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Call:	**LIFE-2022-SAP-CLIMA**		
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Project full name	**Viticulture for Soil Organic Carbon Sequestration**		
Project acronym	**LIFE22-CCA-IT-LIFE VitiCaSe**		
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LIFE VitiCaSe.

The VitiCaSe LIFE project is carried out on 4 pilot farms located in Toscana and Veneto regions, within the borders of the Italian Republic. The project aims to develop an incentive-based carbon farming mechanism which allows farmers and land managers to generate carbon credits by storing organic carbon or by reducing greenhouse gas (GHG) emissions.

LIFE VitiCaSe

Viticulture for Soil Organic Carbon Sequestration

Project Details

Title of project	LIFE VitiCaSe
ID of project	ID 396
Project proponent	1. SOCIETA' AGRICOLA SAN FELICE SPA 2. TENUTE RUFFINO SRL SOCIETA' AGRICOLA 3. CASTELLO DI ALBOLA (pilot 2 : ROCCA DI MONTEMASSI)
Representative	Andrea Saverio CORNACCHIA CEO Via Goito 8, BOLOGNA (Italy) +39 3929050342 asc@carboncreditsconsulting.com
Statement by the project proponent	The CARBON CREDITS CONSULTING S.R.L. states that he is responsible for the preparation and fair presentation of this PDD and all accompanying documentation provided.
Pre-registration date	19/09/2025
Version of PDD	1.1
Date of PDD version	30/06/2026
PDD prepared by	Hasti Farahmand– Agronomist and NbS Specialist (hasti@carboncreditsconsulting.com) Rita Valoroso - Head of Project Development & Implementation (rita.valoroso@carboncreditsconsulting.com)
Sectoral scope of project activity	15 Agriculture
Methodology(ies) applied and version number	The VERRA's VM0042 version 2.0 methodology is incorporated into the project's methodological framework, which serves as the project's foundation. ISCC EU 205 Greenhouse gas emissions (GHG calculation methodologies)
Criteria for validation	☒ ICR requirement document v.6.0 and v.6.1 ☒ ISO 14064-2 ☐ Applied methodology, please specify. ☐ Other, please specify.
Host country(ies)	Italy
Host country approval	☐ Yes ☒ No
Multiple project activities	☒ Yes ☐ No
Type (CDR, RAD, hybrid)	☒ CDR ☐ RAD ☐ Hybrid
MRV cycle:	NA

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Estimated annual average GHG emission mitigation (t CO2-e)	1.760 tCO_2e

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1. Project description

1.1 Purpose, objectives, and general description of the project

The VitiCaSe LIFE project is carried out on 4 pilot farms located in Toscana and Veneto regions, within the borders of the Italian Republic. The pilot farms have already been implementing some carbon farming techniques before the project's start date, namely the use of cover crops, incorporation of pruning residues into the soil after chopping and use of compost every 2 years.

The project aims to develop an incentive-based carbon farming mechanism which allows farmers and land managers to generate carbon credits by storing organic carbon or by reducing greenhouse gas (GHG) emissions.

The project will pursue the following objectives:

1) Define agronomic practices and cultivation techniques to increase the storage of organic carbon in the soils of vineyards.
2) Estimate the carbon credits generated in the vineyards (compared to business-as-usual) through ad-hoc IT technologies.
3) Develop specific monitoring and verifying procedures to allow third-party certification of the carbon credits generated in the vineyards.
4) Test the sale of carbon credits in voluntary markets. Credits will be sold by farmers and acquired by companies wanting to offset their CO_2 emissions.

The expected results of the VitiCaSe project are:

1) A database and manual containing details of sustainable soil management (SSM) practices to be used by farmers to improve carbon stock and carbon sequestration (SSM4SOC) in vineyards.
2) Setting up of a reliable IT tool for estimating carbon stocks in vineyards using the RothC estimation model. Quantification of the baseline and estimation of the potential SOC accumulation for each selected area of intervention and SSM practice.
3) Implementation of the VitiCaSe system in four pilot vineyards covering at least 350 ha.
4) Certification of carbon credits generated in the vineyards and their placement on exchange platforms.
5) Monitoring of technical results (C stock) by collecting and analyzing soil samples.
6) Evaluation of the economic results and the business model for farmers using selected indicators and the Quaderno di Campagna® management information system developed by the project and used by the farmers.
7) Preparation of an exploitation plan for replicating project results.
8) Carbon stored in the vineyards increased by around 3 t/ CO_2 eq during the four years of the project.

At the end of the project (up to 15 years – renewable twice), the total amount of CO_2 sequestered on the soils of the farms involved in the project will depend on the type of SSM adopted:

- Base scenario - cover-crops improvement only: 3,363 t CO_2 eq. Or
- Intermediate scenario - prunes residues incorporated into the soil: 4,147 t CO_2 eq.
- Best case scenario - generic compost (on 3 out of 4 farms): 7,396 t CO_2 eq.

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1.2 Project type and sectoral scope

Sectoral scope (primary)	15
Sectoral scope (other)	Agriculture
Project type (CDR)	Improvement in the use of cover crops, manure, green manuring, soil and crop residues management, aiming at enhancing SOC content in the vineyards' soil.

1.3 Project

Provide information if the project is:

☐ Single location/area or installation

☐ Bundled project (multiple locations/areas or installations)

☒ Grouped project (locations/areas or installations added post validation)

☐ Bundled and grouped project.

For bundled project activities please use appendices for completeness of the PDD, e.g. ex-ante estimation of GHG emission mitigation, images, etc.

1.3.1 Eligibility criteria for grouped project

This project is meant to include multiple instances of project activities organized as a group. According to ICR definition, a grouped project means where additional instances for project activities which meet pre-established eligibility criteria, may be added after project validation. A project activity instance refers to a group of farms that adopt a set of Agricultural Land Management (ALM) activities outlined in the Project Description. The project will be validated based on initial activity instances across the Republic of Italy.

The following eligibility criteria are set out for additional instances that may be added after project validation. The new project instance:

1) **Methodology Applicability**: The initial project activity instance complies with the applicability conditions of the applied methodological framework, as the pilot farms are permanent vineyard systems where Agricultural Land Management activities are implemented to increase soil organic carbon and reduce greenhouse gas emissions. The project activities are consistent with the applied methodology and the Project Description, including improved cover-crop management, incorporation of pruning residues, compost application where applicable, and other sustainable soil management practices.
2) **Project Activity Consistency**: The initial instance implements Agricultural Land Management measures as described in the Project Description. The activities are applied in vineyard systems and include soil and crop residue management, cover crops, green manuring, manure or compost application, and other practices aimed at enhancing soil organic carbon. Therefore, the first instance is fully aligned with the ALM measures defined for the LIFE VitiCaSe project.
3) **Baseline Scenario Consistency**: The baseline scenario for the initial project activity instance is consistent with the baseline approach described in the Project Description. The baseline reflects the continuation of conventional or business-as-usual vineyard management prior to the implementation of the project activities. The initial farms have been assessed using the same baseline logic, including historical land use, soil conditions, climatic conditions, and management practices.
4) **Additionality Consistency**: The initial instance is consistent with the additionality demonstration of the grouped project. The project activities go beyond the baseline scenario and are implemented within the same financial, technological, institutional, and regulatory context applicable to vineyards in Italy. The LIFE VitiCaSe project supports the adoption of improved carbon farming practices and

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the development of a certified carbon credit mechanism, which would not be achieved under the baseline scenario alone.

5) **Geographic Boundary:**
The initial project activity instance is located within the designated geographic boundary of the grouped project, namely the Republic of Italy. The four pilot farms are located in the Toscana and Veneto regions, specifically within Siena, Grosseto, and Venezia provinces. Therefore, the initial instance complies with the geographic boundary criterion.

6) **Legal and Regulatory Framework:**
The initial instance operates under the Italian and European Union legal, environmental, climate, agricultural, and land-use regulatory frameworks applicable to the project areas. All pilot farms are located within Italy and are therefore subject to the same national and EU regulatory framework considered in the validated Project Description.

7) **Ownership:**
For the initial project activity instance, the project proponents shall demonstrate ownership or contractual rights over the emission reductions and removals generated by the participating farms from the project start date. The participating pilot farms are identified in the Project Description, and the carbon rights shall be managed through the project documentation and contractual arrangements with the respective project proponents or participating entities.

8) **Start Date:**
The initial project activity instance follows the grouped project start date as defined in the Project Description. Since the first instance represents the proposed project activity submitted for validation, its start date is aligned with the grouped project start date.

9) **Crediting Eligibility:**
Crediting for the initial project activity instance shall begin in accordance with the crediting rules established for the grouped project. The initial instance will only generate eligible credits for verified emission reductions or removals achieved from the applicable project start date and within the relevant verification period.

10) **Double Registration Prevention:**
The initial project activity instance shall be subject to a completeness check to ensure that the same farms, project areas, and emission reductions or removals have not been registered under another ICR project or other GHG program. This prevents double registration and supports the environmental integrity of the LIFE VitiCaSe project.

11) **Inclusion Procedure:**
The initial project activity instance is included at validation as the proposed project activity of the LIFE VitiCaSe grouped project. All required technical, geographic, management, financial, and monitoring information for the initial farms is disclosed in the Project Description to enable validation and future independent verification. Additional instances may subsequently be included at verification, provided they meet the same eligibility criteria.

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1.4 Location

The project activities are in the Toscana and Veneto regions of the Italian Republic (Error! Reference source n ot found.). In the Toscana region, the project activities are carried out in the Chianti wine production area, within the Siena and Grosseto provinces. In the Siena province, the project locations are the Castello di Albola winery (50 Ha) and San Felice winery (150 Ha), located in the Radda in Chianti and Castelnuovo Berardenga municipalities respectively. In the Grosseto province, the project location is the Rocca di Montemassi winery (50 Ha), located in the Roccastrada municipality.

In the Veneto region, the project activities are carried out in the Tenute Ruffino winery (86 Ha), located in the San Donà di Piave municipality.

Address	Grouped Project
County/province	Italy
Country	Italy
Region	North-East: Veneto Centre: Tuscany
Geographic location	
Latitude	36° N, 8° E; 36° N, 18° E
Longitude	47° N, 8° E; 47° N, 18° E
Map link	https://www.google.com/maps/d/viewer?mid=1O08p6ip1IFVj04cW62ezyv6LGZjvODc&ll=44.32565966267959%2C11.81514390000002&z=8

Table 1. The Project Locations and the respective administrative divisions.

Country	Region	Province	Municipality	Winery	Ha
Italy	Toscana	Siena	Radda in Chianti	Castello di Albola	50
			Castelnuovo Berardenga	San Felice	150
		Grosseto	Roccastrada	Rocca di Montemassi	50
	Veneto	Venezia	San Donà di Piave	Tenute Ruffino	86

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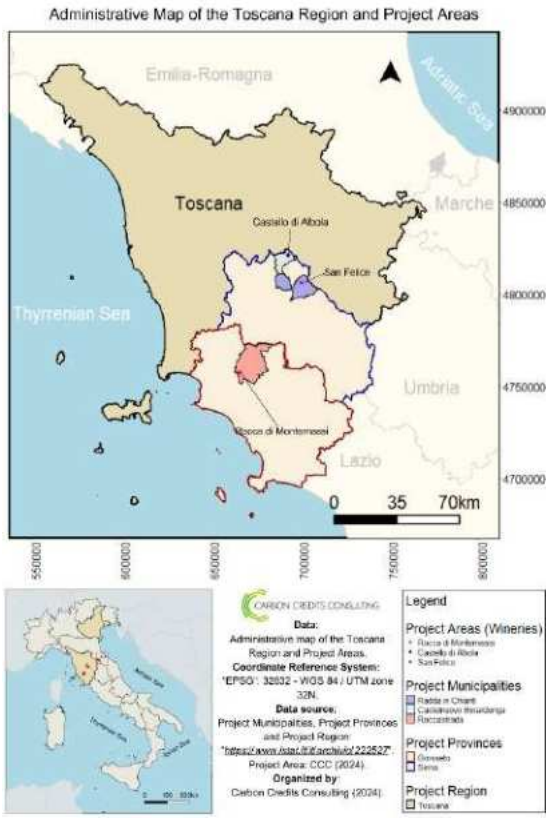


Figure 1. Administrative map of the Toscana Region and highlighting of the Project Municipalities and Project Areas (Rocca di Montemassi, Castello di Albola and San Felice). (Data source https://www.istat.it/it/archivio/222527).

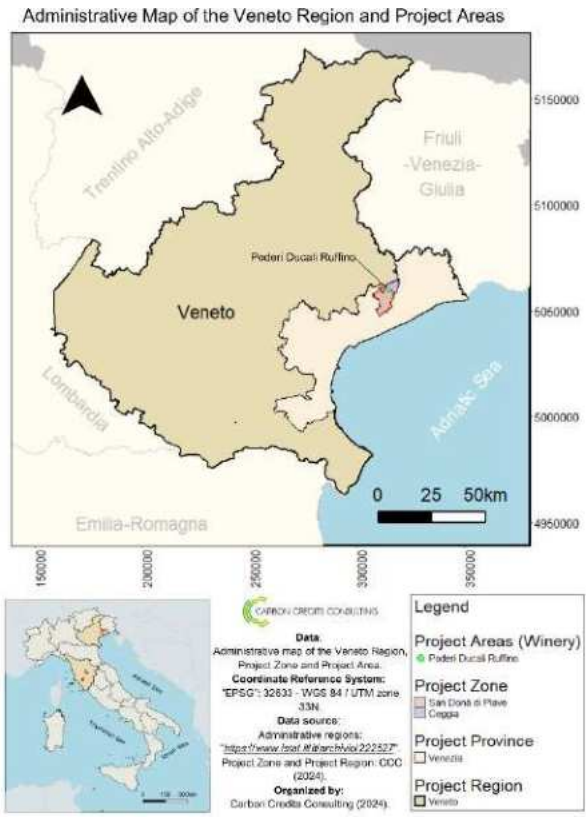


Figure 2. Administrative map of the Veneto Region and highlighting of the Project Municipalities and Project Areas (Tenute Ruffino). (Data source https://www.istat.it/it/archivio/222527).

1.5 Conditions prior to implementation

Climate

Castello di Albola. The climate of the project areas is overall temperate, but it varies depending on the location of the wineries. In the Toscana region, the Castello di Albola winery has 4 different subtypes of temperate climate (*Figure 3*): transitional oceanic - semi continental climate, semi continental oceanic temperate and semi continental temperate climate. All project areas (San Felice, Castello di Albola, Rocca di Montemassi, and Tenute Ruffino) have been under continuous permanent vineyard cultivation for several decades prior to the project start date. No land-use change (e.g. conversion from forest, grassland, or arable land) occurred in the 10 years preceding project implementation.

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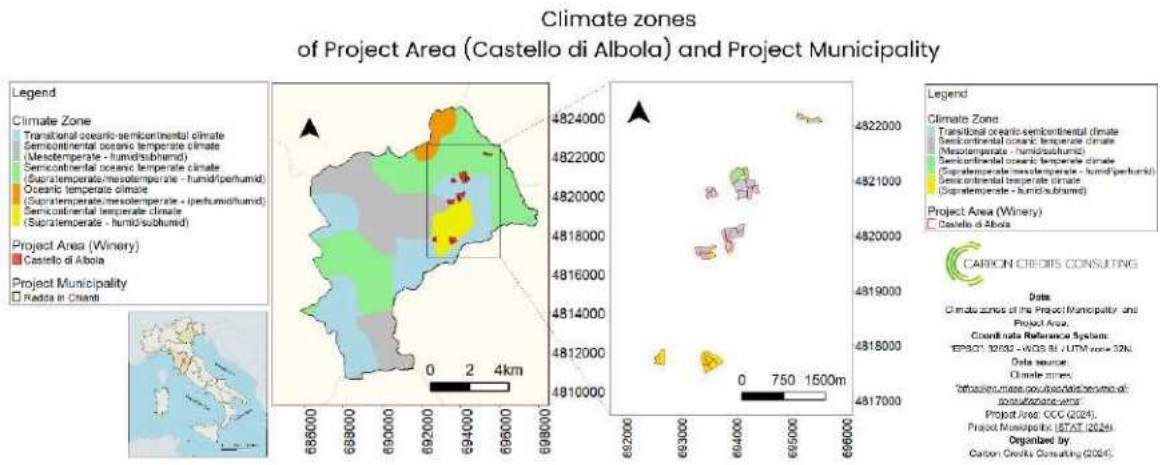


Figure 3. Climate zones of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

The neighboring San Felice winery shares a similar climate to Castello di Albola, namely transitional oceanic - semi continental climate and semi continental oceanic temperate (*Figure 4*).

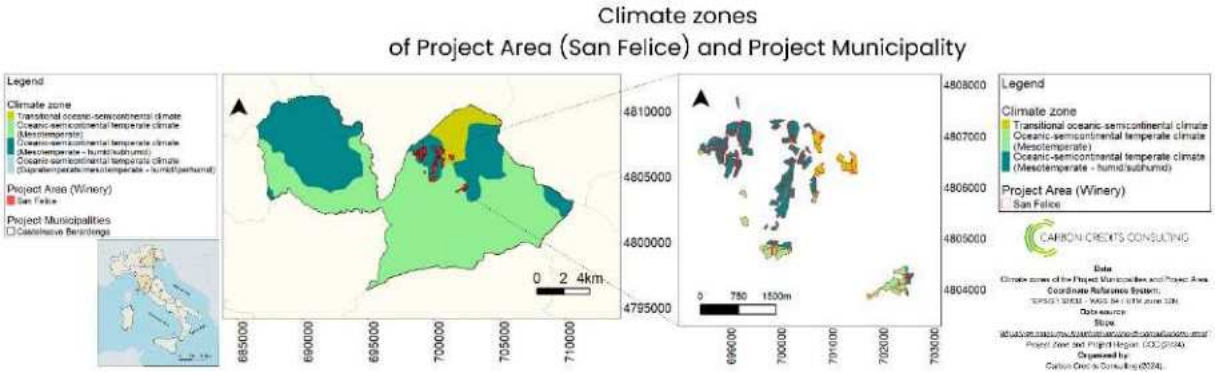


Figure 4. Climate zones of Castelnuovo Berardenga (Project Municipality) and San Felice (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

Rocca di Montemassi. In the project area of Rocca di Montemassi (*Figure 5*), the climate is uniformly transitional oceanic-mediterranean.

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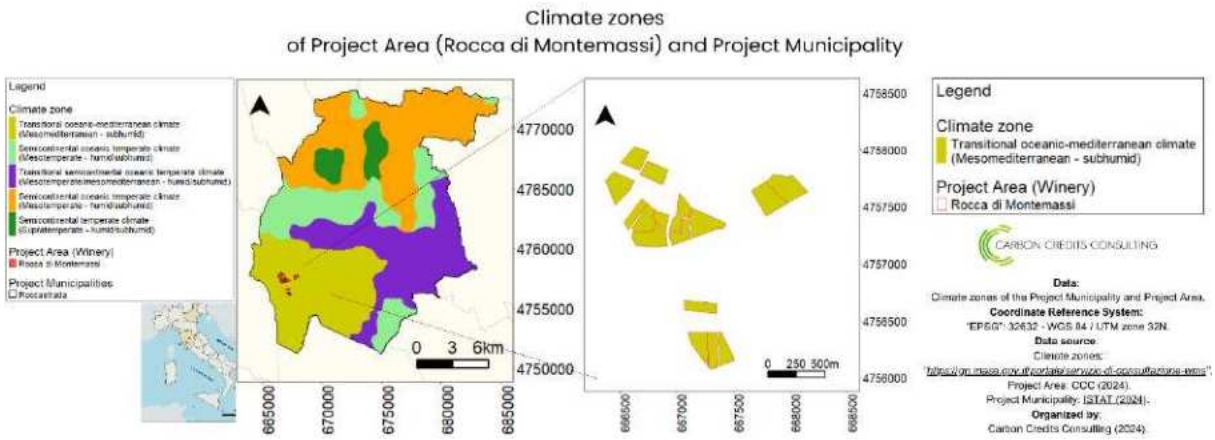


Figure 5. Climate zones of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

Tenute Ruffino. In the project area of Tenute Ruffino (*Figure 6*), the climate is uniformly temperate across the fields.

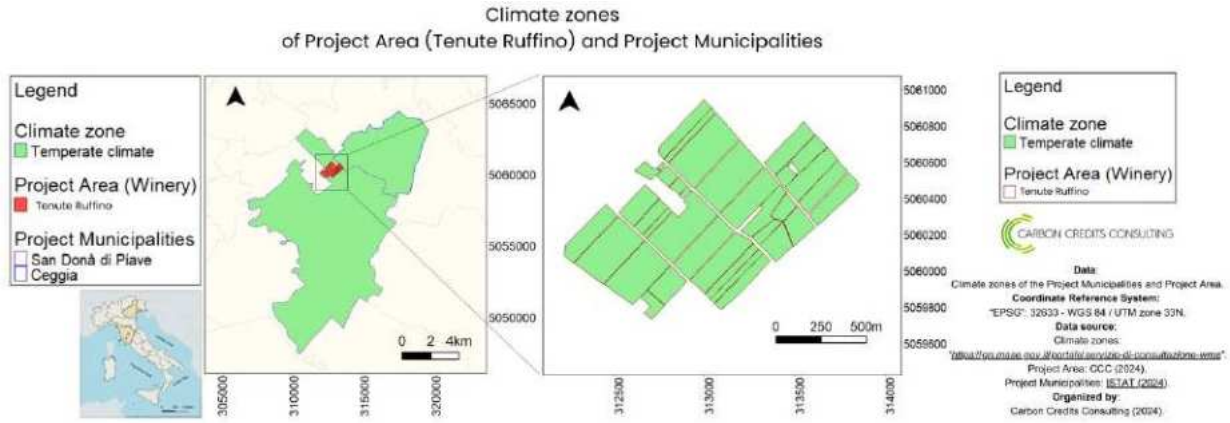


Figure 6. Climate zones of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

Further details of temperature (°C) and rainfall (mm), over the two years prior the starting date of the project, are displayed below for Castello di Albola (*Figure 7*), Rocca di Montemassi (*Figure 8*), San Felice (*Figure 9*) and Tenute Ruffino (*Figure 10*). Peak temperature occurs during the summer months, with an average of about 25°C, while it is around 6°C on average in the Winter and Autumn months. Precipitation in the form of rainfall mostly occurs during the Spring and the Autumn/Winter months, averaging between 3 – 6 mm/month, while it is at its lowest over the summer months, with an average of 0 – 0.3 mm/month.

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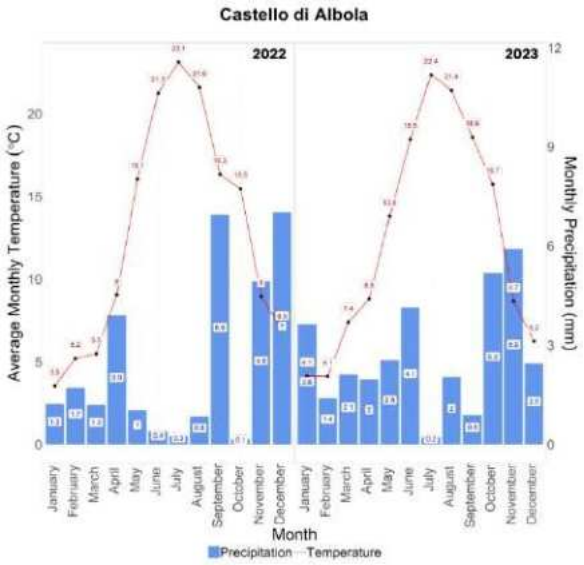


Figure 7. Average monthly temperature (°C) and precipitation (mm) in Castello di Albola for the years 2022-2023. (Data source https://open-meteo.com/en/docs/historical-weather-api)

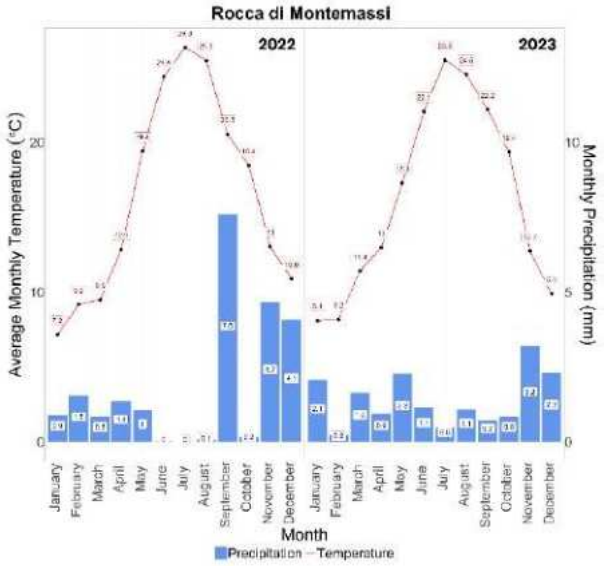


Figure 8. Average monthly temperature (°C) and precipitation (mm) in Rocca di Montemassi for the years 2022-2023. (Data source https://open-meteo.com/en/docs/historical-weather-api)

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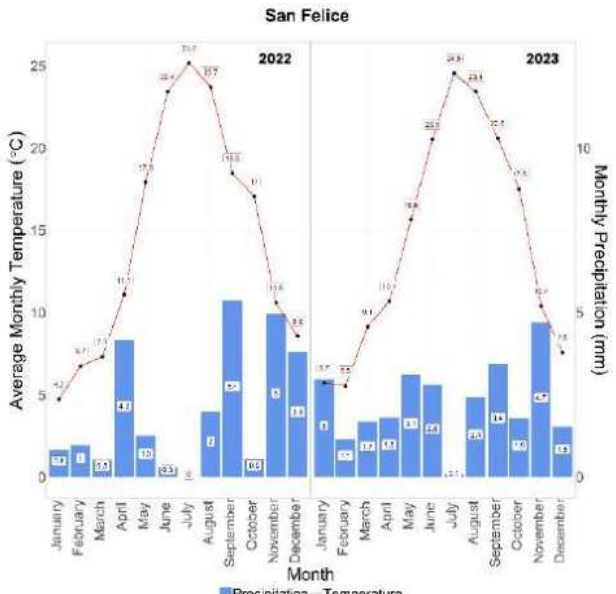


Figure 9. Average monthly temperature (°C) and precipitation (mm) in San Felice for the years 2022-2023 .(Data source https://open-meteo.com/en/docs/historical-weather-api)

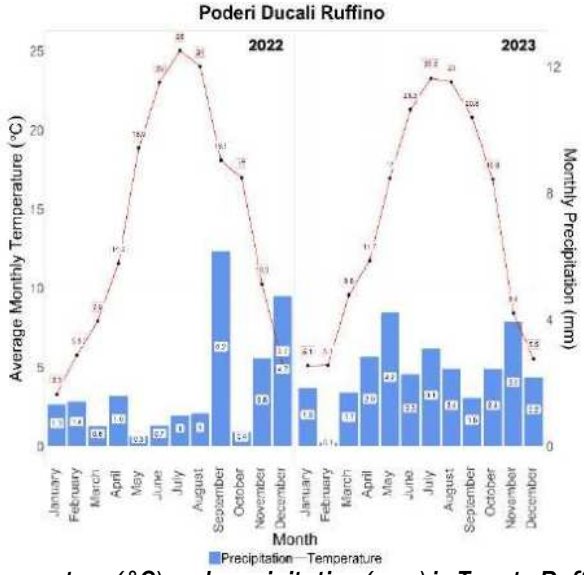


Figure 10. Average monthly temperature (°C) and precipitation (mm) in Tenute Ruffino for the years 2022-2023. (Data source https://open-meteo.com/en/docs/historical-weather-api)

Ecosystem

The ecosystem type of all the project areas (Castello di Albola, Rocca di Montemassi, San Felice and Tenute Ruffino) is that of an agroecosystem, specifically vineyard.

Soil, geology and ecopedology

The ecopedology, soil and geology of the project areas vary considerably depending on the location.

Montemassi. In the winery of Rocca di Montemassi (Grosseto, Tuscany), the project area is characterized by conglomerate and sandy hills (*Figure 11*).

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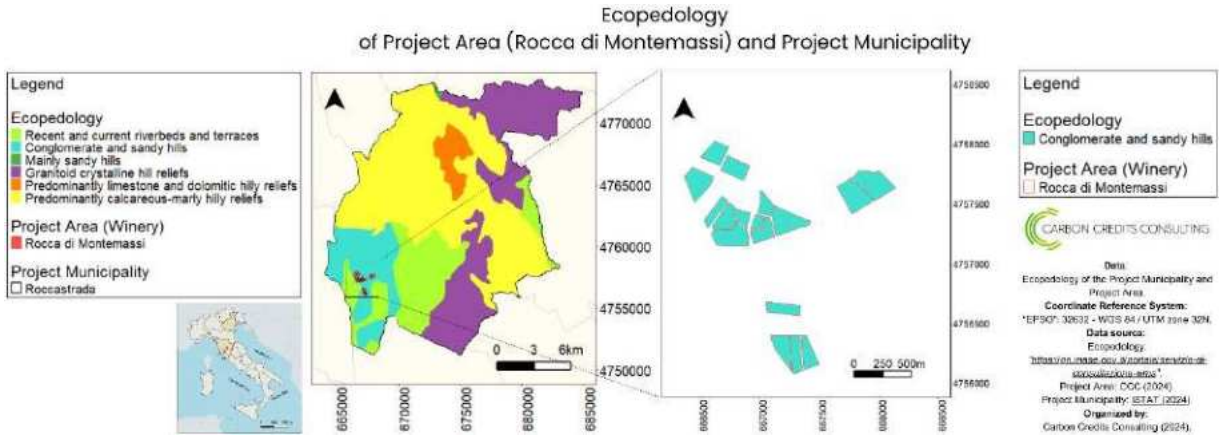


Figure 11. Ecopedology of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

The geology ranges from colluvial, terraced alluvial, fluviolacustrine and fluvioglacial deposits (Pleistocene) to terraced alluvional deposits (Holocene) (*Figure 12*). Soil-wise, the northern plots have a fine-textured cutanic-luvisol, while the southern ones a fine-silty fluvic cambisol (*Figure 13*).

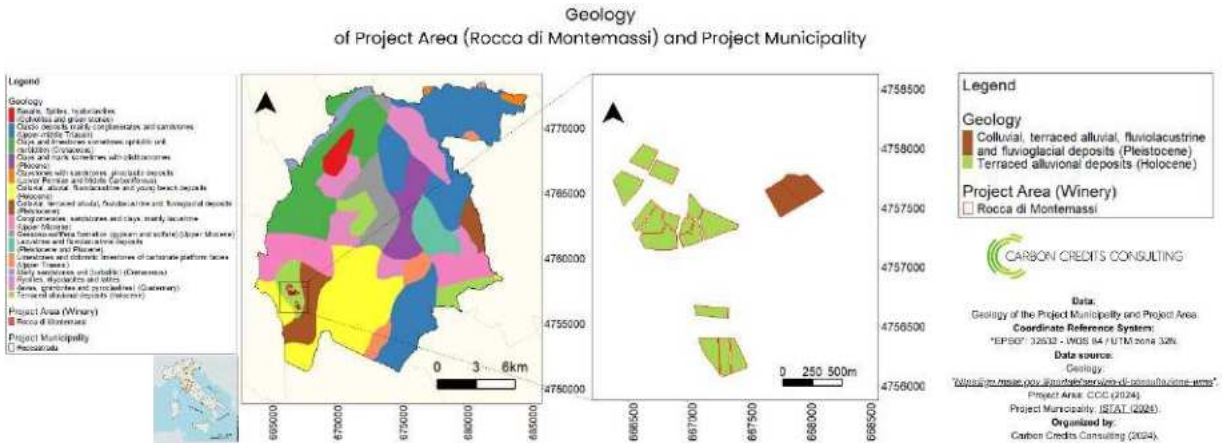
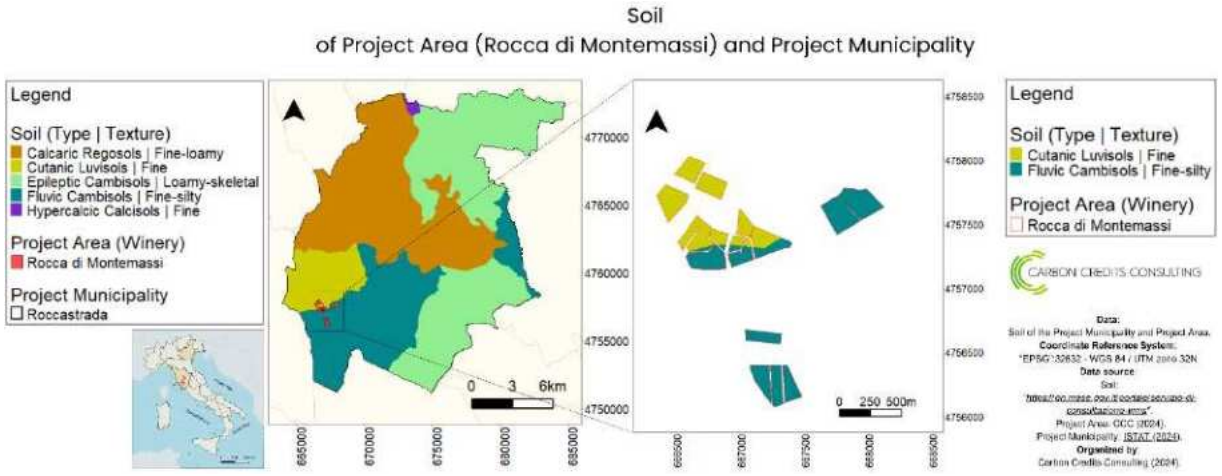


Figure 12. Geology of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).



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Figure 13. Soil of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

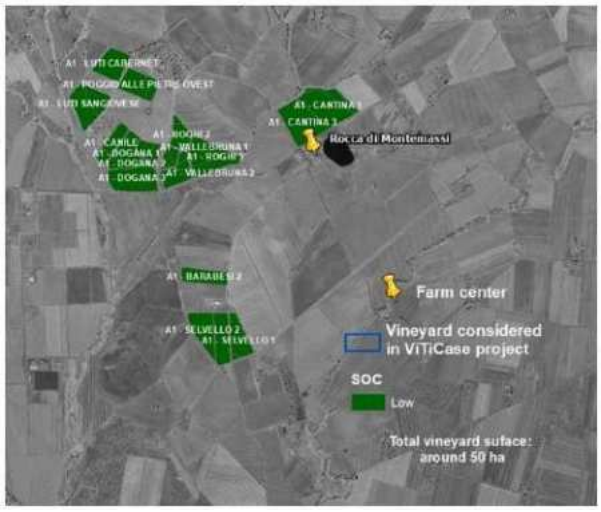


Figure 14. Soil Organic Carbon (SOC) content classes in the Rocca di Montemassi vineyards.



Figure 15. Soil subsystems in the Rocca di Montemassi vineyards.

(Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4)

Table 2. Key Soil Characteristics of Rocca di Montemassi. (Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4)

Soil Region	System	Subsystem	Key Soil Characteristics
RCE - Hilly and mountainous reliefs of central Tuscany, promontories and islands of the archipelago.	RCE_3. Low altitude to moderately sloping hilly surfaces, on a substrate consisting mainly of clay, conglomerates and secondarily of sand, used mainly for agriculture (arable land, olive groves) and secondarily for coppice woodland (Turkey oak, downy oak and holm oak).	Sub-flat summit surfaces and linear slopes with a gentle slope, subject to moderate widespread water erosion; substrate consisting mainly of marls and sandy lacustrine clays; land use consisting of alternate arable crops and vineyards.	Soil reference: DOG2 Clay content: 29.75 Organic matter (%): 1.22
		Slopes with valleys, with a slight to severe gradient, subject to moderate to severe diffuse and channeled erosion, with the	Soil reference: BEL1 Clay content: 22.47 Organic matter (%): 1.76

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		presence of sub-flat summits and slope shelves, little eroded; substrate mainly consisting of polygenic conglomerates; land use consisting mainly of coppice woodland of downy oak, holm oak, hornbeam and, secondarily, of olive grove and arable land.	
PCO - Coastal plains and hilly reliefs facing the sea.	PCO_2. Hilly surfaces located at low altitude, from slightly to moderately sloping, on a substrate consisting mainly of ancient terraced fluvial deposits and alluvial fans, used for vineyards and arable crops, and secondarily for coppice and high forest (pine forest, Turkey oak, holm oak). Xeric and ustic soil and climate regime, thermal.	41. Alluvial terraces from sub-flat to slightly sloping, subject to erosion in the residual summit areas; substrate consisting of ancient terraced alluvial deposits; land use consisting mainly of rotated arable land and secondarily of vineyards and olive groves.	Soil reference: DOG2 Clay content: 29.75 Organic matter (%): 1.22
PCO - Coastal plains and hilly reliefs facing the sea.	PCO_1. Flat surfaces located at low altitude, on a substrate consisting mainly of recent alluvial deposits and reclamation by filling, for predominantly agricultural use (arable land, horticultural crops, olive groves). Xeric, thermal soil and climate regime.	50. Flat alluvial areas of the coastal strip (Fine and Albegna rivers); substrate mainly consisting of recent and current alluvial deposits; land use mainly consisting of rotated arable land, horticultural crops and, secondarily, olive groves.	Soil reference: DOM1 Clay content: 33.75 Organic matter (%): 1.98

Castello di Albola. In Castello di Albola (Siena, Tuscany) the project area is characterized by arenaceous-pelitic hilly reliefs and predominantly calcareous-marly hilly reliefs (***Figure 16***).

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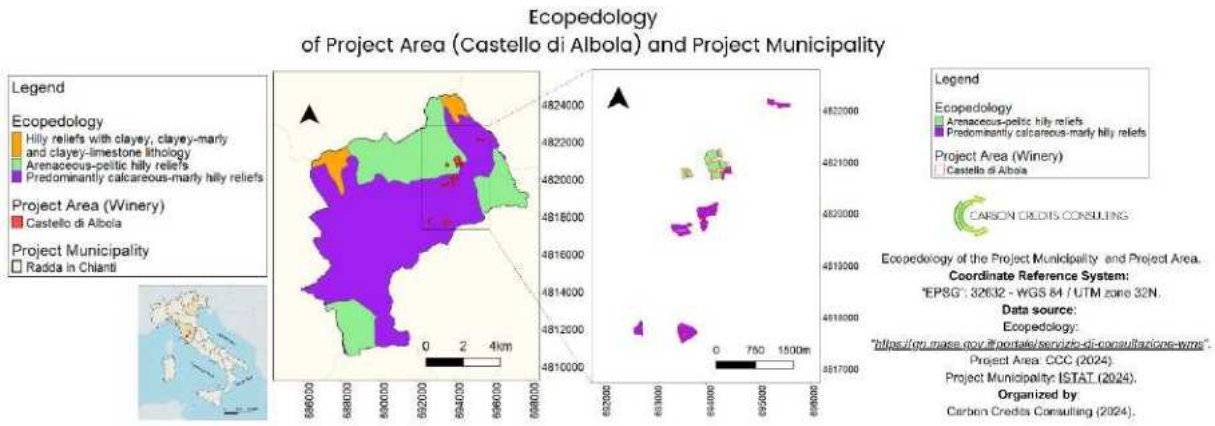


Figure 16. Ecopedology of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

The project areas of the San Felice winery are located on predominantly calcareous-marly hilly reliefs and sandy hills (*Figure 17*). The geology is more variegated, ranging from clays and limestone units in the northern plots (Palagene and Upper Cretaceous), sandstones - arenaceous marls units (Palagene) and limestone-clay units (Cretaceous) in the center and marly sandstone in the south (Palaegene). Soil-wise the southern-facing plots of Castello di Albola are fine-loamy-textured Eutric-Cambisols, while moving northwards the soil texture shifts to coarse-loamy, and the soil type to Calcaric-Cambisols.

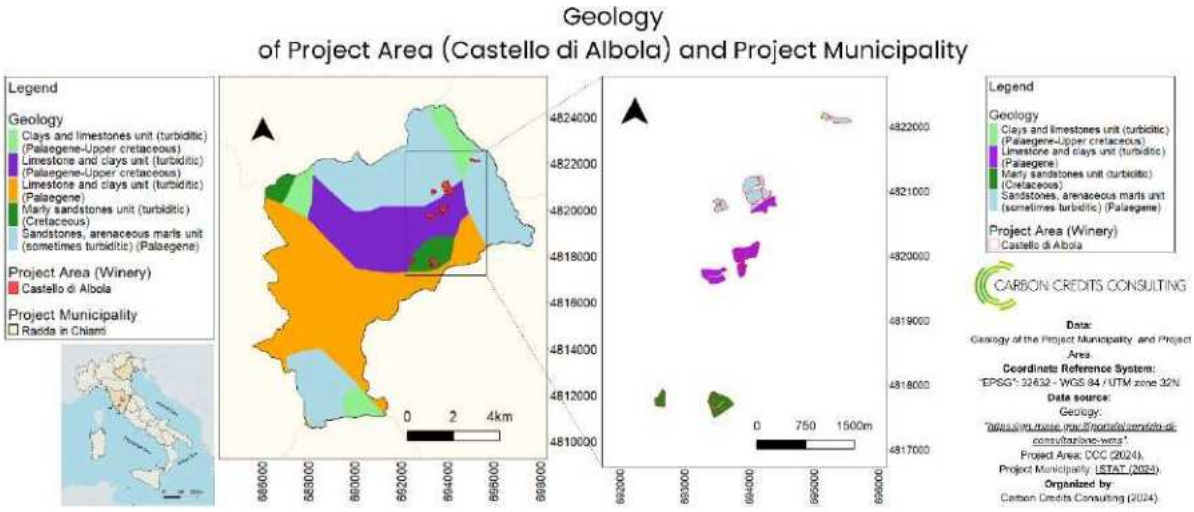


Figure 17. Geology of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

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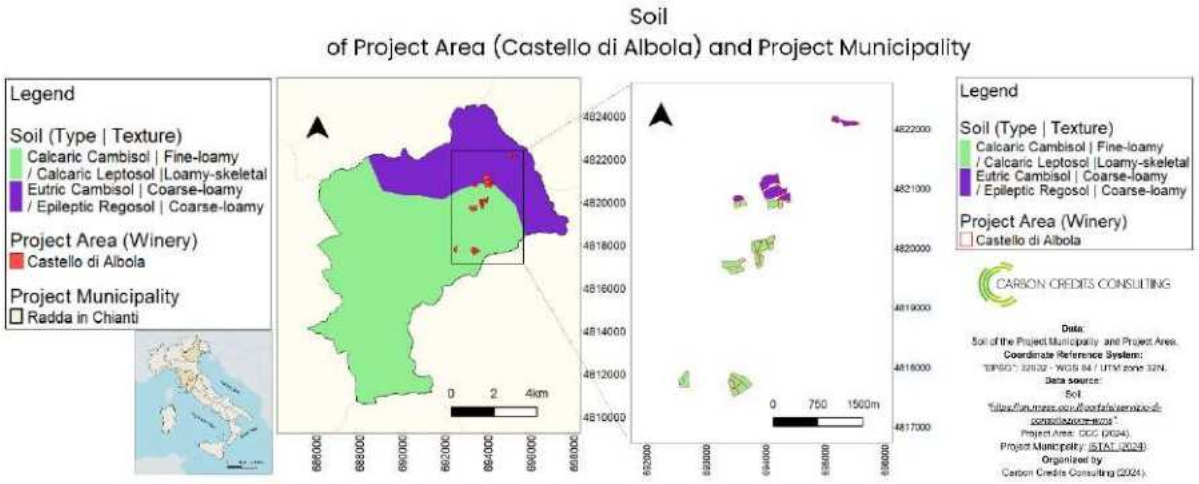


Figure 18. Soil of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

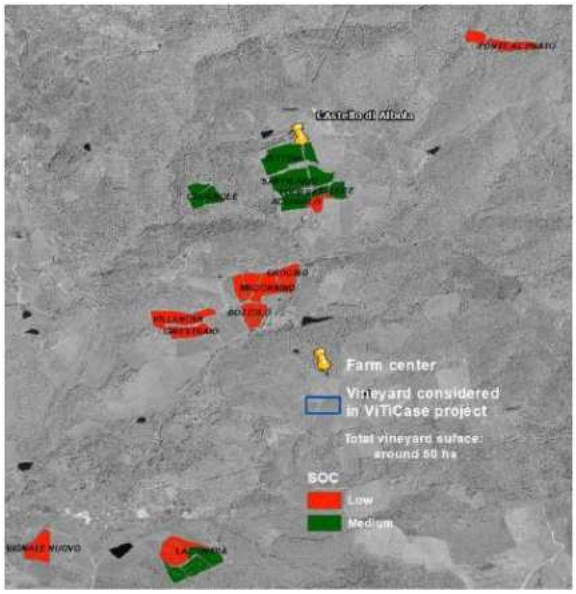


Figure 19. Soil Organic Carbon (SOC) content classes in the Albola vineyards
(Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4).

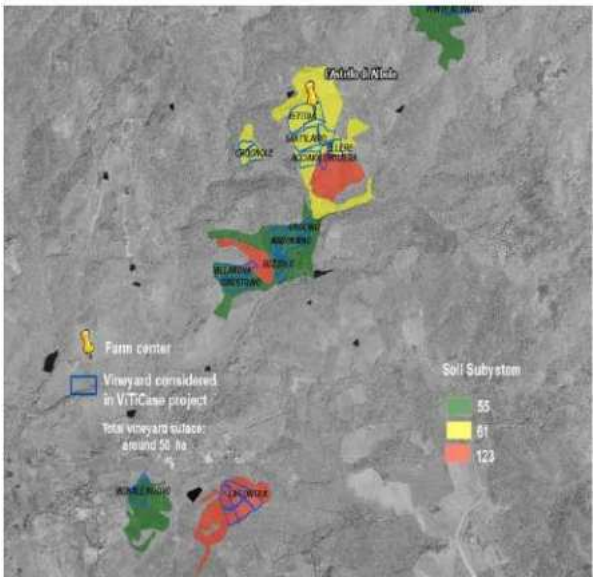


Figure 20. Soil subsystems in the Albola vineyards.

Table 3. Key Soil Characteristics of Castello di Albola. (Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4)

Soil Region	System	Subsystem	Main key soil properties
APP: Mountainous reliefs of the Northern and Central Apennines	APP7. Mountainous surfaces with moderate slopes and hilly surfaces of high and low	55. Linear slopes, sometimes terraced, with a low to high gradient, subject to	Soil reference: GCC1 Clay content: 29.15 Organic matter (%): 1.49

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	altitude with moderate to steep slopes, on a substrate consisting mainly of clay with predominantly agricultural use (permanent meadow, arable land, olive grove and vineyard) and secondarily woodland (beech coppice, mixed coppice of thermophilic deciduous broadleaf trees, coniferous forest). Udic and ustic, mesic soil and climate regime.	moderate to high widespread water erosion and sometimes to mass erosion; heterogeneous substrate consisting mainly of clays and marls with limestones (Undifferentiated Complex, Chaotic and Scaly Clays); land use consisting mainly of olive groves, vineyards, alternate arable land and, secondarily, pasture, shrubland, mixed forest.	Soil reference: VIL1 Clay content: 41 Organic matter (%): 1.54
	APP_4. Mountainous areas of medium to high altitude, very steep and medium and high-altitude hills with steep slopes, on a substrate consisting of arenaceous pelitic flysch and deposits generated by it, used mainly for forestry (chestnut coppice and beech coppice) and secondarily for agriculture (olive grove, vineyard). Udic and ustic, mesic soil and climate regime.	61. Slopes with valleys, from steep to steep, subject to moderate to strong diffuse and channeled surface erosion, with the presence of accumulation areas with lower slope; substrate consisting mainly of sandstones (Macigno type "A"); land use consisting mainly of mixed coppice of deciduous broadleaf trees, secondarily of coniferous woods and, marginally, of arable land and olive groves.	Soil reference: GRT1 Clay content: 12.3 Organic matter (%):1.5
	APP_6. High and medium altitude hilly surfaces with moderate to steep slopes, on a substrate mainly composed of marly calcareous flysch, mainly used for coppice woodland (downy oak, Turkey oak) and secondarily for	123. Incised slopes, moderately sloping to steep, generally eroded to very eroded in the medium-high parts, terraced in the medium-low and low parts; substratum consisting mainly of marly limestones, marl schists and calciferous	Soil reference: CLV1 Clay content: 26.2 Organic matter (%): 2.1

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	agriculture (olive grove, vineyard). Ustic and udic, mesic soil and climate regime.	sandstones (Alberese) and marly limestones (Sillano Formation); land use consisting mainly of vineyards, olive groves, degraded mixed broadleaf forest.	

San Felice. The San Felice project area lies on sandy hills and calcareous-marly hilly reliefs (*Figure 21*). We can distinguish between the northern plots of San Felice characterized by limestone and clay units of the Palaegene and the southern plots, located on terraced alluvional deposits of the Holocene (*Figure 22*). Such geology resulted in San Felice's northern plots being fine/loamy-textured Calcaric-Cambisols, and Eutric/Stagnic- Cambisols with a coarser texture in the southern areas (*Figure 23*).

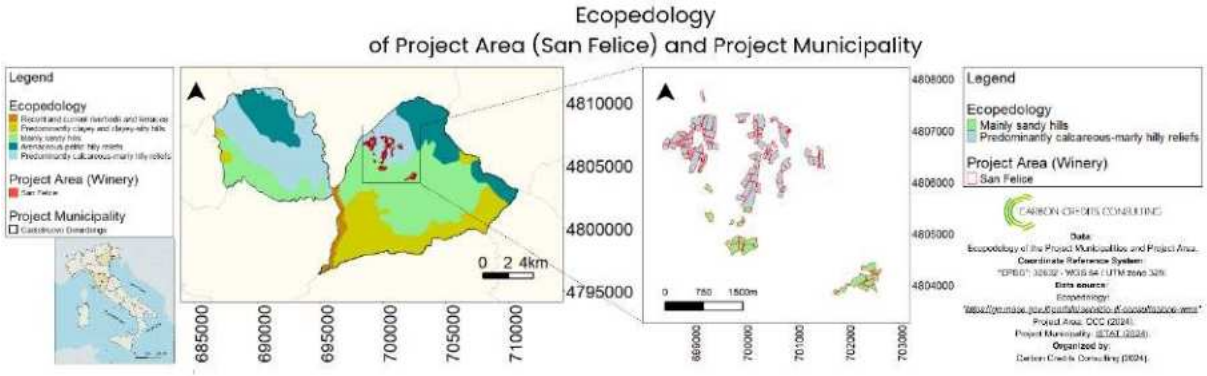


Figure 21. Ecopedology of Castelnuovo Berardenga (Project Municipality) and San Felice (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

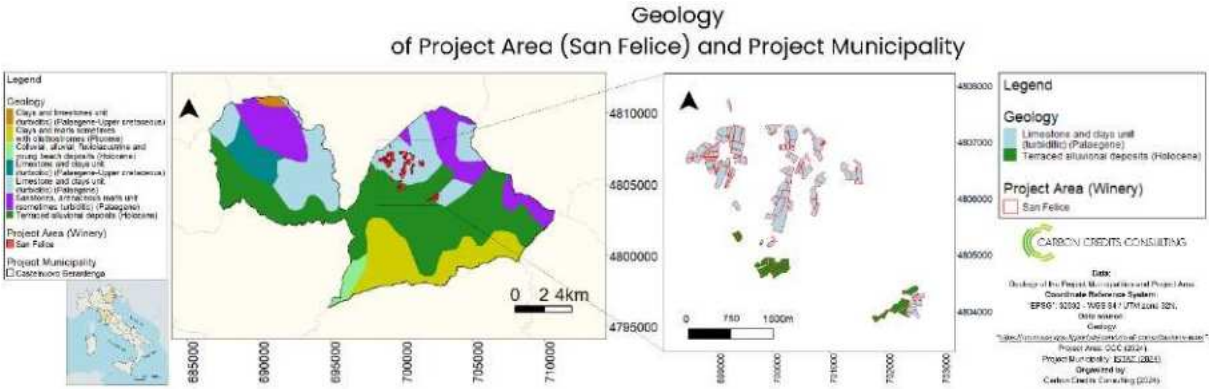


Figure 22. Geology of Castelnuovo Berardenga (Project Municipality) and San Felice (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

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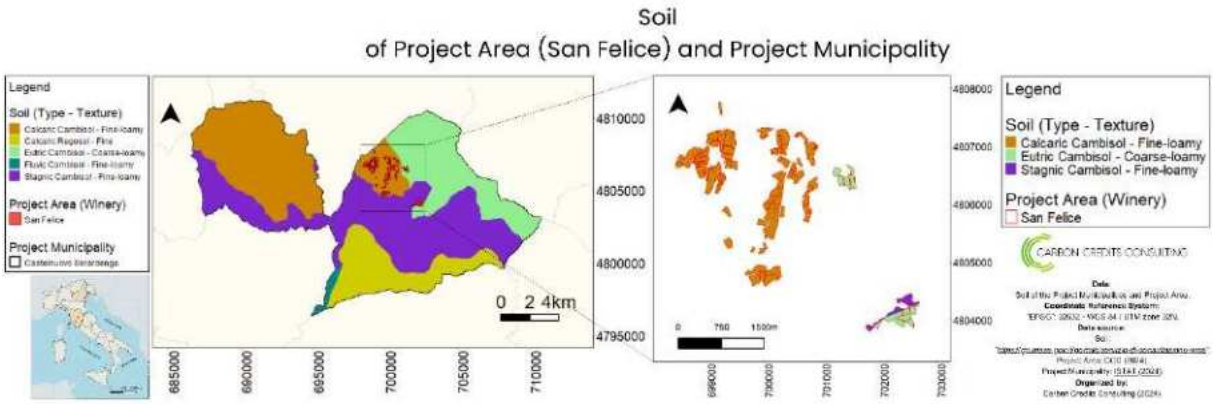


Figure 23. Soil of Castelnuovo Berardenga (Project Municipality) and San Felice (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

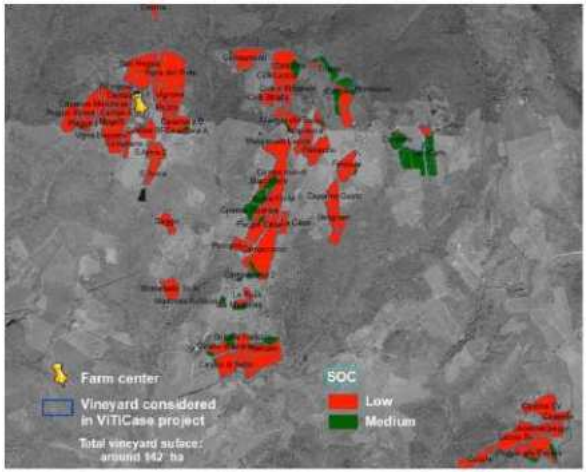


Figure 24. Soil Organic Carbon (SOC) content classes in the San Felice vineyards.

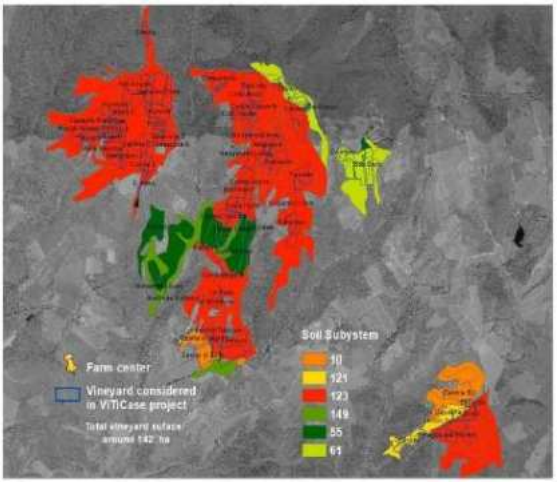


Figure 25. Soil subsystems in the San Felice vineyards.

(Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4)

Table 4. Key Soil Characteristics of San Felice. (Data source: CREA- Characterisation of Pilot farms (soils, management and pedo-climate)- WP 4)

Soil Region	System	Subsystem	Main key soil properties
RCE: Hilly and mountainous reliefs of central Tuscany, promontories and islands of the archipelago.	RCE_3. Low-altitude hilly surfaces with moderate slopes, on a substrate consisting mainly of clay, conglomerates and secondarily of sand, with frequent use mainly for agriculture	10. Slopes with valleys, with a slight to strong slope, subject to moderate to strong diffuse and channeled erosion, with the presence of sub-flat summits and slope shelves, little eroded;	Soil reference: ABB1 Clay content: 22.47 Organic matter (%): 1.7 Soil reference: BEL1 Clay content: 24.47 Organic matter (%): 1.7

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	(arable land, olive groves) and secondarily for coppice woodland (Turkey oak, downy oak and holm oak)	substrate mainly consisting of polygenic conglomerates; land use mainly consisting of coppice of downy oak, holm oak, hornbeam and, secondarily, of olive grove and arable land	
APP: Mountainous reliefs of the Northern and Central Apennines	APP7. Mountainous surfaces with moderate slopes and hilly surfaces of high and low altitude with moderate to steep slopes, on a substrate consisting mainly of clay with predominantly agricultural use (permanent meadow, arable land, olive grove and vineyard) and secondarily woodland (beech coppice, mixed coppice of thermophilic deciduous broadleaf trees, coniferous forest). Udic and ustic, mesic soil and climate regime.	55. Linear slopes, sometimes terraced, with a low to high gradient, subject to moderate to high widespread water erosion and sometimes to mass erosion; heterogeneous substrate consisting mainly of clays and marls with limestones (Undifferentiated Complex, Chaotic and Scaly Clays); land use consisting mainly of olive groves, vineyards, alternate arable land and, secondarily, pasture, shrubland, mixed forest.	Soil reference: GCC1 Clay content: 29.25 Organic matter (%): 1.5 Soil reference: ERM1 Clay content: 30.23 Organic matter (%): 1.57 Soil reference: VIL1 Clay content: 42.57 Organic matter (%): 1.55
	APP_4. Mountainous areas of medium to high altitude, very steep and medium and high-altitude hills with steep slopes, on a substrate consisting of arenaceous pelitic flysch and deposits generated by it, used mainly for forestry (chestnut coppice and beech coppice) and secondarily for agriculture (olive grove, vineyard). Udic and	61. Slopes with valleys, from steep to steep, subject to moderate to strong diffuse and channeled surface erosion, with the presence of accumulation areas with lower slope; substrate consisting mainly of sandstones (Macigno type “A”); land use consisting mainly of mixed coppice of deciduous broadleaf trees, secondarily of coniferous woods and,	Soil reference: PEL1 Clay content: 11.48 Organic matter (%): 1.67 Soil reference: GRT1 Clay content: 14.02 Organic matter (%): 2.15 Soil reference: GRT1 Clay content: 12.17 Organic matter (%): 1.53

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	ustic, mesic soil and climate regime.	marginally, of arable land and olive groves.	
CPL: Internal hilly reliefs originating from Pliocene marine sediments	CPL_1: Low-altitude flat surfaces on a substrate consisting mainly of recent and ancient terraced alluvial deposits, used for agricultural purposes (arable land). frequent Ustic and xeric, thermal soil and climate regime.	149. Valley bottoms (of the rivers Arbia, Asso, Orcia, Cecina and Elsa); substrate consisting of fluvial and fluvial-lacustrine deposits; land use consisting very frequently mainly of alternate arable land and meadows.	Soil reference: STR1 Clay content: 13.11 Organic matter (%): 1.67 Soil reference: STR2 Clay content: 12.11 Organic matter (%): 2.07
	CPL_4. low and medium altitude hilly surfaces, with moderate to steep slopes, on a substrate consisting mainly of Pliocene marine sands, with frequent use mainly for agriculture (olive groves, vineyards and arable land) and secondarily for woodland with downy oak, Turkey oak and holm oak.	121. Slopes with a gentle to moderate gradient, subject to moderate to strong diffuse and channeled water erosion and sometimes to mass erosion; substrate consisting mainly of Pliocene sands; land use consisting mainly of vineyards, olive groves and, secondarily, of rotated arable land.	
APP: Mountainous reliefs of the Northern and Central Apennines	APP_6. High and medium altitude hilly surfaces with moderate to steep slopes, on a substrate mainly composed of marly calcareous flysch, mainly used for coppice woodland (downy oak, Turkey oak) and secondarily for agriculture (olive grove, vineyard). Ustic and udic, mesic soil and climate regime.	123. Incised slopes, moderately sloping to steep, generally eroded to very eroded in the medium-high parts, terraced in the medium-low and low parts; substratum consisting mainly of marly limestones, marlschists and calciferous sandstones (Alberese) and marly limestones (Sillano Formation); land use consisting mainly of vineyards, olive groves, degraded mixed broadleaf forest.	Soil reference: CLV1 Clay content: 26.22 Organic matter (%): 2.11 Soil reference: SOM1 Clay content: 31.37 Organic matter (%): 1.27 Soil reference: VRZ1 Clay content: 37.45 Organic matter (%): 1.68

Tenute Ruffino. In Tenute Ruffino, the project areas lay on colluvial, alluvial fluviolacustrine and young beach deposits, dating back to the Holocene (*Figure 26*). Tenute Ruffino's fields are located on hydromorphic

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morphological depressions, with a calcareous substrate (*Figure 27*), while the soil is a Fluvic Cambisol with a fine-silty texture (*Figure 28*).

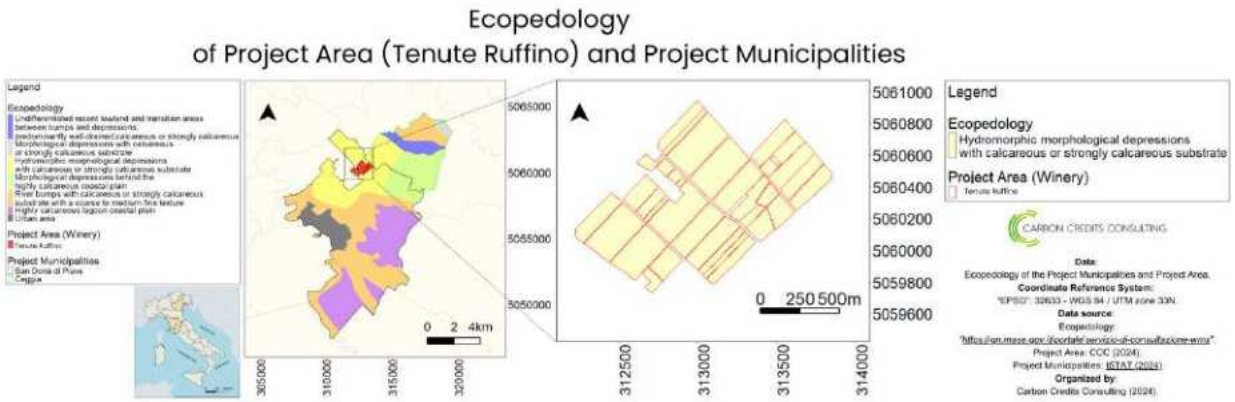


Figure 26. Ecopedology of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

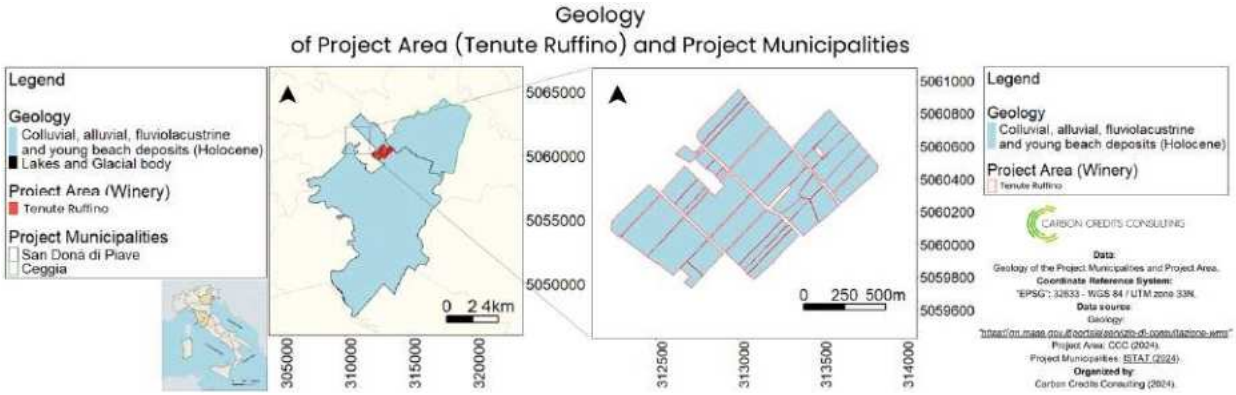


Figure 27. Geology of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

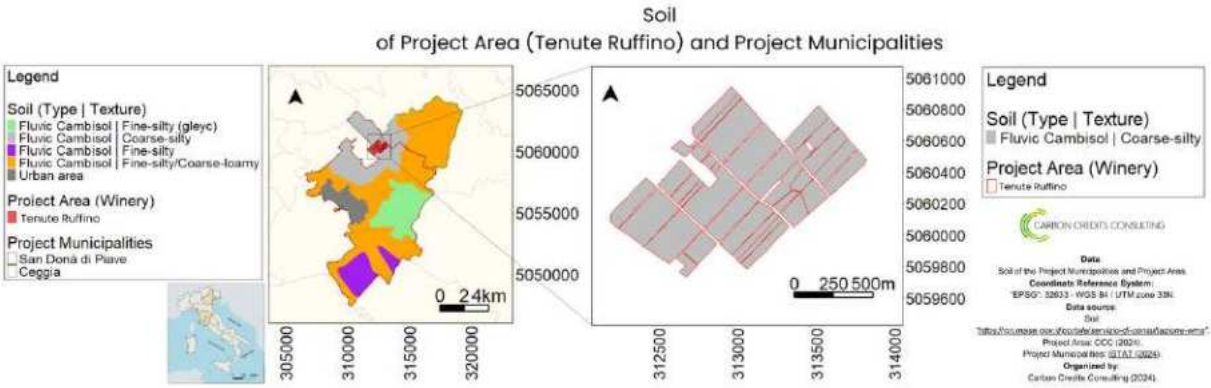


Figure 28. Soil of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

Topography

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Castello di Albola. **The project areas of the Castello di Albola winery, located in the Chianti wine production area, are located on a steep ground, with an average slope of around 10-15% (*Figure 30*) at an elevation of about 400 to 670 meters a.s.l. (*Figure 29*) for the southern and northern fields respectively.**

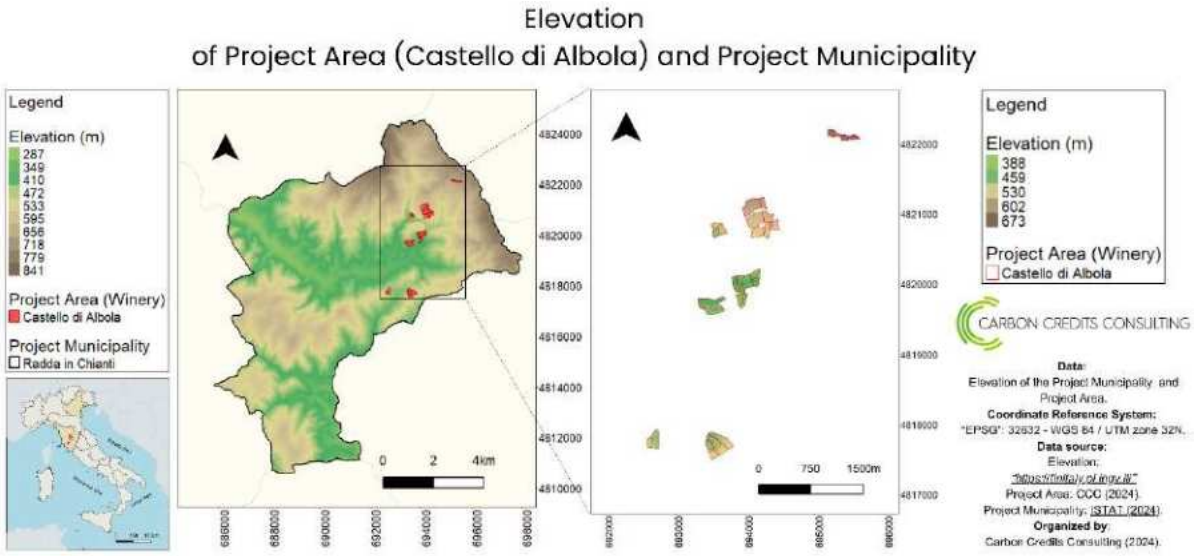


Figure 29. Elevation of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://tinitaly.pi.ingv.it/).

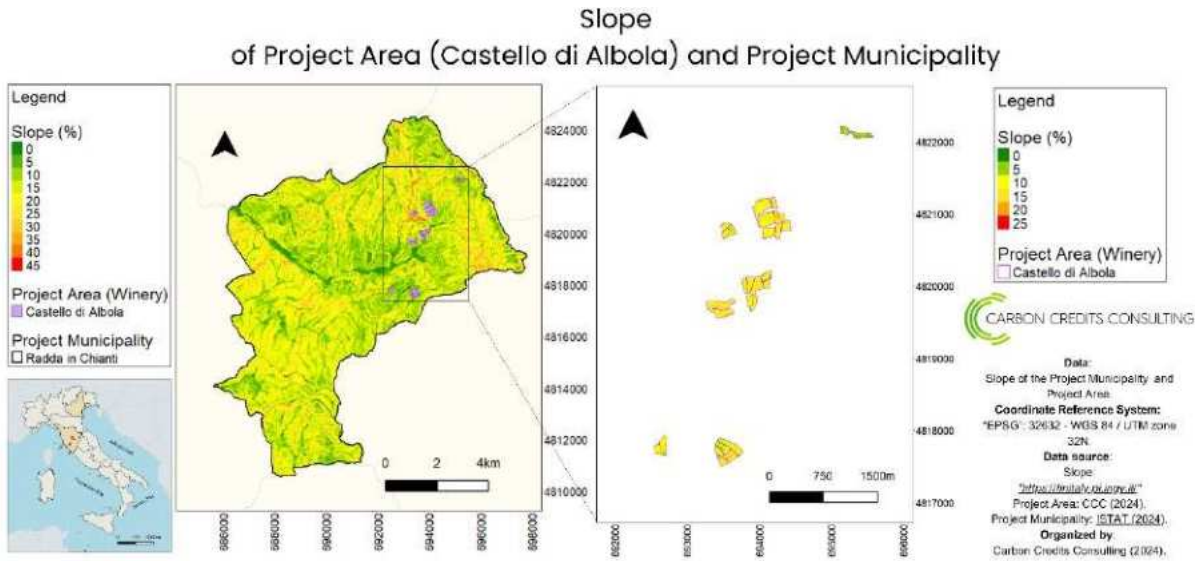


Figure 30. Slope of Radda in Chianti (Project Municipality) and Castello di Albola (Project Area). (Data source https://tinitaly.pi.ingv.it/).

Rocca di Montemassi. **The project area of the Rocca di Montemassi winery is located on a hilly terrain, between 35 and 65 meters a.s.l. *Figure 31*) and a slope between 0 and 25% (*Figure 32*).**

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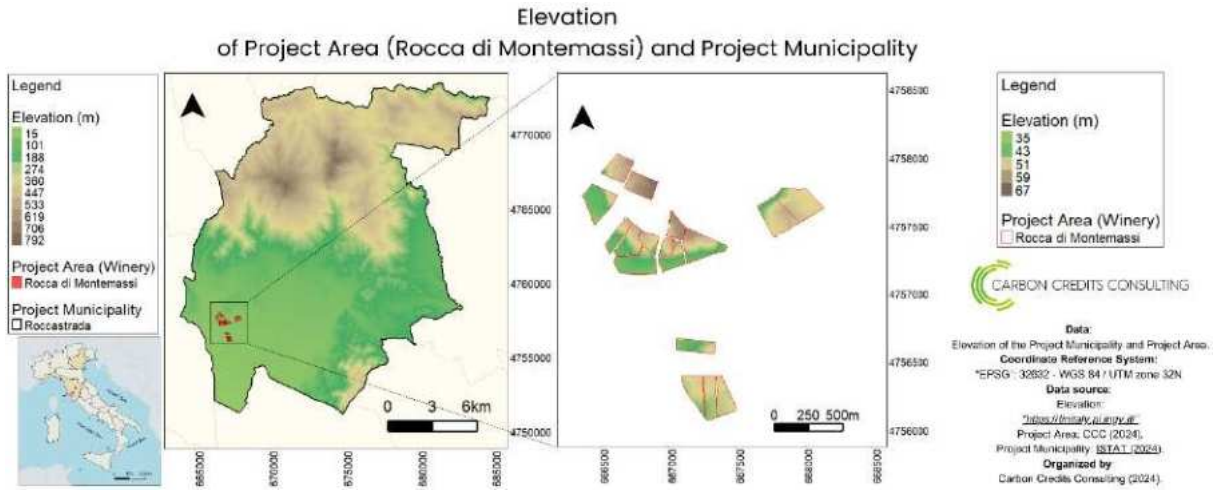


Figure 31. Elevation of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://tinitaly.pi.ingv.it/).

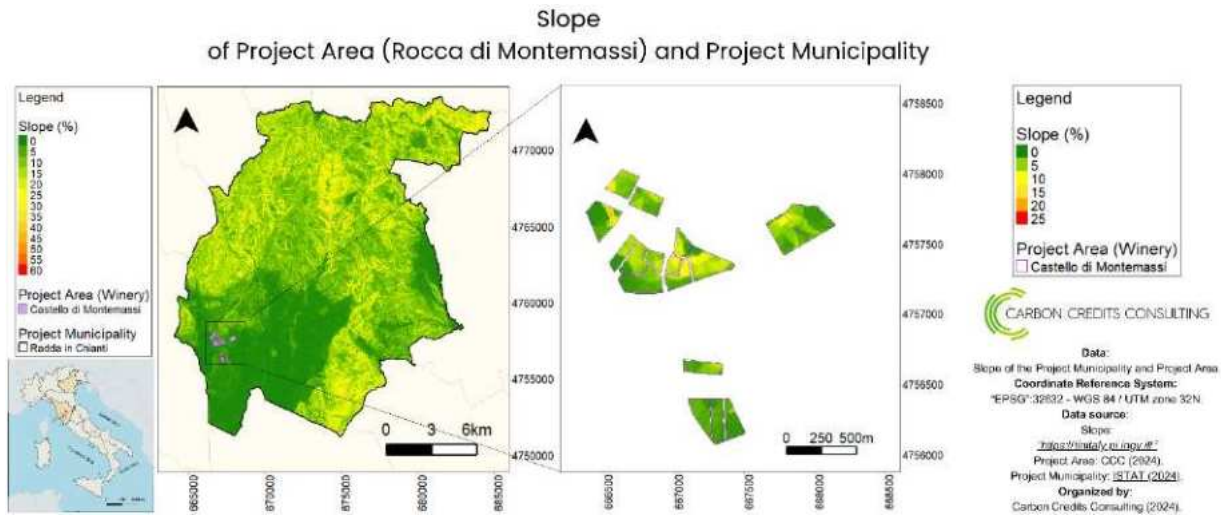


Figure 32. Slope of Roccastrada (Project Municipality) and Rocca di Montemassi (Project Area). (Data source https://tinitaly.pi.ingv.it /).

San Felice. The project areas of the San Felice winery are located on a hilly terrain, between 266 and 347 meters a.s.l. (*Figure 33*) and a slope between 0 and 25% (*Figure 34*).

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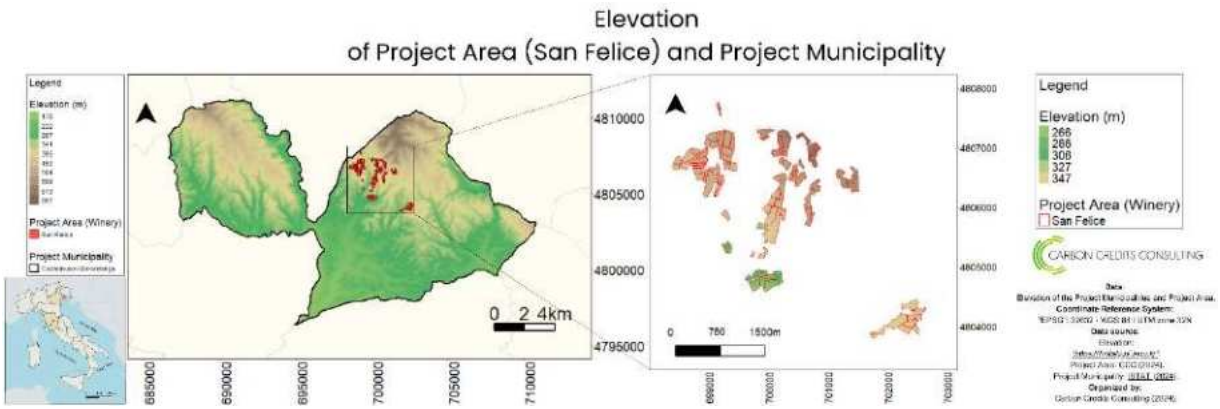


Figure 33. Elevation of Castelnuovo Berardenga (Project Municipalities) and San Felice (Project Area). (Data source https://tinitaly.pi.ingv.it/).

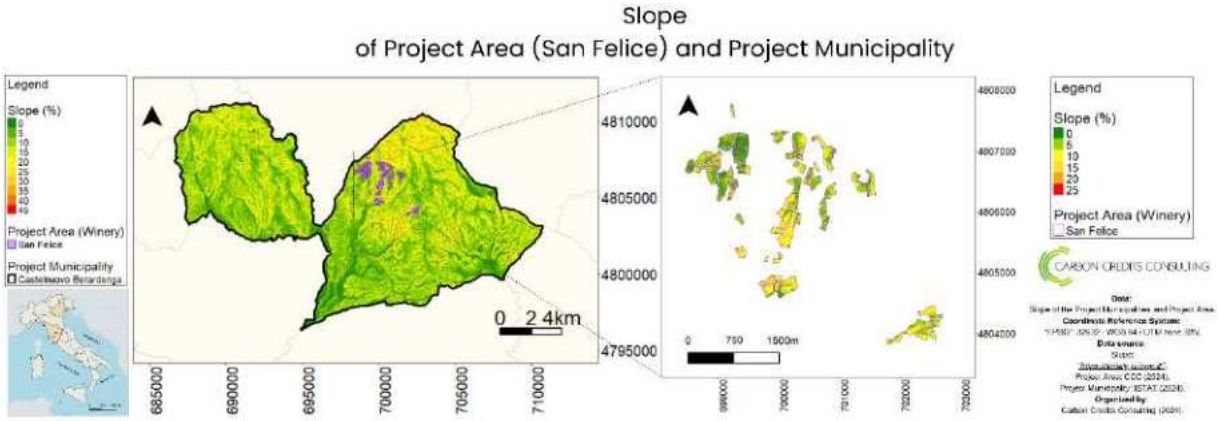
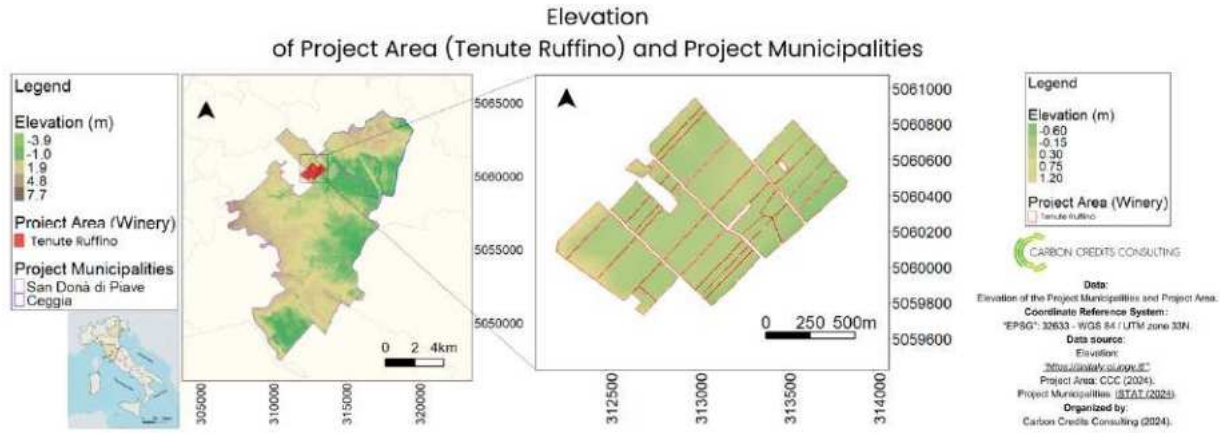


Figure 34. Slope of Castelnuovo Berardenga (Project Municipalities) and San Felice (Project Area). (Data source https://tinitaly.pi.ingv.it/).

Tenute Ruffino. The project areas of the Tenute Ruffino winery are located on a flat terrain, between 1.2 and –0.6 meters a.s.l. (*Figure 35*) and a slope between 0 and 1.5% (*Figure 36*).



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Figure 35. Elevation of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://tinitaly.pi.ingv.it/).

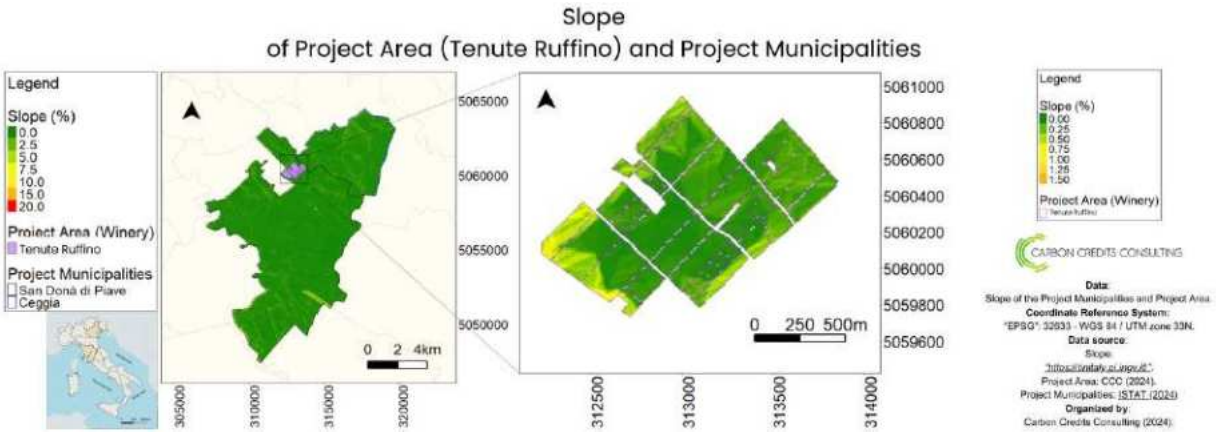


Figure 36. Slope of San Donà di Piave and Ceggia (Project Municipalities) and Tenute Ruffino (Project Area). (Data source https://tinitaly.pi.ingv.it/).

Hydrology

The only vineyard relying on all-year round irrigation system is Tenute Ruffino, hence it is the only one described in the PDD.

Tenute Ruffino. Within the project area of Tenute Ruffino, a system of ditches, pumps and a well is present (*Figure 37*). (Data source CCC, 2024)

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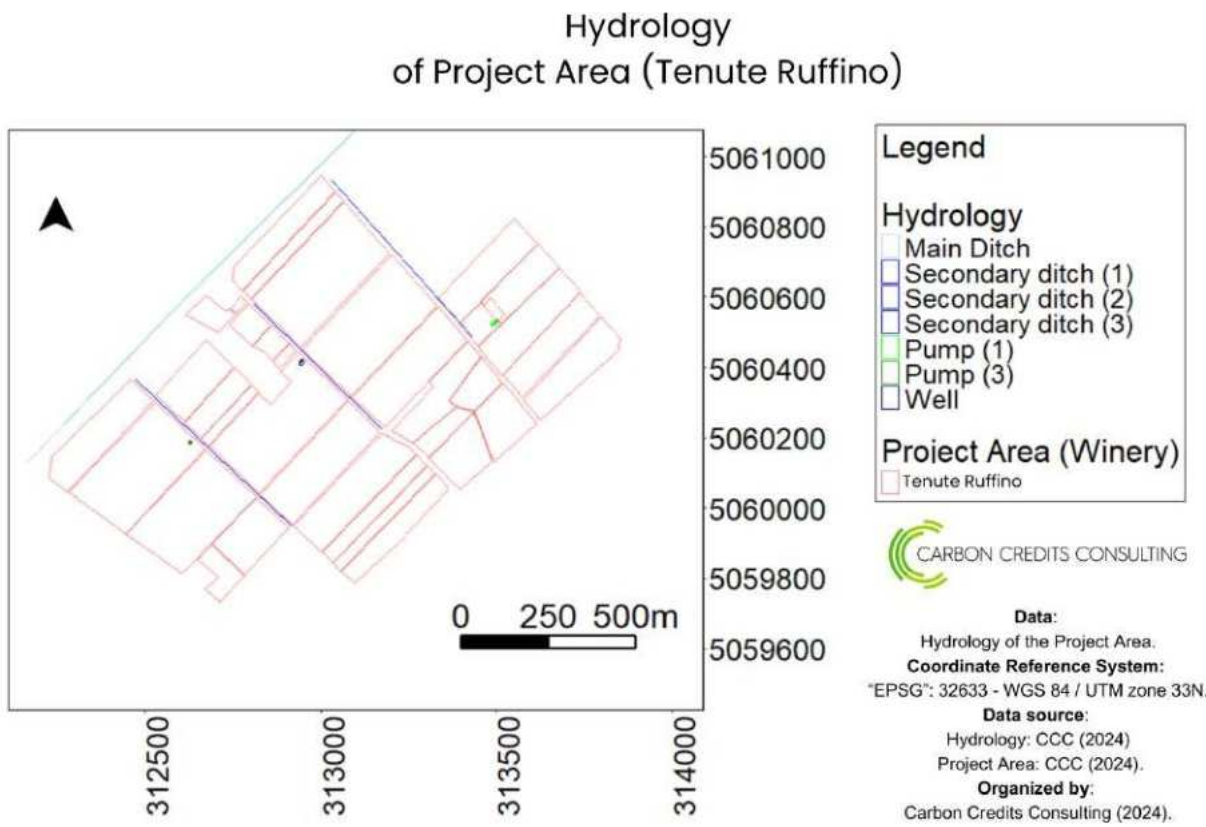


Figure 37. Hydrology of Tenute Ruffino (Project Area).

1.6 Technology applied

The project activities that will be implemented in the project areas are the following:

1. Improvement of in-rows natural grass cover by using self-seeding leguminous crops
2. Improvement of green manuring
3. Use of mycorrhizae
4. Minimum / no tillage
5. Improvement of the crop (vine) residues management after pruning and shredding
6. Use of compost
7. Use of manure

Improvement of in-rows natural grass cover by using self-seeding leguminous crops[1]

Grassing is a low-impact soil management technique used as a possible solution for tillage in orchards. Leguminous cover crops increase soil organic carbon (SOC) sequestration due to the release of carbon via root exudation into the rhizosphere as well as due to nitrogen fixation, that accelerates the C sequestration

[1] Più sostanza organica stabile con il sovescio nel vigneto (More stable organic substance with green manure in the vineyard), R. Morelli, D. Bertoldi, D. Baldantoni, R. Zanzotti. L'Informatore Agrario n. 18, pag. 51 del 12/05/2020. https://www.informatoreagrario.it/filiere-produttive/vitevino/piu-sostanza-organica-stabile-con-il-sovescio-nel-vigneto/ , accessed on September 2024

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potential of the other crops on the field[2]. A meta-analysis study on vineyards reported that the use of cover crops in viticultural soils resulted in an increase in SOC stocks by +22%, with a SOC sequestration rate of 4.45 CO_2-eq. ha^{-1} yr^{-1} [3]. Another meta-analysis study reported instead a 2.86 Mg CO2-eq. ha^{-1} yr^{-1} sequestration in Mediterranean vineyards under the use of cover crops[4].
The use of cover crops is also an essential tool in controlling weeds, including those resistant to herbicides, as they work by hampering weed germination, the emergence of weed seedlings as well as the allelopathic effect of the leguminous crops[5]. The reduction of weed biomass promoted using cover crops can be as big as 68%[6] and long lasting; Moonen and Barberi found a reduction of 22% in the soil weed seed bank 7 years after the introduction of leguminous cover crops[7]. By controlling weeds' emergence and depleting overtime the soil weed seed bank, the use of cover crop directly reduces the need for herbicides and/or mechanical tillage operations, which have well documented detrimental effects on soil organic carbon[8]. Another ecosystem service provided using in-rows leguminous crops that directly affects the soil organic carbon balance, is its effect on soil structure and aggregation. Legume cover crops increase the stability of soil aggregates as well as the content of diluted acid-extractable polysaccharides which work as active binding agents between the soil particles[9]. By improving the soil structure, soil erosion, which is a major driver for soil organic carbon loss, is also reduced. Legume cover crops can effectively reduce the loss of topsoil due to water erosion up to 92%, by absorbing the energy of raindrops, reducing the detachment of soil aggregates and runoff speed and increasing water infiltration[10]. In vineyards, by grassing the soil and mowing the vegetation to a height of 10 - 15 cm, tillage is eliminated. As a result, the vineyard is very well protected from erosion. In addition to the storage of organic carbon (mitigation effect) and the reduced SOC loss, grassing provides an environmental service that increases the biodiversity of the ecological niche, both from the perspective of the species that make up the grass and at the microbial level in the soil[11].

Activity implementation on the Project Areas
The species to be used for the grassing of the vineyard must meet certain characteristics, that is, not grow too tall while covering the soil well, establish well and quickly in autumn, be adaptable to specific soil and climate conditions, not require annual sowing and mowing to reduce soil disturbance. In general, self-reseeding species do not need to be sown every year as the seeds spread autonomously and, in optimal water conditions (autumn) germinate producing new individuals. In the case of non-self-reseeding species, it is advisable to intervene with repeated overseeding after having assessed the quality of the covering.

The species to be included in the mixture have an ecological role that depends largely on the family to which they belong. In general, they should meet the following needs:

[2] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera, 2020

[3] Marks J.N.J. , T.E.P. Lines, C. Penfold, T.R. Cavagnaro, Cover crops and carbon stocks: How under-vine management influences SOC inputs and turnover in two vineyards, Science of The Total Environment, Volume 831, 2022, 154800, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2022.154800.

[4] Effects of vegetation management intensity on biodiversity and ecosystem services in vineyards: A meta-analysis, Winter et al., 2018

[5] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera, 2020

[6] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera, 2020

[7] Size and composition of the weed seedbank after 7 years of different cover-crop-maize management systems, Moonen and Barberi, 2004

[8] Tillage-induced effects on SOC through changes in aggregate stability and soil pore structure, Guo et al., 2020

[9] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera et al., 2020

[10] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera et al., 2020

[11] Abundance and activity of soil organisms in fields of maize grown with a white clover living mulch, Nakamoto, 2006

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- improvement of soil carbon content (abundant and fasciculate root systems, such as grasses and composites)
- improvement of nitrogen content (legumes)
- possible control of nematodes and soil-borne diseases (Cruciferae)
- increase in biodiversity and attraction of pollinating insects (Phacelia)
- autumn-winter cycle to avoid water and nutritional competition with the vine and therefore not require irrigation (many of the species listed below meet this characteristic)

Table 5. Implementation of the project activity "Improvement of in-rows natural grass cover by using self-seeding leguminous crops in the project areas of Rocca di Montemassi, Castello di Albola, San Felice and Tenute Ruffino.

Farm	Farm-dependent reason for implementation	Management
Rocca di Montemassi		Seeding in autumn of self-reseeding legumes and/or non-self-reseeding legumes (1/3 of the dose recommended by the seed provider).
Castello di Albola	Important soil erosion	Seeding of grasses and legumes (½ of the dose recommended by the seed provider)
San Felice	Sufficient soil cover in baseline but unbalanced mixed species favouring grasses over legumes	Seeding in autumn of self-reseeding legumes and/or non-self-reseeding legumes (1/3 of the dose recommended by the seed provider)
Tenute Ruffino	Sufficient soil cover in baseline but unbalanced mixed species favouring grasses over legumes	Seeding in autumn of self-reseeding legumes and/or non-self-reseeding legumes (1/3 of the dose recommended by the seed provider)

Improvement of green manuring

Green manuring is an agronomic practice that consists of sowing an herbaceous crop with pure or consociated essences, intended to be totally buried or mulched. It has the function of fertilizing the succeeding crop or the vineyard within which it is sown. The advantages of this practice, in fact, are mainly related to maintaining the fertility of agricultural soils and reducing the use of mineral fertilizers, thanks to the contribution of organic matter and nutrients contained in the green manure crop. It has been shown that leaving cover crops as a dead mulch on the soil surface improves the soil structure, by increasing soil porosity, water infiltration, reducing bulk density and increasing soil aggregation[12]. The use of green manuring results in the overtime buildup of organic matter in the soil, which not only leads to a better soil structure, but it also increases the soil organic

[12] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera et al., 2020

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carbon content nutrient and nutrient intake for the crops. The increase in SOC due to the use of green manuring has been observed in multiple studies[13]. The improvement of SOC in the soil depends also on the C/N ratio of the green manure. The higher the C/N ratio, the higher the risk of nitrogen immobilization from the microbial community to break through and decompose the excessive carbon in the organic matter buildup. The lower the C/N ratio, the higher the risk of mineralization of the organic matter by the microbial community, leading to nitrogen leaching and N2O emissions for the soil. The use of legumes for green manuring, due to their optimal C/N ratio of usually under 20:1, favours good plant growth and efficient decomposition of the crop residues[14]. The use of a green mulch on the fields also prevents nutrient leaching[15] and decrease weed growth[16]. In addition, in a green manure crop the development of the root system and the burial of plant biomass bring a large amount of organic matter to the soil, improving its structure and chemical - biological properties in the short term, especially if this practice is repeated for several years with highly developed plant material. In annual rotations, moreover, autumn-winter green manures have an environmental function since these crops, called "cover crops," cover the soil between the main crop and the next one by retaining nutrients, particularly nitrogen, in the soil layers explored by plant roots. In this way, the amount of nitrate carried deep into the soil by rainwater can be reduced[17]. In addition, the use of cover crops reduces the phenomenon of surface runoff of rainwater, mitigating soil erosion and the dispersion of nutrients, particularly phosphorus, into surface waters. Green manure has the downside of having to enter the field with mechanical tillage and is not suitable for all types of fields. It is advisable as soon as the green manure crop is buried to apply a timely rotation to avoid nitrate leaching into the water table. Proper application of green manure also involves minimum tillage in order not to lose the benefits of nitrogen fixation and avoid environmental damage.

Use of mycorrhizae[18]

By establishing a symbiotic relationship with plants through the formation of arbuscles and vesicles within the plants' root system, mycorrhizae have several beneficial effects on crop performance. These benefits range from enhancing crop growth, photosynthesis and resistance to salt-alkali stress, to increasing soil nitrogen mineralization rates and total nitrogen plant uptake. In viticulture, the use of mycorrhizae strongly enhances vine response to water stress, protect against root pathogens and abiotic stresses and improve nutrient uptake, such as phosphorus, calcium and potassium. In the very early stages of vine growth, mycorrhizae accelerate the vegetative development of the crop, especially that of the root system, shortening the time required to reach maturity and full productivity. By promoting nutrient uptake, photosynthesis and growth, the use of mycorrhizae plays a key role in the sustainable development of vineyards, contributing indirectly to a higher carbon sequestration potential of the vine as well as a reduced soil erosion due to a better establishment of the crop in the field.

Minimum and no tillage

Conventional tillage, both at high intensity (HT) (>40 cm depth with soil profile inversion) and intermediate intensity (IT) (<40 cm depth and without soil profile inversion) is known for being a driver of SOC loss. The transition of tilled cropland to minimum or no tillage is thought to have a significant potential to mitigate climate change by storing carbon in the soil. In the US, between 30 – 50 % of SOC has been lost since the

[13] The value of catch crops and organic manures for spring barley in organic arable farming, Olesen et al., 2006
[14] Situational analysis of green manure practices implemented in Gaillac vineyard, Bertille, 2019.

[15] A critical review on the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity, Abdalla et al., 2019
[16] Legume Green Manuring: An Option for Soil Sustainability, Meena, 2018

[17] Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Kyocera et al., 2020
[18] Arbuscular Mycorrhizal Fungi – An Essential Tool To Sustainable Vineyard Development: A Review, Popescu, 2016

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advent of plough, indicating the croplands may have the potential to mitigate climate change via the reduction of carbon loss[19]. Tillage intensity plays a key role in determining how much SOC will be affected. A review of 351 studies on tillage effects on SOC, reported that soil organic carbon under intermediate intensity tillage was of 2.09 g/kg [± 0.34 (SE)], as compared to intensive tillage 1.30 g/kg [± 0.22 (SE)]. At lower depths (15 – 30 cm), HT practices had 0.89 g/kg [± 0.20 (SE)] lower SOC than IT ones. The study concluded that the lower the intensity of tillage, especially in terms of soil profile inversion, the lower the SOC loss across the soil profile[20].

An even lower intensity tillage that IT is that of minimum tillage (MT), occurring at depths not exceeding 15 cm and with minimal or no inversion of layers. With one/two passes of the machine, a satisfactory seedbed is obtained while maintaining a cover of crop residues on at least 30 percent of the field surface. The kind of operations allowed are the ones performed with disc harrows, or other carried, semi-carried or trailed implements equipped with working parts that are not moved hydraulically or by the PTO. In viticulture, minimum surface tillage of the sub-row is expected to break up soil crusts. In addition, a single minimum tillage operation is expected for sowing the grass cover essences in the inter-row.

The last degree of tillage intensity is the no tillage (NT) technique, that involves a direct sowing on the previous crop residues, which are left on the soil surface. A systematic review of 351 studies on tillage intensity's effects on SOC, reported that under no tillage practices C stock increase in the upper soil layer (0 – 30 cm) was around 4.6 Mg ha^{-1} (0.78 – 8.43 Mg ha^{-1}, 95% CI) over a period of more than 10 years. The study reported also that higher SOC stocks in the upper soil layer, thanks to no tillage, promoted a higher soil productivity as well as an increased resilience to extreme weather conditions[21]. A meta-analysis on the sequestration potential of no tillage in vineyards, reported that the use of NT led to an average positive SOC change by +20%, resulting in a SOC sequestration rate of 3.50 Mg CO_2-eq. ha^{-1} yr^{-1}. Another meta-analysis study reported an even higher sequestration of 5.13 Mg CO_2-eq. ha^{-1} yr^{-1} [22].
Although no tillage is performed on the field, special seeding machines are needed, capable of cutting the crop residues, making a seed furrow in which to deposit the seed, and covering it under no-tilled soil conditions.

Improvement of the crop (vine) residues management after pruning and shredding
Wood residues have been widely revalued in recent years. These in the form of pruning waste or as wood chips, if buried, significantly increase the stable carbon content in the soil due to the high lignin content. If used in massive quantities, without further action, they could cause a temporary loss of fertility due to the alteration of the C/N ratio in the soil. The improved management of residues is especially important in winegrowing regions where the removal of pruning residues for burning is common, resulting in residue-removal-induced SOC losses. A meta-analysis study reported that the improved use of residues management in vineyards led to a SOC sequestration rate of 2.82 Mg CO_2-eq. ha^{-1} yr^{-1} [23].
Besides SOC improvement, the soil will have overtime numerous benefits from both a chemical and physical point of view. This practice improves water retention in the soil, creating excellent porosity. By providing structure to the soil, it helps combat erosion[24]. Furthermore, wood chips can be used as a natural mulching material, drastically reducing water evaporation from the soil[25]. Green residues contribute to the increase of

[19] How does tillage intensity affect soil organic carbon?, Haddaway et al., 2017
[20] How does tillage intensity affect soil organic carbon?, Haddaway et al., 2017
[21] How does tillage intensity affect soil organic carbon?, Haddaway et al., 2017
[22] The impact of intercropping, tillage and fertilizer type on soil and crop yield in fruit orchards under Mediterranean conditions: A meta-analysis of field studies. Coronado et al., 2019
[23] Meta-analysis on how manure application changes soil organic carbon storage, Gross and Glaser, 2021
[24] Effect of crop residue management on soil organic carbon, soil organic matter and crop yield: An overview, Kumari et al., 2019
[25] Evaporation from soil in relation to residue rate, mixing depth, soil texture and evaporativity, Gill and Jalota, 1995

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organic matter with beneficial consequences on fertility and water availability. In addition, straw, mowing and leaves can be used as mulching material to drastically reduce evaporation of an otherwise bare soil. In tree crops, green pruning residues are already normally left in the field and chopped up together with the mowing of the turf[26].

Planting of bordering hedges

The use of hedges bordering the vineyard provides multiple ecosystem services, spanning from soil erosion control to agrobiodiversity enhancement. A study on natural hedges as an element of functional biodiversity in Central Italy, reported the increase in parasitic insects and decrease of vine pests[27]. Alongside being a natural habitat for predators of wine pests, hedgerows offer protection against air and water fluxes, hence reducing wind and water erosion of the topsoil, a major driver in SOC loss especially on sloping terrain. Crop water availability is also improved by bordering edges, due to shading and windbreak effects that reduce evapotranspiration and retention of moisture in leaf litter. Due to the higher hydraulic conductivity and soil porosity of hedgerows soils, the surface water infiltration is also higher.

Hedges play also a key role in storing carbon both in the aboveground and belowground woody biomass. A study on regulatory services delivered by hedges reported that uncut shrubby hedges may store up to 0.5 t C $ha^{-1}yr^{-1}$, while tree lines up to 3 t C $ha^{-1}yr^{-1}$ [28]. Soil nutrient concentration, like nitrate and phosphate, is considerably higher in hedgerow soils as compared to arable fields[29].

Use of manure

In vineyards, SOC is usually low, and the risks of soil erosion and degradation is high[30]. Hence, the use of manure plays a key role in restoring the SOC and preserving soil from erosion. The effect of manure application on SOC is well documented. A meta-analysis of 101 studies on the impact of manure on soil organic carbon storage, reported that on average the SOC increase due to manure application of 35.4 % (about 0,7 Mg ha^{-1}). Regardless of tillage intensity, manure applications increased the SOC content throughout the soil profile, but more predominantly in shallow and intermediate topsoil (in 0–15 cm by 9.5 Mg ha^{-1} and in 16–20 cm by 13.6 Mg ha^{-1}). Deeper soil layers (> 20 cm) also benefitted from SOC increase, but only by +2.6 Mg ha^{-1}. Soil acidity is an important predictor of how manure can increase SOC concentration, with acidic soils performing better (+ 5.1 Mg ha^{-1}) than neutral or alkaline soils (+ 5.1 Mg ha^{-1}). The type of farmyard manure plays also a key role, with pig manure being the most performing (+41% SOC increase), followed by cattle manure (+32% SOC increase)[31].

1.7 Roles and responsibilities

The vineyard owners are the project proponents being the entities holding statutory, property, and contractual right over the land, vegetation, and management process that generates the emissions mitigations and have overall control and responsibility for the GHG project.

[26] Più sostanza organica stabile con il sovescio nel vigneto (More stable organic substance with green manure in the vineyard), R. Morelli, D. Bertoldi, D. Baldantoni, R. Zanzotti. L'Informatore Agrario n. 18, pag. 51 del 12/05/2020. https://www.informatoreagrario.it/filiere-produttive/vitevino/piu-sostanza-organica-stabile-con-il-sovescio-nel-vigneto/ , accessed on September 2024

[27] Natural hedges as an element of functional biodiversity in agroecosystems: the case of a Central Italy vineyard, Ponti et al., 2005

[28] Regulatory services delivered by hedges: The evidence base, Walton et al., 2014

[29] The role of hedgerows in soil functioning within agricultural landscapes, Holden et al., 2018

[30] Soil organic carbon sequestration rates in vineyard agroecosystems under different soil management practices: A meta-analysis, Payen et al., 2020

[31] Meta-analysis on how manure application changes soil organic carbon storage, Gross and Glaser, 2021

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Carbon Credits Consulting Srl (CCC) is the entity responsible for developing and implementing the project activity, along with Image Line and CREA (technical partners). CCC is responsible for the preparation and fair presentation of this PDD and all accompanying documentation provided[32].

1.7.1 Project proponent(s)

Organization Name	SOCIETA' AGRICOLA SAN FELICE SPA
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Organization Name	CASTELLO DI ALBOLA (pilot 2 : ROCCA DI MONTEMASSI)
Role in the project	Project Proponent
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[32] CINEA (European Climate, Infrastructure and Environment Executive Agency) – Grant Agreement Project 101113620 LIFE22-CCA-IT-LIFE VitiCaSe.

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1.7.2 Others involved in the project

Organization Name	CARBON CREDITS CONSULTING S.R.L.
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1.8 Chronological plan/implementation

The main project milestones are detailed below:

1) Start date: 18/10/2024
2) Baseline period: 01/10/2021-30/09/2024
3) Termination of the project: 17/10/2039
4) Frequency of monitoring, reporting, crediting period: the crediting period is fixed in 15 years, the monitoring and reporting will be at least annually.
5) Validation and verification activities: validation process commencement by April 2025, first monitoring period 2024-2027, verification process at the end of the monitoring period.

1.9 Eligibility

The LIFE VitiCaSe project meets the eligibility criteria and the ICR program in general due to its integrated and multifaceted approach to promoting sustainable and carbon farming practices, aimed at the reduction of CO2 emissions into the atmosphere as well as the capturing of CO2 from the atmosphere and increase Soil Organic Carbon.

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The project crediting start date is 18/10/2024, therefore after 1 January 2020 and then eligible for registration with ICR subject to conformity requirements.

The project applies the ISCC EU Greenhouse Gas methodologies and has established criteria and procedure for quantification of GHG emission mitigations in conformity to the ICR requirements and ISO14064-2. In addition, the VERRA's VM0042 version 1.0 methodology is incorporated into the project's methodological framework, which serves as the project's foundation.

GHG emission mitigations eligibility requirements. The project is focused on the CO_2 Kyoto Protocol gas category and aim to reduce greenhouse gas (GHG) emissions in cropland systems via Improved Cropland Management (ICM) activities. This involves adopting practices that increase soil carbon stocks while removing CO_2 from the atmosphere, as well as activities that reduce the emission of CO_2. Furthermore, no GHG emissions primarily for the purpose of their subsequent reduction, removal, or destruction have been generated during the project.

The project addresses the call LIFE-2022-SAP-CLIMA and the priority area LIFE-2022-SAP-CLIMA-CCM - Climate Change Mitigation because through C sequestration contributes to a «sustainable transition towards a climate neutral economy by 2050». It is consistent with the issue «carbon capture and use; as well as carbon capture and storage» that is one of the issues mentioned, on which the European Union climate policy and legislation focus. The area of intervention considered by the project is the no. 4 "The development of land and sea management practices which have an impact on emissions and removals of emissions, conservation and enhancement of natural carbon sinks" in which "Carbon farming" is mentioned as an approach to be promoted by the funded projects.

The general objective of this project is to create a pilot business model for promoting land-based CO2 removals in the vineyards. The business model will be aimed to stimulate winegrowers to integrate C stocking in the soil management practices and cultivation techniques - create an automated system for calculating/estimating stored C that is credible, reliable, and certifiable by third parties.

The project's primary goal is to bring about changes in the biological carbon stock caused by the project activity on the site. The project area acts as a sink and remains so for the entire lifespan of the project. The project activity is expected to positively impact GHGs sequestration, reduction, and removal, leading to a net sink effect by changing and improving common agricultural practices.

1.10 Funding

Life VitiCaSe has received public funding from the European Climate, Infrastructure and Environmental Executive Agency (CINEA) through the call LIFE-2022-SAP-CLIMA (project number 101113620 – LIFE-CCA-IT-LIFE VitiCaSe), amounting to 1,329,541.88 Euros. These funds will be utilized for the development of the necessary activities for implementing the project activity, and will also cover the essential technical consultancy services, staff salaries, operational expenses, marketing initiatives and support the overall project development. In addition, the provided funding will cover the management costs associated with registering the carbon project.

The funding provided by CINEA has directed to both the project proponents and the other entities involved.

The funding rate for costs represents the 60% of the action's eligible costs; the estimated eligible costs and contribution for the action are described in the Grant Agreement[33].

[33] CINEA – Grant Agreement project 101113620 LIFE22-CCA-IT-LIFE VitiCaSe.

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1.11 Ownership

The project ownership is in the head of the vineyard owners, being the entities holding statutory, property, and contractual right over the land, vegetation, and management process that generates the emissions mitigations and have overall control and responsibility for the GHG project.

The property rights of each vineyard are demonstrated through the company registration certificate, land registry certificate and rental agreement if present (Table 6).

Table 6. Companies' registration certificates, land registries and rental agreements

Company name	Company registration certificate No.	Land Registry certificate No.	Rental Agreement.
Castello di Albola	Numero REA VI-238360	Visura n° T60137/2023	NA
Castello di Albola (pilot 2: Rocca di Montemassi)	Numero REA VI-238360	Visura n° T252512/2024 Visura n° T253128/2024	
San Felice	Numero REA MI-989118	Visura n° T147907/2023	NA
Tenute Ruffino	Numero REA FI-527229	Repertorio n° 24198 Fascicolo n° 15215	YES

All the certificates are available to VVB and ICR during the validation process. (added in a file as references)

1.12 Other certifications

Company name	Certifications
Castello di Albola	Organic, Equalitas
Castello di Albola (Rocca di Montemassi)	Organic, Equalitas
San Felice	Organic, Equalitas, BRC, IFS, ISO 45001
Tenute Ruffino	Organic, SQNPI, Biodiversity friend, ISO 14001, ISO 45001, ISO 9001

1.13 Double counting, issuance and claiming

The project has not been registered or is seeking registration under other GHG programs, therefore double claiming will not occur as it is not registered with any other GHG program, and measures are in place to ensure that GHG mitigation outcomes from this project are unique and accounted for independently. In addition, for the new project instance a completeness check will be carried out before starting the inclusion process to ensure that the project has not been enrolled in another ICR project.

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1.13.1 Host country attestation

Provide information if the project has obtained a letter of assurance and authorization from the host country or countries where the GHG emission mitigations occur. The letter shall be provided in Appendix and uploaded to the registry. See further ICR Article 6.2 procedures.

☐ Host country attestation

☒ No host country attestation

1.13.2 Other registration and double issuance

Is the project registered or intends to be registered with another GHG program?

☐ Yes, (provide evidence on how double issuance will be prevented)

☒ No

Has the project been rejected by another GHG program

☐ Yes, (provide information on the reason for rejection and how the argument is not relevant for ICR registration)

☒ No

If the project is, has been or intends to be registered with another GHG program, evidences of the other registration shall be provided, i.e. registration ID, GHG program, link.

GHG program	NA
Project ID	NA
Link	NA
Status	NA

1.13.3 Double claiming and other instruments

Are the project activities also included in a GHG emissions trading program (other than a GHG program) or is subject to binding emission limit?

☐ Yes, (provide information on how double claiming is prevented)

☒ No

Has the project activity applied for, received, or is planning to receive instruments from another GHG-related environmental crediting system, e.g. IREC or Guarantees of Origin.

☐ Yes, (provide information on how double claiming is prevented)

☒ No

If the project is, has been or intends to be registered with another GHG related environmental crediting system, evidence of the other registration shall be provided, i.e. registration ID, GHG program, link.

GHG program	NA
Project ID	NA
Link	NA
Status	NA

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Do project activities affect GHG emissions accounted for within a value chain (goods/service, i.e. scope 3 emissions and the project proponent or an authorized representative a buyer or a seller of such goods/services?
☐ Yes, (provide information on how double claiming is prevented to safeguard GHG emission reporting and double claiming considering specifically the last paragraph of section 5.8 of the ICR requirement document v6.0, e.g. a public statement for such deduction/addition in reported GHG emissions, reporting to suppliers within the proponents value chain)
☒ No. The project has not been registered or is seeking registration under other GHG programs, therefore double claiming will not occur as it is not registered with any other GHG program, and measures are in place to ensure that GHG mitigation outcomes from this project are unique and accounted for independently. In addition, for the new project instance a completeness check will be carried out before to start the inclusion process to ensure that the project has not been enrolled in another ICR project.

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1.14 Other benefits (SDGs)

The project contributes to achieving other benefits that results in sustainable development goals (SDGs) contributions. The following is the description of how the project activities will result in expected contributions.

		Identification of SDG contributions	
SDG target	Indicator (text from the SDG indicator)	Net impact (implemented activities to increase or decrease)	Contributions
8. Decent work and economic growth			
8.1.1	Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Positive. The project will contribute to enhanced economic productivity through innovative agricultural practices.	The generation of carbon credits from the implementation and certification of the project activities actively support the SDG 8, subtarget 8.1, as it provides an additional income source for the wineries undertaking the practices of carbon farming.
12. Responsible consumption and production			
12.2.1 12.2.2	By 2030, achieve sustainable management and efficient use of natural resources Highly Positive. The project significantly promotes the efficient and sustainable use of natural resources.	Highly Positive. The project significantly promotes the efficient and sustainable use of natural resources.	The project activities will support an environmentally friendly production, by not only increasing the stocking of SOC but also providing additional environmental services, such as increasing the agroecosystem biodiversity. This contributes to the achievement of the subtarget 12.2
13. Climate action			

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13.3.1	Improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning Highly Positive. The project is instrumental in raising awareness and education about climate change.	Improved education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning Highly Positive. The project is instrumental in raising awareness and education about climate change.	The grouped project aims to be a climate action by structuring a climate solution, increasing the carbon stocks in the soil and avoiding the emissions of CO_2. Thus, it can help the goal acting on a sub target that seeks to reduce greenhouse gas emissions. The project will cooperate to this target by reduction/removal of 4,283 tCO_2 in the atmosphere. In addition, specific project activities, such as no tillage or minimum tillage, actively reduce the emissions of CO_2 into the atmosphere, contributing to the goal of the SDG13.
15. Life on land			
15.1.1 15.1.2	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Highly Positive. The project has a significant positive impact on habitat conservation and biodiversity.	The project can promote improvements on life of land to achieve the sub target by restoring degraded land. In this sense, the project activity (e.g. minimum/no tillage and improvement of green manuring and grassing) aiming at avoiding/reducing the emissions of CO_2 will also promote the restoration of degraded land and soil, mostly caused by erosion processes exacerbated by climate change. The project will also help to improve soil fertility, by increasing its carbon stocks.

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1.15 Risk assessment

Project activities are implemented in Italy and comply with applicable national legislation, including Legislative Decree No. 81/2008 on occupational health and safety and Law No. 903/1977 and Legislative Decree No. 198/2006 on gender equality and non-discrimination. Italian labour law strictly prohibits child labour, forced labour, discrimination, and unsafe working conditions. Project activities do not introduce new or hazardous labour practices and are carried out by established agricultural enterprises using formal employment arrangements. Based on this regulatory context and the nature of the activities, no material risks to working conditions, women and girls, minorities, or children have been identified. (Human right and ILO convention in Italy).

	Risks identified	Mitigation measures
Project design	The project is conceived as grouped project which allows to add additional instances of project activities after project validation. No specific risks are identified, unless the double claiming.	For the new project instance, a completeness check will be carried out before starting the inclusion process to ensure that the project has not been enrolled in another ICR project. The new project instance will apply the measures in the same manner specified in the project description. If any change in the project design during the project lifetime, project deviation will be applied, and the project will be re-validated for being eligible to issue ex-post ICCs subject to verification.
Environmental and socio-economic safeguards	For environmental risks refer to below paragraph Environmental Risks table 8.	For the mitigation measures of environmental risks refer to paragraph Environmental Risks, table 8.
	Please refer to Table 9 and 10.	Please refer to Table 9 and 10.
Boundary	The grouped project is developed within the Italian Republic Country. The project activity is in Toscana and Veneto regions. No specific risks are identified since the project activity does not expect to be expanded beyond Italy.	Only wide geographic area is considered for this grouped project.
Baseline determination	The baseline scenario represents activities and GHG emissions that are most likely to occur in the absence of the project activity. It has been accurately determined and all the assumptions, values and procedures to determine the most plausible baseline scenario are described in section 6 of the PD. No risks are identified.	Specific assessment of baseline scenario will be done for each new project activity instance included in the project scope after the grouped project registration, to revalidate the initial assumptions.

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Additionality	The project additionality is demonstrated applying the multilevel principle according to the ICR requirements version 6.1. No risks are identified.	NA
GHG SSR relevant to the baseline	All the GHG SSR identified as relevant to the baseline scenario	NA

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scenario and conservativeness	are controlled by the project proponent, therefore no risks are identified.	
GHG SSR relevant to the project and conservativeness	All the GHG SSR identified as relevant to the project scenario are controlled by the project proponent. The project's identified GHG SSR are the same identified in the baseline scenario. Therefore, no risks are identified.	NA
GHG emission mitigation quantification and conservativeness	The idenfied risk is the uncertainties related to the quantification of GHG emission reductions/removals enhancement.	Criteria and procedures have been selected and applied for quantifying GHG emissions/removals for the selected GHG SSRs, during the project implementation and operation. In addition, quality management procedures to manage data and information, including the assessment of uncertainty are established.
Leakage	All the GHG SSR identified as relevant to the baseline and project scenario are controlled by the project proponent. No leakage have been identified. There are no GHG SSR affected by the project activity that could refer to as leakage. Therefore no risks are identified.	NA
Non-performance	Not applicable. The project does not expect the issuance of ex-ante ICCs.	NA
Non-permanence	The wineries have joined a framework with which they commit to continue in the years following the conclusion of the project, even in the event of a change in the crop destination of the land, the adoption of sustainable soil management practices with the aim of maintaining or increasing the organic matter content accumulated during the project period for the following 50 years.	To ensure continuity and minimize any impacts, wineries are committed to: – Diversification of management practices to improve resilience to climate change. – Adoption of advanced technological tools for monitoring and verifying carbon sequestration. – Collaboration with experts, certification bodies and other stakeholders to identify timely and appropriate solutions to any critical issues.
Non-corresponding adjustments	Not applicable. The project does not expect the issuance of ex-	NA

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	ante ICCs, therefore the non-corresponding adjustment is not applicable.	
Monitoring	Lack in the applying the developed monitoring plan.	Quality management procedures to manage the monitoring plan, the data and the information, including the assessment of uncertainty are established.

Environmental Risks

The following environmental risks have been identified for the project areas.

No hydrogeological risk has been identified in the project areas of Rocca di Montemassi (*Figure 38*), San Felice (*Figure 39*) and Tenute Ruffino (*Figure 40*).



Figure 38. Hydrogeological risk of the Project Area (Rocca di Montemassi). Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

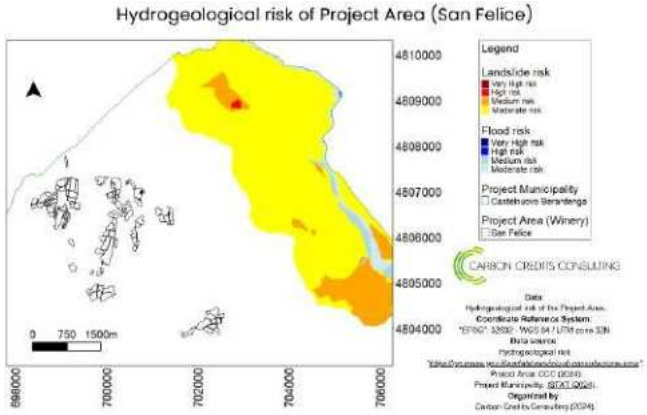


Figure 39. Hydrogeological risk of the Project Area (San Felice). Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

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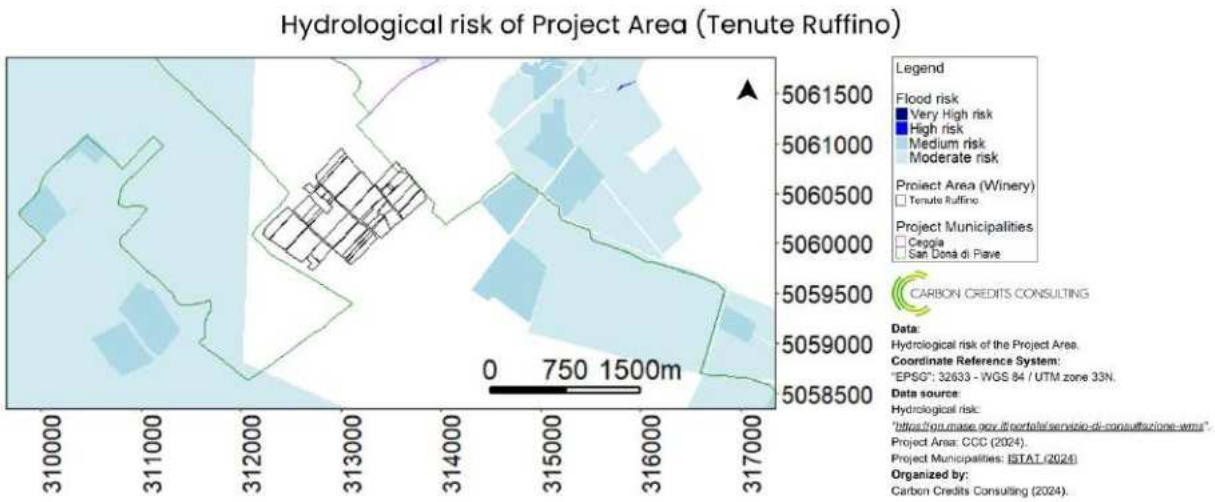
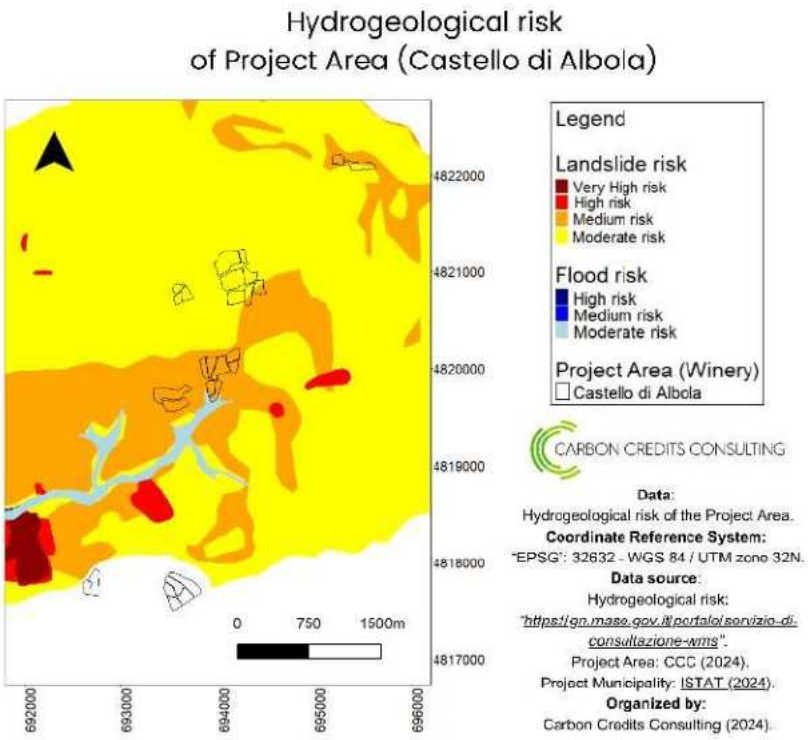


Figure 40. Hydrogeological risk of the Project Area (Tenute Ruffino). Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

Although the project area of Castello di Albola is located within a moderate to medium risk zone for landslide and moderate risk for flooding (*Figure 41*), no adverse events have been reported within the project area. In addition, the farm adopts in the plots with the steepest slopes the cultivation technique of spontaneous grassing on all rows, to avoid the sliding of the ground towards the valley. Furthermore, terracing is used to reduce the slope and the length of the vineyard rows. The plots also have a rainwater collection and drainage systems.



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Figure 41. Hydrogeological risk of the Project Area (Castello di Albola). Data source https://gn.mase.gov.it/portale/servizio-di-consultazione-wms).

The risk of nitrogen percolation is low across all the project areas, due to the great depth of the groundwater table level (between 80 – 100 m in San Felice). In Tenute Ruffino, despite being partially below sea level, the groundwater table is located at 100-150 m (*Figure 42*), making the risk of nitrogen leaching very low (*Figure 43*).

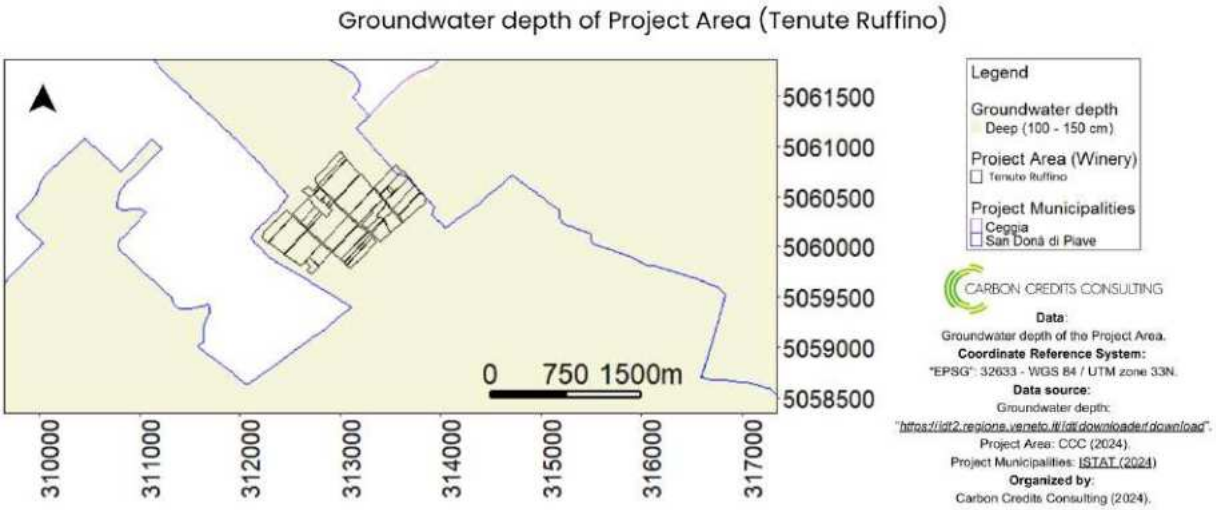


Figure 42. Groundwater depth of the Project Area (Tenute Ruffino). (Data source https://idt2.regione.veneto.it/idt/downloader/download).

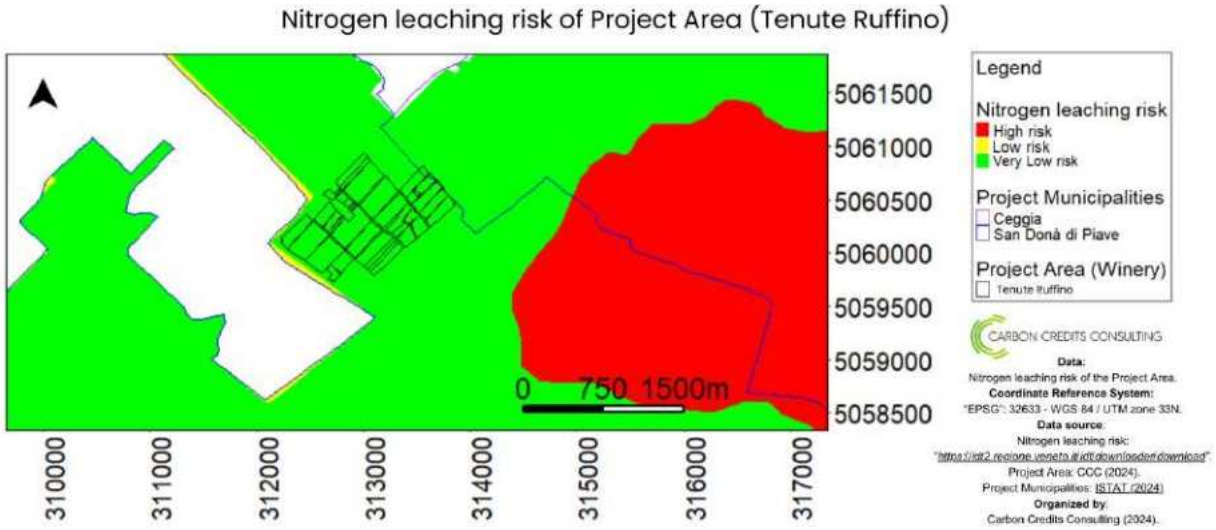


Figure 43. Groundwater depth of the Project Area (Tenute Ruffino). (Data source http://idt2.regione.veneto.it/idt/downloader/download).

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Table 7. Risks identified for the ecosystem.

	Risks identified	*Mitigation or preventative measure(s) taken*
Impacts on biodiversity and ecosystems	No risk identified. Responsible land management and introduction of species that are non-invasive. One of the project activities may enhance biodiversity due to the use of diverse cover crops.	No mitigation or preventative measure needed.
Soil degradation and soil erosion	No risk identified. One of the project's main objectives is to improve soil health through regenerative agriculture practices (no or minimum tillage, user of cover crop) to prevent soil degradation and erosion incorporating cover crops that prevent soil erosion.	No mitigation or preventative measure needed.
Water consumption and stress	No risk identified. The project activities are not expected to result in higher water consumption and stress. The chosen project activities of green manuring, bordering hedges and cover cropping will enhance soil water retention.	No mitigation or preventative measure needed.
Usage of fertilizers	No risks have been identified since the fertilizers used are organic. amendants or manure. Nitrogen leaked potential is low due to the positioning of the water table.	No mitigation or preventative measure needed.

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No invasive species are used in our project activities. The cover crops employed are common, locally-established species that are traditionally cultivated in the reference territories of Grosseto, Siena, and San Donà di Piave areas. Specifically, the cover crop species applied in Tuscany areas are: Barley (*Hordeum vulgare*) and Fava bean (*Vicia faba*).
In the Veneto farm, the cover crop species include: Forage oat (*Avena sativa*), Rye (*Secale cereale*), Medium triticale (× *Triticosecale*), Light-seeded faba bean (*Vicia faba* var. *equina*), Forage pea (*Pisum sativum* var. *arvense*), Protein pea (*Pisum sativum*), Berseem clover (*Trifolium alexandrinum*), Crimson clover (*Trifolium incarnatum*), Squarrose clover (*Trifolium squarrosum*), Common vetch (*Vicia sativa*)
These species are native or long naturalized in the Italian agricultural landscape and pose no risk of invasive spread. Their use in cover cropping is a well-documented agronomic practice in both Tuscany and Veneto region, contributing to soil health, nitrogen fixation (in the case of leguminosae), and habitat provision for pollinators and beneficial insects.[1]
The farms in Tuscany are located in a hilly area, in very steep slopes as for both Albola and San Felice, or less steep as for Rocca di Montemassi. Nevertheless, this hillside topography, combined with the fractured rock geology of the Chianti area, means that groundwater circulation is local and deep, with no significant shallow unconfined aquifer beneath the vineyards.
The Veneto case requires a more articulated description. The Venetian plain has a complex aquifer system where shallow groundwater can be present. San Donà di Piave is located in the lower-middle Venetian plain, in the area between the Piave and Livenza rivers. This means the water table in this area may be relatively shallow.
The following mitigation measures will be included in this project:
1- Use of cover crops: Nitrogen taken up by cover crop roots during the growing season is held in organic form (plant and root biomass), substantially reducing the amount of nitrate available for leaching. Earlier-planted cover crops with greater biomass accumulation achieve the highest reduction in nitrate leaching.
2- Timing and method of organic fertiliser/manure application: Application rates will not exceed the nitrogen requirement of the crop; manure will be applied taking into account the time of mineralisation in order to reach the crop nutrient request timely; Cover crops are used to avoid bare fallow soils and to reduce nitrogen leaching by taking up excess nitrogen. [2]
Water: the following mitigation measures will be included in the PDD and applied at project-instance level:

- Nutrient-management planning: organic amendments/manure shall be applied only according to crop nutrient demand, soil-test results, and documented nitrogen budgets.
- Timing restrictions: no manure or organic fertilizer application during periods of high rainfall, water-saturated soil, flooding, or when substantial drainage/runoff is expected.
- Application-rate controls: nitrogen inputs shall comply with applicable legal limits and shall avoid excess nitrogen application, including accounting for nitrogen supplied by leguminous cover crops.
- Cover crops/ground cover: permanent or seasonal cover crops, preferably grass–legume or crucifer–legume mixtures adapted to local conditions, shall be maintained in inter-rows to capture residual nitrogen, reduce runoff, and limit erosion.
- Buffer zones: no fertilizer/manure application shall occur within applicable setback distances from watercourses, drainage channels, wells, and sensitive groundwater-recharge areas.
- Storage and handling: manure and organic amendments shall be stored and handled to prevent seepage, runoff, and accidental release.

[1] Warren Raffa, D., Virili, A., Carlesi, S. *et al.* Soil management shapes the functional diversity of the inter-row vegetation in Mediterranean vineyards. *Agron. Sustain. Dev.* **45**, 46 (2025). https://doi.org/10.1007/s13593-025-01046-x
Silvestroni, O., Dottori, E., Pallotti, L., Lattanzi, T., Santilocchi, R., & Lanari, V. (2024). Using Legume-Enriched Cover Crops to Improve Grape Yield and Quality in Hillside Vineyards. *Agronomy*, *14*(11), 2528. https://doi.org/10.3390/agronomy14112528
AIAB, 2013. Colture di copertura in agricoltura biologica: caratteristiche delle specie. https://orgprints.org/id/eprint/30573/18/Cover-crops-organic-agriculture_ita_web.pdf
[2] Fabbri et al, 2016. Does a change of irrigation technique impact on groundwater resources? A case study in Northeastern Italy. Environmental Science & Policy, **doi** 10.1016/j.envsci.2016.05.009
Thapa R, Mirsky SB, Tully KL. Cover Crops Reduce Nitrate Leaching in Agroecosystems: A Global Meta-Analysis. J Environ Qual. 2018 Nov;47(6):1400-1411. doi: 10.2134/jeq2018.03.0107. PMID: 30512067.
Sedghi, N., & Weil, R. (2022). Fall cover crop nitrogen uptake drives reductions in winter-spring leaching. Journal of Environmental Quality, 51, 337–351. https://doi.org/10.1002/jeq2.20342

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- Monitoring and records: farms shall retain records of fertilizer type, quantity, date, application area, weather conditions, soil tests, and cover-crop management. Where site screening identifies elevated groundwater vulnerability, additional monitoring and/or reduced nitrogen-input limits shall be applied.
- Corrective action: where monitoring, inspections, or nutrient-balance assessments identify a potential risk of nitrogen loss, fertilizer rates and timing will be adjusted and additional nitrogen-scavenging cover crops or other appropriate measures will be implemented.

Table 8. Risks identified for the stakeholders.

	Risks identified	*Mitigation or preventative measure(s) taken*
Natural and human-induced risks to stakeholders' wellbeing	No risk identified. No risks to stakeholders' wellbeing have been identified.	No mitigation or preventative measure needed.
Risks to stakeholder participation	No risk identified. No risks to stakeholders' participation have been identified.	No mitigation or preventative measure needed.
Working conditions	No risk identified. Working conditions remain the same as prior to the project. The Decree 81/2008 (Consolidated Law on Occupational Safety) is the cornerstone of Italian legislation on workplace health and safety. It applies to all sectors, both private and public, and to all types of workers, imposing obligations on employers and employees.	No mitigation or preventative measure needed.
Safety of women and girls	Project activities are implemented in Italy and comply with applicable national legislation, including Legislative Decree No. 81/2008[3] on occupational health and safety and Law No. 903/1977 and Legislative Decree No. 198/2006 on gender equality and non-discrimination. Italian labour law strictly prohibits child labour, forced labour, discrimination, and unsafe working conditions. Project activities do not introduce new or hazardous labour practices and are carried out by established agricultural enterprises using formal employment arrangements. Based on this regulatory context and the nature of the activities, no material risks to working conditions, women and girls, minorities, or children have been identified. (human right and ILO convention in Italy).	No mitigation or preventative measure needed.
Safety of minority and marginalized groups, including children		No mitigation or preventative measure needed.

[3] https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2008;81~art306

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Pollutants (air, noise, discharges to water, generation of waste, and release of hazardous materials and chemical pesticides and fertilizers)	There is a risk of waste and release of water containing organic fertilizers as with any other agriculture activity.	This is managed and monitored by the farm manager under local regulation constraints.

Table 9. Risks identified related to work and labor.

	Risks identified	*Mitigation or preventative measure(s) taken*
Discrimination Sexual harassment	No risk identified. The PPs promote and support diversity, prohibiting any form of discrimination, sexual harassment, or infringement on human rights. The PPs ensure the application of all applicable laws, regulation, and international standards, including the Universal Declaration of Human Rights and ILO Conventions are adhered to.	No mitigation or preventative measure needed.

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Equal pay for equal work	No risk identified. The PPs operate in accordance with the laws and regulations of the country and make every effort to give equal opportunities to fill the work positions.	No mitigation or preventative measure needed.
Gender equity in labor and work	No risk identified. The PPs operate in accordance with the laws and regulations of the country and make every effort to give equal opportunities to fill the work positions. This is in accordance with the Farm regulations, that support and enforce the protection of equal rights and provide equal opportunities no matter the gender or race.	No mitigation or preventative measure needed.
Forced labor Child labor Human trafficking	No risk identified. The PPs ensure the application of all applicable laws, regulations, and international standards, including the Universal Declaration of Human Rights and ILO Conventions are adhered to. Therefore, the project the project does not and will not use victims of human trafficking, forced labor, and child labor.	No mitigation or preventative measure needed.

1.15.1 Additional information on risk assessment and management of risk

No additional information on risk assessment and management of risk was deemed necessary

1.16 Additional information

No additional information on relevant legislative, technical, economic, sectoral, social, environmental, geographic, site-specific was deemed necessary

1.17 Confidential/sensitive information

Any information has been excluded from the public version of the PDD.
The public version of this PDD contains all relevant project information. No confidential, proprietary, or sensitive information has been excluded or withheld from public disclosure. All technical and operational details presented are complete, accurate, and suitable for public review.

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2 Crediting

2.1 Project start date

The project start date is the date when the activities that result in GHG emission mitigations or removals have been implemented. According to that, the project activities started on 18/10/2024 and are represented by sowing of cover crops and green manure crops in San Felice vineyards.

Project start date	18/10/2024

2.2 Expected operational lifetime or termination date

The expected operational lifetime is three years from the project start date.

2.3 Crediting period

Crediting period for the project in years.

Crediting period	Five years, renewable twice. ☐ Ten years, fixed. ☒ Fifteen years, renewable twice (CDR only). ☐ Other, provide information on how that conforms with ICR requirement document.

2.4 Calendar year of crediting

Calendar year of crediting	Estimated GHG emission mitigations (t CO2-e)
18/10/2024 to 31/12/2024	351
01/01/2025 to 31/12/2025	1.781
01/01/2026 to 31/12/2026	1.648
01/01/2027 to 30/04/2027	503
Total estimated GHG emission mitigations during the crediting period (t CO2-e)	4.283
Total number of years (yrs)	3
Annual average (t CO2-e)	1.760

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3. Safeguards

3.1 Statutory requirements

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Table 10. Statutory requirements

Statutory requirement name	Paragraphs applicable	Description of how it relates to the project	Means of compliance
EU LULUCF Regulation (2018/841)	Paragraphs 7-8-12	Refer to EU Compliance Level (a)	Refer to EU Compliance Level (a)
EU Climate Law (2021/1119)	Paragraphs 22-23-32	Refer to EU Compliance Level (b)	Refer to EU Compliance Level (b)
Fair Labor Standards Act (D.Lgs. 66/2003)	All	Refer to National Compliance Level (Italy) (a)	Refer to National Compliance Level (Italy) (a)
Civil Code	Art 2095	Refer to Labor and work statutory regulations	Refer to Labor and work statutory regulations
Statuto dei Lavoratori (Law No. 300/1970)	All	Refer to Labor and work statutory regulations	Refer to Labor and work statutory regulations
Occupational Health and Safety Act (D.Lgs. 81/2008)	All	Refer to Civil rights and health statutory regulations (a)	Refer to Civil rights and health statutory regulations (a)
Civil Rights Act (Legge n. 903/1977)	All	Refer to Civil rights and health statutory regulations (b)	Refer to Civil rights and health statutory regulations (b)
Italian Law on Disability Discrimination (D.Lgs. 205/2000)	All	Refer to Civil rights and health statutory regulations (c)	Refer to Civil rights and health statutory regulations (c)
Land Use Planning Act (D.Lgs. 42/2004)	Appendix 3.13	Refer to Environmental statutory regulations (a)	Refer to Environmental statutory regulations (a)
Food Security Act (D.Lgs. 193/2007)	Appendix 3.14	Refer to Environmental statutory regulations (b)	Refer to Environmental statutory regulations (b)

Compliance has been met with the following EU and national regulations, ensuring the project aligns with both Eu and Italian-specific environmental, labor, and safety standards. The initiative prioritizes sustainability, adhering to stringent legislative frameworks to promote environmental integrity and social responsibility.

EU Compliance Level

(a) EU LULUCF Regulation (2018/841): This regulation integrates greenhouse gas emissions and removals from land use, land use change, and forestry (LULUCF) into the EU's 2030 climate and energy framework. It mandates Member States to account for emissions and removals from LULUCF, aiming to enhance

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sustainability and climate-friendly land management, thus supporting the EU's commitment under the Paris Agreement towards emission mitigation by 2030 Appendix 3.1.

(b) EU Climate Law (2021/1119): Enacted on 29 July 2021, this law establishes a binding objective for the EU to achieve net-zero greenhouse gas emissions by 2050 and sets an interim target of at least 55% reduction of net emissions by 2030 compared to 1990 levels. It emphasizes the crucial role of both emission reductions and removal enhancements, aligning with the ambitious goals for LULUCF under the European Green Deal Appendix 3.2.

National Compliance Level (Italy)

(a) Fair Labor Standards Act (D.Lgs. 66/2003): This legislation governs labor standards in Italy, including work hours, rest periods, and other conditions of employment, ensuring fair treatment and adequate rest for workers. Appendix 3.6.

Labor and work statutory regulations

The workers in the Project Area fall under the labour and work law in force in the Republic of Italy.

The Italian Constitution (Costituzione Italiana) covers several basic employment rights, including the right to work for fair pay, join a union, receive social security, and have access to equal opportunities. European Union Directive No. 533/91 has been implemented in Italy and requires that information on the main terms and conditions of employment relationships be evidenced in writing in the employment contract and provided to the employee within 30 days of hiring. In general, individual employment contracts must specify:

- parties to the employment agreement
- the starting date of the employment and the duration of the trial period (if any)
- the expiration date if the employment is for a fixed term (where permitted by law)
- the salary, method for calculation of the salary, frequency of payment, and any term or condition related to the salary and fringe benefits
- the working hours
- the annual entitlement to paid holiday leave
- the employee's duties and the related work "category" (Art. 2095 of the Civil Code)

Other sources of labour law include:

- The Civil Code (Codice Civile) covers employment relationship
- A vast number of collective agreements negotiated between the Italian authorities and trade unions that cover issues like wages and holiday entitlements
- The Workers' Statute (Statuto dei Lavoratori) covers the protection of the freedom and dignity of workers, trade unions and union activity in the workplace, and rules on employment. Prohibitions against discrimination have been in place since the 1970's when the Workers' Statute (Law No. 300/1970) came into force and prohibits any kind of discrimination based on gender, political opinions, union-related activity, religion, race, language, disability, age, sexual orientation and

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personal belief. Furthermore, employers may not make employment conditional on the fact that the employee is or is not a member of a Trade Union or that he or she stops being a member or dismiss an employee or discriminate against him/ her when assigning a job, when changing a place of work, in disciplinary procedure or prejudice him/her because of the employee's membership in a trade union association, because of the employee's union-related activity or because the employee has participated in a strike.

Civil rights and health statutory regulations

(a) Occupational Health and Safety Act (D.Lgs. 81/2008): This act ensures the safety and health of workers, outlining the obligations of employers and the rights of employees in the workplace, promoting a safe and healthy working environment. Appendix 3.5.

(b) Civil Rights Act of 1964 (Legge n. 903/1977): Although inspired by the US model, this Italian law addresses anti-discrimination in employment, ensuring equal treatment and opportunities for all employees regardless of gender, race, or other protected characteristics. Appendix 3.7 and 3.8.

(c) Italian Law on Disability Discrimination (D.Lgs. 205/2000): This law provides protections against discrimination for individuals with disabilities, ensuring access to employment, public services, and accommodations. Appendix 3.9 and 3.10.

The workers in the Project Areas are protected by Italy's 2019-2021 mandate in the United Nations Human Rights Council (UNHRC).

In line with the mandate's priorities Italy's human rights actions focus, in particular, on several priority issues: "*the fight against all forms of discrimination; a universal moratorium on the death penalty; the promotion of women's and girls' rights (including campaigns against female genital mutilation and early and forced marriages); the protection and promotion of children's rights (especially of vulnerable children); the protection of freedom of religion and belief and the rights of members of religious minorities; the fight against human trafficking; the promotion of the rights of disabled persons; the protection of the cultural heritage; the protection of human rights defenders. At the same time, Italy has also committed to multiple other initiatives for the protection and promotion of human rights in line with the obligations undertaken at the international level to support civil, political, economic, social and cultural rights. These initiatives have included the fight against racism, xenophobia and all forms of intolerance, anti-Semitism, discrimination —including discrimination based on sexual orientation and gender identity—, the promotion of the rights of persons with disabilities, human rights education, promoting democracy and the rule of law, promoting freedom of opinion and expression and focusing on issues related to migration.* [...] *Italy is also strongly committed both bilaterally and multilaterally to the promotion of gender equality and female empowerment. Italy is part of the UN Convention on the Elimination of All Forms of Discrimination against Women (CEDAW), actively participates in the UN Commission on the Status of Women (CSW) and supports the numerous initiatives promoted on these issues each year within the UN. Italy has played an active role in pushing the Council of Europe Convention on preventing and combating violence against women and domestic violence (Istanbul Convention) which came into force in August 2014 and continues to encourage the widest support for this Convention"*[34].

Furthermore, the project recognizes, respects, and promotes the protection of local communities, and customary rights holders in line with applicable international human rights law, and the United Nations

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Declaration on the Rights of Indigenous Peoples and ILO Convention 169 on Indigenous and Tribal Peoples. However, since there are no Indigenous Peoples in the Project Areas, this section is not applicable.

Environmental statutory regulations

(a) Land Use Planning Act (D.Lgs. 42/2004): This legislation governs land use and planning, ensuring that development is sustainable, respects environmental considerations, and aligns with regional and national planning objectives. Appendix 3.13.

(b) Food Security Act (D.Lgs. 193/2007): This act outlines requirements for agricultural practices, especially concerning the management of highly erodible lands or wetlands, aiming to ensure food safety and security while protecting the environment. Appendix 3.14.

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3.2 Potential negative environmental and socio-economic impacts

Environment	Impacts and safeguards
Air	Mitigation of climate change due to storing of CO_2 into the ground (e.g. Improvement of the crop (vine) residues management after pruning and shredding) or into wood plants (e.g. planting of bordering edges). Reduction of CO_2 emissions into the atmosphere from the soil (e.g. reduced or no tillage).
Land	Improvement of SOC stocks, soil fertility, reduced erosion (e.g. reduced or no tillage, improvement of green manuring, use of manure, improvement of in-rows natural grass cover by using self-seeding leguminous crops).
Water	NA
Natural resources	Improvement in the use of manure and green manuring
Social	**Impacts and safeguards**
Jobs	NA
Health & safety	NA
Education	NA
Welfare	NA
Economy	**Impacts and safeguards**
Growth	Potential additional income for the farmers via the selling of carbon credits
Energy	NA
Technology transfer	NA
Balance of payment	NA

3.3 Consultation with interested parties and communications

The project activity is developed within private areas. In general, the interested parties are the vineyard owners, the technical partners participating in the LIFE project and the agricultural sector associations. All project areas are in Italy and the lands are private and recorded in the official land registry of ownership (Land Registry Certificates). The areas outside the project area are not impacted by the project activity

List of interested parties:

- Vineyard owners: they are private companies, and they hold ownership rights on the lands intended for the implementation of the project as demonstrated by land registry certificates. They are responsible for the management process that generates the emission mitigations, and they have overall control and responsibility for the project activity.
- Agricultural sector associations: they are associations present in the national and/or regional territory, interested in disseminating sustainable agricultural practices.
- Carbon Credits Consulting Srl: is the entity responsible for developing and implementing the project activity.
- Technical partners: Image Line and CREA.

No changes in well-being and other characteristics of the stakeholder groups are expected over the project duration and beyond. Changes in ecosystem services are expected in the area of biodiversity increasing biological diversity through the project activities implementation.

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3.3.1 Stakeholders and consultation

Stakeholder	Vineyard owners, agricultural sector associations (UPA Siena), technical partners.
Legal rights	According to the Italian law, the vineyard owner is the sole owner of his land; by complying with the legal regulations, he can manage his land as he wishes. The ownership rights are bindingly registered in the Italian land register.
Diversity	Land ownership in Italy is governed by the Italian Civil Code (Articles 832–839), which establishes the vineyard owner as the sole proprietor with exclusive rights to use, enjoy, and dispose of the land, provided all legal and regulatory requirements are met. All ownership rights are formally recorded in the Italian Land Registry (Catasto), ensuring legal certainty and transparency. The relevant stakeholders are vineyard owners, permanent and seasonal agricultural workers, and local service providers operating within established rural communities in Tuscany and Veneto. Viticulture represents a long-standing economic and cultural activity in these regions. Project activities are implemented exclusively on privately owned land, do not involve land acquisition or displacement, and do not affect cultural heritage, customary land-use practices, or vulnerable or indigenous groups.
Location	All the stakeholders are located in Italy.
Effects	*The vineyard owners must manage the lands in accordance with the regulations and activities expected by this project. Through improved agricultural practices, a reduction of* ***net*** *CO_2e emissions is expected*
Date of consultation	12/09/2023 and 15/09/2023
Stakeholder engagement	On-line meeting and face-to-face meetings are held with the vineyards owners every 6 months in Italian, the technical partners of the project and the agricultural sector associations. In addition, information about the project is shared publicly through website with project overview and description.
Consultation	The project is implemented exclusively on privately owned vineyard land in Italy and does not involve land acquisition, displacement, or impacts on external communities or indigenous groups. Due to the limited stakeholder scope, Local Stakeholder Consultation was addressed proportionately. Relevant stakeholders (vineyard owners and workers) were informed about project activities, environmental and socio-economic safeguards, statutory requirements, property rights, ICR registration, and grievance mechanisms. No adverse impacts or grievances were identified. During the meetings held in September 2023, the project activity was presented illustrating its development in accordance with the Work Packages provided for by the European LIFE call. Therefore, the activities related to: - creation of a database of agronomic practices, using scientific articles and local/technical press, with the aim of developing a technical manual - construction of a baseline and implementation of new techniques to increase the carbon stored.

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	- monitoring through FADN and life cycle analysis (LCA). - validation and verification process to obtain the registration of the project and the subsequent issuance of the carbon credits generated. - communication of the project, aimed at spreading the existence and the results of the project, creating stable and lasting networks and ensuring a wide replication of the project.
Stakeholder input	Inputs were received from the project beneficiaries, on the methods, tests and possible physical events that could be interesting to promote the project and disseminate the results achieved.
Free prior informed consent	The vineyard owner is the sole owner of his land; by complying with the legal regulations, he can manage his land as he wishes.
Conclusion	The European call LIFE has duration of 4 years within the project activity should be registered and the carbon credits generated.
Ongoing consultation	Regular meetings are held to discuss the current and ongoing status of the project and in the future the results of monitoring. The project is implemented exclusively on privately owned vineyard land in Italy and does not involve land acquisition, displacement, or impacts on external communities or indigenous groups. The project is implemented exclusively on privately owned vineyard land in Italy and does not involve land acquisition, displacement, or impacts on external communities or indigenous groups. Due to the limited stakeholder scope, Local Stakeholder Consultation was addressed proportionately. Relevant stakeholders (vineyard owners and workers) were informed about project activities, environmental and socio-economic safeguards, statutory requirements, property rights, ICR registration, and grievance mechanisms. No adverse impacts or grievances were identified. The logbook has been added.

The references Munna rt al. (2025), Silvestroni et al. (2024), Biella et al. (2024), Pisciotta et al. (2021), and Gattullo et al. (2020), support positive impacts of best agricultural practices implemented in this project, namely cover cropping, organic fertilisation, and reduced tillage:

- Soil health and organic carbon sequestration: Cover crops and organic fertilizers have been documented to increase soil organic matter, improve aggregate stability, and reduce erosion in central and northern Italian agricultural systems.
- Nitrogen cycling and reduced leaching risk: The use of leguminous cover crops (*Vicia sativa*, *Trifolium* spp., *Pisum sativum*) supports biological nitrogen fixation, reducing dependence on synthetic inputs, while appropriate organic amendments application timing limits nitrate losses risk to groundwater.
- Biodiversity and pollinator support: Species such as *Trifolium alexandrinum*, *Trifolium incarnatum*, and *Vicia sativa,* used as cover crops in this project, provide documented floral resources for wild pollinators and beneficial insects in Italian viticultural and arable landscapes.
- Socio-economic benefits: The adoption of best practices contributes to the long-term productivity and resilience of

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the farming operations, while reducing input costs associated with synthetic fertilisers. [4]

Projects activities are expected to have positive effects on soils of the vineyards that will help farmers in growing grapes; positive effects are also expected in an improved resilience of the vineyards facing water stress and drought, that are more and more frequent in these areas due to climate change.
The implementation of the project activities does not entail structural changes to agricultural activities, but adaptations and improvements to farming practices.

Project number: 101113620
Acronym: LIFE22-CCA-IT-LIFE VitiCaSe
Title: Viticulture for Soil Organic Carbon Sequestration

LIFE VitiCaSe

Co-funded by the European Union

Grievance registration

Grievance ID	Source name if applicable	Date lodged	Description of grievance	Date of hearing	Further investigation required (Yes/No)	Action(s) taken	Escalation (Yes/No)	Conclusion reached	Date conclusion reached	Comments

LIFE VitiCaSe Grievance Logbook

- **Introduction**
- The LIFE VitiCaSe project has established a structured project management and governance framework aimed at ensuring transparency, accountability, and continuous control over the achievement of project objectives, in line with the Grant Agreement and the Project Management Guidelines (Deliverable D1.1).
- The Grievances Logbook supports open and structured communication between the project consortium and its participants, helping to prevent misunderstandings, and ensure that corrective actions are taken when necessary.

- **Scope and Purpose**
- This Grievances Logbook is established to formally record, manage and monitor any grievances, complaints or concerns raised by project participants, stakeholders or other relevant actors. It applies to technical, organisational, procedural, communication-related and data-related issues that may arise during the implementation of the LIFE VitiCaSe project. The Logbook contributes to the overall quality management and risk mitigation approach of the project, by providing a clear, traceable, and consistent procedure for handling potential issues in a timely and transparent manner.

[4] Munna, M. N. H., & Lal, R. (2025). Impacts of cover cropping and organic amendments on soil physical quality under temperate climate. *Cogent Food & Agriculture*, *11*(1). https://doi.org/10.1080/23311932.2025.2467452
Silvestroni, O.; Dottori, E.; Pallotti, L.; Lattanzi, T.; Santilocchi, R.; Lanari, V. Using Legume-Enriched Cover Crops to Improve Grape Yield and Quality in Hillside Vineyards. Agronomy 2024, 14, 2528. https:// doi.org/10.3390/agronomy14112528
Biella et al., Vineyard footprint on pollinators is mediated by flower vegetation, organic farming, seasonal and weather factors, a case study from North Italy, Agriculture, Ecosystems & Environment, Volume 378,2025, 109297, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2024.109297.
Pisciotta A, Di Lorenzo R, Novara A, Laudicina VA, Barone E, Santoro A, Gristina L, Barbagallo MG. Cover Crop and Pruning Residue Management to Reduce Nitrogen Mineral Fertilization in Mediterranean Vineyards. *Agronomy*. 2021; 11(1):164. https://doi.org/10.3390/agronomy11010164
Gattullo CE, Mezzapesa GN, Stellacci AM, Ferrara G, Occhiogrosso G, Petrelli G, Castellini M, Spagnuolo M. Cover Crop for a Sustainable Viticulture: Effects on Soil Properties and Table Grape Production. *Agronomy*. 2020; 10(9):1334. https://doi.org/10.3390/agronomy10091334

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- **Roles and Responsibilities**
- The Project Management Team (PMT), responsible for the day-to-day coordination of the project and for the implementation of risk and quality management strategies, ensures that all grievances are properly received, documented, assessed, and addressed according to their relevance and potential impact on project implementation. Where appropriate, grievances that may have strategic implications or require higher-level decision-making can be escalated to the Steering Committee, in line with the decision-making procedures defined by the Project Management Guidelines.
- **Monitoring, Reporting and Audit Trail**
- Grievances are periodically reviewed by the Project Management Team to identify recurrent issues and opportunities for continuous improvement. The Logbook is made available for internal reviews, external audits and certification or verification processes.

- **Confidentiality and Data Protection**
- All personal data contained in this Logbook are managed in compliance with applicable data protection regulations (GDPR). Access to the Logbook is restricted to authorised personnel only.

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3.3.2 Public comments

(The project documents was available on ICR platform under pre-registration step and no comments were received during that period)

Comments received	Action taken
No public comment have been received.	/

3.4 Environmental impact assessment

No environmental impact assessment was carried out for the project activity. The project does not involve any permitting or activities that are required to conduct environmental impact assessments by existing regulation, and no negative impacts are anticipated.

The project activity is not expected to have negative environmental impacts. It is expected to have positive environmental impacts beyond reducing greenhouse gas emissions.

4. Methodology

4.1 Reference to applied methodology and applied tools

The project's methodological framework is built upon the integration of the VERRA's VM0042 methodology, and the ISCC EU 205 Greenhouse Gas Emissions.

Type (methodology, tools, module) ISO 14064-2	Reference ID	Version	Title
Methodology	VM0042	2.0	Methodology for Improved Agricultural Land Management, version 2.0.
Methodology	ISCC EU 205	4.1(2024)	Greenhouse Gas Emissions

4.2 Applicability of methodology

Table 11. Methodology IDs and applicability conditions

Methodology ID	Applicability condition	Justification
VM0042	Projects must introduce or implement one or more new changes to pre-existing ALM practices which: a) Improve fertilizer management (organic or inorganic); b) Improve water management/irrigation. c) Reduce tillage/improve residue management. d) Improve crop planting and harvesting. e) Improve grazing practices.	The implemented project activities follow within the ALM practices a), c), d): • Improvement of in-row natural grass cover by using self-seeding leguminous crops (a,d) • Improvement of green manuring (a) • Use of mycorrhizae (a) • Minimum / no tillage (c) • Improvement of the crop (vine) residues management after pruning and shredding (a,c) • Planting of bordering edges (d) • Use of manure (a)

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VM0042	Project that introduces or implements quantitative adjustments must exceed 5% of the pre-project existing value.	Each project activity will be implemented in a way that either a reduction or an increase by at least 5% with respects to the baseline, will be quantifiable.
VM0042	Project activities must be implemented on land that is either cropland or grassland at the project start date.	The project activities are being implemented on cropland (vineyard) at the project start date as proved by the farms' crop registry.
VM0042	Empirical or process-based models used to estimate stock change.	The Rothamsted Carbon Model (RothC) is applied for determined soil organic content.
VM0042	The project area has not been cleared of native ecosystems within the 10 year's period immediately prior to the project start date.	The project area has not been cleared of native ecosystems within the 10 years immediately prior to the project start date as proved by the farms' crop registry.
VM0042	The project activity is not expected to cause a sustained reduction in productivity of greater than 5%.	Absence of reduction in productivity by project activity. Each one of the chosen project activities has been assessed in order to define whether compliant or not with the methodology requirement stated in Section 4 of the VERRA Methodology VM0042 V2.0: *"This methodology is not applicable under the following conditions: The project activity is expected to cause a sustained reduction in productivity of greater than 5%, as demonstrated by peer-reviewed and/or published studies on activity in the region or a comparable region."* The examined scientific literature was based on studied located in Italian vineyards if available or in areas with a Mediterranean climate when national studies were not found, to guarantee the closest environmental and management conditions possible to the project area. Improvement of in-rows natural grass cover by using self-seeding leguminous crops A study carried out in Sardegna (Italy), on the improvement of in-rows natural grass cover with leguminous crops found that "*grass mixture increased the content of sugar, anthocyanins and polyphenols, whereas legume mixture and natural covering reduced total polyphenols and anthocyanin content, respectively*"[35].

[35] Muscas et al., Effects of vineyard floor cover crops on grapevine vigor, yield, and fruit quality, and the development of the vine mealybug under a Mediterranean climate. 2016

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		A study in the US on the effects of legume cover crop use in Concord Grape, reported a higher yield under a leguminous cover mix as compared to a grass mix, natural cover and soil tillage[36]. Green manuring A study carried out on organically managed farms in Toscana (Italy), found out that "s*ignificantly higher grape yields were found under PBI*" (cover crop mixture of barley (Hordeum vulgare L.) and clover (Trifolium squarrosum L.)) "*and S*" (spontaneous vegetation) "*(about +30% compared with the other treatments), mainly due to higher cluster weight. The most productive treatments (PBI and S) also showed higher pH and malic acid concentration, but lower anthocyanins and total polyphenol index as compared with the other treatments"*[37]. Another study on Barbera vineyard in northern Italy on inter-row floor management reported that in the AGC treatment (alternate tillage and permanent grass every second mid-row), a cover crop mixture was sown in autumn with the following composition: Italian ryegrass (Lolium multiflorum, 20%), Triticale (Triticosecale, 15%), Oats (Avena sativa, 15%), Rye (Secale cereale L. 13%), Vetch (Vicia sativa L., 10%), Pea (Pisum sativum arvense L., 10%), Sainfoin (Onobrychis viciifolia, 5%), Crimson clover (Trifolium incarnatum, 4%), Horseradish (Armoracia rusticana, 4%), White mustard (Brassica alba, 2%) and Indian mustard (Brassica juncea, 2%). The cover crop was then mowed in the following season with a combined function of mulching and green manure. AGC treatments had the highest yield per vine, setting around 4 kg to correspond to 16.7 t/ha[38]. Use of manure

[36] Bair et al., Release of Available Nitrogen after Incorporation of a Legume Cover Crop in Concord Grape. 2008
[37] Raffa et al., Ground vegetation covers increase grape yield and must quality in Mediterranean organic vineyards despite variable effects on vine water deficit and nitrogen status. 2022
[38] Gatti et al., Inter-row floor management is a powerful factor for optimising vine balance in a non-irrigated organic Barbera vineyard in northern Italy. 2022

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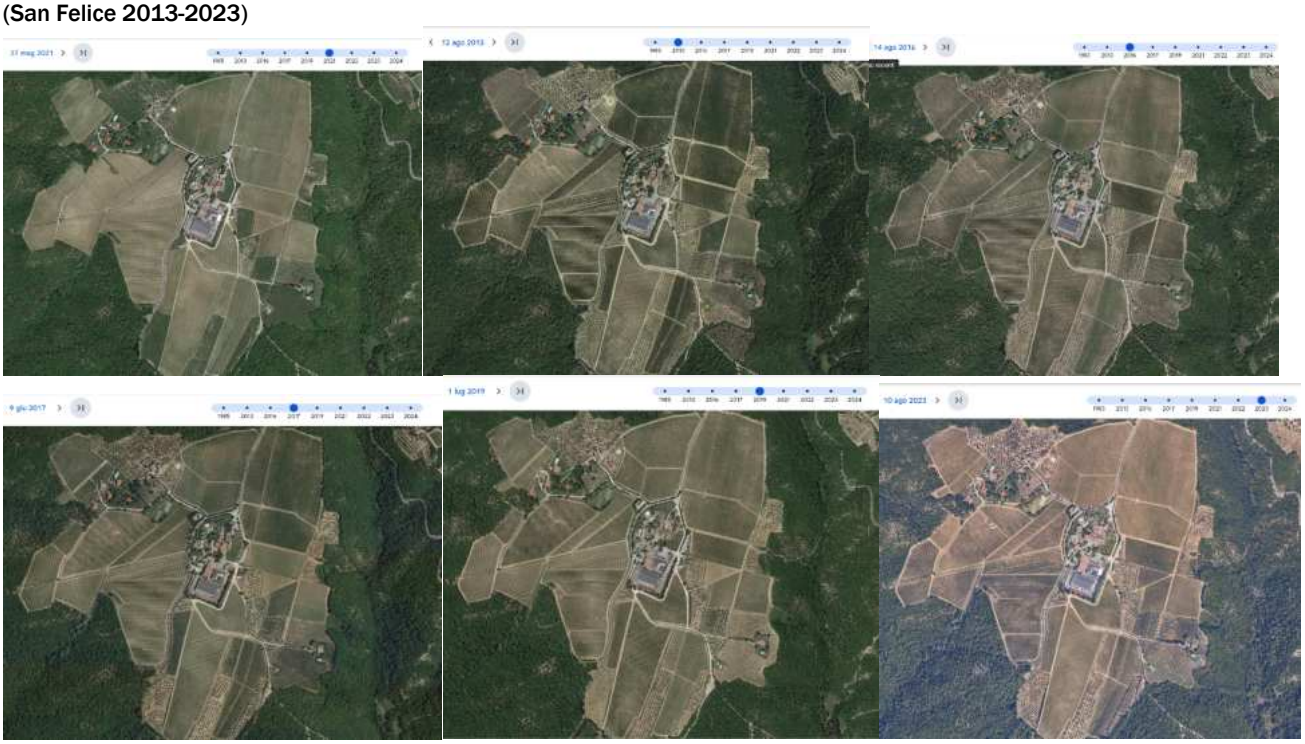
		A study carried out in Spain on vineyards under Mediterranean climate on the effect of organic amendment addition to soil properties and grape yield, found out that *"the studied fertilizer treatments were without organic amendments (C), sheep/goat manure (SGM) and distillery organic waste compost (DC). The SGM and DC treatments were applied at a rate of 4600 kg ha^{-1} (fresh weight, FW) and 5000 kg ha^{-1} FW, respectively. The use of organic amendments improved soil fertility and grape yield, especially in the drip-irrigated trellising vineyards*"[39]. A US study on the application of poultry manure in vineyard reported with the application of manure, the yield and quality of grapes increased compared to the control. In 1985, the yield of berries increased, compared to the control, by 26%, while in 1986 by 61%.[40] Use of mycorrhizae A study carried out in Croatia on mycorrhizal fungi use in a "Cabernet Sauvignon" grape variety vineyard, reported that "*symbiotic grapevines, in general, expressed improved leaf gas exchange parameters and higher yield parameters, especially regarding the number of clusters per vine. It should be emphasized that mycorrhizal fungi affected higher total flavan-3-ols, total anthocyanins, and total polyphenols in berry skin in both experimental years*"[41].
VM0042	The project activity is not a biochar application.	The project activity does not apply biochar application, and biochar is not applied as a soil amendment in the project area.
VM0042	The project activity does not occur on a wetland.	The project activity does not occur on a wetland.Based on spatial analysis using the official Copernicus CORINE Land Cover 2018 (CLC) vector dataset, none of the project parcels intersect land classified under wetland categories (CLC codes 411, 412, 421, 422, 423). Therefore, the project areas are not located on mapped wetlands according to the CLC 2018 classification. The GIS file has been added in the file for VVB.

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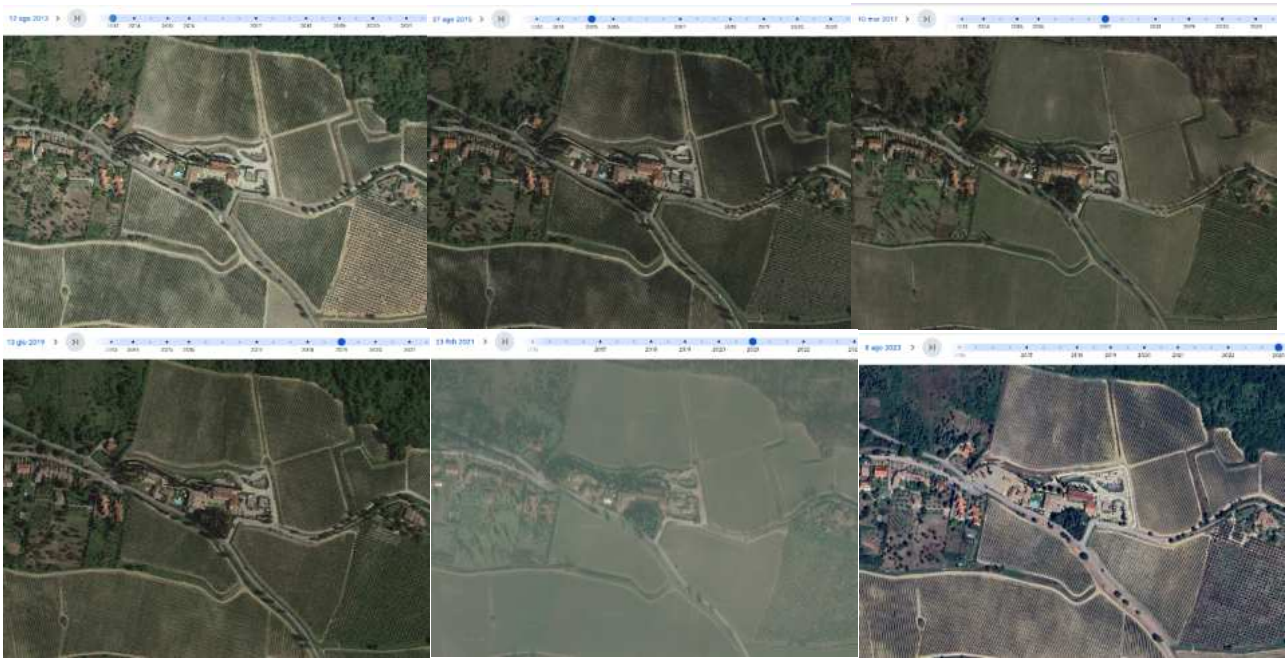
[39] Antonio Marín-Martínez et al., Effect of Organic Amendment Addition on Soil Properties, Greenhouse Gas Emissions and Grape Yield in Semi-Arid Vineyard Agroecosystems. 2021
[40] Mahendra S. Bhangoo et al., Application of Poultry Manure Influences Thompson Seedless Grape Production and Soil Properties. 1988
[41] Marko Karoglan et al., Mycorrhizal Fungi Enhance Yield and Berry Chemical Composition of in Field Grown "Cabernet Sauvignon" Grapevines (*V. vinifera* L.). 2021

Satellite images for 10 years

(San Felice 2013-2023)

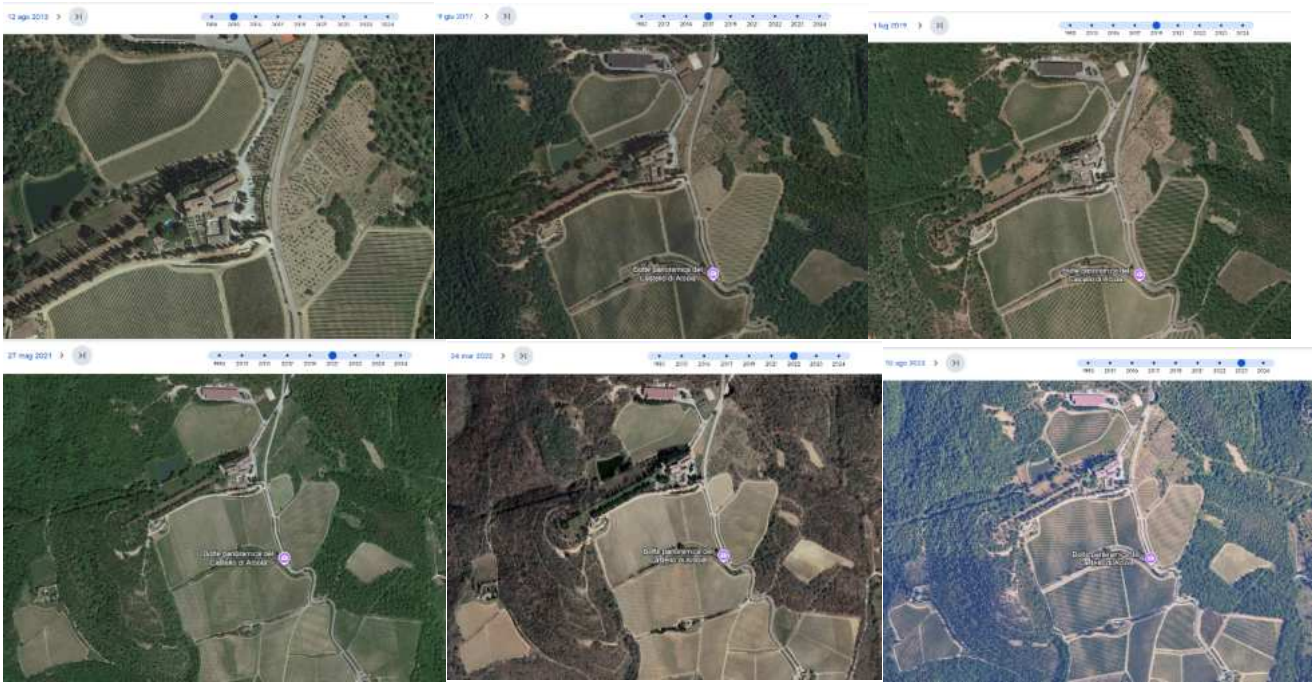


(Ruffino 2013-2023)



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(Albola 2013-2023)



Pilot 2: Castello Albola (Rocca di Montemassi)



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ISCC EU 205	Greenhouse Gas Emissions	Applied for emissions calculation for cultivation, and emission saving from soil carbon accumulation via improved agricultural management.

4.3 Deviation from applied methodology

No deviation applied.

4.4 Other information relating to methodology application

The VERRA's VM0042 version 2.0 methodology is incorporated into the project's methodological framework, which serves as the project's foundation, therefore they are not criteria for validation/verification. ISCC EU 205 has been followed for the GHG emissions and removal calculation.

5. Additionality

According to the ICR Requirements version 6.0, the additionality shall be demonstrated with a positive outcome of a project additionality test. A multilevel principle, ranging from level 1 to level 5 is expected by the requirements, where level 1 and level 2 are obligatory and level 3 to level 5 are optional. At least one of the optional levels shall be applied; in the project specific case level 3 is applied.

5.1 Level 1 - ISO 14064-2 GHG emissions additionality

The ISO14064-2 does not use the term additionality, but it provides a concept of additionality describing the relationship between cause and effect. For any cause and effect, the effect can be described as being additional if it would not have occurred in the absence of the cause. GHG reductions/removals enhancements caused by a project activity may is considered additional if these are greater than the quantity that would have occurred in the absence of the project.

Compared to the baseline (the quantitative reference of emissions/removals that have occurred in the absence of the project activity) the project activity by introducing or implementing one or more new changes to pre-existing ALM practices, results additional to what would occur compared to the determined GHG baseline scenario.

Further details on the baseline scenario are available in section 6 and on the project scenario in section 8.

5.2 Level 2a – Statutory additionality

The agricultural practices proposed by the project activity is not required or mandated by any law or regulations in the project Country.

5.3 Level 2b – Non-enforcement additionality

NA.

5.4 Level 3 – Technology, institutional, common practice additionality

The agricultural practices proposed by the project activity do not represent common practices in Italy. In Italy, potential CO2 sequestration ranges between 5.7 and 7.2 tC ha-1 year-1, in function of different management practices[42]. The most effective practices (organic amendments and no tillage in the inter-row) can store up to 11 tC ha-1 year-1, with differences due to climate and soil characteristics. Due to the large range of climates and soils present in Italy and to the different cultivated varieties (567 varieties officially

[42] Sustainable viticulture: The carbon-sink function of the vineyard agro-ecosystem, Brunori et al., 2016

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registered), vineyards management is extremely differentiated across the Country, and this results in different impacts and levels of SOC, suggesting that practices to sequester SOC might need to be precisely tailored and fine-tuned according to local characteristics.



Improperly shredded pruning residues in Castello di Albola



Improperly shredded pruning residues in Tenute Ruffino



Soil erosion: the accumulation of soil on the collar of the plant at the end of the sloping row is evident



Soil erosion: the accumulation of soil on the collar of the plant at the end of the sloping row was visible

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Improperly shredded pruning residues in San Felice and soil tillage

Soil health refers to ability of the soil to sustain the productivity, diversity and environmental services of terrestrial ecosystem. For these reasons, preventing and reversing soil degradation has become a priority in both global and European strategies. Nonetheless, concrete soil protection and restoration measures must define and implemented at national and local scales. In Italy, soil been extensively impacted in recent decades by human activities, leading to erosion and mass movements, sealing and land consumption, contamination, salinization, and decline in organic matter.

Hence, advancing soil science research is essential for bridging the gap between societal needs and state-of-the-art on soil knowledge.

In Italy, soil science can make a significant contribution to addressing key challenges across multiple sectors, including the management of landscapes and cultural and natural heritage; the sustainable management of agricultural and forest systems; soil-based production processes; and the design and implementation of Common Agricultural Policy (CAP) measures. Achieving these objectives requires, as a priority, strengthening the knowledge base on soils and degradation processes.

Loss of SOC is a serious issue in Italy because the relatively poor level of national soils, estimated to be 2% by a multivariate spatial regression

model based on 7000 measured data. In this context, arable land and orchards showed much lower values (on average 1.4%) as affected by climatic condition and unsustainable long- term soil management practices).

Multiple and diversify barriers are identified for soil knowledge like: technical, networks, communication, profitability and investment, capacity building, policy institutional, social. Here's a clearer, more polished rephrasing:

With regard to soil knowledge development, the barriers identified mainly fall under the categories of "capacity building" and "networks." This shows that scientific and technical limitations play a major role in hindering knowledge advancement, along with insufficient coordination and weak connections among public authorities, research institutions, farmers, and farmers' associations. Opportunities to overcome these barriers include shifting from top-down to bottom-up research approaches, increasing research funding and critical mass in the soil science field, and strengthening coordination between public authorities and research institutions.

The lack of communication among actors is the main barrier to knowledge sharing and transfer—whether between researchers, farmers, advisors, society, or policymakers. The most effective opportunities lie in targeted, well-designed communication and dissemination efforts from universities, educational institutions, and research organizations, developed in collaboration with stakeholders.

The use of different methodologies for soil sampling, analysis, storage, and mapping—along with the absence of a common data policy and the fragmentation of existing datasets—as the main bottlenecks hindering knowledge harmonization, organization, and storage. In Italy, soil data collection and processing are carried out at the regional level, and one of the major issues in soil assessment is the lack of harmonized data. Promoting harmonized and standardized methodologies aligned with international data-storage standards, establishing national infrastructures, and developing interactive web-based soil data platforms as actions to overcome these barriers.

The at economic and political factors hinder the practical application of soil knowledge. Specifically, the lack of scientific support for policymaking as the main barrier, developing region-specific soil management strategies would help

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overcome it. The weak integration of soils into the circular and bioeconomy—an issue that affects farm profitability—as a key barrier; targeted policies, measures, and incentives are needed to address it. In addition, the main obstacles are limited profitability (yields and profits may not align with farmers' expectations) and technological constraints (poor internet connectivity in rural areas, absence of shared decision-support ICT tools, and limited applied agricultural technology). The development of region-specific soil management strategies is an opportunity.

[5]Perennial agricultural systems, such as vineyards, are attracting increasing attention for their potential to contribute to climate change mitigation by implementing management practices aimed at increasing SOC levels, aligning with the goals of CF and sustainable land management.
Viticulture is a significant sector in EU agriculture, contributing both to economic revenues and job creation, as well as to landscape shaping and identity preservation. In semi-arid and temperate Mediterranean climates, vineyards often show lower SOC levels compare to other cropping systems, reaching some of the lowest SOC levels recorded, often falling below the critical threshold of 1%. This is likely due to the interplay of climatic conditions and intensive agricultural practices. Opportunities to change soil management for improving Carbon storage could be particularly relevant in large vineyard areas. However, despite their awareness of the advantages of CF practices, the majority of farmers continue to rely on conventional agricultural methods. The results highlighted that most small farm owners are hesitant to adopt Carbon Farming practices due to management costs and the need to purchase new equipment; they fear a potential loss of income. Moreover, the lack of qualified agronomists hinders the transfer of knowledge. Overall, these findings suggest that a combination of financial incentives, supportive policies, and effective knowledge transfer systems could be crucial for accelerating the transition to Carbon Farming practices in viticulture.

Common practice analysis.

The agricultural practices proposed by the project activity do not represent common practices in Italy. In Italy, potential CO2 sequestration ranges between 5.7 and 7.2 tC ha-1 year-1, in function of different management practices42. The most effective practices (organic amendments and no tillage in the inter-row) can store up to 11 tC ha-1 year-1, with differences due to climate and soil characteristics. Due to the large range of climates and soils present in Italy and to the different cultivated varieties (567 varieties officially registered), vineyards management is extremely differentiated across the Country, and this results in different impacts and levels of SOC, suggesting that practices to sequester SOC might need to be precisely tailored and fine-tuned according to local characteristics.
[2]In the vineyard the farmers implement at least one agronomic practice in their field and not a combination of practices as per the proposed project activity. The most widely adopted agronomic practices among farmers are green manure with nitrogen-fixing crops (28%), grassing (21%), the use of organic-mineral fertilizer (10%), no or minimum tillage (10%), and the application of manure or organic soil amendments (10%).
The boundary selected for the common practice analysis is the Country Italy where the proposed project activity is located. From the point of view of registered project developed as carbon project, on VCS project view page there are 4 projects under validation, 1 project rejected, 1 project under registration requested and 1 registered project. The registered project is cropping agriculture (wheat, corn, sorghum, forage) and the goal is to reduce the use of synthetic fertilizer and the fuel used in an intensive fuel technology for irrigation; therefore, cannot be compared with the proposed project activity. In addition, in ICR registry the project ID48 AgroEcology Italy is focused on tree planting and agroforestry.
Based on the above assumption the proposed project activity is not considered common practice in Country Italy. [6]

5.5 Level 4a – Financial additionality I

NA

5.6 Level 4b – Financial additionality II

NA

[5] S.Vanino, V.Baratella, R.Epifani, U.Neri, C.Piccini, G.Sannino, L.C.Pinna, S.De Leo, P.Nino, S.Palermo, G.Mongardi, R.Farina – The cost of carbon stock soil practices in Mediterranean vineyards: from scientific evidence to farmers' perspective. 2024
[6] S.Vanino, V.Baratella, R.Epifani, U.Neri, C.Piccini, G.Sannino, L.C.Pinna, S.De Leo, P.Nino, S.Palermo, G.Mongardi, R.Farina – The cost of carbon stock soil practices in Mediterranean vineyards: from scientific evidence to farmers' perspective. 2024

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5.7 Level 5 – Policy additionality

NA

6. Baseline scenario (Data source: The cost of carbon stock soil practices in Mediterranean vineyards: from scientific evidence to farmers' perspectives and Soil priorities for Italy. A multi-stakeholder consultation, barriers and opportunities for research system (Vanino Silvia, et al).

According to the ICR Requirements version 6.0 the baseline scenario means a hypothetical reference case that best represents the conditions most likely to occur in the absence of the proposed project activity.

Castello di Albola

Management

The Castello di Albola winery, located in the municipality of Radda in Chianti (Siena province and Toscana region), has a total of 50 Ha dedicated to the project activities. The winery produces organic wine, using the Sangiovese, Cabernet-Sauvignon and Chardonnay varieties. The vine training system used are guyot and pruned-spur cordon-trained and the planting layout is 2.5 m x 0.8 m.

Being an organic producing winery, only organic fertilizer, pesticides and fungicides are allowed. They are described in the QdC farm registry Tillage practices include the use of rippers and harrows, while the pruning of the vines includes mechanical and manual pruning as well as the use of defoliators.

Practices used in the baseline

The farm holds both organic and "Equalitas" certifications and is covered by multi-risk insurance for its crops. The practices currently adopted in the vineyards can be described as follows:

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1. Minimum tillage in 50% of the area
2. Spontaneous grass cover and Leguminosae cover crop in alternate rows: one row with grass cover and another with 1 leguminous species, usually filed bean ('Favino').
3. Organic fertilization
4. Use of fungicides allowed in organic farming
5. Use of pesticides of natural origins allowed in organic farming
6. Burning of wood residues
7. The vineyards are not irrigated
8. The harvest is both mechanical and manual.

The farm uses third party contractors for the manual management of greenery and dry pruning.

Table 12. Man-hours used to manage the crops.

Crops operations	Man/hours per hectare
Mechanical processing and mechanical treatments	60 hours/hectare
Manual Green Management	130 hours/hectare of which: 74 hours/hectare farm 56 hours/hectare subcontracted
Manual dry pruning	90 hours/hectare of which: 50 hours/hectare farm 40 subcontracted
Ordinary maintenance	30 hours/hectare
Mechanical harvest	7 hours/hectare on 80 hectare
Manual harvest	35 hours/hectare on 25 hectare

San Felice

Management

The San Felice winery, located in the municipality of Castelnuovo Berardenga (Siena province and Toscana region), has a total of 150 Ha dedicated to the project activities. The farm has the following certifications: Organic, Equalitas, BRC E IFS, ISO 45001; the farm began its conversion to organic in 2023. The winery produces wine, using the Sangiovese variety. The vine training system used is the Guyot and the planting layout is 2 m x 1 m.

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Being an organic producing winery, only organic fertilizer, pesticides and fungicides are allowed. They are described in the QdC farm registry. Tillage practices include the use of rippers. The pruning of the vines includes manual and mechanical pruning as well as the use of defoliators.

Practices used in the baseline

The farm has the following certifications: Organic, Equalitas, BRC E IFS, ISO 45001; the farm began its conversion to organic farming in 2023. The farm is covered by multi-risk insurance for its crops. The practices currently adopted in the vineyard are:

1. Spontaneous grassing on 50% of the cultivated hectares:
2. Grassing and green manure in alternate rows: one spontaneous row and another with green manure with nitrogen-fixing crops
3. Organic fertilization
4. Manure application: around 72,000 kg/ha manure (only in 4 vineyard unit - new vineyard plants)
5. Use of fungicides and pesticides allowed in organic farming
6. Burning of wood residues
7. Vineyards are not irrigated
8. The crop operations of pruning, stripping, ploughing, foot cleaning, cage are done manually
9. The harvest is both mechanical and manual.

The farm uses third party contractors for the manual management of greenery and dry pruning for 50 ha. The following man-hours are used to manage the crop each year.

Table 13. Man-hours used to manage the crops.

Crops operations	Man/hours per hectare
Pruning and crown control	Manual dry pruning (74) Ligature of “tralci” (63) Checkering (35) Manual pulping (45) Mechanical shaving (2.5)
Soil fertility management and defense	Spreading of fertilizers (1) Application of fungicides (14) Application of pesticides (2)

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Tillage	Processing with ripper (5) Interrow (10)
Maintenance of vineyards	Maintenance of poles and wires (30)
Harvest	Manual harvesting (48) Mechanical harvesting (2)
Planting and transplanting	Planting (2.5)

Rocca di Montemassi

Management

Rocca di Montemassi is another property of the "Albola" company situated in Roccastrada near Grosseto (Tuscany), whose lands extend for 400 hectares. In Rocca di Montemassi viticulture, breeding and the production of oil, legumes and cereals coexist: the farm comprises 106 hectares of vineyards, to produce wine of DOC Maremma Toscana, 145 hectares of arable land, 9.5 hectares of olive groves, and includes a cattle farm. The farm has a total of 50 Ha dedicated to the project activities, with 21% planted with Petit Verdot, 20% of Vermentino, 18% of Syrah, 12.6% of Merlot and the remaining area dedicated to Sangiovese, Cabernet Sauvignon, and Viognier. The vine training system used is the guyot and the planting layout is 2.3 m x 1 m. The number of vines is 4500 per hectare. Being an organic producing winery, only organic fertilizer, pesticides and fungicides are allowed. They are described in the QdC farm registry. Tillage practices include the use of rippers. The pruning of the vines includes chemical and mechanical pruning as well as the use of defoliators.

Practices used in the baseline

The farm holds both Organic and Equalitas certifications and is covered by multi-risk insurance for its crops.

The practices currently adopted in the vineyard are:

1. Spontaneous grassing and green manure in alternate rows: one spontaneous row and another with green manure with nitrogen-fixing crops
2. Organic fertilisation
3. Use of pesticides and fungicides allowed in organic farming
4. Minimum tillage
5. Burning wood residues

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7. Vineyards are irrigated with micro-irrigation system (drip irrigation), water consumption is equal to 20mm/hectare (about 2.5 interventions per year)
8. The harvest is both mechanical and manual.

Table 14. Man-hours used to manage the crops.

Crops operations	Man/hours per hectare
Mechanical processing and mechanical treatments	60 hours/hectare
Manual Green Management	130 hours/hectare Of which: 90 hours/hectare farm 40 hours/hectare subcontracted
Manual dry pruning	90 hours/hectare Of which: 70 hours/hectare farm 20 subcontracted
Ordinary maintenance	30 hours/hectare
Mechanical harvest	7 hours/hectare on 80 hectare
Manual harvest	35 hours/hectare on 25 hectare

Tenute Ruffino

Management

The Tenute Ruffino winery, located in the municipality of San Donà di Piave (Venezia province and Veneto region), has a total of 86 Ha dedicated to the project activities. The winery produces organic wine, using the Pino grigio, Pinot nero, Glera, Chardonnay and Sauvignon Rytos varieties. The vine training system used are espalier and pruned-spur cordon-trained and the planting layout is 100 m x 800 m.

Being an organic producing winery, only organic fertilizer, pesticides and fungicides are allowed. They are described in the QdC farm registry.

Tillage practices include the use of rippers. The pruning of the vines includes chemical and mechanical pruning as well as the use of defoliators.

Practices used in the baseline

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The practices currently adopted in the vineyard during the growing season 2023/24 are: • Spontaneous grassing on 100% of vineyard surface

- Organic fertilization
- Use of fungicides and pesticides allowed in organic farming
- Tillage: deep pruning in autumn (at a depth of 40 to 80 cm depending on the vineyard
- No residue management
- Vineyards are irrigated with a sub-irrigation system: during the growing season 2023/24, the amount of water provided was 1200 mc/ha
- In recent years, 300 meters of hedges with native plants have been planted to increase biodiversity

Usually, when climatic conditions are good (autumn not too rainy), grassing with green manure with nitrogen-fixing crops is used on 50% of the cultivated hectares. That is, in alternate rows: one spontaneous row and another with green manure with 1 nitrogen-fixing crop.

Table 15. Man-hours used to manage the crops.

Crops operations	Man/hours per hectare
Mechanical processing and mechanical treatments (soil processing, fertilizer application and defense products)	55 hours/hectare
Manual management of the green	30 hours/hectare
Mechanical management of the green	3 hours/hectare
Dry pruning (manual)	60 hours/hectare
Dry pruning (mechanical)	3 hours/hectare
Ordinary maintenance	10 hours/hectare
Mechanical harvesting	2 hours/hectare

Methods

1. Design of soil sampling

The soil sampling was carried out by the CREA Team, including both researchers and technical staff. Soil sampling took place in a pilot area of approximately 3 hectares per farm. Within each area, 24 plants were selected, divided into 3 control rows and 3 treatment rows. Around each selected plant, following a standard grid, 3 sub-samples (0-30 cm)—one near the plant and two in the inter-row—were taken to form 1 bulk sample.

On each farm, 24 bagged soil samples (each weighing approximately 500g) were collected. From this set, 12 samples underwent texture and fractionation analyses, and 12 samples underwent chemical analyses. Additionally, 24 undisturbed soil samples were collected from adjacent areas for physical and hydrological analyses, using a core sampler. The total sample count was 192 (4 farms * 48 samples), encompassing both the bagged and core samples. The soil samples were collected in March-April 2024, as described in Table 1.

In March 2025 (Table 1), mycorrhizal sampling took place at the Tenute Ruffino and Rocca di Montemassi farms. Soil cores were collected using cylinders near several grapevines. We dug to a depth of approximately 25 cm, aiming to include as many roots as possible.

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Farms	Period-Soil sampling	Mycorrhizae sampling
Castello di Albola	19/3/2024	
San Felice	5/4/2024	
Rocca di Montemassi	20/3/2024	7/3/2025
Tenute Ruffino	4/4/2024	6/3/2025

Table 1 - Period of soil samples.

In the following sections, the description of the soil characteristics at each pilot farm is provided.

1. Soil sampling in Castello di Albola

Under the supervision of agronomist Jacopo Ferrari, the "Santa Caterina-Tettoia" vineyard was sampled. We selected the control area within the same parcel to ensure an identical slope. In this vineyard the inter-rows alternate natural grassing (tilled annually at 10 cm depth without layer inversion) and cover crop (faba bean). Soil samples were collected in 4 core drills: two next to the plant and two in the middle of the strip. The undisturbed soil samples for the bulk density assessment were collected with steel cylinders in the middle of the inter-row.

The following areas have been identified:

- **Control:** From row 1 to row 17
- **Treatment:** From row 18 to the end of the plot



Figure 2 - Soil sampling in Castello di Albola experimental area.

2. Soil sampling in San Felice

In collaboration with Leonardo Bellaccini, technical head of the farm, the "San Carlo" vineyard was identified as the most suitable for the sample collection.

This vineyard was established in 2000, featuring alternating rows with natural grassing and a fava bean cover crop (used for green manure). The control area was selected within the same plot.

The following areas have been identified:

- **Control:** From row 59 to the end of the plot.
- **Treatment:** From row 1 to row 58.

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Figure 3 - Soil sampling in San Felice experimental area.

3. Soil sampling in Rocca di Montemassi

Under the supervision of agronomist Stefano Galbiati, the "Dogana1" vineyard have been identified as the most suitable for the sample collection.

This vineyard presented alternating rows of natural grassing and a cover crop of faba beans and barley (used for green manure). The control area was selected within the same plot.

The following areas have been identified:

- **Control:** From row 1 to row 19
- **Treatment:** From row 20 to the end of the plot (row 31)



Figure 4 – The Rocca di Montemassi experimental area

4. Soil sampling in Tenute Ruffino

Under the supervision of agronomist Mattia Tintinaglia, the "A1-GLERA 2009 FG5MP37" vineyard was identified as the

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most suitable for the sample collection.

The sampled vineyard featured grass cover in all rows. Typically, the rows should alternate between natural grassing and cover crop, but due to heavy rainfall during seeding periods, it hasn't been possible to saw the cover crops for over three years. The control area was selected within the same plot.

The following areas have been identified:

- **Control:** From row 18 to row 34
- **Treatment:** From row 1 to row 17.



Figure 5 - Soil sampling in Tenute Ruffino experimental area

2. Soil parameters

Soil physico-chemical parameters were analyzed as follows:

- **Soil texture** was determined by particle size analysis via sedimentation, in accordance with Stokes' Law, using a Sedigraph to quantify the relative proportions of sand, silt, and clay.
- **Bulk density** (g cm^{-3}) was measured using the core sampling method.
- **Soil pH** was determined in distilled water using a calibrated pH meter (inoLab® Multi 9310 IDS), following the ISO 10390 standard.
- **Soil organic carbon (SOC)** content (g kg^{-1}) was analyzed using a LECO TOC Analyzer (model RC-612; LECO Corporation, 1987).
- **Total nitrogen (Ntot)** (g kg^{-1}) was quantified with a LECO FP-528 Nitrogen Analyzer (LECO Corporation, St. Joseph, MI, USA).
- **Macro- and micronutrient concentrations** were assessed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES, Thermo Scientific iCAP PRO), in accordance with the EPA Method 3035A for acid digestion.

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Figure 6 - Soil samples in the CREA laboratory.

3. Economic and environmental data collection

We collected data from each pilot farm to conduct the environmental and economic assessment of vineyard production under different Sustainable Soil Management (SSM) practices aimed at improving carbon (C) stocking. The environmental focus on the pilot farms is based on Life Cycle Assessment (LCA) analysis, which aims to quantify the potential impacts—specifically CO_2-equivalent emissions and fossil resource consumption—of various SSM practices, including Business as Usual (BAU).

The focus of economic impacts on pilot farms is based on LCC (Life Cycle Cost) and FADN (https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html) methodology of different SSM practices (including BAU).

The definition of the appropriate indicators and data needed to perform the assessment:

- economic data to evaluate economic impact
- emission data to evaluate environmental impact.

Economic and emission data gathered, as well as the appropriate indicators and the related procedure for their calculation, has been described in detail in deliverables D6.1: "*Framework for environmental/economic assessment in pilot farms".*

The following table summarizes the collected information and unit size from the pilot farms for the evaluation. Business as usual data were collected at the end of 2024 (agricultural year 2023/2024).

Table 3 - Economic data collected with relative unit size.

1. **Production of grapes for wine**	**Economic Unit size**	**Physical Unit size**
Crop production (CP): QL/HA	Q/ha	Q/ha
prize grape(P): €/ql	€/Ql	
2. Specific costs for:	€/ha	
a) Seeds and plants	€/ha	kg/ha
b) Fertilisers	€/ha	kg/ha
b) Manure	€/ha	kg/ha

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c) Crop protection	€/ha	(kg-l-n)/ha
d) Water for irrigation	€/ha	mc/ha
e) Insurance	€/ha	
f) Certification	€/ha	
g) Contracting	€/ha	
h) Diesel	€/ha	l/ha
i) Electricity	€/ha	kwh/ha
j) Human work	€/ha	
k) Machinery	€/ha	

7.Project boundary

Following project's methodological framework which is built upon the integration of the VERRA's methodology VM0042 and the ISCC EU 205 Greenhouse Gas Emissions, the following sources (SSR) are included or excluded from the project boundary in the baseline and project scenario.

Table 16. Selected carbon pools in the baseline and project scenarios.

SSR	Controlled/ related/ affected	GHG	Included? Y/N	Justification/ explanation	Coordinates

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Aboveground woody biomass	Controlled	CO2	NO	~~The project activities significantly reduce the pool compared to the baseline~~	As it is a grouped project, there are several locations available.
Aboveground non-woody biomass	Controlled	CO2	Yes	The carbon pool is included because it is subject to significant changes during the project. This pool is particularly important as it represents the biomass derived from cover crops, which plays a key role in increasing carbon inputs to the soil and enhancing carbon sequestration.	
Belowground woody biomass	Controlled	CO2	Yes	Belowground woody biomass is included as the project activities significantly increase the pool compared to the baseline	
Belowground non-woody biomass	Controlled	CO2	Yes	Carbon pool is included because it is subject to significant changes or potential changes are transient in nature	
Litter	Controlled	CO2	NO	~~Carbon pool is included, because it is subject to significant changes or potential changes are transient in nature~~	

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Dead wood	Controlled	CO2	Yes	The residues incorporated into the soil or left on the ground after pruning and chipping represent an important C input to soil	
SOC	Controlled	CO2	Yes	Major carbon pool affected by project activity that is expected to increase in the project scenario	

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Table 17. Identification of GHG SSRs.

SSR		Controlled/ related/ affected	GHG	Included? Y/N	Justification/ explanation	Coordinates
Baseline	SOC	Controlled	CO2	Yes	Quantified as stock change in the pool, rather than an emissions source	As it is a grouped project, there are several locations available.
	Fossil fuels	Controlled	CO2	Yes	Sources of fossil fuel emissions are vehicles (mobile sources, such as trucks, tractors) and mechanical equipment required by the ALM activity.	
	Manure deposition	Controlled	CH4	Yes	Where livestock are present in the project or baseline scenarios, CH4 and N2O emissions from manure deposition and management must be included in the project boundary.	
		Controlled	N20	Yes		
	Use of nitrogen fertilizers	Controlled	N20	Yes	Where, in the baseline scenario, the project area would have been subject to nitrogen fertilization or where nitrogen fertilization is greater in the with-	

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					project scenario relative to the baseline scenario, N2O emissions from nitrogen fertilizers must be included in the project boundary.	
	Use of nitrogen fixing species	Controlled	N20	Yes	Where nitrogen-fixing species are planted in the project, N2O emissions from nitrogen-fixing species must be included in the project boundary.	
	Woody biomass	Controlled	C02	Yes	Quantified as stock change in the pool rather than an emissions source	
Project	SOC	Controlled	C02	Yes	Quantified as stock change in the pool, rather than an emissions source	As it is a grouped project, there are several locations available.
	Fossil fuels	Controlled	C02	Yes	Sources of fossil fuel emissions are vehicles (mobile sources, such as trucks, tractors) and mechanical equipment required by the ALM activity.	
	Manure deposition	Controlled	CH4	Yes	Where livestock are present in the project or baseline scenarios, CH4 and N2O emissions from manure deposition and management must be included	
		Controlled	N20	Yes		

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					in the project boundary.	
	Use of nitrogen fertilizers	Controlled	N20	Yes	Where, in the baseline scenario, the project area would have been subject to nitrogen fertilization or where nitrogen fertilization is greater in the with-project scenario relative to the baseline scenario, N20 emissions from nitrogen fertilizers must be included in the project boundary.	
	Use of nitrogen fixing species	Controlled	N20	Yes	Where nitrogen-fixing species are planted in the project, N20 emissions from nitrogen-fixing species must be included in the project boundary.	
	Woody biomass	Controlled	C02	Yes	Quantified as stock change in the pool rather than an emissions source	

8. Quantification of GHG emission mitigations

8.1 Criteria and procedures for quantification

The three following options can be applied for the calculation of Soil Organic Matter:

- IPCC methodology, as defined in 2006 guidelines
- Field measurements
- Field measurements combined with crop and soil modelling

For field measurements and combined field measurements and modelling methods, the first field measurement defines the initial SOC value that will be used for the initialization of the RothC model described below.

In this project "*Field measurements combined with crop and soil modelling*" has been selected as methodology to calculate carbon sequestration in the soil.

Description of the Rothamsted carbon model (RothC)

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Introduction

Soil organic carbon is the main component of Soil Organic Matter (SOM) whose main component is organic carbon. Soil Organic Carbon (SOC) dynamics are controlled by complex interactions of biotic and abiotic factors, such as weather, aggregate stability, infiltration capacity, mineralization rate, and biodiversity, several of which are, in turn, influenced by agricultural practices. The known factors acting on SOC dynamic, i.e. soil properties, climate, land use and crop management, have been incorporated into simulation models and once validated for a specific region and land-use, the model can be used to predict the effect of soil, crop management and climate on soil organic carbon content (Coleman et al., 1997, Jenkinson et al., 1999, Kelly et al., 1997, Smith et al., 1997).

The Rothamsted Carbon Model (RothC) (Coleman & Jenkinson, 1996, 1999; Coleman et al., 1997; Jenkinson et al., 1999) is widely recognized for its simplicity and reliability. It requires minimal inputs, all of which are easily obtainable, yet it consistently delivers accurate simulations. Smith et al. (1997) reported that RothC was among a group of models that performed exceptionally well in a comparative analysis of nine soil organic carbon (SOC) models, using long-term data from seven sites representing a wide range of land uses, soil types, and climatic conditions.

Due to its versatility, RothC has been extensively used in over 80 countries, covering a variety of climates and soils. These include tropical, subtropical, temperate, sub-humid, Mediterranean, and other climates (Coleman et al., 1997; Falloon & Smith, 2002; Guo et al., 2007; Ludwig et al., 2007; Skjemstad et al., 2004; Zimmermann et al., 2007). The model has been applied to various ecosystems, including grasslands, croplands, and forests in the UK (Coleman et al., 1997); forest soils in Brazil (Cerri et al., 2007) and Zambia (Kaonga & Coleman, 2008); arable soils in Germany (Coleman et al., 1997; Ludwig et al., 2007), Australia (Coleman et al., 1997; Skjemstad et al., 2004), the Czech Republic (Coleman et al., 1997), China (Guo et al., 2007; Ludwig et al., 2010), and Kenya (Kamoni et al., 2007); and olive groves in Spain (Nieto et al., 2010), in Italy (Farina, Francaviglia).

The Rothamsted Carbon Model (RothC)

The RothC model (Coleman and Jenkinson, 1996, 1999; Jenkinson et al., 1999), simulates SOC dynamics and has been tested in a large range of pedoclimatic conditions and cropping system management. The model requires relatively easily available inputs and produces reliable and accurate simulations (Falloon and Smith, 2002; Skjemstad et al., 2004; Guo et al., 2007; Ludwig et al., 2007, 2010; Nieto et al., 2010; Francaviglia et al., 2012; Farina et al., 2013, 2017, 2021; Robertson and Nash, 2013). Soil C is split into five pools: four active compartments, Decomposable Plant Material (DPM), Resistant Plant Material (RPM), Microbial Biomass (BIO) and Humified Organic Matter (HUM), each decomposing by a first order kinetics and specific decomposition rate (years^{-1}), and one inert organic matter pool (IOM). All C inputs, from plants or external organic fertilizers, are split between DPM and RPM, with a variable ratio depending on the type of material. Both DPM and RPM decompose to form CO_2 (lost from the system), BIO and HUM, depending on soil clay content (Coleman and Jenkinson, 1999) (Figure 44).

Structure and functioning of RothC model

Soil Organic carbon dynamics in RothC

RothC uses a monthly time step to calculate total organic carbon (t ha^{-1}), microbial biomass carbon (t ha^{-1}) on a year to centuries basis.

Incoming plant carbon is divided between DPM (Decomposable Plant Material) and RPM (Resistant Plant Material) based on the DPM/RPM ratio of the specific plant material. For most agricultural crops and improved grasslands, a DPM/RPM ratio of 1.44 is used, meaning 59% of the plant material is DPM and 41% is RPM. For unimproved grasslands and scrub (including savannas), a ratio of 0.67 is applied. In deciduous or tropical

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woodlands, the ratio is 0.25, with 20% DPM and 80% RPM. Farina et al. used a DPM/RPM ratio of 0.3 for vineyards and olive groves. All plant material passes through these two compartments once and only once. Both DPM and RPM decompose into CO_2, BIO (biomass), and HUM (humus). The proportion of decomposition into CO_2 versus BIO and HUM is influenced by the soil's clay content (refer to section 1.7). BIO and HUM are further divided into 46% BIO and 54% HUM. Both BIO and HUM continue to decompose, producing more CO_2, BIO, and HUM over time (Figure 44). Farmyard manure (FYM), being more decomposed than typical crop material, is divided as follows: 49% DPM, 49% RPM, and 2% HUM.

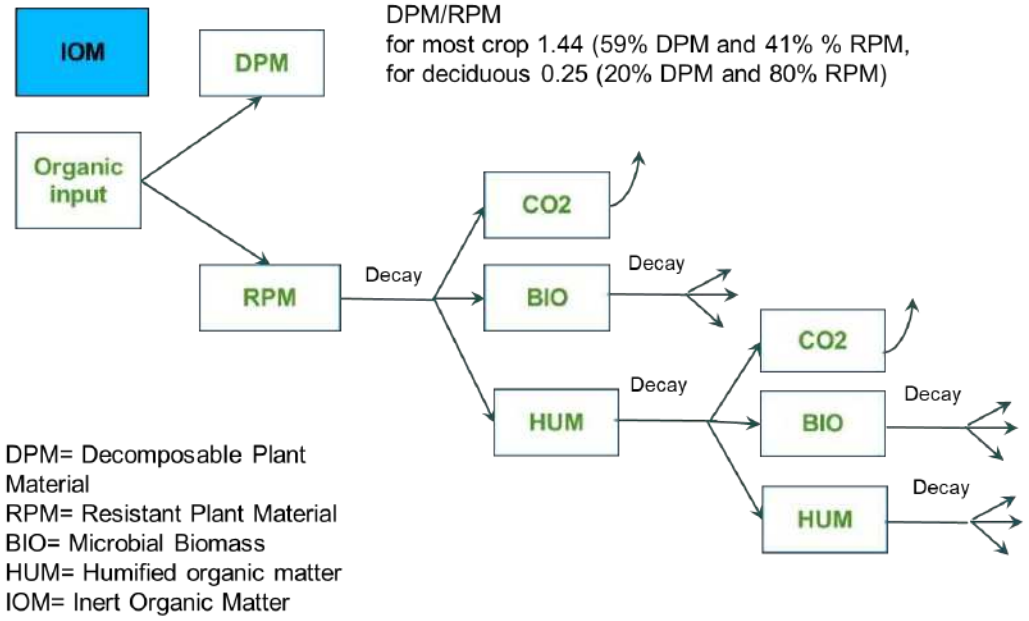


Figure 44. Model structure.

Hence, if an active compartment contains Y t C ha^{-1}, this declines to Y^{-abckt} t C ha^{-1} at the end of the month, where:

- a is the rate modifying factor for temperature
- b is the rate modifying factor for moisture
- c is the plant retainment rate modifying factor
- k is the decomposition rate constant for that compartment
- t is 1 / 12, since k is based on a yearly decomposition rate.

So Y^{-abckt} is the amount of the material in a compartment that decomposes in a particular month.
The decomposition rate constants (k), in $years^{-1}$, for each compartment are set at:

Compartment	$year^{-1}$	year
DPM	10	
RPM	0.3	
BIO	0.66	
HUM	0.02	

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Calculation of rate modifying factors

***Temperature*:**

The rate modifying factor (a) for temperature is calculated using the following formula:

$$a=\frac{47.91}{1+e(\frac{106.06}{T+18.27})}$$

Where:

T is the average monthly air temperature (°C).

In Figure 45 is reported a graphical representation of the rate modifying factor across temperatures.

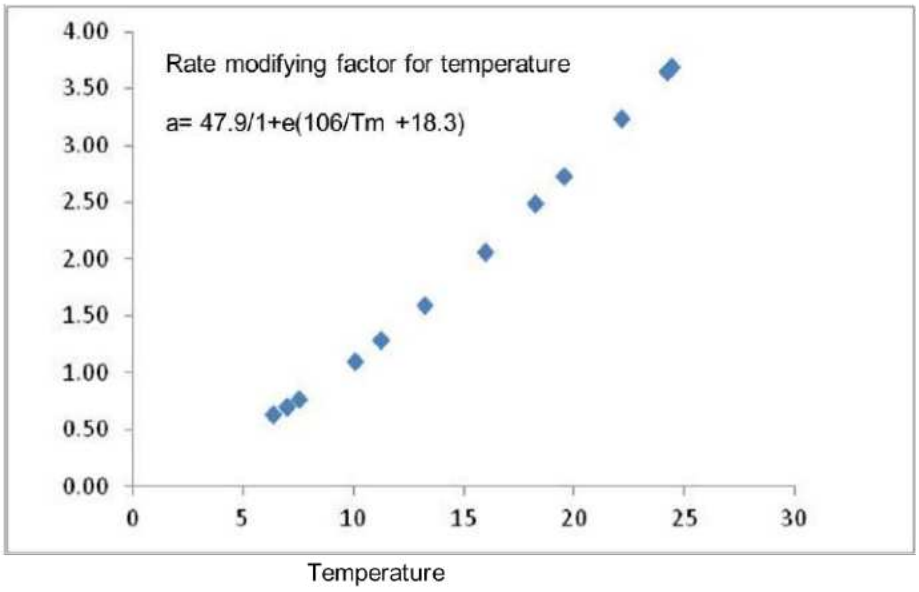


Figure 45. Rate modifying factor for temperature.

Moisture*:*

The rate modifying factor (b) for topsoil moisture deficit (TSMD) is determined through the following steps:

1. **Calculate the Maximum TSMD**

For the 0–23 cm soil layer (depth of soil in Rothamsted fields), the maximum TSMD is calculated as:

Maximum TSDM=-(20+1.3(%clay)-0.01 (%clay)^2

For example, at Rothamsted, where the clay content is 23.4%, the maximum TSMD is: = -44.9

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2. Adjust for Different Soil Layer Thickness If the soil layer differs in thickness, the calculated maximum TSMD is adjusted by dividing by 23 and multiplying by the actual thickness in cm.
3. Calculate the Accumulated TSMD The accumulated TSMD for the specified soil layer is calculated starting from the first month (January) where 0.75 × (open pan evaporation) exceeds rainfall, i.e. the soil is considered at field capacity. This continues until the maximum TSMD is reached, at which point it remains constant until rainfall once again exceeds 0.75 × (open pan evaporation), causing the soil to rewet.

If open pan evaporation data is not available, potential evapotranspiration can be estimated using Müller's (1982) tables by selecting a site with similar climatic conditions or the Thornwaite (1948) equations using temperature data with geographical corrections. Note that the model is primed to use open pan evaporation data, which is multiplied by 0.75 for evapotranspiration. If Müller's or Thornthwaite's data is used, divide it by 0.75 before inputting into the model.

4. Bare Soil Moisture Deficit (BareSMD): The maximum TSMD calculated above assumes the presence of actively growing vegetation. If the soil is bare, the maximum TSMD is divided by 1.8 to account for the reduced evaporation, giving the BareSMD. The soil cannot dry out beyond BareSMD unless the accumulated TSMD is already less than BareSMD, in which case it cannot dry out further.
5. Calculation of rate modifying factor (b) for each month

If accumulated (acc) TSDM<0.444 TSDM

b=1

otherwise

$$b=0.2+(1\text{-}0\text{-}2)\ x\ \frac{(\max TSDM - accTSDM)}{(maxTSMD - 0.444TSDM)}$$

The rate modifying factor (b) for soil moisture is represented in Figure 46

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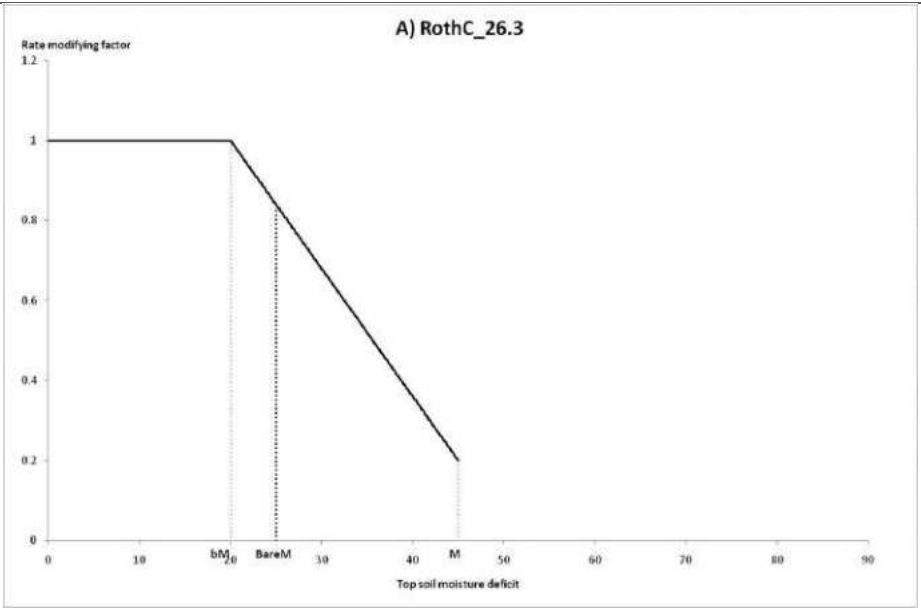


Figure 46. Rate modifying factor for soil moisture level.

Soil cover factor

The soil cover factor (c) slows decomposition if growing plants are present. In some version of the model this factor is called the 'retainment factor'
If soil is vegetated c=0.6
If soil is bare c=1.0

Partitioning of Carbon Between CO_2 Loss and BIO + HUM Formation: The CO_2 / (BIO + HUM) Ratio

The model accounts for soil texture by adjusting the partitioning between CO_2 evolved and the formation of BIO (biomass) + HUM (humus) during decomposition, instead of using a rate-modifying factor like the one applied for temperature.
The CO2 / (BIO + HUM) ratio (x) is determined by the clay content of the soil using the equation:
$x=1.67\times(1.85+1.60\times e^{-(0.0786\times \%clay)}$
Where *x* represents the CO2 / (BIO + HUM) ratio.

- The proportion of carbon evolved as CO_2 is given by:

$$\frac{x}{x+1}$$

- The proportion of carbon formed as BIO + HUM is:

$$\frac{1}{x+1}$$

The scaling factor 1.67 is applied to adjust the CO_2 / (BIO + HUM) ratio to 3.51 for Rothamsted soils (23.4% clay). This same factor is used for all soils.

Calculation of the Equivalent Radiocarbon Age

Radiocarbon measurements are typically expressed in two ways:

1. % Modern:

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$$\%Modern = 100 \times \left(\frac{\text{Specific Activity of Standard}}{\text{Specific Activity of Sample}}\right)$$

2. $\Delta^{14}C$ Value:

$$D^{14}C = 1000 \times \left(\frac{Specific\ Activity\ of\ sample - Specific\ Activity\ of\ Standard}{\text{Specific Activity of Standard}}\right)$$

The relationship between these two expressions is:

$$\Delta^{14}C = 10 \times (\%Modern) - 1000$$

The standard used is defined as 0.95 of the 14C activity of the NBS (National Bureau of Standards) oxalic acid standard.

In the model, the equivalent radiocarbon age is related to Δ14C by the equation:

$\Delta^{14}C$= 1000 exp(-radiocarbon age / 8035) - 1000

This calculation uses the conventional half-life of 14C, which is 5568 years.

The equivalent radiocarbon age is defined as the radiocarbon age of a homogeneous sample that has the same radiocarbon content as the measured (non-homogeneous) sample.

For time periods before 1860, the model assumes that the radiocarbon age of plant material entering the soil each year is zero, meaning its Δ14C value is zero and it is 100% modern. After 1860, the radiocarbon content of incoming plant carbon (expressed as % modern) is determined by an internal table.

The age of the IOM fraction is set by default to 50,000 years, implying that it contains virtually no 14C (Δ14C = -998.0) and that it is of geological age rather than pedological age.
In most cases, radiocarbon measurements are not available, therefore IOM is set using the equation set by Falloon et al, (1998)
$IOM = 0.049 TOC^{1.1339}$
Where:
TOC is the total organic carbon t C ha^{-1}
IOM is the inert organic matter t C ha^{-1}

Data requirement

Running RothC requires the following data:
(a) Climatic data: monthly rainfall (mm), potential evaporation (mm) and mean air temperature (°C);
(b) Soil data: clay content (%), initial soil organic carbon (SOC) (Mg C ha-1), bulk density (BD, g cm-3), depth of the soil layer considered (cm);
(c) Land use and land management data: Soil cover, C input from plants and organic fertilisers (Mg C ha-1) measured or estimated.
a) Climatic data could be obtained by nearby climate stations or available dataset at national, European (e.g. Agri4Cast) or global scale, conveniently downscaled to be as close as possible to the real weather of the site considered. The potential evapotranspiration (ET) if not measured directly, can be calculated using the Thornthwaite equation (Thornthwaite, 1948). The amount of water applied by irrigation is normally added to the rain in the weather file.

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b) The soil data at plot scale are usually obtained by direct sampling. Soil samples are collected to assess the SOC, the texture, the hydrological constants (field capacity and permanent wilting point) as well as the bulk density on undisturbed samples. The SOC used for the initialisation of the model is an average of all samples collected at the beginning of the experiment. The variability (standard error, standard deviation) is used to validate the model simulations across a range of real values. The bulk density is used to transform g of C per kg of soil in Mg C ha-is and is normally the average of that measured in all plots at the beginning of the experiment. The samples collected in the plot should reflect as closely as possible the inherent variability of the site considered.

When no plot measurements are available, data from pedological database can be used, after appropriate methods of upscaling the profiles data to a larger area. Indicators of errors (Root mean square error and R^2) should be reported as a measure of uncertainties of upscaling and spatialisation procedures.

c) land use and management data at plot scale can be retrieved from surveys with farmers. When working at a larger scale data from LPIS (Land Parcel Identification System) coupled with RICA might allow the identification of the parcel, the crop, the management practices applied.

The most tricky and crucial input to the model is the estimation of carbon input from crops, residues and exogenous organic matter.

Workflow for modelling with RothC

In modelling there are specific steps to follow: data collection of each homogeneous unit;, data harmonisation and quality check, calibration, validation, initialization, run of the model, output analysis, preparation of tables, graphs and maps (Figure 47). These steps are distinct but interconnected and contribute to the development and accuracy of a model's use.

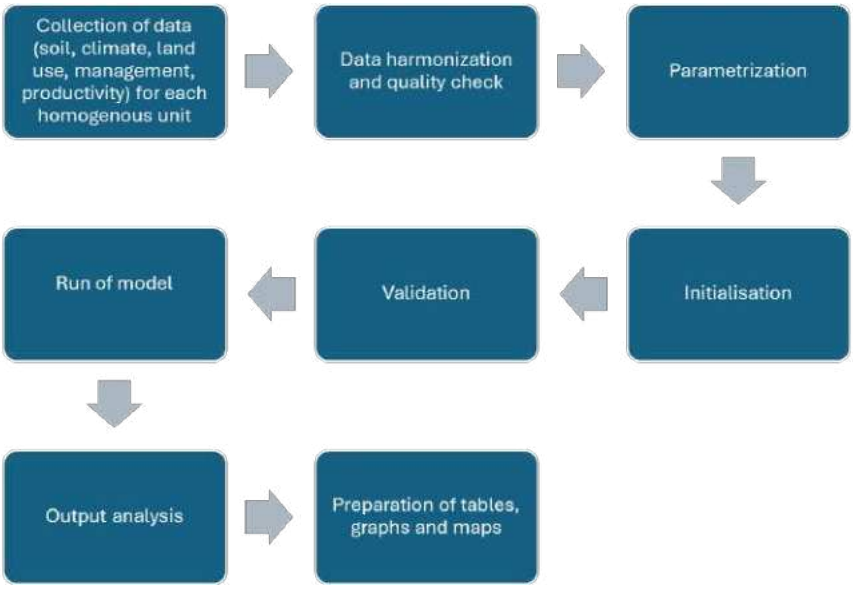


Figure 47. Steps for the development of the model

Data collection

The collection of data is an essential step of the modelling process. We have already described the data required to run RothC model.

In brief they are:

-crop factors: C inputs to soil from crops and organic amendments (kg) and an estimation of the degradability of the material

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-management factors: RothC considers only irrigation and soil cover (presence or absence of an active growing crop) while other factors such as minimum or no tillage cannot be simulated in the current RothC version.
-soil factors: initial C content and bulk density (to calculate the stock of C in t per hectare), texture (% silt, clay and sand), gravel presence.
-climate factors: monthly climate (mean temperature, rainfall and evapotranspiration).

Data harmonization and quality check

The data should undergo a careful harmonization and quality check that entails the verification of data quality (ranges, identification and possible discard of outliers, credibility of data when they are collected by external sources, error quantification (when possible).

Calibration

Calibration is the process of adjusting model parameters to improve the agreement between model predictions and a known set of observed data. The goal of calibration is to fine-tune the model to reflect the behavior of the system as accurately as possible. Normally RothC is not calibrated since internal parameters were set after long term data observation and it is not advisable to change them without having a robust set of data.
The internal parameters encompass the equations that regulate soil water content, soil temperature and soil cover. An example of changing internal parameters can be found in Farina et al. (2013) where the hydrologic functions were modified to take into account the higher capacity of Vertisols in Mediterranean climate to dry out in summer compared to soil in temperate regions, following field observations.

Validation

Validation is the process of testing the model's performance using independent data that was not used during calibration. This step evaluates the model's ability to generalize to new situations.

Initialization

Initialization involves setting the initial conditions for the model at the beginning of a simulation. These initial conditions describe the starting state of the system being modelled.
The model begins its simulations from a known state, which influences the model's predictions over time. Proper initialization ensures that the model's results are realistic from the start. As for the initialisation of the model, RothC is normally initialized using the current SOC content measured at the beginning of the experiment using the default distribution over the SOC pools. The model is run iteratively to equilibrium (10.000 years) to generate the input required to match the initial stock of SOC. The aboveground C inputs of the vineyard are estimated using literature data, whilst belowground are estimated according to Farina et al. (2018, 2020) both for vineyards as for spontaneous herbs.
RothC can be used also in the "inverse" mode, to predict how much C must enter the soil each year to maintain the measured or estimated stock of soil organic C. The inverse mode is essential in any case where we don't have a time series of TOC measurement in the site or the area.

Model run

To run the model, it is essential to first prepare files for weather, soil, crop, and the model setup. In the DOS and Windows versions, these files are named as follows:
a) Site file: Contains monthly mean climate data and soil characteristics, such as clay percentage (%).
b) Crop file: Includes monthly carbon input from crops, farmyard manure (FYM), and information on soil cover (represented as 1 or 0).
c) Setup file: Provides instructions necessary for the model to operate.
Once the model is launched, several processes are executed. Upon completion, two output files are generated:

a) A detailed file that documents all steps of the modeling process.

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b) A summary table showing the annual Total Organic Carbon (TOC) content in t/ha. Modification of RothC to simulate Italian vineyards

Output analysis

The output provided by RothC can be seen both in table and graphical forms.
They report for each year of simulation (even though even a monthly output can be obtained).
One of the recognised limitations of RothC in its original version, is that it could not be used to simulate the fate of carbon in systems including crops with different DPM/RPM ratios simultaneously in the same plot. Indeed, in the systems where the modelling is conducted two different types of crops are present simultaneously i.e. vines and herbaceous spontaneous plants or seeded cover crops, inputting carbon to soil characterised by different decomposition rates. The output needs to be validated at site level using the model performance metric described in Table 18.

The uncertainty assessment considers both **measurement uncertainty** and **model input uncertainty**. Measurement uncertainty is quantified using replicated soil sampling and expressed as the **95% confidence interval** of the observed SOC stocks. Model input uncertainty is addressed through scenario-based adjustment of baseline carbon inputs within literature-based ranges, while maintaining fixed RothC structural parameters, decomposition constants, and soil properties. Model consistency is verified by comparing simulated SOC stocks against the observed SOC confidence intervals.

Table 18. Model performance metrics (P, predicted value; O, observed value; n, number of P/O pairs; i, each of P/O pairs; $\bar{O}$, mean of observed values; $\bar{D}$, average of the differences between predicted and observed values; SD, standard deviation of the difference es between predicted and observed values; S_D, standard deviation of the differences between estimated and observed values).

Performance metric	Equation	Unit	Value range and purpose
RRMSE, relative root mean square error (Jørgensen et al., 1986)	$RRMSE = 100 \cdot \frac{\sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}}{\bar{O}}$	%	0 (optimum) to positive infinity: the closer the values are to 0, the better the model performance
EF, modelling efficiency (Nash and Sutcliffe, 1970)	$EF = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$	-	negative infinity to 1 (optimum): the closer the values are to 1, the better the model
Coefficient of determination (R^2) of the linear regression estimates versus measurements / R, Pearson's correlation coefficient of the estimates versus measurements (Addiscott and Whitmore, 1987)	$R^2 = \frac{\sum_{i=1}^{n}(P_i - O_i) \cdot (O_i - \underline{O})}{\sqrt{\sum_{i=1}^{n}(P_i - \underline{P})^2 \cdot \sum_{i=1}^{n}(O_i - \bar{O})^2}}$		0 (absence of fit of the regression line) to 1 (perfect fit of the regression line): the closer the values are to 1, the better the model
	$R = \sqrt{R^2}$	-	-1 (full negative correlation) to 1 (full positive correlation): the closer the values are to 1, the better the model

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P(t), Paired Student t-test probability of means being equal	$P(t) = \text{Probability}\left(\frac{\overline{D}}{\frac{S_D}{\sqrt{n}}}\right)$	-	0 (absence of agreement) to 1 (perfect agreement): the closer the values are to 1, the better the model
d, index of agreement (Willmott and Wicks, 1980)	$d = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(\lvert P_i - \overline{O}\rvert + \lvert O_i - \overline{O}\rvert)^2}$	-	0 (absence of agreement) to 1 (perfect agreement): the closer the values are to 1, the better the model

Modifications to the model VitiCaSe

For VitiCaSe we have used the RothC in Python version that was recently made available by Rothamsted on ZENODO (Coleman et al., 2024), different from the previous one that was written in FORTRAN.
The intent of the project is to build a friendly tool that can be used by technician to predict the effect of carbon farming practices in their farms in the medium and long term and to account for ca sequestered for carbon farming certifications.

Detail of the modifications

Changing the C input source

One of the recognized limitations of the original RothC model is its inability to account for simultaneous inputs of plant material from different sources (e.g., woody and herbaceous), which have distinct DPM/RPM ratios and thus different decomposition rates. This limitation prevents the model from simulating systems with both vines and cover crops at the same time.
To address this, we modified the code to enable such functionality. This modification is not new and was previously applied by Deligios et al. (2021) in an excel version of the model, giving excellent results in a long-term experiment.
This modification was implemented in the Python code by Image Line Srl

CH_4 emissions from soil

CH_4 (methane) emissions from upland soils (i.e. in aerobic conditions) are negative or close to zero, therefore, vineyards do not produce methane but oxidize CH_4 to CO_2. That level of oxidation is reduced by N-fertilizing and can be considered as negligible[43].

Table 19 shows the different greenhouse gas source categories according to the Nomenclature For Reporting (NFR).

Table 19. Activity data sources, methods and emission factors for agriculture soils. CS: Country Specific, T1: Tier 1, T2: Tier 2, NS: National Statistics, D: IPCCC default.

Direct/Indirect N2O emissions from managed soils				
NFR	Category	Method	Activity data	Emission factor

[43] Roger et al., Les sols : sources et puits de methane. Soils: sources and sinks of methane., 2003

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3Da1	Inorganic N-fertilizers (includes also urea application)	CS,T1,T2	NS	CS,D
3Da2a	Animal manure applied to soils			
3Da2b	Sewage sludge applied to soils			
3Da2c	Other organic fertilisers applied to soils (including compost)			
3Da4	Crop residues applied to soils			
3Db	Indirect emissions from managed soils			
	Atmospheric deposition: Volatilized N from agricultural inputs of N			
	Nitrogen leaching and runoff: N from fertilizers and other agricultural inputs that is lost through leaching and run-off.			

The GHG calculation procedure follows the methodological workflow described in the modelling protocol. Soil organic carbon dynamics are simulated using the **RothC model**, initialized through an equilibrium (spin-up) phase, followed by forward simulation under baseline and project scenarios. The calculations use measured soil properties, climate data, management practices, and carbon inputs to estimate changes in SOC stocks and the associated GHG removals.

8.1.1 Baseline emissions

Please refer to section 8.1.

8.1.2 Project emissions

According to the ISCC EU 205 Version 4.1 methodology, the project emissions for cultivation are calculated as follows:

Emissions from the cultivation (e_{ec})

$$e_{ec}\left[\frac{kg\ CO_2eq}{ton}\right] = \frac{\left(EM_{fertiliser} + EM_{N2O} + EM_{inputs} + EM_{fuel} + EM_{electricity}\right)\left[\frac{kg\ CO_2eq}{ha * yr}\right]}{yield\ raw\ material\ \left[\frac{ton}{ha * yr}\right]}$$

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The sum of GHG emissions from fertilizers, plant protection products (inputs), fuel and electricity (EM, in kg CO2eq per ha) is divided by the yield in kg to receive the specific GHG emission per kg of grape. The emissions of the different inputs (EM) are calculated by multiplying the input data with the respective emissions factors. The unit for EMinput is always kg active ingredient of product applied.

$$EM_{fertiliser} = fertiliser\ input\ \left[\frac{kg\ nutrient}{ha * yr}\right] * EF_{production}\left[\frac{kg\ CO_2eq}{kg\ nutrient}\right]$$

The amount of fertilizer used always refers to the main nutrient/active ingredient (e.g. nitrogen). For direct and indirect N2O (EMn20) emissions from agricultural soils EF will be derived from the national inventory of emissions (NIR) in agriculture (ISPRA. 2024), based on and conform to the EMEP/EEA Guidebook (EMEP/EEA, 2023) and the IPCC Guidelines (IPCC, 1997; IPCC, 2006). National emission factors are used as well as default emission factors from international guidebooks, when national data are not available.

For organic nitrogen fertilizers and crop residues left on the field N2O-field emissions must be calculated. The IPCC methodology must be applied to ensure that N2O emissions from soils are considered, including what are described as both "direct" and "indirect" N2O emissions of synthetic and organic nitrogen fertilizers and crop residues.
The farms part of the projects are all organic farms, therefore they use only organic fertilisers apart from one farm who was transitioning to organic farming during the baseline scenario and from the 2021-2022 crop year there is no evidence, in the farm registry, of synthetic fertilisers use. Therefore, only organic fertilisers were used by the farms. As described in the **ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024**, the N20 field emissions derived from organic fertilisers and from crop residues is calculated as follows:

$$N_2O_{Total} - N = [N_2O_{Direct} - N + N_2O_{Indirect} - N]$$

For mineral soils, the calculation of direct N2O emissions shall follow the following equation:

$$N_2O_{Direct} - N = [(F_{SN} + F_{ON}) * EF_1] + [F_{CR} * EF_1]$$

F_{SN}	~~Annual N synthetic fertilizer input [kg N/ha year]~~	Not allowed in organic farm --> value set to 0	
F_{ON}	Total organic N fertilizer input [kg N/ha year]	Source: Applied amounts from farm registry; NPKCaO composition from techincal sheets of commercial products	
F_{CR}	Total crop residues N-input [kg N/ha year]	Source: For vines pruning: literature; for green manure: From farm registry + literature	In the baseline scenario, vines pruning were burnt, therefore no field N2O emissions occurred from vines residues
EF_1	Emission Factor for N_2O emission from N inputs [kg N_2O-N/kg N inputs]	4.1 - 2024. IPCC guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf and "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories"	Value = 0.01

For both mineral and organic soils, the calculation of indirect N2O emissions shall follow the following equation:

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For both mineral soils, the calculation of indirect N2O emissions shall follow the following equation:

$$N_2O_{Indirect} - N = [(\sout{F_{SN} * Frac_{GASF}}) + (F_{ON} * Frac_{GASM})] * EF_4] + [(\sout{F_{SN}} + F_{ON} + F_{CR}) * Frac_{Leach-(H)} * EF_5]$$

$Frac_{GASF}$	~~Fraction of N synthetic fertilizer applied that volatises as NH_3, NO_x [kg N volatilised/kg of N applied]~~	~~Value = 0.1~~
$Frac_{GASM}$	Fraction of applied organic N fertilizer applied that volatilises as NH_3, Nox [kg N volatised/kg N applied or deposited]	Value = 0.2
EF_4	Emission Factor for N_2O emission from atmosheric deposition of N on soils and water surfaces [kg N_2O-N/(kg NH3-N + Nox-N volatilised)]	Value = 0.01
FracLeach-(H)	Fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff [kg N/kg of N additions]	Value = 0.3
EF_5	Emission Factor for N2O emission from leaching and runoff [kg N2O-N/kg N leached and runoff]	Value = 0.0075

N2O-N emissions are then converted into N2O by multiplying the results by:

* 44/28 = 1.5714

N2O emissions are then converted into CO2 equivalent by multiplying the results by the N2O GWP over a 100-year time horizon, according to the ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024:

265

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Finally, the results of the calculation of N2O emission from managed soil shall be converted from N_2O – N to N_2O according to the following equation: Conversion factor to convert weight N to weight N_2O (kg N_2O/kg N)

As stated in the Implementing Regulation (EU) 2022/996, 1 g N_2O is equal to 265 g CO_2eq for the purposes of calculating CO2 equivalence.

For calculating fuel emissions from the use of farm machinery (EM_{fuel}) the fuel consumption of all activities during field-preparation, seeding, fertiliser and pesticide application, harvesting and collection must be determined, documented and multiplied with the EF for the respective fuel type e.g. diesel, gasoline, heavy fuel oil, biofuels.

If electricity is consumed from the grid, the emission factor of the regional electricity mix ($EF_{electricity}$) shall be used. In the case of the EU the most logical choice is the whole EU.

$$EM_{fuel} = fuel|consumption \left[\frac{l}{ha * yr}\right] * EF_{fuel} \left[\frac{kg\ CO_2eq}{l}\right]$$

$$EM_{electricity} = electricity\ consumption \left[\frac{kWh}{ha * yr}\right] * EF_{electricity} \left[\frac{kg\ CO_2eq}{kWh}\right]$$

8.1.3 Leakage

Based on the VCS VM0042 methodology the improved agricultural land management projects may result in leakage through new application of organic amendments from outside the project area (i.e. organic amendments applied in the project forum outside of the project area, that were not previously applied in the historical look-back period); productivity declines. Where the sum of increases in greenhouse gas emissions from any leakage source is less than 5% of the total net anthropogenic GHG emission reductions and removals due to the project, such sources may be deemed de minimis and may be ignored.

Leakage from new application of organic amendments from outside the project area.

Where new manure, compost or biosolids are applied in the project that were not applied in the historical look-back period, there is a risk of activity shifting leakage. To account for this type of leakage, a deduction must be used unless any of the following apply:

1) The manure or compost applied in the project are produced on-site from farms within the project area.

2) The manure is documented to have been diverted from an uncontrolled anaerobic lagoon, pond, tank or pit from which there is no recovery of methane for generation of heat and/or electricity; or

3) The manure, compost or biosolids are documented to not have been used as a soil amendment.

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The deduction represents the portion of manure, compost or biosolids carbon that remains in the project area without degrading, and which would have otherwise been applied to agricultural land outside of the project area.

The following equation estimates the leakage from imported manure, compost or biosolids that are diverted from other applications and could have led to an increase of SOC outside the project boundary in the absence of the project activity.

$$LE_{OA,t} = \sum_{l} \left(M_manure_{wp,l,t} \times CC_{wp,l,t} \times 0.12 \times \frac{44}{12} \right) \quad (34)$$

Where:

$LE_{OA,t}$	=	Leakage from organic amendments in year t (t CO_2e)
$M_OA_{wp,l,t}$	=	Mass of organic amendment applied as fertilizer in the project area in year t (tonnes)
$CC_{wp,l,t}$	=	Carbon content of organic amendment applied as fertilizer in the project area in year t (t C/t manure)
0.12	=	Fraction of manure (i.e., organic amendment) carbon expected to remain in project area soils (unitless)
$\frac{44}{12}$	=	Ratio of molecular weight of carbon dioxide to carbon

Accounting for leakage from productivity declines.

Market leakage is likely to be negligible because the land remains in agricultural production in the project scenario.

8.2 Quantification of Net-GHG emissions and/or removals

Please refer to section 8.1

Table 20. Quantification of Net-GHG emissions and/or removals

Year	Baseline emissions (tCO_2e)	Project emissions (tCO_2e)	Estimated leakage (tCO_2e)	Reductions (tCO_2e)	Removals (tCO_2e)	Total GHG emission mitigations (tCO_2e)
18/10/2024 to 31/12/2024	166	100	0	66	285	351
01/01/2025 to 31/12/2025	993	598	0	395	1,386	1,781
01/01/2026 to 31/12/2026	993	598	0	395	1,253	1,648
01/01/2027 to 31/08/2027	331	199	0	132	371	503
Total	2,484	1,496	0	987	3,295	4,283

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Aannual average	83	50	0	33	114	147

All the following information has been collected based on interviews to the farms in April 2026.
In the case of San Felice, the **manure** is produced by a company belonging to the same holding, but located in Umbria (neighbouring region to Tuscany). It is a livestock company which stocks manure in pits, with no valorisation of the methane emissions for energy production. Moreover, between 2023 and 2024, the livestock company faced some renovation works in the manure storage infrastructure and therefore it was necessary to quickly move out of the plant most of the manure, which didn't have any other planned destination of use. For these reasons, based on the VM0042 VCS standard, the leakage related to the use of manure should not be accounted for (See VM0042 IMPROVED AGRICULTURAL LAND MANAGEMENT, version 2.2, pag. 51: " To account for this type of leakage, a deduction must be used unless any of the following apply: 1) The manure or compost applied as a project activity in the project are newly produced on-site from farms within the project area; 2) The manure is documented to have been diverted from an uncontrolled anaerobic lagoon, pond, tank, or pit42 from which there is no recovery of methane for generation of heat and/or electricity; or 3) The manure, compost, or biosolids are documented to not have been used as a soil amendment.). Regarding **green manure (N2O-fixing species),** seeds are bought from a big local retailer and no impact is foreseen in terms of supply for other farms in the region. For this reason, it is sufficient to consider the GHG emissions associated with the green manure inside the project boundaries. The company has a wide **agricultural machinery** fleet which is able to fulfil all farms requirements, even after the introduction of CF practices. The fleet is annually renewed based on the farm requirements, due to some old machines which have to be replaced with more efficient and performant machines. For these reasons, it is sufficient to consider the GHG emissions due to the use of machinery inside the project boundaries.
Similarly, in the case of "Castello d'Albola", **manure** was applied to one vineyard "Villanova", starting in 2024/2025 agronomic campaign (around 32 t/ha), while in the previous years, no manure was applied. Manure was bought from a livestock (bovine) extensive farm in Emilia-Romagna (neighbouring region to Tuscany) where the manure is produced in pits, without CH4 valorisation for energy production and where there was an excess of manure storage. In fact, Emilia Romagna region is characterized by Nitrates Vulnerable Zones and therefore, the application of manure is limited by dedicated regulations for avoiding excessive nitrates leaching. For these reasons, based on the VM0042 VCS standard, the leakage related to the use of manure should not be accounted for. The application of manure to the soil in the 2025-2026 agronomic campaign was not possible because of difficulties in accessing the fields (very wet season) and for the next years the application of manure is questioned due to the cost of transportation. Regarding the **green manure (N2O fixing species)**, seeds are self-produced by the company, and therefore there is no risk of leakage in terms of lower green manure availability on the market. For this reason, it is sufficient to consider the GHG emissions associated with the green manure inside the project boundaries. Regarding **agricultural machinery,** the farm mostly rely on internal equipment (a small portion of internal agricultural works are assigned to a contractor). For this reason, it is sufficient to consider the GHG emissions due to use of machinery inside the project boundaries.
The Ruffino farm doesn't use any **manure** because the vineyards are located in flat areas, below the see level, and therefore it is important to avoid entering the vineyards with machinery, if not strictly necessary, to protect the soil, especially the grass cover, in order to avoid water accumulation and mud formation soon after rain events. Regarding the possible leakage on **agricultural machinery** use, the farm declares that they have 2 internal workers and several machinery. The latter is under-utilized and therefore an increase in agricultural operations due to carbon farming projects is not a problem in terms of increasing the use of this machinery. The farm also relies on contractors, that are big companies with many workers and machinery available, therefore there is no risk on leakage in terms of reduced availability of this machinery for other farms in the region. For this reason, it is sufficient to consider the GHG emissions due to use of machinery inside the project boundaries. Finally, the **green manure seeds** are bought on the market with no risk of leakage because these seeds are widely available and therefore no impact is forecasted. For this reason, it is sufficient to consider the GHG emissions associated with the green manure inside the project boundaries.

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Montemassi has an internal production of bovine **manure**; however, cows graze in the wild, therefore the valorisation of cow dung as soil amendment in vineyards is difficult and only very limited. From the campaign 2024-2025 manure (40 t/ha) has been applied in some parcels. The manure was purchased from the neighbouring livestock company that was not using it previously as soil amendment, but just stocking it in mounds. The seeds for **green manure** are produced internally and exceeding quantities are sold outside of the company. For this reason, it is sufficient to consider the GHG emissions associated with the green manure inside the project boundaries. The implementation of the new CF practices (mycorrize, manure and organic fertilizers) is managed internally both with workers and **machinery** and did not have any impact in terms of shortage of labour and machinery use. For this reason, it is sufficient to consider the GHG emissions due to use of machinery inside the project boundaries.

8.3 Risk assessment for permanence

(Refer to table 8 and 9)

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9 Monitoring

9.1 Monitoring plan

The main objective of monitoring is to quantify stock change of SOC and emissions of CO_2, CH_4 and N_2O resulting from the project scenario during the verification period.

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Data to be collected, data collection techniques and data archiving procedures.

Anticipated frequency of monitoring for each variable.

Quality assurance and quality control (QA/QC). The IPCC Good Practice Guidance Chapter 8 defines quality assurance (QA) and quality control (QC) and provides guidance on the elements to be considered for transparency and review.

QC is a system of routine technical activities to measure and control the quality of inventory as it is being developed. The QC system is designed to: a) provide routine and consistent checks to ensure data integrity, correctness and completeness; b) identify and address errors and omissions; c) document and archive inventory material and record all QC activities. QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. The following table identify the QC activities:

QC Activity	Procedures
Check that parameter and units are correctly recorded and that appropriate conversion factors are used.	Check that units are properly labelled in calculation sheets. Check that units are correctly carried through from beginning to end of calculations. Check that conversion factors are correct.
Check the integrity of database files.	Confirm that the appropriate data processing steps are correctly represented in the database. Ensure that data fields are properly labelled and have the correct design specifications. Ensure that adequate documentation of database and model structure and operation are archived.
Undertake review of internal documentation.	Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. Check integrity of any data archiving arrangements of outside organization involved in inventory preparation.
Check time series consistency	Check for consistency in the algorithm/method used for calculation Check recalculation method
Compare calculation to previous estimates.	Current inventory estimates (ex-post) shall be compared to previous estimates (ex-ante). If there are

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	significant changes or departures from expected trends, re-check the calculation and explain any difference.

Roles and responsibilities

Role	Responsibilities
Monitoring Manager	The Monitoring Manager is responsible for: Planning and management of the monitoring process. Training of dedicated personnel Quality assurance of field monitoring Data analysis and reporting
Monitoring Supervisor (field)	The monitoring supervisor is responsible for: Supervise the field monitoring Record data on fields sheets Check completeness of the entered data Correct data collection Calibration of the measurement equipment's Enter data from field sheets Data archiving (raw data and excel files)
Monitoring field team	The field team is responsible: Take field measurements Ensure accuracy of the measurements
QA/QC team	The QA/QC team is responsible for: Define methods for accuracy checks on data acquisition Carry quality control on field measurements and data entry. Ensure that the inventory represents the current emissions and sinks.

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9.2 Data and parameters remaining constant

Table 21 Data and parameters remaining constant

Data / Parameter	It is the quotient obtained by dividing the molecular weight of CO_2 (44,010 g/mol) by the molecular weight of carbon (12,011 g/mol) in g CO_2eq/g C
Unit	g CO_2eq/g C
Description	It is the quotient obtained by dividing the molecular weight of CO_2 (44,010 g/mol) by the molecular weight of carbon (12,011 g/mol) in g CO2eq/g C
Origin of data	IPCC Guidelines[7]
Value applied	3,66
Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express CO_2e / g C
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage
Comments	-
Data / Parameter	Emission factor diesel (EF_{fuel})
Unit	kg CO_2 /L
Description	Emission factor used to estimate impact of diesel fuel consumption in terms of CO_2 emissions
Origin of data	Emission factors analysis – Transport sector Reports 28/2003APAT
	3.14
Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express KgCO_2e/ L
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage
Comments	-
Data / Parameter	Emission factor electricity (EFelectricity)
Unit	kg CO_2 / kWh
Description	Emission factor used to estimate impact of electricity consumption in terms of CO_2 emissions

[7] www.ipcc-nggip.iges.or.jp/public/2019rf/index.html
Fattori-di-emissione-produzione-consumo-energia-elettrica – EMISSIONI

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Origin of data	iLCCT Database_2025
Value applied	0.274
Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express Kg CO_2 / kWh
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage
Comments	-
Data / Parameter	Global Warming Potential (GWP)
Unit	-
Description	Global Warming Potential of N_2O
Origin of data	ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024
Value applied	265
Justification of choice of data or description of measurement methods and procedures applied	It supports the quantification of N_2O to global warming relative to CO_2
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage

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Comments	-
Data / Parameter	Emission Factor for N from inorganic fertilizer
Unit	kg CO_2e / unit of fertilizer
Description	Emission factor used to estimate impact of inorganic fertilizer in terms of CO_2 emissions
	European Commission: Standard values for emission factors, v 1.0. 2015
Value applied	Not used in this project, because the farmer involved doesn't use N inorganic fertilizer. For the others inorganic fertilizer, we use the following value: P2O5-fertiliser: 1.01 K2O-fertiliser: 0.58 CaO-fertiliser: 0.13
Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express kg CO_2e / unit of inorganic fertilizer
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage
Data / Parameter	Emission Factor for N from organic fertilizer
Unit	kg CO_2e / unit of fertilizer
Description	Emission factor used to estimate impact of organic fertilizer in terms of CO_2 emissions
Origin of data	ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024.
Value applied	Emission Factor for N2O emission from N inputs [kg N2O-N/kg N inputs]: 0.01 + Indirect N2O emission (0.2 for NH3; 0.01 for Nox [kg N volatised/kg N applied or deposited; 0.3 for leaching ; 0.0075 for run off. N2O-N emissions are then converted into N2O by multiplying the results by: * 44/28 = 1.5714 N2O emissions are then converted into CO2 equivalent by multiplying the results by the N2O GWP over a 100-year time horizon, according to the ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024: 265
Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express kg CO_2e / unit of organic fertilizer
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage
Data / Parameter	Emission Factor for N from manure
Unit	kg CO_2e / unit of manure

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Description	Emission factor used to estimate impact of manure in terms of CO_2 emissions
Origin of data	IPCC Guidelines. ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024.
Value applied	Emission Factor for N2O emission from N inputs [kg N2O-N/kg N inputs]: 0.01 + Indirect N2O emission (0.2 for NH3; 0.01 for Nox [kg N volatised/kg N applied or deposited; 0.3 for leaching ; 0.0075 for run off. N2O-N emissions are then converted into N2O by multiplying the results by: * 44/28 = 1.5714 N2O emissions are then converted into CO2 equivalent by multiplying the results by the N2O GWP over a 100-year time horizon, according to the ISCC EU 205 Greenhouse Gas Emissions, Version 4.1 - 2024: 265

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Justification of choice of data or description of measurement methods and procedures applied	It is used in carbon footprint assessment to express kg CO_2e /unit of manure
Purpose of Monitoring	☒ Calculation of baseline emissions ☒ Calculation of project emissions ☐ Calculation of leakage

9.3 Data and parameters monitored

Table 22. Data and parameters to be monitored.
The electricity is used only for irrigation and Only MONTEMASSI and RUFFINO are irrigated

Data / Parameter	$EM_{fertilizer_organic}$
Unit	Kg organic fertilizer/ha
Description	Quantity of organic fertilizer used
Origin of data	Farm registry
Value applied	For each farm, each year and each field, the value of applied organic fertilisers was monitored through the QdC farm registry.
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real farming practices applied
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	$EM_{fertilizer_inorganic}$

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Unit	Kg inorganic fertilizer / ha
Description	Quantity of inorganic fertilizer used
Origin of data	Farm registry
Value applied	For each farm, each year and each field, the value of applied organic fertilisers was monitored through the QdC farm registry.
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real farming practices applied
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	EM_manure
Unit	Kg manure / ha
Description	Quantity of manure used
Origin of data	Farm registry
Value applied	For each farm, each year and each field, the value of applied organic fertilisers was monitored through the QdC farm registry.
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real farming practices applied
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	EM_{fuel}
Unit	L diesel / ha year
Description	Quantity of diesel used
Origin of data	declaration from farm owner
Value applied	"Amount diesel (L/ha) (data collected from farm owner)" ALBOLA 373 MONTEMASSI 344 RUFFINO 450 SAN FELICE 460
Justification of choice of data or description of	Best data available, because it corresponds to the real diesel consumption from

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	bills

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measurement methods and procedures applied	
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	$EM_{electricity}$
Unit	Kwh / ha year
Description	Quantity of electricity used
Origin of data	declaration from farm owners + calculation by CREA
Value applied	Montemassi: 38.93 Ruffino: 77.86
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real consumption based on bills
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	EM_{input} (insecticides)
Unit	Kg CO_2eq/kg active ingredient
Description	-
Origin of data	Farm registry
Value applied	For each farm, each field and each year the applied insecticide was retrieved from the farm registry
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real farming practices applied
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	EM_{input} (Fungicides)
Unit	Kg CO_2eq. /kg active ingredient
Description	-

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Origin of data	Farm registry
Value applied	For each farm, each field and each year the applied insecticide was retrieved from the farm registry
Justification of choice of data or description of measurement methods and procedures applied	Best data available, because it corresponds to the real farming practices applied the fungicides with biological origin based on different bacteria for the prevention of various fungal diseases have an emission factor = 0. While emission factor = 1 for fungicides with copper mineral component (https://www.manica.com/wp-content/uploads/2020/01/Catalogo_Manica_Agrofarmaci_2020_web.pdf) and 1.53 for fungicides with sulfur mineral component (https://carboncloud.com/agricultural-model/)
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-
Data / Parameter	$EM_{crop_residues}$
Unit	Kg crop residues / ha year
Description	Quantity of crop residues used
Origin of data	Pruning measured at the field level in the farm compared with scientific literature "Pruning Biomass Potential in Italy Related to Crop Characteristics, Agricultural Practices and Agro-Climatic Conditions" Luigi Pari, Vincenzo Alfano, Daniel Garcia-Galindo, Alessandro Suardi and Enrico Santangelo, (2018)
Value applied	1,15 t D.M./ha
Justification of choice of data or description of measurement methods and procedures applied	Best available data because collected directly in the farms of the project and compared with more general data from literature reviews
Monitoring frequency	Yearly
Purpose of data	Calculation of project emissions
Quality assurance and control	QA /QC procedures to ensure accurate data collection as described in section 9.1
Comments	-

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measurement methods and procedures applied	

10. Management of data quality

Please refer to section 9.1.

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Appendix I – Confidential information

Appendix II – [Other]

No additional information is needed for improving transparency.

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