LIFE Project Number

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Deliverable "Swot Analysis"

Sub-action B2.4 "Second report on SWOT analysis of soil and plant data in the considered vineyards"

LIFE+ PROJECT Soil4Wine

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1. Introduction: Project overview

Soil4Wine project "*Innovative approach to soil management in viticultural landscape*" aims to achieve a better soil management in the whole viticultural system. It also targets development and testing of an innovative Decision tool and management solution.

This report presents the structure and main outcomes of sub-action B2.4 related to Soil4Wine project Action B.2 "Demonstration in vineyards" from M1 (01.01.2017) until M36 (31.12.2019). HORTA is the responsible for this action and UCSC is the other partner involved.

2. Material and Methods

2.1 Data collection

Data collection for assessing strengths, weaknesses, opportunities and threats rising from using the Decision Tool (DT) and from solutions implementation was launched as foreseen in the first project year. First feedbacks from Demo farmers on α- tool were collected during the co-development meeting (M8:01/08/2017 at Res Uvae) and, considering the nature of the α-tool itself (i.e., not yet user-friendly – excel file) it was decided to collect feedbacks on usefulness and expectations, rather than on the degree of user-friendliness using oral interviews. Details have been in Deliverable B3.1 *"Report on involvement of "demo farmers" (co-development and education/training)"* which contains all the activities and discussions held during the co-development meetings.

As foreseen in the proposal, a sampling plan was developed to collect soil and plant parameters in the demonstration vineyards: soil samples were collected at M10 and physical/chemical analyses were externalized to a specialized laboratory; vine performance parameters were collected at harvest (M8-M9 and M20-21) and winter pruning (M11-M12). Weather stations and soil temperature and humidity sensors were installed at M12 and, since then, real-data data collection started. In spring 2018 floristic surveys were performed to complete the first-year data collection; likewise indices related to the environmental impacts of the different management solutions were calculated through the DSS "vite.net" on the grape growing season 2018 and 2019. .

During season 2019, soil samplings were performed into all demonstration vineyards and different tests were performed: i) slake test (about soil stability) (Tongway & Hindley, 1995) ii) biodiversity evaluation of soil according to the presence and abundant of specific arthropods (QBS-ar, Parisi et al., 2004) and iii) biodiversity evaluation of soil according to the presence and type of earthworms (QBS-e, Paoletti et al., 2013).

All the results obtained during the sampling plan were aggregated according to the different type of innovation tested in the demo farms. In particular, three groups were created:

- ***Spontaneous grassing vs sown cover crops***: this group was composed by the demo farms SP1, SP4 and TBC1 (TBC2 have been considered for the 2nd evaluation round only, because the cover crops sowing was performed in M22);
- ***Tillage vs green manure***: this group was composed by the demo farm SP2;
- ***Spontaneous grassing vs green manure***: this group included demo farms SP3[1], VT1 and VT2.
- ***Underground pipe drains***: this group was composed by the demo farm Res Uvae.

[1] SP3 vineyard was explanted by the owner in the end of 2018

The evaluation of soil erosion was visually performed at the end of the growing season using the assessment scale presented in Deliverable B2.4 *"First report on SWOT analysis of soil and plant data in considered vineyards"*

2.2 SWOT Analysis

SWOT analyses derive their name from the assessment of the Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T) faced by an industry, sector, company or any organisation (Gao and Peng, 2011). The idea of a SWOT analysis has its roots in strategic management research conducted in the 1960s and 1970s (Sevkli et al., 2012), and arises from the perspective that the performance of a given (typically, but not only, economic) agent with respect to a particular objective depends upon the way in which the management of that agent interacts with both the internal characteristics of the agent, and the broader external context in which the agent must act (but over which the agent has no direct control in the short term) (Houben et al., 1999).

The value of a SWOT analysis stems not just from its ability to highlight ways in which an agent's internal and external environments interact to affect its success (Houben et al., 1999), but also from its ability to be used in the development and implementation of long-term strategies to achieve particular objectives (Houben et al., 1999; Gao and Peng, 2011; Sevkli et al., 2012). There are various classes of strategies that can follow from a SWOT analysis: e.g. those that link Strengths and Opportunities ('SO Strategies'), those that link Weaknesses and Opportunities ('WO Strategies'), those that jointly focus on the Strengths and Threats ('ST strategies'), and those that arise from the joint assessment of Weaknesses and Threats ('WT Strategies'). For example, SO strategies exploit the fact that Strengths may help to capitalise upon external Opportunities, whereas WO strategies focus upon the pursuit of external Opportunities to lessen the severity of Weaknesses. Similarly, ST strategies focus on the potential for existing internal Strengths to mitigate the impact of external Threats, while WT strategies consist of actions intended to reduce both internal Weaknesses and external Threats simultaneously (Sevkli et al., 2012).

3. Results from the two demonstration seasons (2018 and 2019)

Soil sampling performed during season 2019 was necessary to obtain information about soil characteristics and soil quality according to the biodiversity indexes tested.

The slake test involved the immersion of fragments of surface soil (approx. 1 cm^3) in a beaker of rain water and the observation of the response of the fragments over a period of several minutes. Different classes of soil are identified and allow to evaluate the soil stability during rain:

- **Class 1 - very unstable soil**: fragment collapses completely in less than 5 seconds often with a myriad of air bubbles, into a shapeless mass.
- **Class 2 - unstable soil:** fragment substantially collapses over about 5-10 seconds, a thin surface crust remains, but >50% of the sub-crust material slumps to an amorphous mass.
- **Class 3 - moderately stable soil:** surface crust remains intact, some slumping of sub-crust material, but<50%.
- **Class 4 - stable soil**: whole fragment remains intact after 5 minutes. This level of stability may remain for many hours.

The results obtained from the samples collected in the different soil management strategies are shown in Figure 1. Only in few cases (sub-samples) a low soil stability was observed (class 1 or 2) while, generally, all soils showed a moderate to high level of stability. It was quite clear that the soil managed the most (tillage and green manuring) showed the lowest stability, while permanent and spontaneous grassing resulted in an organization of more stable soil fragments. This is a promising result because it means that the intrinsic soil quality is good and a proper management can minimize soil losses due to erosion during rain.

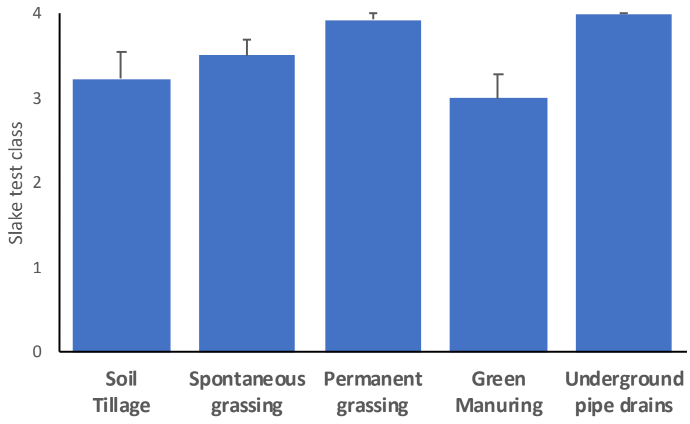


Figure 1 – Slake test results on different soil fragments sampled from the demo-vineyards. Bars represent the average values of the same type of demo farm; whiskers show the standard error.

Earthworms belong to macrofauna, but some species can reach the dimension attributed to megafauna and are considered soil engineers, as they are able to modify soil structure and features by their etho-physiological action. The QBS-e index aims to assess the soil health based on the monitoring of the earthworm community hosted within, considering that earthworms are recognised as good bioindicators, and they are also, in general, well known by farmers (unlike other groups of soil organisms which are little appreciated by farmers such as microorganisms, micro- or meso-fauna). This index facilitates the estimation of the sustainability of soil management practices, and it can be used also by non-experts, directly in the field.

The obtained results showed quite clearly that in the vineyards more frequently managed (i.e. tilled soil or green manuring) the QBS-e index is lower compared to more steady soil were grassing is established (Figure 2).

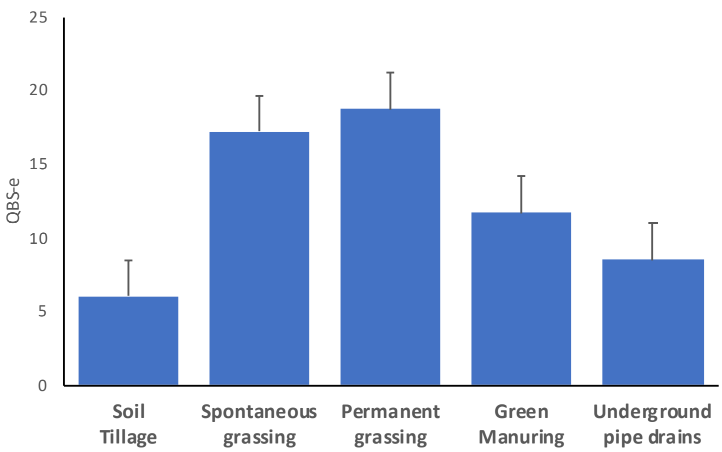


Figure 2 – QBS-e index about the biodiversity evaluation on the basis of earthworms presence and abundance in the differently managed soil of the demo-farms. Bars represent the average values of the same type of demo farm; whiskers show the standard error.

The QBS-ar is one of the indices that have been conceived and developed in recent years. It is a metric based on the concept that the number of microarthropod groups morphologically well adapted to the soil is higher in high quality soils than in low quality soils. QBS-ar joins the biodiversity of soil microarthropods community with the degree of soil animals' vulnerability and provides information on the soil biological quality, which is an indicator of land degradation. This index was developed to combine two important aspects regarding soil microarthropods: 1) their presence in the soil, intended as biodiversity; 2) their capability to adapt to soil conditions, intended as vulnerability. QBS-ar index applies to the soil microarthropod community to: 1) evaluate the adaptation of microarthropods to the soil environment, and 2) overcome the well-known difficulties of taxonomic analysis at the species level for soil microarthropods. QBS-ar index focuses on the presence of morphological characters that indicate adaptation to soil by microarthropods, and it does not require complex taxonomic identification at the species level. In the tested strategies, the average level of QBS-ar did not differ significantly (Figure 3). Nevertheless, a certain trend was highlighted in the green manuring soil management strategy were the average value of the index was constantly higher. The same positive effect on arthropods presence was observed where underground pipe drains was installed and it was probably linked with the deep soil tillage necessary for the installation of pipe drains (Figure 3).

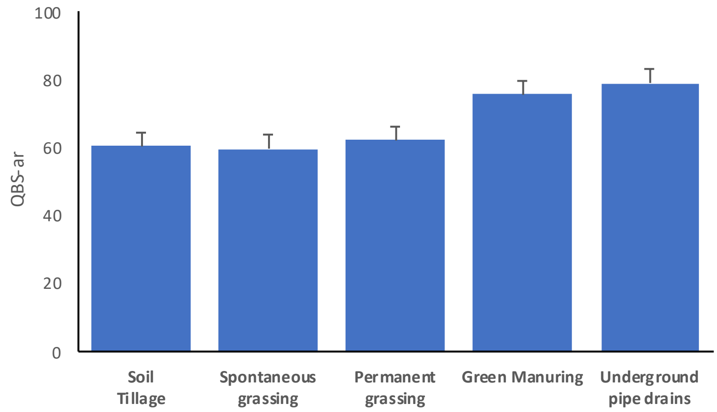


Figure 3 – QBS-ar results in the different soil management types tested in demo farms. Bars represent the average values of the same type of demo farm; whiskers show the standard error.

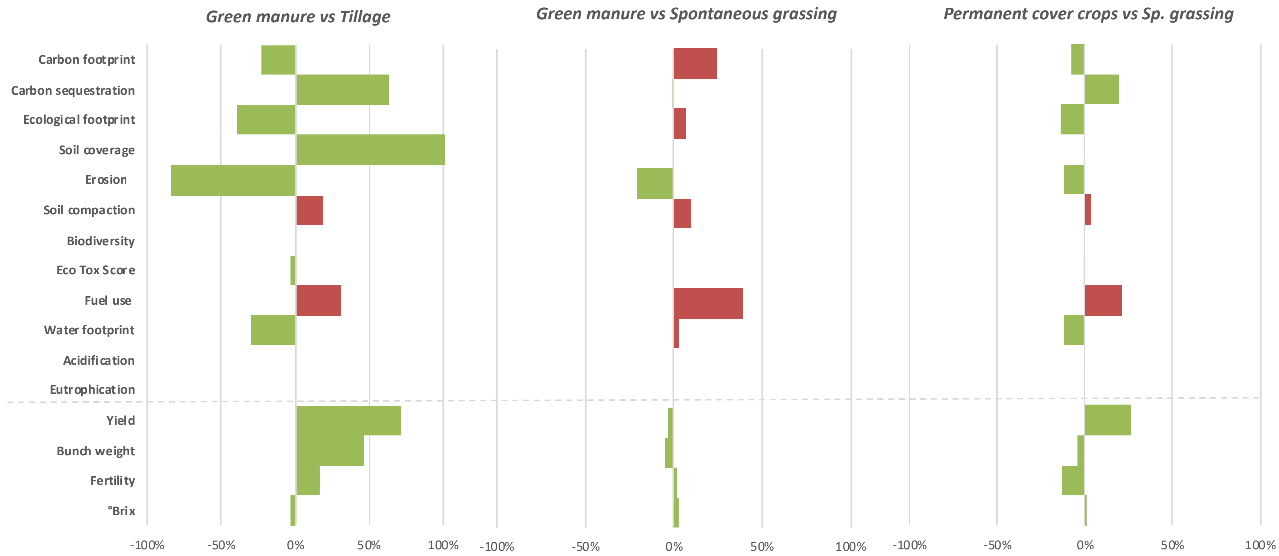
Table 1 reports main results for some agronomical parameters (i.e. vine yield, sugar concentration, vine balance etc.) and some environmental indicators (i.e. carbon, water and ecological footprints and carbon sequestration) which were calculated using vite.net® in the different demo-vineyards. For each group the average result of each indicator obtained in the second season (2019) is reported in comparison to the previous season (2018). Vine yield under standard management techniques ranged from 7,1 t/ha in 2018 (soil tillage) to 19,7 t/ha in 2019 (spontaneous grassing) while with the innovative techniques it ranged from 10,8 t/ha (in 2018) to 17,6 t/ha (in 2019) both with green manure. The least sugar concentration was recorded in 2018 (20.3° Brix) in the native grass plots, while the maximum was 24,2° Brix recorded in the tillage practice in 2019. Cluster weight ranged from 84 g in 2018 (soil tillage) to 491 gr in 2019 (spontaneous grassing), whereas shoot fruitfulness went from 1.08 to 2.33 clusters/shoot (both green manure techniques; Table 1). The carbon footprint ranged from 0,09 to 0,149 t CO_2 eq/t/ha in the innovative management with sown cover crops and soil tillage, respectively. The water footprint indicator ranged from 889 m^3 H_2O/t/ha in 2018, under the condition of spontaneous grassing, to 1615 m^3 H_2O/t/ha in 2019, under the condition of soil tillage (Table 1).

The results obtained with the innovative management techniques were then compared with the standard ones for each of the three groups and the main variations are reported in Figure 1.

Table 1 – Main indicators considered for the different soil management solutions and for the two growing seasons: data are means averaged over each demo farm.

Description		**Std**: spontaneous grassing **Inn**: sown cover crops		**Std**: tillage **Inn**: green manure		**Std**: spontaneous grassing **Inn**: green manure	
Experimental vineyards (code)		SP1 - SP4 - TBC1 - TBC2		SP2		SP3 - VT1 - VT2	
		2018	**2019**	**2018**	**2019**	**2018**	**2019**
Yield (t/ha)	Standard	13.6	12.3	7.1	6.3	17.9	19.7
	Innovative	16.9	13.6	10.8	12	17.6	14.3
Carbon footprint (t CO_2 eq/t/ha)	Standard	0.100	0.137	0.116	0.149	0.093	0.132
	Innovative	0.090	0.134	0.097	0.104	0.112	0.164
Water footprint (m^3 H_2O/t/ha)	Standard	1526	1054	1198	1615	889	1116
	Innovative	1187	896	908	988	893	1171
Ecological footprint (global ha/t/ha)	Standard	0.234	0.296	0.384	0.435	0.164	0.170
	Innovative	0.180	0.244	0.258	0.236	0.170	0.185
Carbon sequestration (t C/ha)	Standard	3.5	3.1	1.9	1.8	4.1	4.8
	Innovative	4.2	3.3	2.8	3.1	4.2	4.5
Cluster weight (kg)	Standard	0.166	0.214	0.084	0.106	0.289	0.491
	Innovative	0.200	0.195	0.137	0.140	0.281	0.474
Vine fertility (clusters/shoot)	Standard	1.76	1.68	2.17	1.70	1.12	1.09
	Innovative	1.79	1.59	2.33	2.20	1.08	1.13
Sugar concentration (°Brix)	Standard	22.5	21.4	22.6	24.2	20.3	21.5
	Innovative	21.4	22.0	22.7	22.3	21.2	21.6
Ravaz index (kg/kg)	Standard	5.2	7.9	7.3	6.5	8.4	10.8
	Innovative	5.9	7.0	7.8	9.5	7.6	9.3
Soil Erosion (t soil/ha)	Standard	9.2	9.8	106.9	31.2	31.1	14.5
	Innovative	6.0	9.7	199.6	16.4	12.5	14.5

Figure 4 – SWOT analysis of different standard managements (i.e. spontaneous grassing and tillage) compared to innovative solutions (i.e. sown cover crops and green manure). Output about vines data and environmental indexes are expressed as a proportion of the variation of each innovative solution compared to the standard practice. Environmental indicators are evaluated for their effect (i.e. green and red showing positive and negative, respectively) while for grapevine indicators an evaluation is not expressed since it may vary on the basis of the oenological target.



During fall 2019, another data set for all parameters was taken in all the demonstration farms both in innovative and standard vineyards. These data were used to carry out a simulation of the standard and innovative management in each combination (i.e. under the same 2019 conditions), but with the new soil parameters obtained (i.e. soil analysis) (Table 2). This was done in order to simulate what will happen in season 2020, during the "after-LIFE" activities when the demo-vineyards will be managed with the innovative approaches.

Table 2 – Main parameters considered for the different soil management solutions at the end of the project (M34): data are means averaged over each demo farm (0-20 cm depth)

Description		**Std**: spontaneous grassing **Inn**: sown cover crops		**Std**: tillage **Inn**: green manure		**Std**: spontaneous grassing **Inn**: green manure	
Experimental vineyards (code)		SP1 - SP4 - TBC1 - TBC2		SP2		VT1 - VT2	
		2019		**2019**		**2019**	
pH	Standard	7.05		8.03		7.91	
	Innovative	7.04	-0.21%	8.05	+0.25%	7.87	-0.57%
Soil organic matter (g/kg)	Standard	23.76		21.4		22.6	
	Innovative	21.35	-10.17%	22.7	+6.07%	23.1	+2.21%
N total (mg/kg)	Standard	1.67		1.64		1.14	
	Innovative	1.27	-11.25%	1.55	-5.49%	1.21	+6.61%
P available (mg/kg)	Standard	6.25		4		3.5	
	Innovative	10	+60%	16	+300%	3	-14.29%
K exchangeable (mg/kg)	Standard	173.5		291		3.95	
	Innovative	164.75	-5.04%	308	+5.84%	3.78	-7.66%
Nitrates (NO_3^-) (mg/kg)	Standard	215.17		234.34		251.66	
	Innovative	221.39	+2.89%	207.7	-11.33%	216.82	-13.84%
Cu total (mg/kg)	Standard	50.18		56.02		117.59	
	Innovative	40.42	-19.46%	46.34	--17.28%	108.7	-7.56%
C/N	Standard	10.87		7.57		14.66	
	Innovative	9.65	-11.25%	8.53	+12.68%	10.55	-28.01%

Degree of humification (DH) (%)	Standard	39.87		51		33.55	
	Innovative	45.6	+14.36%	49.3	-3.33%	34.70	+3.43%
Electrical conductivity (µs/cm)	Standard	0.18		0.16		0.71	
	Innovative	0.183	+1.39%	0.2	+25%	0.21	-70.21%

Table 3 – Main indicators that showed a significant modification introducing the soil data analysis obtained with the sampling at the end of the season 2019. Data showed represent the variation from the results obtained in each experimental farm, grouped according the innovation tested, for both standard and innovative soil management techniques during season 2019, but with soil data and characteristics assessed in fall 2019.

	Carbon footprint (t CO_2 eq/t/ha)		**Ecological footprint** (global ha/t/ha)		**Water footprint** (m^3 H_2O/t/ha)		**Soil acidification** (SO_2 eq t/t yield)	
	2019	**2019***	**2019**	**2019***	**2019**	**2019***	**2019**	**2019***
Green manure **vs** Tillage	-23%	-43%	-39%	-46%	-31%	-33%	--	-50%
Green manure **vs** native grassing	-8%	-37%	-14%	-37%	-12%	-24%	--	-25%
Sown cover crops **vs** native grassing	+25%	+21%	+7%	+10%	+3%	+8%	--	--

*same management practices of 2019, but with modified soil data and characteristics (according to the soil sample and analysis performed in M34)

All innovative management practices reduced the carbon footprint albeit to a different extent: a two fold reduction occurred with *green manure* vs *soil tillage* and a more than three fold reduction was shown by green manure as compared to native grassing. Even in the sown cover crop management the carbon footprint showed a reduction. It is interesting to notice that two innovative techniques out the three tested were able to significantly reduce the soil acidification, and thus reduce the impact on environment.

3.1 Vine performance and environmental data

Native grassing vs sown cover crops

The implementation of sown cover crops as innovative soil management technique increased vine yield by 26% on average, compared to native grass.

Assessment of soil chemical parameters (Table 2) showed that innovative technique reduced soil organic matter content (-10.17%) but increased the degree of humification (DH) (+14.36%) of organic carbon. In terms of chemical fertility Phosphorus increased by 60% and total Cu was reduce (-19.46%). C/N ratio in innovative plot was maintained on value that represent an equilibrium between mineralisation and humification processes.

The innovative solution also produced positive variations in terms of carbon sequestration, ecological and carbon footprint. The assessed reduction of soil erosion was estimated at 12% vs the standard practice. The average cluster weight of the innovative solution was almost the same (-4%) as compared to the standard.

Tillage vs Green manure

The adoption of green manure (innovative soil management technique) led to the highest increase in yield per vine (71% on average) as compared to the conventional of soil tillage. As shown in Figure 1, the green manure brought to very positive results in terms of carbon sequestration increase (+63%), reduction of ecological footprint (-39%), water (31%) and carbon footprints (-23%) compared to the standard practice. The average cluster weight of the innovative solution significantly increased (+47%) compared to the standard.A good increase in shoot fruitfulness was registered in the plot with the innovative solution while no significant in terms of sugar concentration was detected.

Assessment of soil chemical parameters (Table 2) showed that green manure act positively upon parameters of soil chemical fertility (N, P, K), reducing nitrates (-11.33%) and increasing soil organic matter content (+6.07%). C/N ratio in innovative plot moved to value that represent an higher equilibrium between mineralisation and humification processes. In terms of ecological impact, total Cu was reduced by innovative technique (-17.28%),

Native grass vs green manure
The green manure led to a slightly higher yield than the standard management of spontaneous grassing. In the vineyard managed with green manure average cluster weight, vine fertility and sugar concentration did not show large differences to the standard grassing with spontaneous species.

Application of innovative technique increased soil organic matter content (+2.21%). Considering soil minerals, N total content increased (+6.61%) and nitrates content (-13.84%) decreased. Availability of P and K (exchangeable) was reduced. C/N ratio in innovative plot was reduced (-28.01%) towards a value that represent an higher equilibrium between mineralisation and humification processes. In terms of ecological impact total Cu was reduce by innovative technique (-7.26%),

3.2 Strengths

Spontaneous grassing vs sown cover crops
The sown cover crops innovative solution, compared to spontaneous grassing, allowed to improve soil structure and canopy vigor and to reduce the runoff. The innovative solution was able to decrease the surface soil erosion, the water logging and the compaction of superficial soil layer, while it contributed to increase the soil walkability, the biodiversity and the soil organic matter. No significant competition with the grapevine was perceived in the plots with sown cover crops compared to the spontaneous grassing.

Tillage vs green manure
The adoption of green manure (innovative soil management technique) led to the highest increase of yield (71% on average) compared to soil tillage. A good increase in vine fertility was registered in the plot with the innovative solution while no appreciable variation in terms of sugar concentration in the grape juice was observed.

Spontaneous grassing vs green manure
As shown in Figure 1, the innovative management practice led to a reduced soil erosion. This should also lead to an improvement of soil structure, reduction of compaction and reduction of water logging. Biomass produced by green manure in the inter-row space resulted not to be an obstacle in returning into the field for agronomical operations before cutting.

3.3 Weaknesses

Spontaneous grassing vs sown cover crops
In some cases and years, the sown cover crops presented a stunted growth and a slow establishment rate. The innovative technique also led to increased fuel consumption compared to the standard, because of the management needs for soil preparation and sowing of the cover crops; though this effect tended to offset over time.

Tillage vs green manure

The average bunch weight of the innovative solution heavily increased (+47%) compared to the standard: this aspect may be more or less positive depending on the specific susceptibility to bunch rot of the grapes variety (i.e. heavier bunches tend to be more compact, with a thinner skin and are more exposed to rot risk). The innovative technique showed an increased fuel consumption, compared to the standard, because of the management needs for green manuring procedures.

Spontaneous grassing vs Green manure

On average, the plots managed with the innovative technique registered a less favorable carbon footprint than the conventional practice. This, as well as the increased fuel consumption compared to the standard, is due to the management needs for green manuring procedures. Also, the water and ecological footprints of the innovative plots resulted to be slightly higher.

3.4 Opportunities

Sown cover crops and green manure represent the innovative techniques most likely to be adopted in the future by the demo-farms. The group of demo-farmers which is more positive about the possibility of a large-scale adoption of the innovative solution is the one who implemented sown cover crops. Grape health is largely perceived by demo-farmers as an opportunity linked to the adoption of innovative solutions. All the farmers unanimously proposed a pre-sowing manuring for the cover crop in order to improve its growth.

3.5 Threats

The main threat perceived by the farmers implementing permanent cover crops as innovative solution was primarily economical (i.e. seed cost or payment for external service). Conversely, cover crops are not perceived as a threat in terms of productivity, vigor, sanity and quality of grapes. The demo-farmer testing green manure instead of tillage, considers, as major threats, the need to spend for the implementation of solution the major threat in adopting innovative technique along with a reduction in both sanity and quality of grapes due to the presence of the cover crops. Also the group of farmers adopting green manure vs spontaneous grassing consider the idea of spending money for the adoption of the innovative technique a threat, .

4. Conclusions

The innovative soil management technique which gave the most positive results in terms of yield, carbon sequestration, ecological, water and carbon footprints was green manure to replace soil tillage. The same technique also led to higher bunch weight and vine fertility; thus its adoption needs to be evaluated also on the basis of the pursued oenological target. Sown cover crops installment showed very good results, in particular from the environmental point of view, and allowed also a great increase in terms of yield. Finally, green manure in comparison to the spontaneous grassing of the vineyard showed some limitation since the increased number of management interventions worsened the environmental impact.

The simulation performed on 2019 results, with the adjustment of soil data and characteristic on the basis of the soil sampling performed during fall 2019, showed very promising results. In particular, after only two seasons many environmental parameters showed a possible highly enhancement due to the improved quality of the soil. These results should be confirmed in future assessment, and the "after-LIFE" activities planned seem to be very well suited to this goal.

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