VENETO AGRICOLTURA

EXPERIMENTATION 2 - PROJECT AGROFORCARB

arpav
Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto

AgroForCarb

Interreg
Co-funded by the European Union
Alpine Space

DIVERSE

Application of ACFO together with incorporation of agricultural digestate and broadleaf wood chips for immobilization of organic carbon and increase in soil organic matter

Introduction

The AGROFORCARB project involves long-term experimental activity on agricultural land in Veneto Agricoltura's pilot and demonstration farms: Vallevecchia - Caorle (VE) and Sasse Rami - Ceregnano (RO). The experimental activity consists in determining whether solid digestate from the anaerobic digestion of agro-livestock biomass can be distributed as a soil conditioner to partially replace chemical fertilization; the digestate is mixed with wood chips from tree pruning in agroforestry systems embedded with minimum tillage techniques to detect the main pedological parameters, including the dynamics of nitrogen transformation, carbon and biodiversity in soils.

The project team:

- Veneto Agricoltura (U.O. Extensive Crops and Livestock)
- Regional Agency for Environmental Protection and Water Systems (ARPAV) - Soil Quality Organizational Unit

Objectives

- Increase organic matter in soils and in soil carbon sequestration potential;
- Improve soil fertility, in particular biological quality;
- Reduce use of chemical fertilizers;
- Absorb atmospheric CO_2;
- Improve the environment;
- Reconcile biodiversity with sustainable biogas production systems;
- Valorize carbon credits.

The project was launched in the autumn of 2018 under a collaboration agreement with ARPAV and was joint funded until 2024 by Veneto Agricoltura and ARPAV. From 2025 to 2027, its activities will be partially funded by the Interreg Alpine Space programme project "DIVERSE".

General agronomic management practices

Consistent with the objectives, all trial plots are cultivated according to the principles described in the Project Sheet ACFO - Flexible Holistic Conservation Farming - Regenerative Farming.

Crop rotation of field trials on the two experimental farms

Crop rotation for first three-year period (2019-2021)

Sasse Rami/Vallevecchia: wheat (2018-2019), maize (2020), soybean (2021), wheat (2021-2022);

Crop rotation for second three-year period (2022-2024)

Sasse Rami

2022: second crop soybean (harvested October) - solid digestate + wood-chip distribution (October) - autumn cover barley + pea (sown November);

Vallevecchia

2022: sorghum cover (terminated October) - solid digestate + wood-chip distribution (November) - autumn barley + pea cover (sown November);

Sasse Rami - Vallevecchia

2023: cover termination (barley-pea) - maize sowing (April) - distribution of solid digestate + wood chips (October Sasse branches/November Vallevecchia) - wheat (sown November and December respectively);

2024: wheat harvesting (June/July) - sorghum cover sowing (July) - sorghum harvesting (intermizoo) - solid digestate + wood-chip distribution (October/November Sasse Rami and November Vallevecchia), cover rye + vetch (Vallevecchia), cover barley (Sasse Rami) November.

Crop rotation for third three-year period (2025-2027)

Sasse Rami - Vallevecchia

2025: Cover termination (April-May) - soybean planting (April-May) - soybean harvest (autumn) - digestate distribution (autumn) - wheat sowing (autumn);

2026: Wheat intercropping with pratense/repens clover (February-March) - after threshing, if clover cover absent, sow summer cover (sorghum) and distribute digestate (summer) in pre-sowing - if clover cover present, distribute digestate (spring 2027);

2027: Cover termination and distribution of digestate before maize sowing (March-April). Only with temperate soils; possible digestate distribution in autumn if not carried out in spring; autumn cover sowing.

SASSE RAMI EXPERIMENTAL AREA

Pilot and demonstration farm Sasse Rami				
Plot	**Surface (ha)**	**Thesis**	**Type of treatment**	**Fertilization method**
108	1.4758	Digestate	Organic fertilization Chemical fertilization	SOIL DIGESTATE INTEGRATIVE
113	1.6337			
115/a	0.8733			
110	1.5333	Digestate + Wood chips	Organic fertilization Chemical fertilization	DIGESTATE + WOOD CHIPS INTEGRATIVE
112	1.6001			
115/b	0.8733			
109	1.5034	Control witness	Organic fertilization Chemical fertilization	NO YES
111	1.5667			
114	1.6773			

VALLEVECCHIA EXPERIMENTAL AREA

Pilot and demonstration farm Vallevecchia				
Plot	**Surface (ha)**	**Thesis**	**Type of treatment**	**Fertilization method**
11	1.0558	Digestate	Agroforestry	NO
17	1.0874		Organic fertilization	Soil DIGESTATE
21	1.0602		Chemical fertilization	INTEGRATIVE
09	1.0584	Agroforestry Digestate + Wood chips	Agroforestry	YES
14	1.0362		Organic fertilization	DIGESTATE + WOOD CHIPS
19	1.0747		Chemical fertilization	INTEGRATIVE
12	1.0892	Control witness	Agroforestry	NO
16	1.0484		Organic fertilization	NO
22	1.0688		Chemical fertilization	YES
08	0.979	Former Agroforestry Witness	Agroforestry	YES
13	1.1056		Organic fertilization	NO
18	1.0775		Chemical fertilization	YES

Comparing experimental theses

1) **THESIS D** (digestate): the thesis envisages the distribution only of the solid fraction of the digestate and its consecutive burial with minimum tillage operations; the contribution of the organic soil conditioner is supplemented by mineral fertilization in pre-sowing and/or in coverage, which is needed to meet the real nitrogen needs of the cultivated agricultural crop.
2) **THESIS D+C** (digestate + wood chips): this thesis envisages spreading solid digestate mixed with wood chips obtained from chipping broadleaf trees in-the-field and the immediate burial of the two matrices, as well as the residues of the previous crop, with minimum tillage operations; as for Thesis D (digestate), chemical fertilizer is added in pre-seeding and/or in coverage to supplement the needs of the agricultural crop.
3) **THESIS T:** this thesis is a control where a standard cultivation scenario is scheduled; the plots are managed as arable land, with the addition of chemical fertiliser only.

Digestate + wood chip spreading protocol

Supply of solid digestate: agreement on the supply of digestate between the producer (biogas plant) and the receiver (Veneto Agricoltura), which uses it agronomically. The purpose of signing the agreement is to provide assurance of the destination of the digestate produced by the anaerobic digestion plant and its correct agronomic use on agricultural land by the end user. The digestate and wood chips are distributed in a similar manner to that used for manure; the vehicle used is a manure spreader that can spread manure and solid digestate, as well as other palatable materials, such as poultry manure and compost.

Manure-spreader trailer and field distribution of digestate and wood chips.

Incorporation of digestate and wood chips by minimum tillage.

Digestate supply - Vallevecchia

BIOGAS PRODUCTION PLANT: located in the locality of Brussa - Caorle (Venice) - 999 kWel of installed power, 90% of which is provided by dedicated agricultural crops (vegetable silage) and the remaining 10% or so by livestock effluent.

DIGESTATE TYPE: agro-livestock;

CHARACTERISTICS (physical state) palatable;

ANNUAL QUANTITIES: 260,000 kg, equal to 520 m^3.

Digestate supply - Sasse Rami

BIOGAS PRODUCTION PLANT: located in the municipality of Villadose (Rovigo) - installed electric power of the plant is 999 kWel, 93% fuelled by dedicated agricultural crops, including residual crops not constituting waste, and 7% by by-products of cereal processing from the Consortium's own plant.

DIGESTATE TYPE: agro-industrial;

CHARACTERISTICS (physical state) palatable;

ANNUAL QUANTITIES: 350,000 kg, equal to 1000 m^3.

Wood chip supply

The hardwood chips used in the experimental trials come from specialised producers and retailers of wood chips, mainly for energy use, in various sizes and qualities, according to requirements.

The results of the chemical-physical analyses carried out by the Biofuel Analysis Laboratory at the University of Padova's Department of Land and Agro-Forestry Systems (TESAF) on 4 samples of wood chips (approximately 55-60 litres/sample)

taken from the heaps stored outdoors at the Vallevecchia (2 samples) and Sasse Rami (2 samples) are given as an example.
The parameters analysed are:
- ash content;
- water content;
- calorific value;
- particle size distribution;
- apparent density;
- C/N ratio.

Parameters analysed Vallevecchia company								
Sample	**Water content as is (%)**	**Fine particle content (%)**	**Steric density as fed basis (kg/m³)**	**Ash content % d.m.**	**Calorific value d.m. (MJ/kg)**	**Estimated lower calorific as fed basis (MJ/kg)**	**Nitrogen % d.m.**	**Carbon % d.m.**
B1	62.3	7.3	350	4.80	19.17	5.22	0.32	48.6
B2	60.5	5.1	320	3.4	19.46	5.70	0.36	48.8

Particle size distribution					
Main fraction (min. 60%)		**Fine fraction (≤3,15 mm)**	**Coarse fraction**	**Max. lenght of coarse fraction**	**Max. surface of coarse fraction**
P16S	3,15 mm <P ≤16 mm	≤16%	≤6% (>31,5 mm)	≤45 mm	≤2 cm²
P31S	3,15 mm <P ≤31,5 mm	≤10%	≤6% (>45 mm)	≤150 mm	≤4 cm²
P45S	3,15 mm <P ≤45 mm	≤10%	≤10% (>63 mm)	≤200 mm	≤6 cm²

Wood species: broad-leaved;
Sample collection mode **B1**: sub-samples from the pile (fine-homogeneous, coarse-homogeneous, and heterogeneous);
Sample collection mode **B2**: wet material taken from within the pile.

Parameters analysed company Sasse Rami								
Sample	**Water content as is (%)**	**Fine particle content (%)**	**Steric density as fed basis (kg/m³)**	**Ash content % d.m.**	**Calorific value d.m. (MJ/kg)**	**Estimated lower calorific as fed basis (MJ/kg)**	**Nitrogen % d.m.**	**Carbon % d.m.**
A1	28.4	9.8	300	2.3	19.50	12.33	0.25	49.2
A2	46.5	6.2	300	2.43	19.53	8.61	0.22	49.3

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Agronomic surveys

- ❑ plant density of maize, wheat and soya, according to the protocols in use on these crops;
- ❑ surveys on the presence of wheat diseases;
- ❑ surveys on the spread and type of weeds present;
- ❑ analysis of mycotoxins present on maize and wheat grain;
- ❑ production surveys (through mapping);
- ❑ cover crop biomass and nutrient content modelling with Methode Mercì to be validated with chemical analysis of biomass composition.

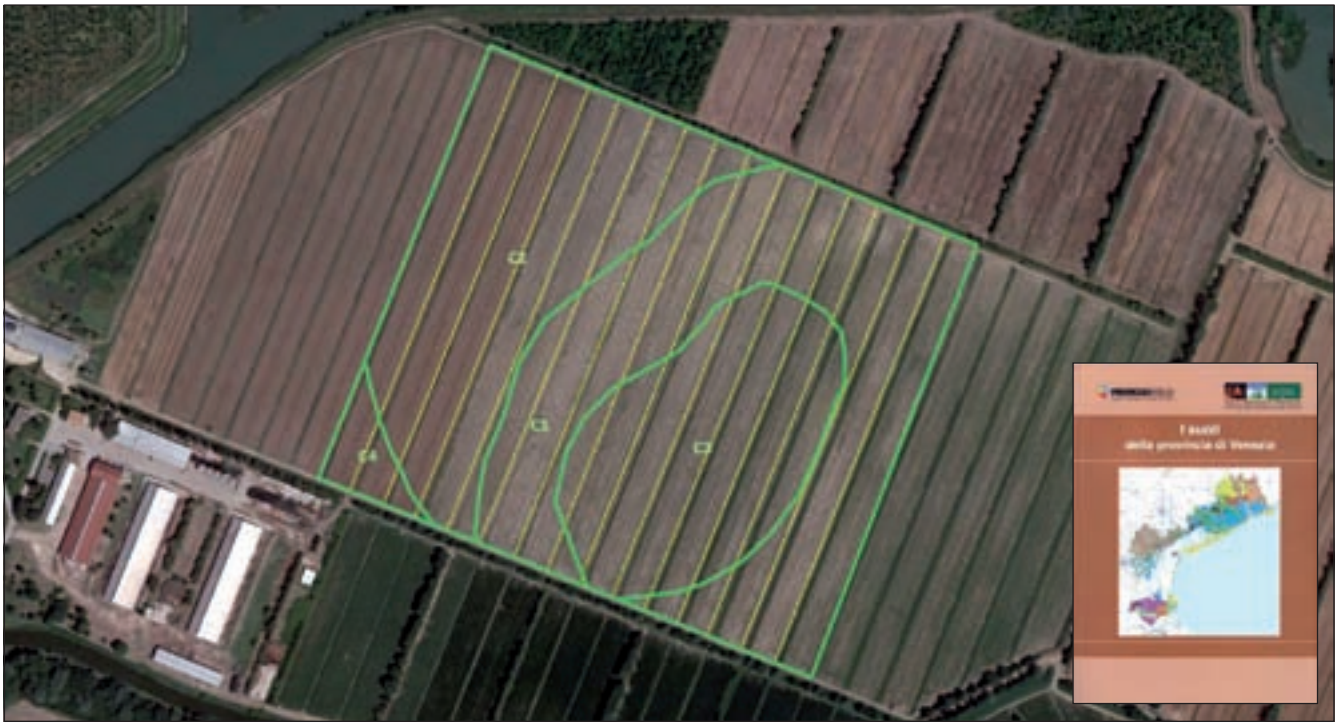
Pedological monitoring activities (ARPAV)

At the beginning of the project and at the end of each three-year experimental period, soil sampling is conducted at the same georeferenced positions for the main parameters potentially affected by agronomic practices.

- ❑ In 2018, soil characteristics were ascertained from 63 pedological samples and detailed maps were created for the two experimental sites;
- ❑ When the project started (2018), at the end of the first (2021) and of the second three-year period (2025): surface samples were taken at two georeferenced positions for each experimental plot and sample analysis (mainly on organic matter and nutrients) was conducted;

- From 2019, annual soil biological quality monitoring (QBS-ar) penetrometric tests were conducted to assess soil compaction (72 samples/year) and samples were taken for bulk density and soil moisture;
- Soil aggregate stability tests using the slake-test developed by the Soil Health Institute are planned at the same points (from 2025).

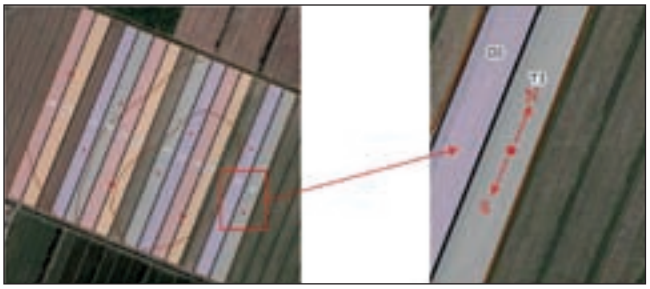
Detailed scale soil map of Sasse Rami experimental plots and framing in 1:50,000 scale soil map of Rovigo province. (ARPAV 2020 https://www.arpa.veneto.it/temi-ambientali/suolo/protezione/agroforcarb); (ARPAV 2018 https://www.arpa.veneto.it/temi-ambientali/suolo/conoscenza-dei-suoli/carte-1-50.000/rovigo).



Detailed scale soil map of Vallevecchia experimental plots and framing in 1:50,000 scale soil map of Venice province (ARPAV 2020 https://www.arpa.veneto.it/temi-ambientali/suolo/protezione/agroforcarb); (ARPAV 2008 https://www.arpa.veneto.it/temi-ambientali/suolo/conoscenza-dei-suoli/carte-1-50.000/carta-dei-suoli-della-provincia-di-venezia).

Planned analytical parameters:

- N, P, K, C org (on all samples);
- pH, EC1:2, Cu, Zn, nitrogen forms (on one sample per plot).



Example of sampling positions of different theses at Vallevecchia site and detail of sod collection mode for determination of soil biological quality through microarthropods (QBSar). *Photo Arpav*

Sampling of undisturbed clod for determination of soil biological quality by microarthropods (QBSar). *Photo Arpav*

Digestate sampling

Prior to distribution at each experimental site, digestate samples are taken annually from the storage trenches of each biogas plant, on which N and nitrogen forms, P, K, Cu, and Zn analyses are performed.
In order to obtain the primary sample, individual samples taken at various points in the solid digestate pile are mixed thoroughly so as to obtain a homogeneous mass from which samples are collected for laboratory analysis.

Images of digestate sampling at Brussa biogas plant, Caorle (VE); detail of heap storage of separated solid used as a soil amendment in Agroforcarb experimental site at Vallevecchia and sample collection for analysis. *Photo Arpav*

RESULTS

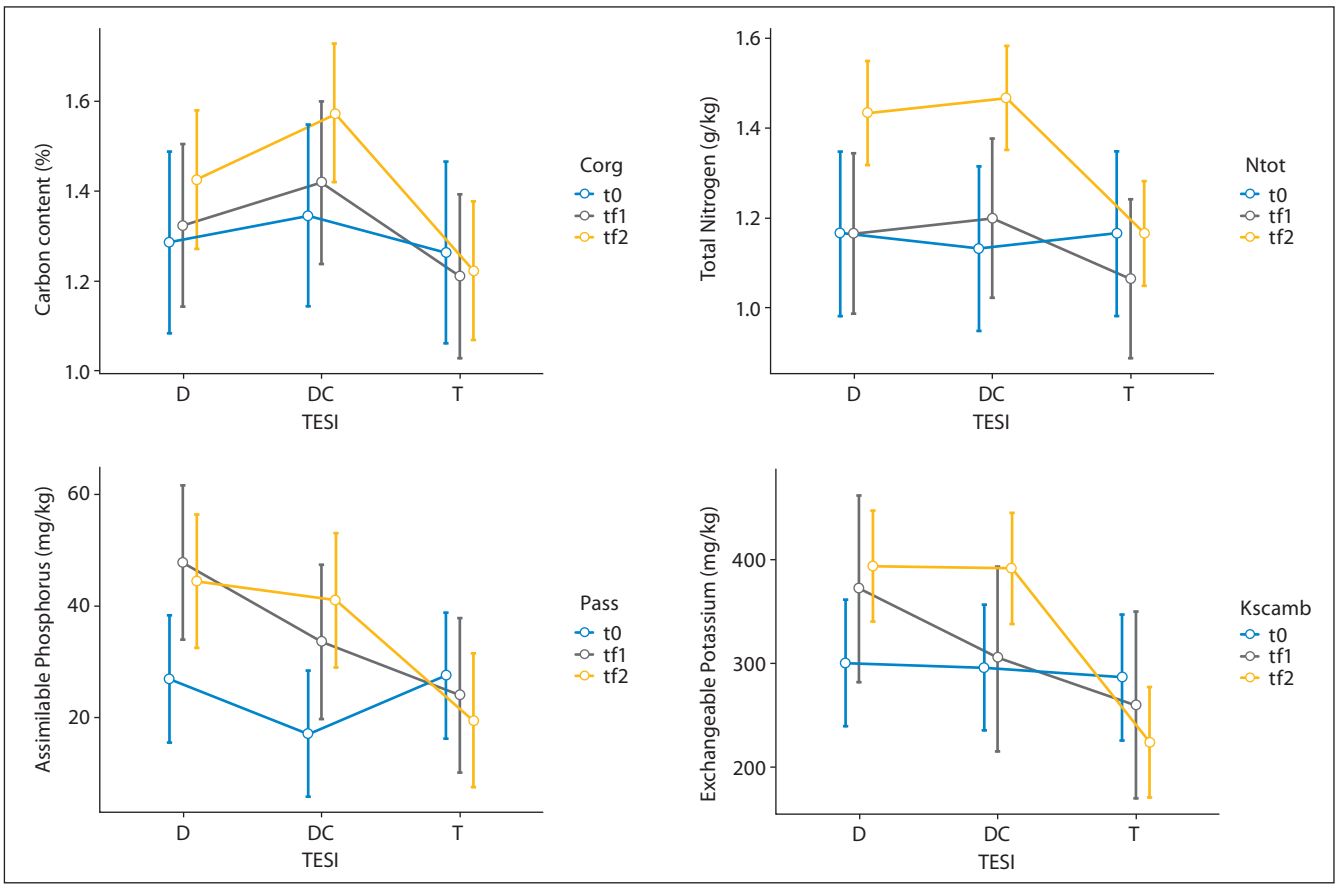
VALLEVECCHIA

Currently, only partial data are available because sampling is planned for 2025 at all 27 positions sampled at the beginning of the experiment (2018, t0) and in the interim period (2021, tf1). In 2024 (tf2), analyses were performed at only 12 points, together with sampling for soil biological quality.
Significant changes in the soil take a long time to be detected; however, after three years (tf1), the following trends were observed, in comparison to the control (T):

- for thesis D (Digestate): an increase in assimilable phosphorus and exchangeable potassium, slight increase in organic carbon;
- for thesis D+C (digestate and wood chips): increase in organic carbon, total nitrogen, assimilable phosphorus, small increase in potassium;
- no significant effect for bulk densities, Cu and Zn, and salinity.

After the second three-year period of experimentation (tf2), significant increases were observed in:

- organic carbon for digestate thesis (D) and even greater ones for digestate + wood chips thesis (D+C);
- total nitrogen for both theses compared to the control;
- assimilable phosphorus for the digestate + wood chips (D+C) thesis;
- exchangeable potassium for both theses but more evident for digestate + wood chips (D+C).

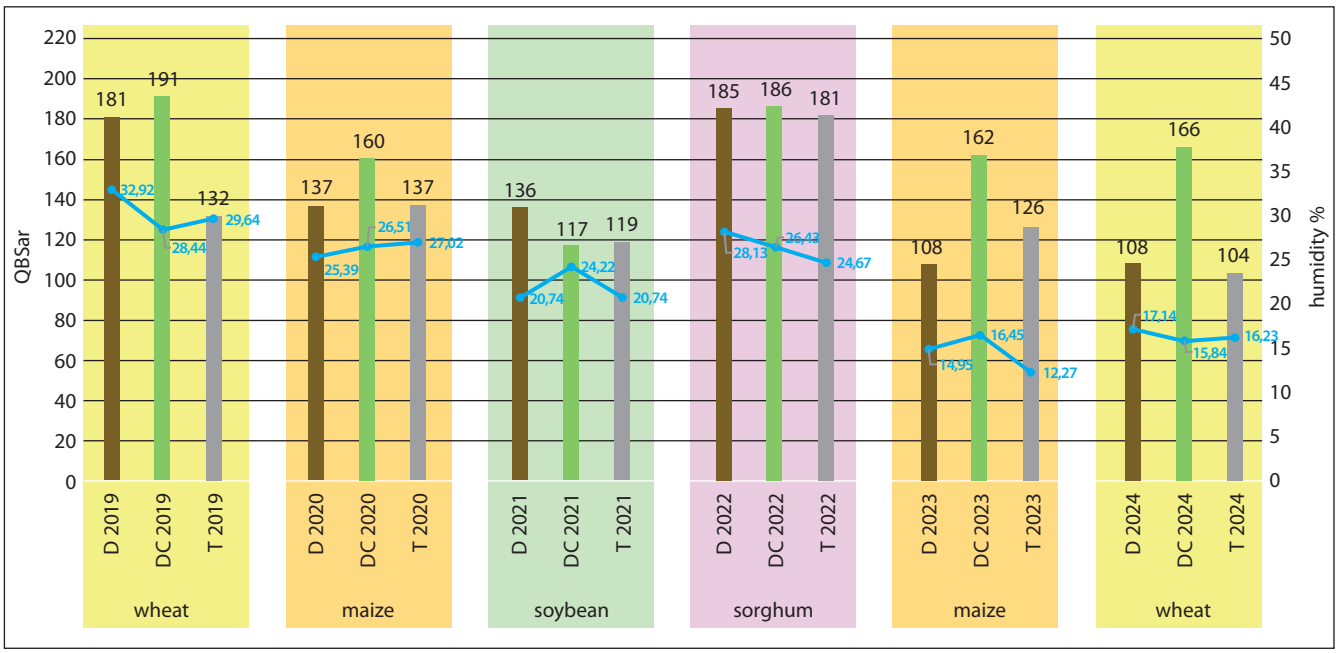


Organic Carbon content (%), Total Nitrogen (g/kg), Assimilable Phosphorus (mg/kg), and Exchangeable Potassium (mg/kg) of soils in different theses compared at Vallevecchia, in three periods (2018-t0, 2021-tf1, 2024-tf2).

Experimental results on soil biological quality (QBSar)

Theses treated with digestate and wood chips (D + C) show a consistently high QBSar index (except for 2021 for causes yet to be clarified), even in the driest years (2024 and especially 2023). Theses treated with digestate only and control theses are apparently influenced by soil moisture and show very similar values in most experimental years.

The Soil Biological Quality Index is influenced by many variables such as land use, moisture, cultivation practices and others, and the microarthropod response is much slower than the soil chemical response, thus needing more years of study.



QBSar index over six years of experimentation. In light blue, soil moisture (%) in the different theses at same time of sample collection.

SASSE RAMI

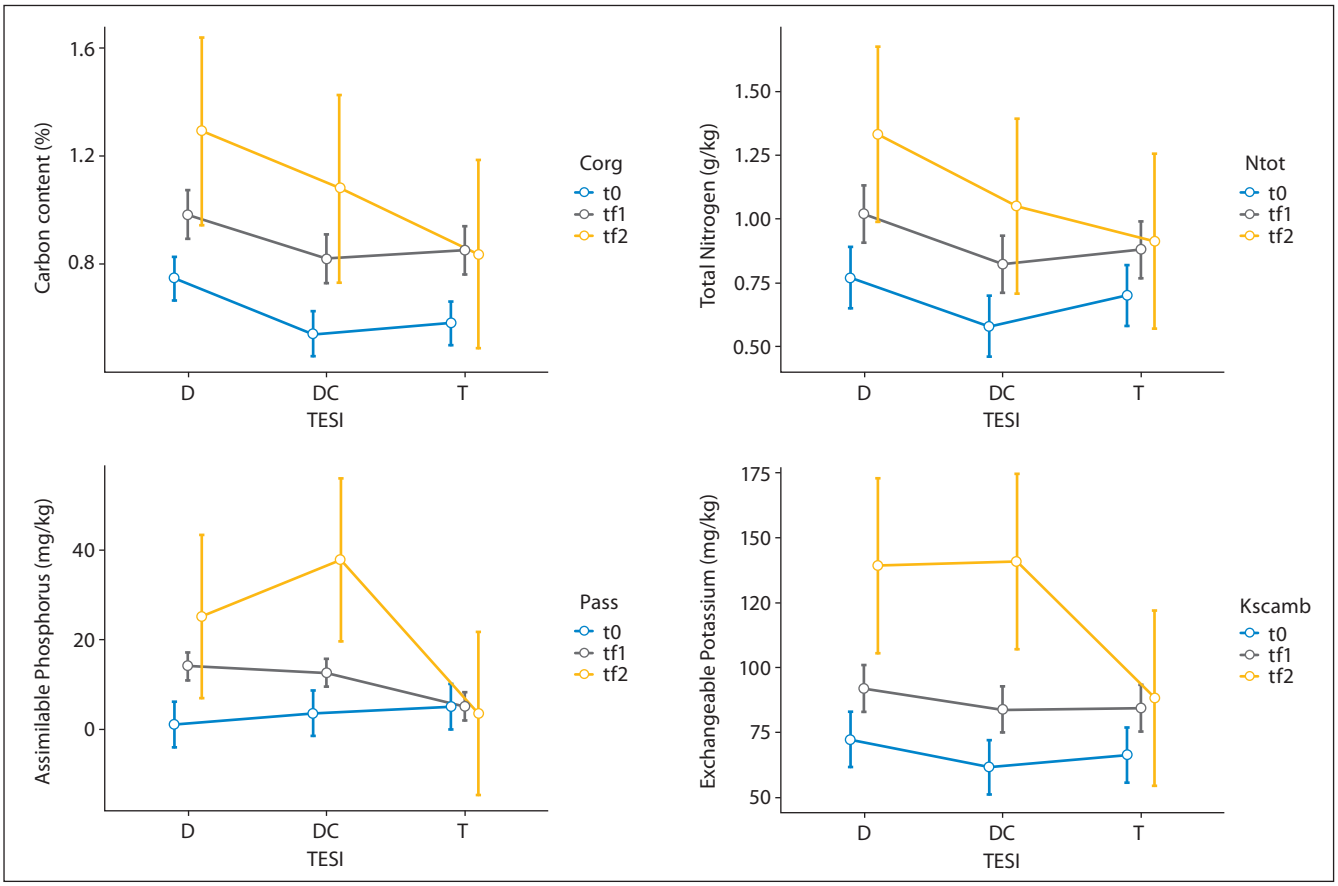
After three years of experimentation (tf1), the following was observed in comparison with the control (T):

- thesis D (Digestate): an increase in organic carbon, total nitrogen and assimilable phosphorus content;
- thesis D+C (digestate and wood chips): although to a lesser extent than digestate alone, an increase in organic carbon, total nitrogen, assimilable phosphorus and potassium;
- no significant effect for bulk densities, Cu and Zn, and salinity.

In these coarse soils, with poor initial organic matter content, an increase in organic carbon was also noted in the control soils as a result of conservation agronomic practices.

After the second three-year period of experimentation (tf2), significant increases were observed in:

- organic carbon for thesis with digestate only (D) and in joint digestate and wood chips thesis (D+C);
- total nitrogen for both treatments compared to the control;
- assimilable phosphorus for the digestate + wood chips (D + C) thesis, to a lesser extent for the digestate-only (D) thesis;
- exchangeable potassium for both theses (D+C and D).



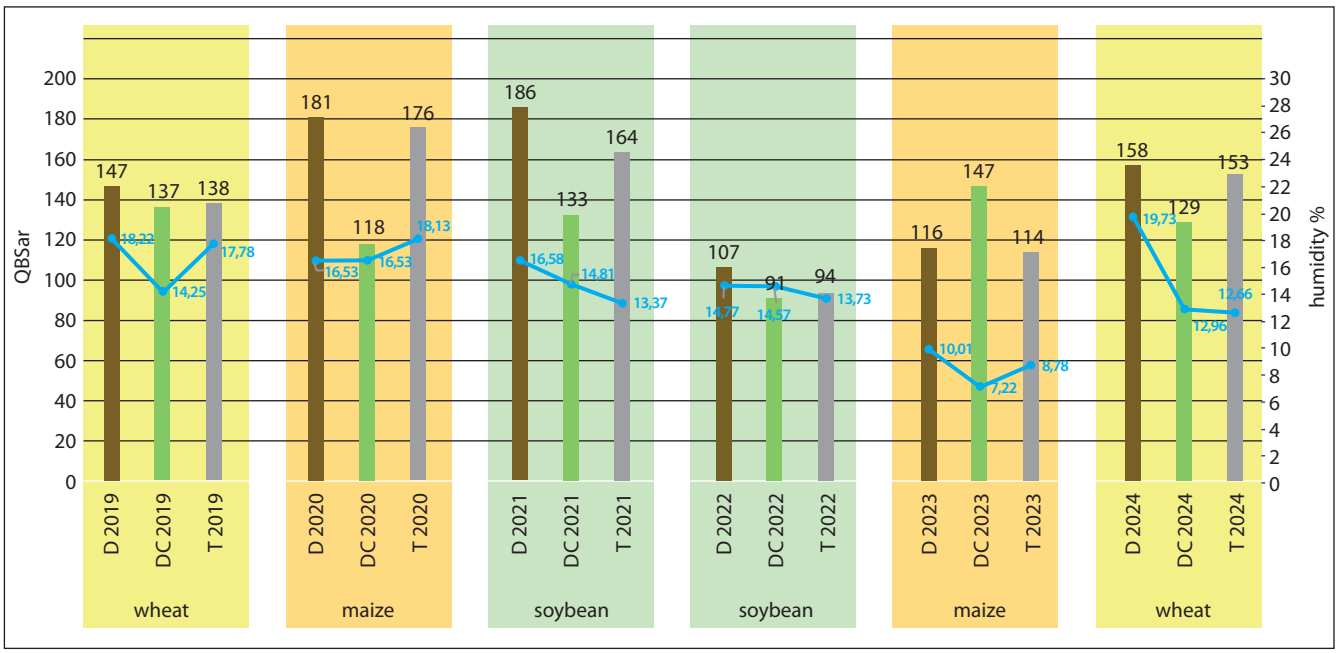
Organic Carbon content (%), Total Nitrogen (g/kg), Assimilable Phosphorus (mg/kg), and Exchangeable Potassium (mg/kg) of soils in different theses compared at SasseRami, in three periods (2018-t0, 2021-tf1, 2024-tf2).

Experimental results on soil biological quality (QBSar)

The QBSar index in the digestate thesis (D) appears to be higher in all years of the experiment than in the control (T) and woodchip digestate (D + C), the exception being the data collected in 2023.

The year 2023 was among the driest, thus leading to a decrease in the index in both the control and digestate theses, but not in the woodchip digestate thesis, which showed the highest value across the whole experiment.

As also mentioned above for the Vallevecchia site, the Soil Biological Quality index is influenced by many variables such as land use, moisture, cultivation practices plus others, and the response of microarthropods is much slower than the physical and chemical response of the soil, thus needing more years of study.



QBSar index over six years of experimentation. In light blue, soil moisture (%) in the different theses at same time of sample collection.