Interreg CENTRAL EUROPE

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MAURICE

Deliverable 2.3.1

D.2.3.1 - Adaptation measure field test and hydraulic and agricultural characterization of the pilot area

Version 1

02 2025

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Adaptation measure field test and hydraulic and agricultural characterization of the pilot area

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A. Introduction

This report describes the characterization activities, conceptual model and implementation of the adaptation measure carried out in the context of the Interreg project MAURICE for the Italian Pilot Action, located West from Milan. The Pilot Area is described in detail in the Deliverable 2.1.1. To provide some context also in this report, a map of the area is provided in Figure 1, showing the monitoring network and the area's peculiar physical characteristics, such as lowland springs and the extensive and capillary irrigation canals network.

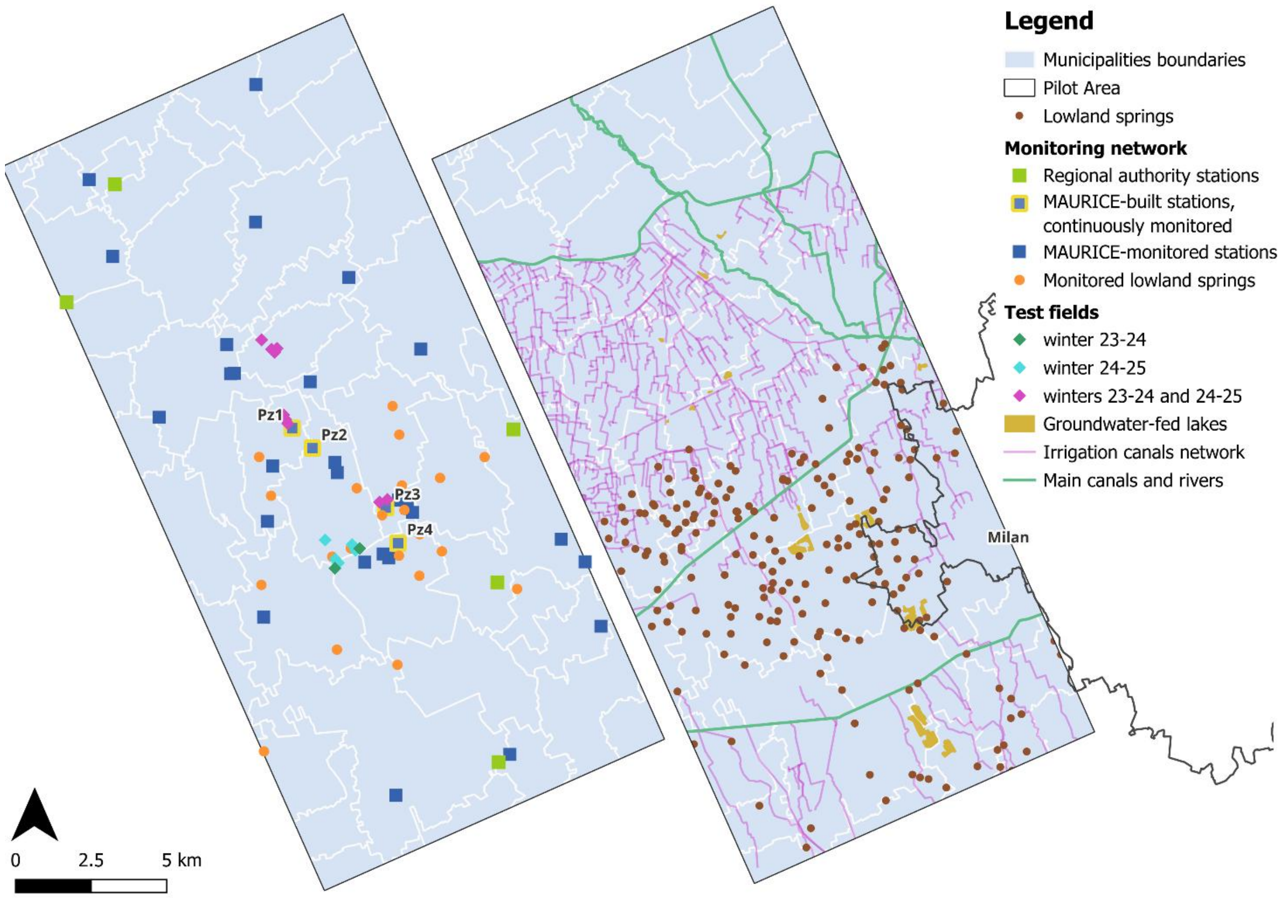


Figure 1 - Pilot Area visualization. On the left, the groundwater and lowland springs monitoring network is shown, on the right some physical characteristics of the area are represented

B. Characterization activities

Description

To be able to build the necessary agricultural and groundwater models, additional information on the Pilot Area characteristics was needed, especially on irrigation channels and lowland springs. To collect this information, a characterization activities plan has been defined over time, consisting in measures with infiltrometers, filling tests of channels, irrigation discharge measures and slug tests in available piezometers and wells. The list of activities, their investigated characteristics and the number and date of the tests were listed and explained in Deliverable 2.1.1. Due to technical issues, pumping tests were not possible to be performed in time for this Deliverable and have been thus substituted by slug tests, easier tests to obtain the same information, although less precise. The pumping tests are however planned for the next project's Period, and their results will be presented in Deliverable 2.1.2. In this chapter, the results of the characterization activities are reported and commented.

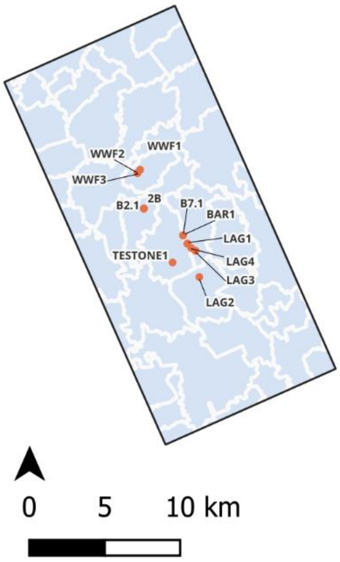
Results

Infiltrometer measurements

Infiltrometer measurements are field tests performed with an infiltrometer and two concentric steel rings, consisting in registering the time it takes for a column of water to infiltrate into the soil, then estimating the vertical hydraulic conductivity by fitting a time-water column height curve. In this project, the test was performed on canals' bed to retrieve their hydraulic conductivity and use it to estimate the canals' losses. The tests were carried out in some points in two different periods, to assess a change in the canals' behaviour before the summer irrigation period and after the winter irrigation, carried from December the 1st 2023 to January the 28th 2024.

The locations where the measurements have been performed are shown in **Errore. L'origine riferimento non è stata trovata.**. In Table 1, the measurements are listed. The hydraulic conductivity ranges between 5 10^5 and 1.9 10^6, a range typically observed for fine sands, silts or weathered clay soil. This is coherent with the canals bed's composition, since traditionally the canals bed is obtained adding layers of surrounding soils and clay to obtain a lower permeability. The average hydraulic conductivity of the canals' bed decreases of one order of magnitude considering the repeated measures for points LAG1, LAG3 and B2.1, varying from 3.65 10^5 to 4.6 10^6. This proves what the farmers already told: providing water on the channels during winter increases the canals efficiency, since it decreases its bed permeability, an effect they also observe during the summer irrigation period.

Table 1 - Infiltrometer tests results in terms of hydraulic conductivity (K). Latitude and longitude are in the WGS84 reference system. The locations of the tests are shown in the map on the left. Period: BI, before the traditional summer irrigation period, AWI: after the winter irrigation test period for 23/24 winter. Related to: fields related to the location of the test



Test id	Lat.	Lon.	K [m/s]	Date	Related to	Period
WWF1	45.5199811	8.976497	1.6E-05	28/03/2023	L4	BI
WWF2	45.518046	8.974264	2.1E-06	28/03/2023	L1, L2, L3	BI
WWF3	45.5180376	8.9742493	1.9E-05	28/03/2023	L1, L2, L3	BI
B7.1	45.481249	9.012741	1.1E-05	30/03/2023	SE1, SE2	BI
TESTONE1	45.465159	9.003893	1.2E-05	30/03/2023	SO1, SO2, SO7	BI
LAG1	45.476294	9.016357	9.3E-06	30/03/2023	SE1, SE2	BI
LAG2	45.456549	9.026436	3.3E-06	30/03/2023	-	BI
LAG3	45.472116	9.023148	4.8E-05	30/03/2023	SE1, SE2	BI
BAR1	45.481082	9.012725	2.3E-06	30/03/2023	SE1, SE2	BI
B2.1	45.497044	8.979643	5.0E-05	30/03/2023	N2, N3	BI
LAG1	45.476294	9.016357	3.1E-06	15/02/2024	SE1, SE2	AWI
LAG3	45.472116	9.023148	2.9E-06	15/02/2024	SE1, SE2	AWI
B2.1	45.497044	8.979643	7.8E-06	15/02/2024	N2, N3	AWI
LAG4	45.47373	9.01954	4.7E-06	05/03/2024	SE1, SE2	AWI
2B	45.497044	8.979643	1.9E-06	05/03/2024	N1, N2, N3	AWI

Discharge measurements

Discharge measurements have been measured in the locations shown in Figure 2 in two different contexts, irrigation canals and lowland springs. In the first, daily measurements were performed by Consorzio Est Ticino Villoresi at the weirs located at the derivations along the canal's course, to monitor the provided discharge to the experimentation fields of the proposed adaptation measure (explained in detail in chapter D. Implementation of the adaptation measure) and to the field irrigated during summer's irrigation season. While these measurements will be the topic of Deliverable 2.1.2, additional measures were undertaken using tracers and a magnetic-inductive flow velocity sensor (model OTT Nautilus) to assess the losses of the canals providing water to the experimentation fields. These are provided in Table 2, alongside the source of measurements, the fields served by the canals and the downstream canals. Some points present "Fontanile Laghetto" as a downstream canal, this is due to the spring's unused channel is now fed directly from the irrigation network to feed downstream fields, thus the canal does not have its own name but gets it from the lowland spring.

Analysing the collected data, it was possible to estimate the linear losses in the canals by subtracting to the starting discharge the ending discharge and dividing by the length of the canal. The losses and the operations needed to obtain them are provided in **Table 3**. As outlined in Table 2, IRR6 and IRR7 presented a derivation during the measuring campaigns. This derivation was estimated being equal to the 32.5% of the upstream discharge, and the percentage was used to assess the canals' losses also during the first measurement.

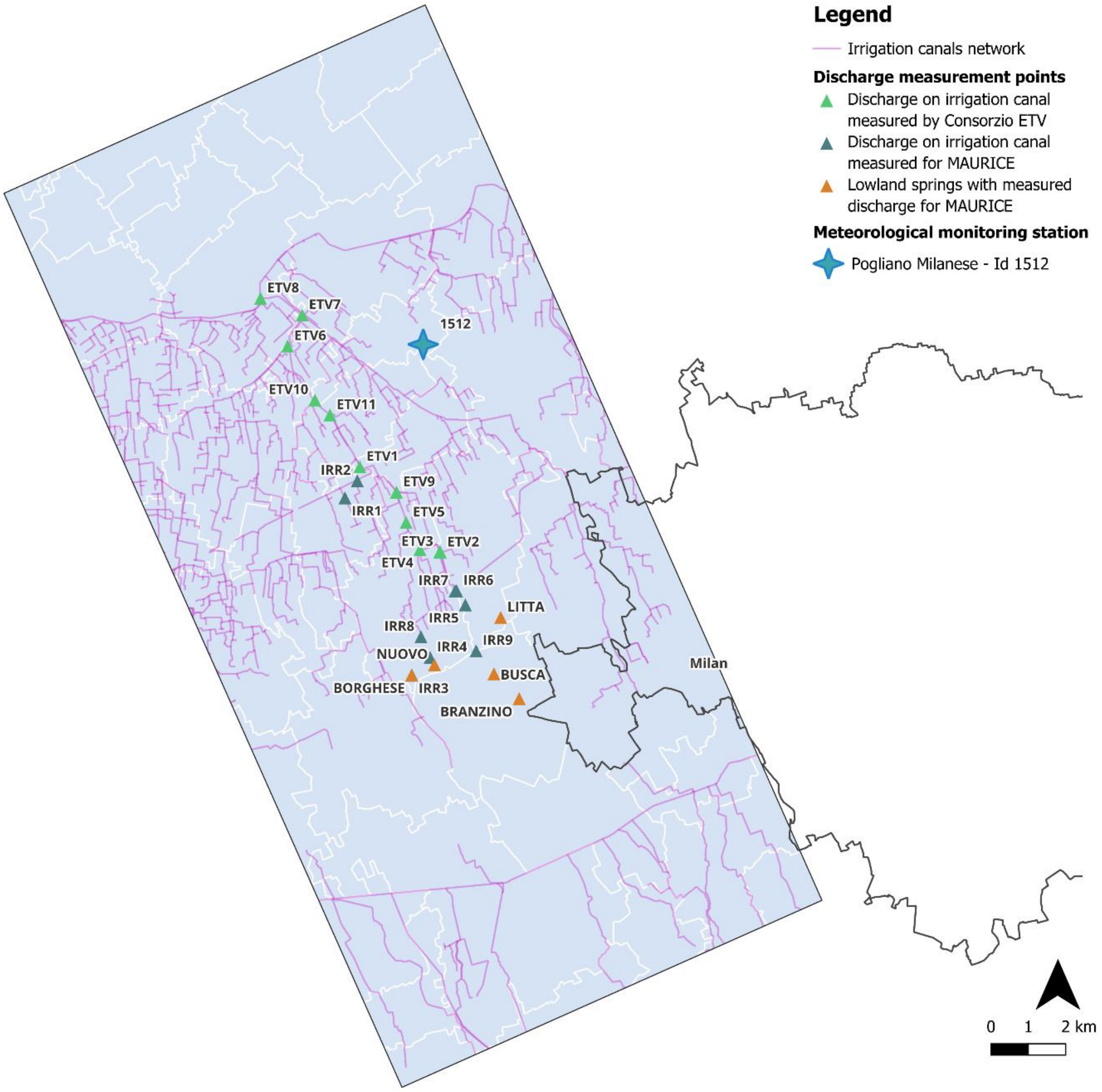


Figure 2 – Location of the discharge measurement points in the Pilot Area

Table 2 - Discharge measurements in Pilot Area's canals, with specified source of the data (m. means measurement), experimentation fields served by the canal and downstream canals and observation points

Date	Code	Discharge [l/s]	Source	Fields served	Downstream canal and observation point
22/12/2023	ETV2	358	ETV	SE1, SE2	7 Bareggio - Fontanile Laghetto - Quaternary canals (IRR5)
22/12/2023	IRR5 *	134	Flowmeter m.	SE1, SE2	Quaternary canals
22/12/2023	ETV1	324	ETV	N1, N2, N3	2 Bareggio - Quaternary canals (IRR2, IRR1)
22/12/2023	IRR2	277	Flowmeter m.	N1, N2, N3	2 Bareggio - Quaternary canals (IRR1)
22/12/2023	IRR1	244	Flowmeter m.	N1, N2, N3	Quaternary canals
19/01/2024	ETV5	216	ETV	SO1, SO2, SO7	6/A Bareggio - Fontanile Testone - Quaternary canals (IRR8, IRR4)
19/01/2024	IRR8	74	Flowmeter m.	SO1, SO2, SO7	Fontanile Testone - Quaternary canals (IRR4)
19/01/2024	IRR4	53	Flowmeter m.	SO1, SO2, SO7	Quaternary canals
19/01/2024	ETV2	319	ETV	SE1, SE2	7 Bareggio - Fontanile Laghetto - Quaternary canals (IRR7, IRR6, IRR5)
19/01/2024	IRR7	255	Tracers m.	SE1, SE2	Fontanile Testone - Quaternary canals
19/01/2024	IRR6 *	172	Tracers m.	SE1, SE2	Quaternary canals
19/01/2024	Derivation IRR6-IRR7 *	83	Tracers m.*		

* A derivation was present in both days, but the first one couldn't be measured. To assess the entity of the derivation, two measures were taken on the following campaign. The derivation was equal to the 32.5% with respect to the observed discharge at IRR7.

Table 3 - Linear canal losses related to experimentation fields

Fields	Distance (d) [m]	Distance between	Canal bed material	Linear loss [l/s/m]	Operation to obtain the loss
SE1, SE2	1818.5	ETV2 and IRR5	Compressed soil/Soil	0.123 [0.099]	(ETV2-IRR5)/d [(ETV2-IRR5*(1+0.325))/d]
N1, N2, N3	939.7	ETV1 and IRR2	Concrete	0.0499	(ETV1-IRR2)/d
N1, N2, N3	787.3	IRR2 and IRR1	Damaged concrete	0.0422	(IRR2-IRR1)/d
SO1, SO2, SO7	3870.0	ETV5 and IRR8	Concrete/Soil	0.0367	(ETV5-IRR8)/d
SO1, SO2, SO7	772.9	IRR8 and IRR4	Soil	0.0272	(IRR8-IRR4)/d
SE1, SE2	1234.0	ETV2 and IRR6	Compressed soil	0.1191 [32% derivation]	(ETV2-IRR6)/d

Discharge measures in lowland springs were both aimed at monitoring their behaviour in time and understand their behaviour in response to the implementation of the adaptation measure, as well as the normal summer's irrigation season. Along this, the water height inside the spring was monitored monthly for all the springs and hourly for 3 of them, and the data collected will be the presented and analysed in Deliverable 2.1.2. Discharge measures were performed using three different methods: tracers, a magnetic-inductive flowmeter (model OTT Nautilus) and a Thomson weir. The observations are listed in Table 4. A discrepancy between the measurements taken with tracers and the flowmeter was found, so the measurements with tracers were discontinued and the flowmeter method was selected as the preferred method.

A clear increase in the lowland springs' discharge can be noted during the summer irrigation period, when most of the Pilot Areas fields are irrigated. The discharges observed at the beginning and after some time of the implementation of the adaptation measure show an increase in the water withdrawn by the springs (Borghese 14/11/2024 – 04/02/2025), showing a connection between the measure proposed and an additional supply to these peculiar ecosystems.

In Table 4 the cumulative precipitation of the 7 days before the discharge measure is provided. From an in-depth analysis which is being carried out and will be presented in Deliverable 2.1.2, the water height (linked with the discharge) is significantly correlated with the cumulative precipitation occurred in the previous 7 days. For periods longer than this, the correlation decreases. By observing the relationship between discharge and precipitation (Figure 3), we can observe how it is not possible to derive a correlation between the two parameters. This could be related to the discharge measurements being taken at only a few moments in time, and also in different seasons. The irrigation season, in fact, plays a high role in the discharge of lowland springs, and this role is also subject to the monitoring results which will be reported in Deliverable 2.1.2.

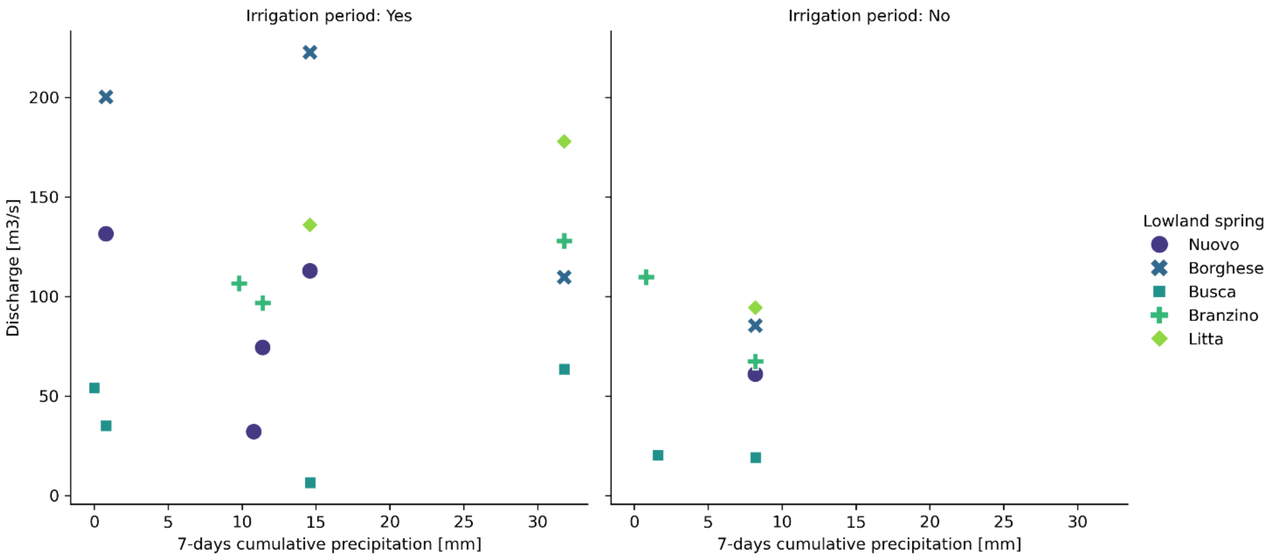


Figure 3 - Scatterplot of lowland springs' discharge and 7-days cumulative precipitation, distinguishing between measurements taken during inside and outside irrigation periods (for irrigation period are here considered both winter and summer irrigation periods, separated in Table 4)

Table 4 - Discharge measurements taken at lowland springs and 7-days cumulative precipitation (locations of discharge measuring points and meteorological station shown in Figure 2)

Date	Lowland spring	Discharge [l/s]	Discharge (tracers) [l/s]	Precipitation of the previous 7 days [mm]	Summer irrigation period	Winter irrigation period
19/01/2024	Nuovo	32.0	75.9	10.8	No	Yes
09/04/2024	Nuovo	60.9	53.4	8.2	No	No
14/11/2024	Nuovo	131.4		0.8	No	Yes
09/12/2024	Nuovo	74.3		11.4	No	Yes
04/02/2025	Nuovo	112.8		14.6	No	Yes
09/04/2024	Borghese	85.3		8.2	No	No
29/05/2024	Borghese	109.6		31.8	Yes	No
14/11/2024	Borghese	200.2		0.8	No	Yes
04/02/2025	Borghese	222.6		14.6	No	Yes
08/02/2024	Busca	20.3	23.0	1.6	No	No
09/04/2024	Busca	19.0		8.2	No	No
29/05/2024	Busca	63.4		31.8	Yes	No
31/07/2024	Busca	54.1		0	Yes	No
14/11/2024	Busca	35.1		0.8	No	Yes
04/02/2025	Busca	6.4		14.6	No	Yes
09/04/2024	Branzino	67.3		8.2	No	No
29/05/2024	Branzino	127.9		31.8	Yes	No
18/06/2024	Branzino	106.5		9.8	Yes	No
14/11/2024	Branzino	109.7		0.8	No	No
09/12/2024	Branzino	96.7		11.4	No	Yes
09/04/2024	Litta	94.3	66.1	8.2	No	No
29/05/2024	Litta	177.8		31.8	Yes	No

Slug tests

A slug test is a hydrogeological field test used to determine the hydraulic conductivity of an aquifer surrounding a well or piezometer. The slug test is particularly useful for obtaining quick, cost-effective estimates of aquifer properties without requiring extensive pumping tests. It involves a sudden change in water level within the well, either by adding (falling test) or removing (rising test) a known volume of a solid object (slug). The recovery of the water level over time is recorded by a datalogger and was in this case analysed with the AquiferWin software, using the Bouwer and Rice (1976) empirical relationship to estimate the hydraulic conductivity of the subsurface materials.

The slug tests were conducted in Pz1, Pz2, Pz3, and Pz4, shown in Figure , which are part of the project-funded network. Given the depth of the piezometers (20 m), the investigation focuses exclusively on the shallow aquifer. This aquifer, placed in an alluvial plain dominated by a fluvial sedimentary system, is composed of medium to coarse sediments, ranging from gravel to medium sands, with hydraulic conductivity values typically between 10^{-3} and 10^{-5} m/s. Sporadic and localized layers of finer sediments (silt-clay) are present, but they are limited in extent and thickness. The piezometers were selected because their stratigraphy is well-documented, they are easily accessible, and they fall within areas used for off-season irrigation. This strategic choice allows for a more accurate dataset of the aquifer's hydraulic properties, which will be essential for the implementation of the numerical flow model.

The data obtained from the slug tests were analysed using the Bouwer-Rice approach set based on the piezometer's configuration and aquifer characteristics. In Figure 4, the couple of rising and falling tests for Pz1 is shown, with their interpretation in the Bouwer & Rice diagram. The calculated hydraulic conductivity values for each test location are summarized in Table 5. Three slug tests were performed for each piezometer, interpreting both the falling and rising curves, resulting in a total of six interpretations per piezometers. The results indicate a slight variability in hydraulic conductivity across the test locations, suggesting minor differences in the composition and permeability of the subsurface materials. Considering all the estimated values, Pz3 exhibits the highest average hydraulic conductivity (2.49×10^{-4} m/s), followed by Pz2 (2.28×10^{-4} m/s), Pz4 (1.97×10^{-4} m/s), and Pz1 (9.00×10^{-5} m/s), which shows the lowest values. These and other processed results are shown in Table 6. The slightly higher values observed in Pz3 and Pz2 may indicate a presence of coarser sediments or slightly better pore connectivity, whereas Pz1, with the lowest K values, could suggest a relatively finer-grained sediment composition.

In all piezometers, the average hydraulic conductivity of the rising tests (K Up) is higher than that of the falling tests (K Down). The difference between K Up and K Down ranges from 3×10^{-6} m/s in Pz2 (where the values are nearly identical) to 5.3×10^{-5} m/s in Pz1 (the most pronounced difference). This trend suggests that the aquifer may exhibit slight anisotropy or differences in pore structure response between water level rise and fall. By analysing the stratigraphies of all four piezometers, it is observed that Pz1 exhibits a substantial layer of sand and gravel from 9 meters to 20 meters, unlike the other piezometers which primarily show gravel and sand, hence a higher amount of gravel, characterized by higher hydraulic conductivities. This characteristic may explain the varying but limited differences in hydraulic conductivity between Pz2, Pz3, and Pz4 compared to Pz1.

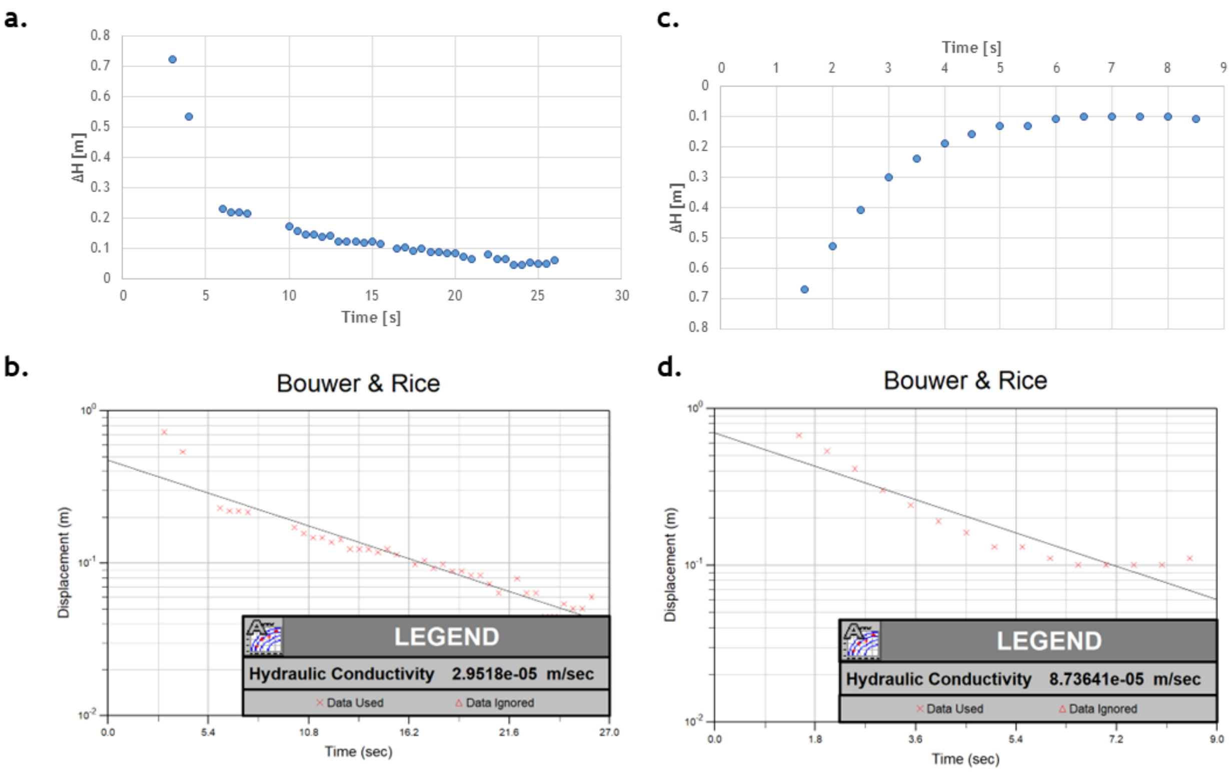


Figure 4 – Head variation observations in Pz1 during the (a) rising and (c) falling tests, and their interpretation through the Bouwer & Rice diagram (b for rising, d for falling).

Table 5 - Results of the slug tests. For each point, the test (composed of rising and falling parts) was repeated three times, and for each time two K where estimated: associated with the rising (up) and one associated with the falling (dwn).

Pz1	K [m/s]	Pz2	K [m/s]	Pz3	K [m/s]	Pz4	K [m/s]
a_dwn	2.95E-05	a_dwn	2.06E-04	a_dwn	1.60E-04	a_dwn	3.41E-04
a_up	8.74E-05	a_up	2.17E-04	a_up	1.09E-04	a_up	2.87E-04
b_dwn	4.07E-05	b_dwn	2.44E-04	b_dwn	2.26E-04	b_dwn	1.23E-04
b_up	1.04E-04	b_up	2.68E-04	b_up	2.33E-04	b_up	1.12E-04
c_dwn	1.20E-04	c_dwn	2.44E-04	c_dwn	3.06E-04	c_dwn	1.17E-04
c_up	1.57E-04	c_up	1.90E-04	c_up	4.59E-04	c_up	2.05E-04

Table 6 – Processed results of the slug tests. K Up and K Down represents the hydraulic conductivities obtained from a rising test and a falling test, respectively.

	Mean K [m/s]	Min K [m/s]	Max K [m/s]	Range K [m/s]	Mean K Up [m/s]	Mean K Down [m/s]
Pz1	8.97E-05	2.95E-05	1.57E-04	1.28E-04	1.16E-04	6.34e-05
Pz2	2.28E-04	1.90E-04	2.68E-04	7.8E-05	2.25E-04	2.31E-04
Pz3	2.49E-04	1.09E-04	4.59E-04	3.50E-04	2.67E-04	2.31E-04
Pz4	1.97E-04	1.12E-04	3.41E-04	2.29E-04	2.01E-04	1.94E-04

Agricultural characterizationIn the project area, approximately 45% of the soil is used for urban purposes, while the remaining 55% is dedicated to agriculture. Given the considerable presence of agriculture in the area and the significant percolation flows resulting from irrigation practice, the IdrAgra model was selected to estimate groundwater recharge. This model simulates plant growth and performs a daily hydrological balance considering as input meteorological data, land use, soil hydraulic properties and irrigation methods while reproducing the irrigation management practices implemented by farmers.

The model operates in different modes. In the initial phase, simulations were carried out using the “need” mode, which allows to estimate the net irrigation requirements of the plants at the field level and, by the aggregation of the requirement of all the field, to estimate the water availability needed at the source. This procedure made it possible to compare the estimated water requirements at the inlet of the sub-districts with the measured series, to assess the fulfilment of irrigation requirements and thus to highlight any differences in water transport efficiencies between the sub-districts within the domain. In these simulations, the area was divided into three unit based on different water resource management strategies:

- North of Villoresi
- ETV
- Navigli

The first unit is part of the ETV district concerning land reclamation but is not served by the irrigation network. Therefore, irrigation is provided via wells combined with high-efficiency irrigation methods, in order to simulate the farmers' intention to minimize pumping costs.

In the ETV area, the Consortium provides an irrigation service from 1 April to 30 September, following a seven-day rotation. For this area, the simulation assumed that water would be available for individual fields once a week.

In the area served by the Naviglio Grande, management is not directly controlled by the Consortium but by the users, and detailed information about the irrigation methods is not available. The main crop in this area is rice, traditionally irrigated by flooding. Therefore, flooding irrigation was assumed for rice, while flow irrigation was simulated for other crops.

As a result of these initial simulations, significant variability in efficiencies was observed across the sub-districts. This is being taken into account in the current project phase, which involves using the model in “consumption” mode. For this, the model requires input flow series in addition to the previously mentioned inputs. In these simulations, the ETV area was subdivided into eighty irrigation unit, identified as area for which daily input flow rates were reconstructed using data provided by the Consortium. For North of Villoresi and Navigli areas available information do not allows the implementation of the model in “consumption” mode.

To implement the model, it was necessary to collect spatialised data from regional databases and from the dialogue with the Consotium and the farmers. Urban areas have been classified into different categories based on the degree of surface sealing sourced from the DUSAF database, a regional map providing five categories based on the extent of impermeable surfaces. Each of these categories was assigned a percentage of sealed surfaces, based on the study by Piccioli (2022), with adjustments made as needed to reflect the specific characteristics of the area.

Regarding agricultural land use, the SIARL database was used, a 20 x 20 m map that identifies 21 different classes. The dominant crops in this area are corn, fodder crops, and rice, which together cover about 50% of the agricultural land. Through discussion with farmers involved in the project, we obtained more detailed information on the experimental fields, including sowing and harvesting dates. Figure 5 presents the spatial distribution of land use in the study area and the boundaries of the Bareggio irrigation sub-district, where the fields where winter irrigation is practised are located. The position of the experimental fields and the crop successions practised on them for the years 2023 and 2024 are shown in detail. The successions turn out to be representative of those of the whole domain, reflecting the most common patterns adopted in the area.

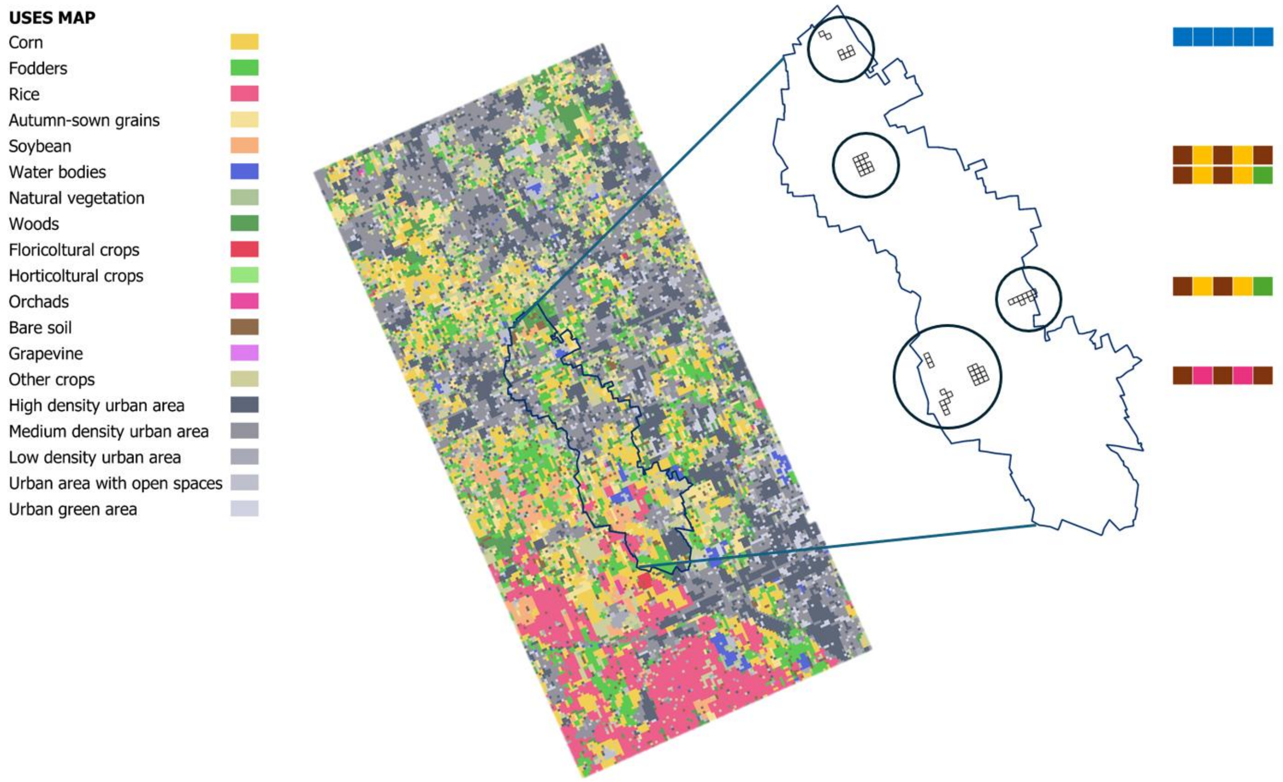


Figure 5 - Spatial distribution of simulated land use. The detail shows the irrigation sub-district including the experimental fields, Bareggio, their location, and the cropping sequences followed in the four areas highlighted with a circle for the years 2023–2024

From the dialogue with the Consotium, information about local irrigation management and irrigation practices have been collected. According to local agricultural practices, corn and rice are always irrigated, while fodder crops are managed differently depending on the planting year and water availability. Irrigation of rice plots depends mainly on the irrigation sub-district in which they are located: where water is subject to rotation, most farmers practice a dry sowing and irrigate with the flow method. In the sub-districts served by the Naviglio Grande, where water is not managed directly by the Consortium but by the users, the traditional method of continuous flooding is often used.

Concerning irrigation network, information regarding the path of the channels and the type of lining, where known, was provided by the Consortium. In addition, flow measurements conducted on the canals, reported in Table 1Table 2, were crucial for the characterization of individual irrigation sub-districts.

Soil characteristics and their spatial distribution were derived from LOSAN database and from the pedological map of ERSAF Lombardia. The hydraulic characterisation of the soils was done by applying the pedotransfer functions of Rawls and Brakensiek (1989).

Processes simulated by the model will be detailed in Deliverable 2.1.2.

C. Conceptual model

The Pilot Area has been schematized in a conceptual model proposed in Figure 6. The scheme is subdivided into five main blocks: 1. Atmospherical variability; 2. Regional-to-local irrigation system managed by Consorzio Est Ticino Villoresi (ETV); 3. Aquifer system between river Ticino and Milan; 4. Agricultural system in Consorzio ETV-managed network; 5. Field scale agricultural and groundwater system.

The “blocks” communicate through water flows: for example, precipitation from the atmosphere influences the irrigation system, the aquifer recharge and the green water supply for the agricultural system. The water then flows in each one of these divisions, with different behaviours depending on the considered system. For example, the aquifer system has inward flows towards the unconfined and confined aquifer through recharge from precipitation, irrigation and surface water, as well as outward flows through extractions, drainage and surface water uptake.

The agricultural and irrigation system is managed in this project by the means of IdrAgra, a software able to consider the needed parameters to represent and simulate these systems. Then, the aquifer system is managed by a model developed in MODFLOW, a code which integrates the drivers and parameters needed to represent aquifers and their recharge. Combined, these two approaches can represent both the dynamics at the study area level and at field level. As outlined in this report, at field level other factors need to be considered other than the general characterization of the area, such as lowland springs and localized extractions. The framework developed in this project through this conceptual model is able to consider both regional and local drivers, thus providing a sound structure to evaluate the adaptation measure proposed.

In this context, climate change poses interrogatives on the water availability as it propagates through variation in frequency and intensity of precipitation, alongside increase in temperature, meaning a change in the regimes of blue and green water for irrigation and increased evapotranspiration from crops. Climate change is thus included in the scheme, as its effects can influence both the system and the adaptation measure efficacy in the area.

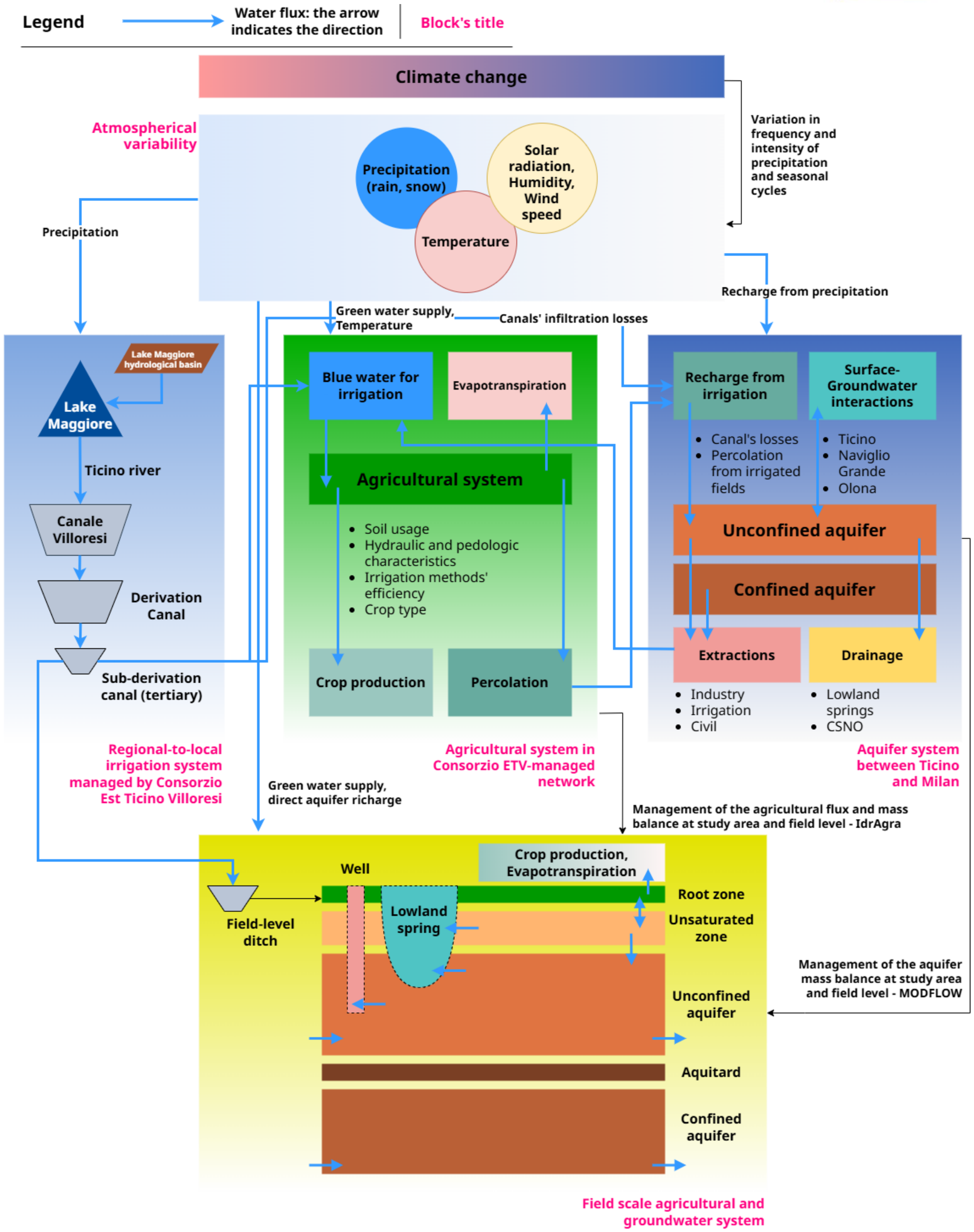


Figure 6 – Scheme of the study area's conceptual model, highlighting water flows. The model is subdivided into five main blocks: 1. Atmospherical variability; 2. Regional-to-local irrigation system managed by Consorzio Est Ticino Villoresi (ETV); 3. Aquifer system between river Ticino and Milan; 4. Agricultural system in Consorzio ETV-managed network; 5. Field scale agricultural and groundwater system.

D. Implementation of the adaptation measure

The Italian Pilot Action revolves around the test of a climate change adaptation measure harnessing the link between surface water, irrigation and groundwater in the Milan area. The proposed implementation measure follows this idea by providing water to selected fields during autumn and winter (seasons of historically high availability of water in the region) as a source of additional recharge for the underlying aquifer. This recharge translates to an additional volume of water stored in the aquifer, which can then be used as an emergency source for irrigation in cases of drought, which will likely experience an increase in frequency and intensity in the future (IPCC, 2021). The aquifer can thus be seen as a “buffer” natural reservoir, capable of retaining the additional storage long enough to be used in case of emergency and, at the same time, not needing additional infrastructure to be built, avoiding landscape impacts and high investments. The existing canals’ network, in fact, covers the area extensively, with capillary canals deriving from main ones serving most fields in the region. Consorzio Est Ticino Villoresi, partner of the MAURICE project, manages the broadest of the many irrigation consortia in the area. Thanks to their collaboration, three farmers located in the Pilot Area were involved in the project to test the measure on their fields. In Figure 7, the location of the selected fields is shown. A total of approximately 33 ha of fields is thus included in the experimentation.

Over the 2023/2024 and 2024/2025 winters, water was provided in these fields, with the discharges and schedules reported in Table 7, for a total of 1.2 m^3/s provided in 23/24 and 1.3 m^3/s provided in 24/25. To be able to monitor the adaptation measure’s implementation, four groundwater levels monitoring points were built close to the main irrigation areas and hydrogeologically downstream (Figure 7), to catch the effect in the aquifer of the additional recharge provided during the tests.

The expected outcomes include an increase in the groundwater level in the fields’ area, meaning both an increase in the water stored in the aquifer and an increased availability for lowland springs’ discharges, limiting their depletion during winter and spring months. The tests’ results will be reported in Deliverable 2.1.2, commenting the monitoring data.

The observed data are then used to build, train and run two numerical models, one representing the agricultural and irrigation system and one representing the aquifer system, to simulate different possible configuration of the adaptation solution (e.g. more fields, a different distribution of the fields, multiple years of implementation of the measure), also under different climate change scenarios. As schematized in Figure 6, climate change can propagate in the studied context in the form of variations in frequency and intensity of precipitation and seasonal cycles. Including them in the simulation can thus help understanding if the proposed adaptation measure can be sustainable in a changing context.

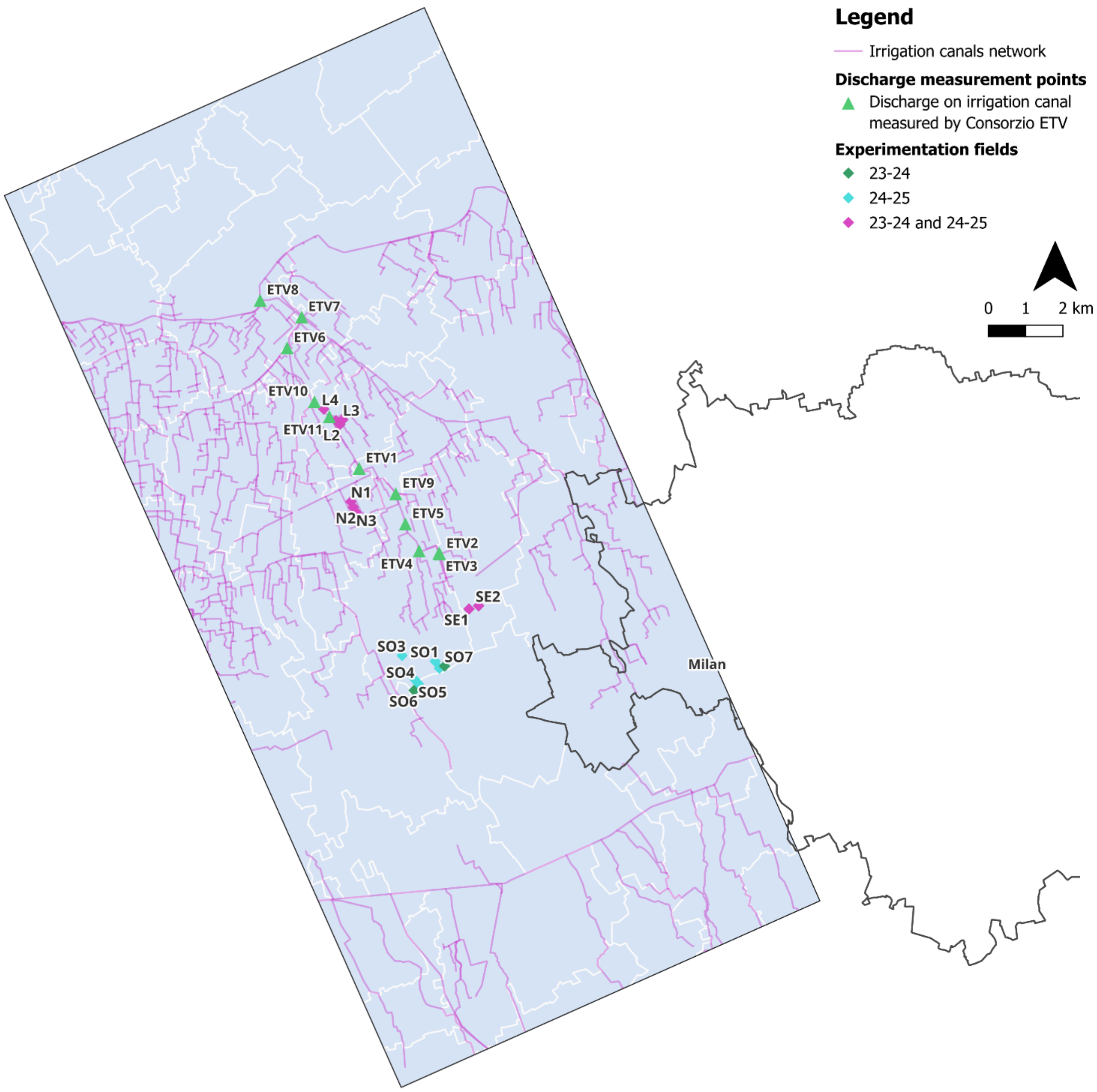


Figure 7 – Experimentation fields locations and discharge measurement points monitored by Consorzio ETV

Table 7 - Irrigation registry of discharges provided to the experimentation fields. The measuring stations' locations and fields' locations are shown in Figure 7

Winter season	Start of irrigation	End of irrigation	Supplying canal's id	Field code	Mean discharge* [l/s]	Measuring station
23-24	01/12/2023	29/01/2024	3bis Bareggio	SO6	77	ETV9
23-24	01/12/2023	29/01/2024	6/6a Bareggio	SO7	185	ETV5
23-24	01/12/2023	29/01/2024	2 Bareggio	N1, N2, N3	324	ETV1
23-24	13/12/2023 09:00	16/12/2023 09:00	7 Bareggio	SE2	345	ETV2
23-24	16/12/2023 09:00	18/12/2023 09:00	7 Bareggio	SE1	345	ETV2
23-24	18/12/2023 09:00	21/12/2023 09:00	7 Bareggio	SE2	345	ETV2
23-24	22/12/2023 09:00	08/01/2024 09:00	7 Bareggio	SE1, SE2	345	ETV2
23-24	08/01/2024 09:00	10/01/2024 17:00	7 Bareggio	SE2	345	ETV2
23-24	10/01/2024 17:00	12/01/2024 16:00	7 Bareggio	SE1	345	ETV2
23-24	15/01/2024 10:00	17/01/2024 17:00	7 Bareggio	SE2	345	ETV2
23-24	18/01/2024 10:00	20/01/2024 10:00	7 Bareggio	SE1	345	ETV2
23-24	10/10/2023	22/10/2023	Bocca Cantoni	L4	50	ETV10
23-24	06/11/2023	19/11/2023	Bocca Cantoni	L4	50	ETV10
23-24	01/12/2023	14/01/2024	Bocca Cantoni	L4	50	ETV10
23-24	22/01/2024	28/01/2024	Bocca Cantoni	L4	50	ETV10
23-24	10/10/2023	29/10/2023	1 Valdarenne	L1, L2, L3	200	ETV11
23-24	06/11/2023	19/11/2023	1 Valdarenne	L1, L2, L3	200	ETV11
23-24	01/12/2023	14/01/2024	1 Valdarenne	L1, L2, L3	200	ETV11
23-24	22/01/2024	28/01/2024	1 Valdarenne	L1, L2, L3	200	ETV11
24-25	10/11/2024	10/12/2024	3bis Bareggio	SO3, SO4, SO5	77	ETV9
24-25	28/12/2024	10/01/2025	3bis Bareggio	SO3, SO4, SO5	77	ETV9
24-25	10/11/2024	10/12/2024	6/6a Bareggio	SO1, SO2	178	ETV5
24-25	28/12/2024	10/01/2025	6/6a Bareggio	SO1, SO2	178	ETV5
24-25	24/11/2024	17/12/2024	7 Bareggio	SE1, SE2	251.5	ETV2
24-25	17/12/2024	20/02/2025	7 Bareggio	SE1, SE2	251.5	ETV2
24-25	16/10/2024	20/02/2025	2 Bareggio	N2	307.35	ETV1
24-25	16/10/2024	20/02/2025	Bocca Cantoni	L4	50	ETV10
24-25	16/10/2024	20/02/2025	1 Valdarenne	L1, L2, L3	200	ETV11

*The discharge is provided without removing the losses estimated in Table 3

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