Drought Resilience Improvement in Vineyard Ecosystems

LIFE19 ENV/IT/000035

Report on ecosystem services

Sub-action B4.2
30.12.2023

Summary

The DRIVE project is aimed also to the definition of the ecosystem services related to the adoption of resilient techniques in demonstrative vineyards (Action B4).
For each demo farms, four ecosystem services have been assessed, in physical and monetary terms:

- Soil erosion protection
- Carbon sequestration
- Pollination
- Water storage

In this document, adopted methodology are explained and results showed.

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Ecosystem services and agricultural practices

During the DRIVE LIFE project, different agricultural practices have been tested in pilot vineyards, aimed both to soil management and to canopy management in order to enhance the vineyard's resilience to water stress. Presented elaboration refeer only to soil management solutions.
Details about the applied innovative solution are reported in Deliverable B2 "*Report on the implementation of resilience plans in the DEMO farms*"

The first step of the Sub-Action B4.2 "*Ecosystem services*" has been dedicated to the definition of the proper ecosystem services, and the second step has been the identification of the correlations with the applied water resilience techniques.
In the following table, these correlations have been synthetized.

		RESILIENCE TECHNIQUES							
		CANOPY TREATMENTS		***SOIL MANAGEMENT***					
				permanent artificial grassing	*between rows mulching*		*"mow and blow" (piling of grass under the row)*		*green manuring*
		kaolin	*anti-transpirant*		*N*	*C*	*N*	*C*	*N/C*
ECOSYSTE, SERVICES	Soil water storage			X	X	X	X	X	X
	Plant water storage	X	X						
	Pollination			X	X	X	X	X	X
	Erosion protection			X	X	X	X	X	
	Biodiversity preservation			X					
	Soil carbon sequestration				X	X	X	X	X
	Carbon sequestration in the plant	X	X						
	Soil fertility				X	X	X	X	X
	Pest management				X	X			

On the basis of the application of experimental protocols in the selected vineyards and the preliminary results obtained, among the ones indicated in the Table, four ecosystem services have been selected for the assessment:

- **Soil erosion protection**
- **Pollination**
- **Soil carbon sequestration**
- **Soil water storage.**

These ecosystem services have been quantified for each pilot vineyard.
Involved DEMO farms are:
Colli Piacentini:

- SRT: Sartori – Creta
- GNP: Braghieri – Genepreto
- VCB: Az. Ampeli – Vicobarone

Oltrepò Pavese:

- BRP: Az. Dacarro – Borgo Priolo
- CNV: Piaggi – Canevino
- SMV: Az. Ottina Enrico – Santa Maria della Versa

In the following table adopted techniques are described for each DEMO farm. The composition of the sown seed-mixtures may involve the use of different proportions of cereals, legumes, brassica and other botanical families according to the specific needs of the vineyard. The field trials selected a seed-mixture with predominance of grasses (C), one with mostly leguminous (N) and a third one (B) with a more balanced legume-to-grass ratio and the presence of small fractions of brassica and other species.

DEMO FARM CODE*[1]	Project area[2]	Traditional management (Control)	Adopted techniques
VCB	CP	Ploughed	Green manure applied using three different winter cover-crop (N, C, B)
GNP	CP	Ploughed	Green manure applied using balanced and grass-prevalent winter cover crop (C)
CRT	CP	Alterate grassing	Rolling and the "mow and blow" termination of C cover crop
BRP	OP	Ploughed	Green manure applied to B and C winter cover crops.
SMV	OP	Spontaneous grassing	-Application of all termination techniques to C and N cover crops -Under row sowing and transplanting of ground cover species
CNV	OP	Ploughed	Between-row rolling of C cover crops.

[1] DEMO farms codes are refereed to Deliverable B2.1 "Report on chemical-physical features and hydraulic properties of selected vineyard soils"
[2] CP = Colli Piacentini; OP = Oltrepò Pavese

Biophisical quantification

The used methodologies for ES's **biophysical quantification** are the following:

1. Soil erosion protection

The adoption of resilient techniques reduces the soil loss due to sheet and rill erosion.

This ecosystem service is calculated defining the tons of soil that is not eroded thanks to sustainable practice.

The calculation method is based on RUSLE "*Revised Universal Soil Loss Equation*"[3]

$$A = R \times K \times L \times S \times C \times P$$

Where

A is the annual soil loss due to erosion [t/ha year];

R the rainfall erosivity factor;

K the soil erodibility factor;

LS the topographic factor derived from slope length and slope gradient;

C the cover and management factor;

P the erosion control practice factor.

The avoided soli loss is calculated comparing the RUSLE value of vegetated soil with the bare soil.

2. Pollination

This ecosystem service has been quantified through the calculation of Pollen Potential of the cover crops mixture.

Bees are attracted to plants during blossoming by the sweet substance called nectar and pollen, which is also part of their diet.

Using the CREA database on nectar and pollen potential estimated for more than 369 plant species we developed an aggregate index quantifying the honey production potential for the different cover crop mixtures used in the DRIVE LIFE project.

The index is considering the nectar and pollen potential (from 1 to 4, low and high, respectively) as well as the duration of the flowering period for each plant species.

3. Soil carbon sequestration

Resilient techniques increase the absorption of CO_2 in soil.

This ecosystem service is calculated defining the tons of absorbed Carbon in soil thanks to sustainable agriculture practices.

The calculation method is based on *IPCC Good Practice Guidance for LULUCF*, Chapter 3.3 Cropland. The case considered is "Cropland remaining cropland".

$$\Delta_{CC} = \Delta_{CClb} + \Delta_{CCsoils}$$

Where

[3] https://esdac.jrc.ec.europa.eu/themes/rusle2015

Δ_{CC} = annual change in Carbon stocks in soils in cropland remaining cropland
Δ_{CClb} = annual change in Carbon stocks in soils in living biomass
$\Delta_{CCsoils}$ = annual change in Carbon stocks in soils

In consideration that crops using in DRIVE LIFE pilot vineyards are not permanent crops, the focus is on soil contribute. The formula is:

$$\Delta C_{CCSoils} = \Delta C_{CCMineral} - \Delta C_{CCOrganic} - \Delta C_{CCLime}$$

Where
$\Delta C_{CCSoils}$ = annual change in Carbon stocks in soils in cropland remaining cropland [tons C yr^{-1}]
$\Delta C_{CCMineral}$ = annual change in Carbon stocks in mineral soils [tonnes C yr^{-1}]
$\Delta C_{CCOrganic}$ = annual Carbon emissions from cultivated organic soils (estimated as net annual flux) [tons C yr^{-1}]
ΔC_{CCLime} = annual C emissions from agricultural lime application [tons C yr^{-1}]

And

$$\Delta C_{CCMineral} = [(SOC_0 - SOC_{(0-T)}) \bullet A] / T$$

$$SOC = SOC_{REF} \bullet F_{LU} \bullet F_{MG} \bullet F_I$$

Where:
$\Delta_{CCMineral}$ = annual change in carbon stocks in mineral soils [tonnes C yr^{-1}]
SOC_0 = soil organic carbon stock in the inventory year [tons C ha^{-1}]
$SOC_{(0-T)}$ = soil organic carbon stock T years prior to the inventory [tons C ha^{-1}]
T = inventory time period [yr] (default is 20 yr)
A = land area of each parcel [ha]
SOC_{REF} = the reference carbon stock [tonnes C ha^{-1}]
F_{LU} = stock change factor for land use or land-use change type [dimensionless]
F_{MG} = stock change factor for management regime [dimensionless]
F_I = stock change factor for input of organic matter [dimensionless]

4. Soil water storage

Resilient techniques as cover crops increase the infiltration of water in soil, increasing the stock of groundwater.

This ecosystem service has been calculated through different methods:

Soil Water Storage

Direct measures of Soil Water Storage (SWS) in sensors located in pilot vineyards (see Deliverable "***Report on chemical-physical features and hydraulic properties of selected vineyard soils"*** and ***"Report on effectiveness of resilience strategies in DEMO farms"*** for details). This information is expressed in mm and represent the change of water level in the ground during the year, due to the porosity. The SWS capacity is defined as the total amount of water that is stored in the soil within the plant's root zone. The soil texture and the crop rooting depth determine this.

Volume Water Content

Volume Water Content (VWC) estimated through STARWARS model (Von Beek, 2002). The information is expressed in % and the model is designed to evaluate the effects of vegetation on hillslope hydrology. The model includes the process of evapontranspiration. The soil profile is subdivided in three layers (0-30 cm, 30-70 cm, 70-100 cm).

Effective infiltration

It's calculated defining the cube meters of water infiltrated in the ground thanks to sustainable agriculture. The calculation method is based on effective infiltration.

$$I_{eff} = P_{eff} \text{ x } CIP_{g} \text{ x } CIP_{pend/suolo}$$

where

I_{eff} = effective infiltration
P_{eff} = effective rainfall (data are refeered to weather station installed in each DEMO farms)
CIP_{g} = infiltration factor related to permeability (Civita, 2005)
$CIP_{pend/suolo}$ = infiltration factor related to slope gradient and soil use

P_{eff} is calculated with the equation

$$P_{eff} = P_{a} – ET_{c}$$

with Thornthwaite-Mather method (1954).
Coefficient K_c s for each seed mixture were defined adapting the reference value defined by FAO (*Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage*) according to crops seasonal growth and mixtures composition. Furthermore, as the soil cover crops covering are limited to a part of the year, the Kc was considering accordingly.

$$ET_{c} = ET \text{ x } K_{c}$$

where

$$ETp_j = 16 \cdot \left(10 \cdot \frac{t_j}{I}\right) \cdot L_j$$

where

ETp_j = average monthly potential evapotranspiration [mm/month]
T_j = average monthly temperature [°C] (data are refeered to weather station installed in each DEMO farms)
L_j = heat index
a = factor related to average yearly thermal index
I = average yearly thermal index

and

$$I = \sum_{i=1}^{12} \left(\frac{t_j}{5}\right)^{1.514}$$

$a = 0.49239 + 1.792 \times 10^{-2} \times I - 7.71 \times 10^{-5} \times I^2 + 6.75 \times 10^{-7} \times I^3$

Each method gives different information that have been integrated to estimate the amount of infiltrated water and the differences between different techniques.

Economical evaluation

For the ES's **economic evaluation**, used methodologies are indicated in the following table.

Ecosystem service	Monetary method
erosion protection	replacement costs (equivalent soil)
pollination	citizens' survey on WTP
carbon sequestration	carbon credit price (voluntary market)
fresh water storage	replacement costs (resource rent)

The value of **soil erosion protection** has been derived by the methodology adopted in the yearly report on the State of Natural Capital in Italy, elaborated by Italian Ministry of Environment. This method considers the substitution of lost soil with universal topsoil. The value is 26 €/ton.

The economic estimation of **water storage** is based on the cost of water for agricultural use in Emilia Romagna Region. Only the part related to the value of natural resource (without other components of the rate, as adduction and purification) is considered. The value is 0,2 €/m^3.

The economic estimation of **carbon sequestration** is based on the values used in the voluntary carbon market for offset projects developed in the agriculture sector (State of the Voluntary Carbon Markets 2023, Ecosystem Marketplace). The value is between 10 and 20 €/ton CO_2eq.

About the **contingent valuation**, economic values can be defined on the basis of results of surveys carried out in recent European projects: LIFE Soil4Wine (LIFE15 ENV/IT/000641)and LIFE Agrestic (LIFE17 CCM/IT/000062).Both the projects represent useful and suitable references, because defined how innovative agricultural techniques affect ecosystem services and carried out surveys that lead to the definition of the willingness to pay of a representative sample of people for agrifood products cultivated through practices that have positive effects on ecosystem services.
These projects have used the contingent valuation, a direct method in which, using focus groups, interviews or questionnaires, a representative number of people is asked to state his/her willingness to pay (WTP) for maintaining/providing the specified ES. This method is strategic to determine the value of goods that are not commonly exchanged on real market, and the research requires to organize a survey based on a relatively high number of individual evaluations.
Agrestic LIFE project is particularly interesting because has analyzed the contribution of Agriculture to natural capital preservation.
During the project, the WTP has been analyzed through a survey divided in two phases: a focus group involving 81 persons, aimed at defining a range of economic values for the following ecosystem services: habitat quality, landscape quality, pest and disease management, pollination.

The way how the sustainable agricultural practices affect each ecosystem service has been considered. This phase has been followed by the submission of a questionnaire to 580 persons. WTP for pollination resulting from the survey is of 10% more of the common price of the product. In DRIVE LIFE this percentage has to be applied to grapevine.

Ecosystem services assessment

1. Soil erosion protection

In the following table are indicated the values of eroded soil (in tons/ha) considering different conditions:

- Bare soil
- Traditional management
- Temporary grassing
- Permanent grassing

DEMO farm	bare soil	vineyard bare soil	vineyard grassocover	grass cover
BRP	195,8	68,5	29,4	8,1
CNV	210,5	73,7	31,6	8,8
CRT	80,4	28,2	12,1	3,3
GNP	165,6	57,96	24,84	6,89
SMV	83,96	29,39	12,59	3,49
VCB	36,44	12,75	5,47	1,52
Average	**128,78**	**45,08**	**19,33**	**5,35**

From the table it's evident that the adoption of grassing techniques generates benefits in terms of avoided soil loss. The average % of improvement goes from 57% to 85%.

2. Pollination

To calculate the pollen potential, it's been necessary to define the months in which the cover crops and grasses cover the soil (in yellow in the table).
According to the species composition of each cover crops mixtures (for demonstrative plots) (Details in Deliverable B2 "*Report on the implementation of resilience plans in the DEMO farms")* and more abundant specied in spontaneous vegetation/weeds for traditional management, the total pollen and nectar potential were assessed.

SOIL COVERAGE	Total Pollen potential	Total Nectar potential	J	F	M	A	M	J	J	A	S	O	N	D
N	10.5	12	0	0	1	1	1	1	0	0	0	0	0	0

C	28	28	0	0	1	3	3	3	2	1	1	0	0	0
B	37.5	40	0	0	2	4	4	4	2	1	1	0	0	0
SPONTANEOUS GRASSING	26.7	32	0	0	0	4	4	4	4	4	4	3	0	0
BARE SOIL (PLOWED)	9	6	0	1	1	1	1	1	2	2	1	1	0	0

In consideration of the techniques applied in the pilot vineyards, the effects on pollen potential (PP) are the following:

Demo farm	Soil covering	PP	Variation
VCB	CONTROL	9	
	N	10,5	17%
	C	28	211%
	B	37,5	317%
CRT	CONTROL	17,8	
	B	28	57%
GNP	CONTROL	9	
	N	10,5	17%
	SB	37,5	317%
CNV	CONTROL	9	
	C	28	211%
SMV	CONTROL	26,66667	
	C	28	5%
	N	10,5	-61%
BRP	CONTROL	9	
	B	37,5	317%
	N	10,5	17%

From the table it's evident that the adoption of different mixtures generates really diversified benefits. The improvement of pollen potential goes from 17% to 317%. Only in one pilot site and with only one technique, the performance is lower than control.

3. Soil carbon sequestration

For the calculation of the carbon stock change due to the adoption of resilient techniques, the Tier 2 approach has been applied, considering the SOC measured in pilot vineyards in the first project year. Innovative tecniques considered for the changing scenarios are: Green manuring and mulching (comprising "mow and blow" and "mulching between rows" techniques" as they are equal in terms of reference needed parameters)

DEMO farm	Innovative technique	Cstock (ton C/ha/year) change

BRP	Green manure	0,26
CNV	Mulching	0,41
CRT	Mulching	0,29
GNP	Green manure	0,24
SMV	Mulching	-0,02
SMV	Green manure	-0,29
VCB	Green manure	0,9

The pilot site located in Vicobarone shows a value really higher than the other sites and this is probably due to previous soil management practices (like as manuring). The average value, not considering VCB, is 0,15 tC/ha/y.

4. Soil Water Storage

The first type of analysis carried out is relative to direct measurement on site about SWS.
The following table shows the results.

DEMO FARM	SOIL MANAGEMENT	SEED MIXTURE	ΔSWS dry period 2021 (June-September) (mm)	ΔSWS wet period 2021-2022 (October - February) (mm)	ΔSWS dry period 2022 (March-September) (mm)	ΔSWS wet period 2022-2023 (October - February) (mm)	ΔSWS total (mm)
BRP	Control		-162	195	-373	261	**-80**
	Green manuring	B	-122	335	-388	352	**177**
	Green manuring	N	-131	205	-331	244	**-13**
GNP	Control		-111	91	-244	142	**-122**
	Green manuring	N	-82	174	-241	186	**37**
	Green manuring	B	-161	122	-310	159	**-190**
CNV	Control		-303	327	-487	310	**-153**
	Rolling	C	-247	228	-418	231	**-206**
SMV	Control		-350	305	-421	117	**-350**
	Green Manuring High[4]	C	-335	186	-458	78	**-528**
	Green ManuringMedium	C	-388	270	-474	85	**-507**
	Green Manuring Low	C	-319	301	-416	108	**-326**
CRT	Control		-236	204	-272	243	**-61**
	Rolling	C	-197	135	-214	196	**-80**

[4] In SMV Green manure soil management High, Medium and Low refeer to the position of the selected sensors along the vineyard side.

	mow and blow	C	-225	155	-285	251	**-104**
VCB	Control		-385	163	-513	294	**-440**
	Green Manuring	C	-217	176	-527	310	**-259**
	Green Manuring	B	-	204	-576	405	**33**
	Green Manuring	N	-250	231	-416	274	**-161**

The trend is really different through the seasons. An average value of performance resilient techniques vs. control could be defined and shows an improvement of 18%.

The STARWARS model has been make run considering data related to 344 days (1/6/2021 – 10/05/2022).
The following table shows the values of VWC (%) for the 3 layers considered in each pilot vineyards.

Demo farm	Grass			B			C			N			Artificial grassing			Bare soil		
BRP	20	41	50	19	38	41	17	35	27	18	35	24	20	46	52	19	32	22
CNV	20	44	52	21	47	52	22	47	52	20	38	35	19	40	43	17	35	25
CRT	8	20	20	8	20	20	8	20	20	8	20	20	8	20	20	7	20	20
GNP	19	41	50	18	35	36	17	37	39	18	36	37	17	34	35	16	32	21
SMV	23	47	52	19	41	44	20	43	46	22	47	52	19	41	46	18	36	37
VCB	19	42	51	18	36	39	18	38	43	18	39	43	18	35	37	17	34	36
average	**18**	**39**	**46**	**17**	**36**	**39**	**17**	**37**	**38**	**17**	**36**	**35**	**17**	**36**	**39**	**16**	**32**	**27**

The table shows that resilient techniques improve the volume of water content in comparison to bare soil. The average improvement, considering all the period, goes from 3% to 6%.

The effective infiltration (m^3) is used to compare different techniques adopted in pilot sites.

			Innovative management			
			grass	**B**	**C**	**N**
		average	*378*	*460*	*452*	*461*
traditional management	**grass**	*378*	-	-21,7%	-19,5%	-21,9%
	B	*460*	17,8%	-	1,7%	-0,2%
	C	*452*	16,3%	-1,8%	-	-2,0%
	N	*461*	18,0%	0,2%	1,9%	-

Economic evaluation

As indicated in previous chapter, it has been possibile to make an estimation of economic value of ecosystem services, adopting different type of methodologies.
Also in this case, the value is different among pilot sites and years, but in the following table average values per hectare are indicated.

Ecosystem service	Physical value	Unit	Economic Value	Unit
Soil erosion protection	25	t/ha	**670**	€/ha
Carbon sequestration	0,15	tC/ha	**11**	€/ha
Pollination	17	%	**550**	€/ha
Soil water storage	455	m^3/ha	**90**	€/ha

Conclusions

The deliverable synthetizes the assessment of the ecosystem services in pilot vineyards:

Colli Piacentini:

- SRT: Sartori – Creta
- GNP: Braghieri – Genepreto
- VCB: Az. Ampeli – Vicobarone

Oltrepò Pavese:

- BRP: Az. Dacarro – Borgo Priolo
- CNV: Piaggi – Canevino
- SMV: Az. Ottina Enrico – Santa Maria della Versa

For each pilot site, 4 ecosystem services have been quantified.
The value of performances changes in a high way in consideration of the year, the local conditions and the adopted practices.
In general, the adoption of resilient techniques permitted to improve environmental performances, because in all pilot vineyards, ecosystem services increased.
In particular, soil erosion protection is the ecosystem service that highlighted the better improvement and an interesting economic value.