e.g. 1.5 kg of lavender, rosemary or tansy), the cost of the material is given by the missing sale quota, equal to an average of € 15 per treatment. The cost of the other production factors (machines, operators, etc.) is, as for the other farming system, equal to 40 € per ha. In the spring-summer cycle, in which the treatments are carried out weekly for four months, there will be a total of 16 treatments. The total cost of direct defense, in this case, will be equal to: (40 + 15) * 16 = € 880.

Crops yield and selling prices

The production per hectare of the main representative crops in the two production systems and the direct sales prices per kg are shown in Table 8. Table 7

An economic analysis of the two farming systems was carried out considering the average costs and the average revenues, as described above.

As shown in Table 8 the market prices of natural-produced vegetables are higher than the market prices of organic vegetables. Total revenues can be computed by multiplying the average yield by the market price. Following this computation, we estimated an average value of revenues, by representative crops, averaging the revenues of the three years considered.

Figure 5 shows the box plot of total revenues (normalized on a 0–100 scale) for the two farming systems.

The overall variability of revenues from the natural system is larger than the overall variability of the revenues from organic system. Nevertheless, this is not supposed to create an economic incentive to specialize only in the most profitable crops, as biodiversity is one of the "musts" of natural farming. The distribution of revenues from organic farming is closer to the normal distribution, unlike the distribution of revenues from natural farming, as shown by the Q-Q plots in Figure 6.

Table 8. Crop production and direct sales prices of the two production systems.

Summer vegetables												
	2017				2018				2019			
	Production ($t\ ha^{-1}$)		Price (€ kg^{-1})		Production ($t\ ha^{-1}$)		Price (€ kg^{-1})		Production ($t\ ha^{-1}$)		Price (€ kg^{-1})	
Product	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic
Table tomatoes	5.89	5.47	4.20	2.20	4.97	4.71	3.80	1.90	6.74	5.12	3.80	1.90
"Catalogna" chicory	8.76	8.54	2.90	1.30	7.43	6.95	3.20	1.40	9.21	9.86	2.90	1.30
Savoy cabbage	7.94	7.11	3.00	1.90	8.33	7.41	2.80	1.90	8.47	6.24	2.80	1.80
Roman Courgettes	4.51	4.96	3.00	1.50	3.98	4.65	3.00	1.40	4.86	5.33	3.00	1.40
Beetroot	3.92	4.70	3.00	2.00	4.18	4.63	3.00	2.10	4.61	5.18	3.30	2.10
Lettuce	5.18	5.90	2.20	1.00	4.13	4.88	2.20	1.00	4.56	4.76	2.30	1.00
Winter vegetables												
Product	2017				2018				2019 (***)			
	Production ($t\ ha^{-1}$)		Price (€ kg^{-1})		Production ($t\ ha^{-1}$)		Price (€ kg^{-1})		Production ($t\ ha^{-1}$)		Price (€ kg^{-1})	
	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic	Natural	Organic
Broccoli	5.76	5.11	2.50	1.80	4.83	4.57	2.70	1.90				
Endive	3.44	4.06	2.80	1.50	3.25	4.12	2.80	1.50				
Chard	2.58	2.33	2.20	1.40	2.34	2.45	2.30	1.30				
Fennel	7.86	8.42	2.40	1.60	8.24	8.86	2.50	1.70				
Onion	1.89	2.23	2.20	1.20	2.12	3.01	2.30	0.90				
Potatoes	6.92	7.76	1.90	1.00	7.43	7.96	2.10	1.00				

*** Production was not detected due to the Covid-19 pandemic

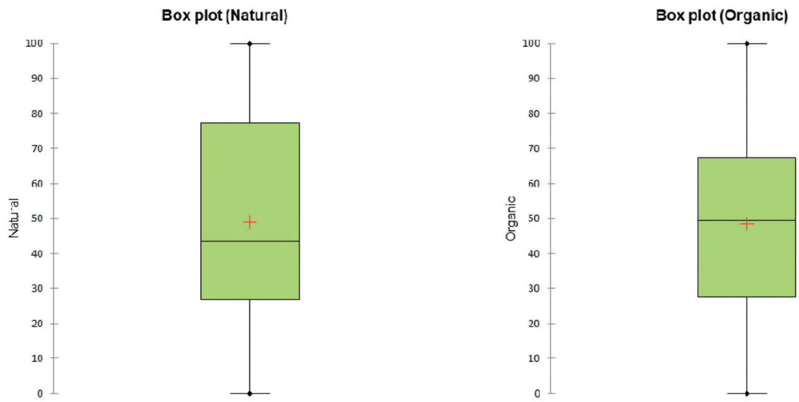

Figure 5. Box plot of total revenues (normalized on a 0–100 scale) for the two farming systems.

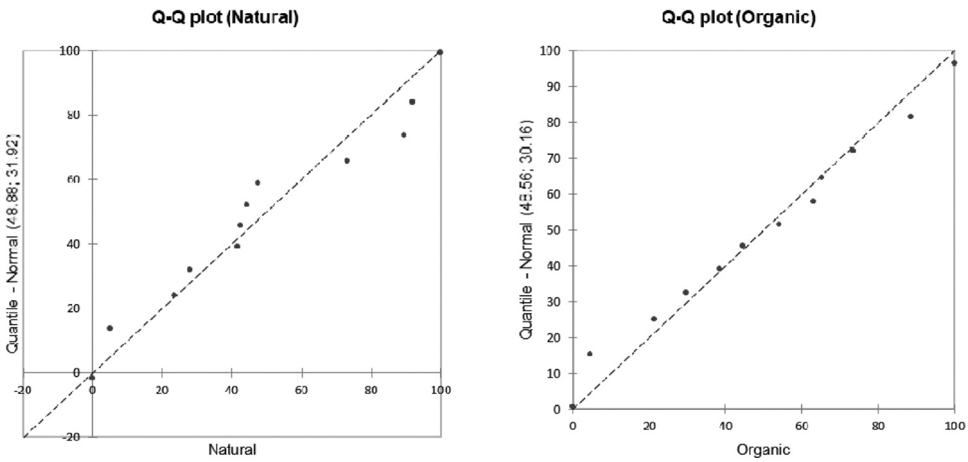

Figure 6. Distribution of revenues in the two farming systems.

According to our estimates, the average revenues from natural farming are 14,673.60 € ha^{-1}; the average revenues from organic farming are 8,320.93 € ha^{-1}. We tested the difference in the mean revenues using a 2 samples t-test, which rejected the null hypothesis that the difference between the means is equal to 0, with an alpha of 0.05. Results of the t-test are shown in Table 9.

95% confidence interval on the difference between the means:

Table 9. T test of the revenues difference.

Difference	6,352.674
t (Observed value)	2.812
|t| (Critical value)	2.074
DF	22.000
p-value (Two-tailed)	0.010
alpha	0.050

[1668.001; 11037.346]

It is worth noting that our estimates are based on the strong assumption that production is entirely sold at the average market prices. This assumption might not be always respected in reality. As regards crop protection, there are two possible cost options for natural farming: A) indirect protection has a relatively high initial cost, due to the investment of planting of perennial flowers, officinal and aromatic plants in the first year. We assumed that the initial cost of € 1,083 can be spread over 8.5 years. Thus the average annual cost of indirect defense is around € 127.4 ha^{-1}. B) as an alternative, the direct defense in natural farming costs around 880 € ha^{-1}. If we add the cost of soil management (around 520 € ha^{-1}), we have an average total cost equal to 647.41 € ha^{-1} in the case of indirect defense, and 1,400 € ha^{-1} in case of direct defense. Organic farming costs are equal to 1,248.7 € ha^{-1} (€ 550 for soil management plus € 698.7 for crop defense).

An estimate of the average profit deriving from the two systems can be easily computed by the difference between total revenues and total costs. The average annual profits from natural farming are 14,026.19 € ha^{-1} in the case of indirect defense; 13,273.6 € ha^{-1} in the case of direct defense. The average annual profit from the organic farming system is 7,072.23 € ha^{-1}.

Discussion

This study shows for the first time that the conversion from organic to natural agriculture in sloping soils counteracts losses of fertile soil, with consequent environmental benefits.

The effects of the production system change can be observed mainly in the increase of organic matter in the natural management system and in the position effect in organic farming. The movement of TOC and clay toward the bottom of the plot is an index of colloid loss, with the consequent reduction of fertility in the upper part of the plot, due to this type of loss (Oades 1984; Wuddivira and Camps-Roach 2007).

The microbial diversity also increased with the change from organic to natural management, while in the organic plot, the lowest number of bacterial and fungal colonies was observed in the top of the plot, confirming also in this case a decline in fertility from the biological point of view (Paul 2016). As for the soil's physical properties, the system change has induced an improvement in the structure stability highlighted by the variations in the bulk density and in the infiltration capacity due to the creation of the humigenous topsoil layer (Dexter 1988; Young, Orsini, and Fitzpatrick 2015). Along the slope of the organic plot, a decrease in the degree of structure was observed climbing toward the top as a consequence of the continuous tilling of the soil that induces erosion.

Ecosystem services linked to production with natural techniques also increase, as regards the supply of food and the re-use of biodegradable waste. The economic performance of natural farming increases due to the increase of both salable production and sales prices, as demonstrated in this innovative study.

The results of this work assume importance in consideration of the ongoing climate change, which in the Mediterranean areas induces a decrease in the number of rainy days and, at the same time, a greater intensity of rainfall in some cases, which can have harmful effects, especially in situations where the soil has no coverage (Kim, Seo, and Chen 2019). Climate change and degradation of natural resources may increase the frequency and magnitude of disturbances, i.e.droughts, floods, whirlwinds, rapid price changes, food availability and distribution (Srinivasrao, Arun, and Shankar 2018).

Natural farming, such as climate resilient agriculture, in a sustainable approach increase productivity and resistance of plants and reduce greenhouse gases (GHG) through carbon sequestration by means of planning productivity, adaptation, and mitigation (FAO IFAD, UNICEF, WFP, WHO. 2017). All the organic farms subjected to the performance survey are characterized by farming practice which includes direct marketing and on-farm processing. In fact, they produce honey, wax, goat wool, olive oil, hemp and sunflower oil, as well as vegetables and aromatic and medicinal herbs. Two of these farms have activated laboratories for the processing of agricultural products: one for the extraction of oil from seeds and the preparation of canned vegetables and the other for the first processing of aromatic plants and honey extraction. Climate resilient practices are often applied by small farmers in apiculture systems, in animal husbandry systems and in the production of vegetables in integrated agricultural systems (Global Forest Watch (GFW) 2017).

The use of aqueous extracts derived by self-cultivated plants for the protection of vegetables, classified as basic or phytostimulant substances, is becoming widespread in natural farming, replacing or in addition to permitted agrochemicals, with consequent environmental benefits (Beni et al. 2018b). Plant extracts have been used for a long time to control pests. Improvement in our knowledge of their allelochemical activity creates a new challenge by using these substances in plant protection (Nashwa and Abo-Elyousr 2012; Rinaldi et al. 2019).

On the farms investigated, the direct selling prices were higher in the natural system than in the organic one. Gross salable production was also higher in natural management. In addition, with the introduction of this production system, greater support for the income of organic farmers was obtained, also through the sale of integrated production. Different cost structures, and strong differences in profits highlight the advantages of natural farming in horticultural production, when compared to the organic farming.

The economic difference between the two system becomes clearer introducing the costs. The main difference in production costs refers to the crop defense costs. As already explained, natural farming is based on indirect protection, or, as an alternative, on few direct treatments. Sustainability and cost-effectiveness of natural agriculture are even more when we consider the reduced risk of crop loss (and of the consequent reduced risk of economic losses). Natural farming reduces the risk of losing the harvested product due to adverse weather conditions, making the long-term sustainability of natural system more attractive, than organic system.

Finally, this group of farms is developing scale economies due to the relationships that have been established between farms and farmers' associations in the area, social agriculture networks and joint purchasing groups. Natural agriculture introduces genetic diversity that can be a valuable tool for improving food security and adapting to climate change. Such practices also can significantly increase the productivity, income and resistance of plants and animals in severe environmental conditions (Pszczółkowski, Sawicka, and Kiełtyka-Dadasiewicz 2017). The economy of small agriculture continues to play a key role in Italy and in the other Mediterranean countries. Small farmers' performance improvement requests the adopting of a new production approach and technical, technological and biological innovations as well as removing obstacles to trade at regional and global level (Barrett, Carter, and Timmer 2010).

Conclusions

The results obtained in this research confirm for the first time that natural farming may contribute to decreasing soil vulnerability to erosion and nutrient leaching in addition to an increase in soil organic matter content, improving soil structure and sequester CO_2 in the soil. Both higher direct selling prices and major gross salable production in the natural system than in the organic one provide support for the income of organic farmers and develop scale economies in an integrated agricultural approach. The gradual replacement of organic agriculture with natural techniques must, therefore, be encouraged, especially in small and medium-sized farms and in urban, family and social agriculture.

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References

Agricoltura Naturale Community. 2020. https://www.facebook.com/Agricoltura-Naturale-1260375113987943/

Agricoltura Naturale Sinergica. 2020. https://www.facebook.com/Agricoltura-naturale-sinergica-685139211519226/

Barrett, C. B., M. R. Carter, and C. P. Timmer. 2010. A century-long perspective on agricultural development. *American Journal of Agricultural Economics* 92 (2):447–68. doi:10.1093/ajae/aaq005.

Beni, C., L. Casorri, E. Masciarelli, B. Ficociello, O. Masetti, S. Rinaldi, U. Neri, P. Papetti, and A. Cichelli. 2018b. Characterization of garlic (Allium sativum L.) aqueous extract and its hypothetical role as biostimulant in crop protection. *Journal of Food Agriculture and Environment* 16 (3–4):38–44.

Beni, C., P. Servadio, S. Marconi, U. Neri, R. Aromolo, and G. Diana. 2012. Anaerobic digestate administration: Effect on soil physical and mechanical behavior. *Communications in Soil Science and Plant Analysis* 43 (5):821–34. doi:10.1080/00103624.2012.648359.

Beni, C., S. Socciarelli, U. Neri, C. Fontana, and R. Pelegrim Prado. 2018a. Synergistic agriculture vs organic farming. first results. *Proceedings of XLVII Conference of Italian Society of Agronomy: L'Agronomia nelle nuove Agriculturae*, Marsala, TP, Italy - september, 12-14. ISBN: 978-88-904387-4-5.

Blake, G. R., and K. H. Hartge. 1986. Bulk density. In *Methods of soil analysis part 1: Physical and mineralogical methods*, ed. A. Klute, 363–75. 2nd ed. Madison, WI.: ASA. and SSSA.

Boix-Fayos, C., J. De Vente, J. Albaladejo, and M. Martinez-Mena. 2009. Soil carbon erosion and stock as affected by land use changes at the catchment scale in Mediterranean ecosystems. *Agriculture, Ecosystems & Environment* 133 (1–2):75–85. doi:10.1016/j.agee.2009.05.013.

Boix-Fayos, C., M. Martínez-Mena, P. Pérez Cutillas, J. De Vente, G. G. Barberá, W. Mosch, J. A. Navarro Cano, L. Gaspar, and A. Navas. 2017. Carbon redistribution by erosion processes in an intensively disturbed catchment. *Catena* 149 (3):799–809. doi:10.1016/j.catena.2016.08.003.

Cappello, G. C. 2019. *La civiltà dell'orto: La coltivazione elementare*. L'Età dell'Acquario Publ. Turin, IT. 185. ISBN: 8833360997

Chiwetalu, U. J., C. C. Mbajiorgu, and N. J. Ogbuagu. 2020. Remedial ability of maize (Zea-Mays) on lead contamination under potted condition and non-potted field soil condition. *Journal of Bioresources and Bioproducts* 5 (1):51–59. doi:10.1016/j.jobab.2020.03.006.

Cosentino, S. L., V. Copani, G. Scalici, D. Scordia, and G. Testa. 2015. Soil erosion mitigation by perennial species under Mediterranean environment. *BioEnergy Research* 8 (4):1538–47. doi:10.1007/s12155-015-9690-2.

Dexter, A. R. 1988. Advances in characterization of soil structure. *Soil and Tillage Research* 11 (3–4):199–238. doi:10.1016/0167-1987(88)90002-5.

FAO, IFAD, UNICEF, WFP, WHO. 2017. The state of food security and nutrition in the world. In *Building resilience for peace and food security*, Rome, IT: 132. Food and Agriculture Organization.

Fiebrig, I., S. Zikeli, S. Bach, and S. Gruber. 2020. Perspectives on permaculture for commercial farming: Aspirations and realities. *Organic Agriculture* 10 (3):379–94. doi:10.1007/s13165-020-00281-8.

Fini, A., C. Degl'Innocenti, and F. Ferrini. 2016. Effect of mulching with compost on growth and physiology of Ulmus 'FL634' planted in an Urban Park. *Arboriculture & Urban Forestry* 42 (3):192–200.

Gee, G. W., and J. W. Bauder. 1986. Particle size analysis. In *Methods of soil analysis, part 1, physical and mineralogical methods*, ed. A. Klute, 383–411. 2nd ed. Madison, WI., USA: American Society of Agronomy.

Global Forest Watch (GFW), 2017. *Country profile – The Philippines. Global Forest Watch*. Accessed 12 february 2021. http://www.globalforestwatch.org/country/PHL .

Gram, A. 1984. *U.S. Department Of health and human services, public health services, centers for disease control*. CDC, Atlanta, Ga, USA.

Hazelip, E. 2014. *Synergistic Agriculture*. A. A. M. Terra Nuova. Publ., Florence, IT: ISBN 886681040X.

ISTAT. 2016. *Indagine sulla struttura e sulle produzioni delle aziende agricole italiane*. Rome, Italy: Istituto Centrale di Statistica.

Jones, A., P. Panagos, S. Barcelo, F. Bouraoui, C. Bosco, O. Dewitte, C. Gardi, M. Erhard, J. Hervás, R. Hiederer, et al. *The State of Soil in Europe. A contribution of the JRC to the European Environment Agency's Environment State and Outlook*. Report SOER 2010.

Kim, G. U., K. H. Seo, and D. Chen. 2019. Climate change over the Mediterranean and current destruction of marine ecosystem. *Scientific Reports* 9 (1):18813. doi:10.1038/s41598-019-55303-7.

Mancin, A., E. H. Ip, S. Saldana, and T. A. Arcury. 2012. Synergistic agriculture. *European Journal of Integrative Medicine* 4 (184):e205–e211. doi:10.1016/j.eujim.2012.07.908.

Martínez-Mena, M., J. López, M. Almagro, J. Albaladejo, V. Castillo, R. Ortiz, and C. Boix-Fayos. 2012. Organic carbon enrichment in sediments: Effects of rainfall characteristics under different land uses in a Mediterranean area. *Catena* 94:36–42. doi:10.1016/j.catena.2011.02.005.

Monica, R. 2001. Comparison of anastomosis groups of Rhizoctonia solani by polyacrylamide gel electrophoresis of soluble protein. *Phytopathology* 73:903–06.

Nashwa, S. M. A., and K. A. M. Abo-Elyousr. 2012. Evaluation of various plant extracts against the early blight disease of tomato plants under greenhouse and field conditions. *Plant Protection Science* 48 (No. 2):74–79. doi:10.17221/14/2011-PPS.

Nelson, D. W., and L. E. Sommers. 1982. Total carbon, organic carbon and organic matter. In *Methods of soil analysis, part 2: Chemical and microbiological properties*, ed. A. L. Page, R. H. Miller, and D. R. Keeney, 539–79. 2nd ed. Madison, WI., USA: ASA and SSSA.

Oades, J. M. 1984. Soil organic matter and structural stability: Mechanisms and implications for management. *Plant and Soil* 76 (1–3):319–37. doi:10.1007/BF02205590.

Orto Sinergico Community. 2020. https://www.facebook.com/Orto-sinergico-378926915474408/

Panagos, P., P. Borrelli, J. Poesen, C. Ballabio, E. Lugato, K. Meusburger, L. Montanarella, and C. Alewell. 2015. The new assessment of soil loss by water erosion in Europe. *Environmental Science & Policy* 54:438–47. doi:10.1016/j.envsci.2015.08.012.

Paul, E. A. 2016. The nature and dynamics of soil organic matter: Plant inputs, microbial transformations, and organic matter stabilization. *Soil Biology & Biochemistry* 98:109–26. doi:10.1016/j.soilbio.2016.04.001.

Pinamonti, F. 1998. Compost mulch effects on soil fertility, nutritional status and performance of grapevine. *Nutrient Cycling in Agroecosystems* 51 (3):239–48. doi:10.1023/A:1009701323580.

Pszczółkowski, P., B. Sawicka, and A. Kiełtyka-Dadasiewicz. 2017. The role of ProBioEm technology in shaping soil quality. In: *Proceedings of the Conference of sciences. 'Biodiversity of the environment – significance, problems, challenges'*. IUNG-PIB, Puławy, pp. 150–51. 30–31 May, ISBN: 978-83-7562-258-4

Rakow, D. A. 1998. *Types and uses of mulch in the landscape*. Elmira, NY, USA: Cornell Cooperative Extension. 14904–1766. http://chemung.cce.cornell.edu/resources/mulch-in-the-landscape .

Rete Rurale Nazionale (RRN). 2019. *Bioreport 2017-2018: Organic Agriculture in Italy*. Rome, IT: MIPAAFT Publ.. 181. ISBN 97888-3385-000-9.

Rezendes, I., E. Roncaglio Baseggio, L. Galon, D. Brandler, C. Tiago Forte, I. Aspiazú, M. Barretta Franceschetti, and A. Ferreira Da Silva. 2020. Allelopathy of weeds on the growth of vegetables. *Communications in Plant Sciences* 10 (2020):8–17. doi:10.26814/cps2020002.

Rinaldi, S., L. Casorri, E. Masciarelli, B. Ficociello, U. Visconti, P. Papetti, U. Neri, and C. Beni. 2019. Prospects of garlic extract use as pest control in sustainable agriculture. *Fresenius Environmental Bulletin* 28 (2):535–40.

Sawicka, B. 2019. Resilient agricultural practices. In *Zero hunger. Encyclopedia of the UN sustainable development goals*, F. W. Leal, A. Azul, L. Brandli, P. Özuyar, and T. Wall. ed., Cham, CH: Springer International Publishing:42-51. doi:10.1007/978-3-319-69626-3.

Shyam, D. M., S. Dixit, R. Nune, S. Gajanan, and G. Chander. 2019. Zero budget natural farming – An empirical analysis. *Green Farming* 10 (6):):661–667.

Srinivasrao, C. H., K. Arun, and S. C. H. Shankar. 2018. Agriculture resistant to climate change – Strategies and perspectives. *Techopen*. ISBN: 978-953-51-3896-9. doi:10.5772/intechopen.68382.

Starr, G. C., R. Lal, R. Malone, D. Hothem, L. Owens, and J. Kimble. 2000. Modeling soil carbon transported by water erosion processes. *Land Degradation and Development* 11 (1):83–91.

Tariq, S. R., and A. Ashraf. 2016. Comparative evaluation of phytoremediation of metal contaminated soil of firing range by four different plant species. *Arabian Journal of Chemistry* 9 (6):806–14. doi:10.1016/j.arabjc.2013.09.024.

Wuddivira, M. N., and G. Camps-Roach. 2007. Effects of organic matter and calcium on soil structural stability. *European Journal of Soil Science* 58 (3):722–27. doi:10.1111/j.1365-2389.2006.00861.x.

Young, R., S. Orsini, and I. Fitzpatrick. 2015. *Soil degradation: A major threat to humanity*. , Bristol, UK: Sustainable Food Trust. http://sustainablefoodtrust.org.