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MEDWATERICE

ENVIRONMENTAL, ECONOMIC AND SOCIAL SUSTAINABILITY OF ALTERNATE WETTING AND DRYING RICE IRRIGATION IN NORTHERN ITALY

Authors

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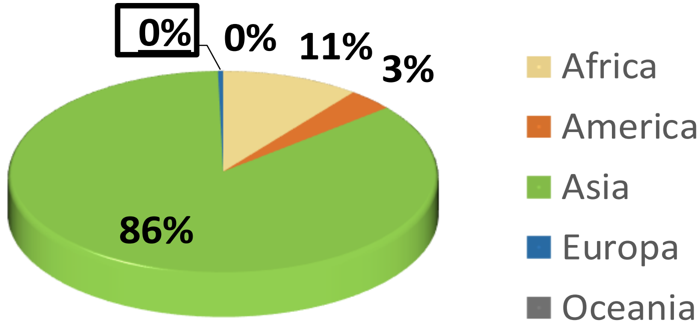
Towards a sustainable water use in Mediterranean rice-based agro-ecosystems

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

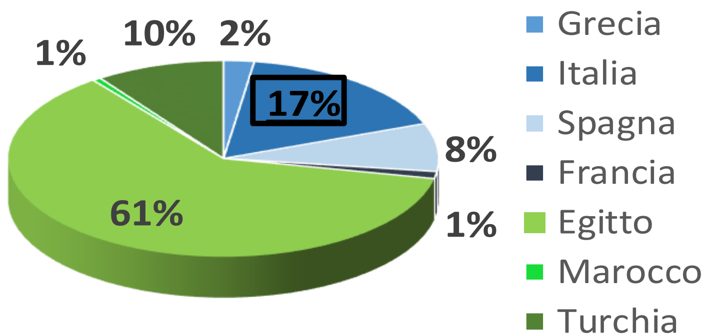
Rice in the World, in the Mediterranean Basin and in Europe

World



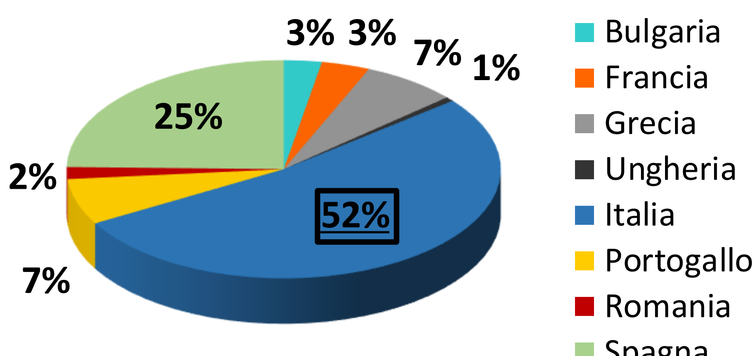
162 milion ha
755 milion tons
(FAOSTAT, 2019)

Mediterranean Basin



1,3 milion ha
10.3 milion tons
(FAOSTAT, 2019)

Europe



420.000 ha
2.8 milion tons
(FAOSTAT, 2019)

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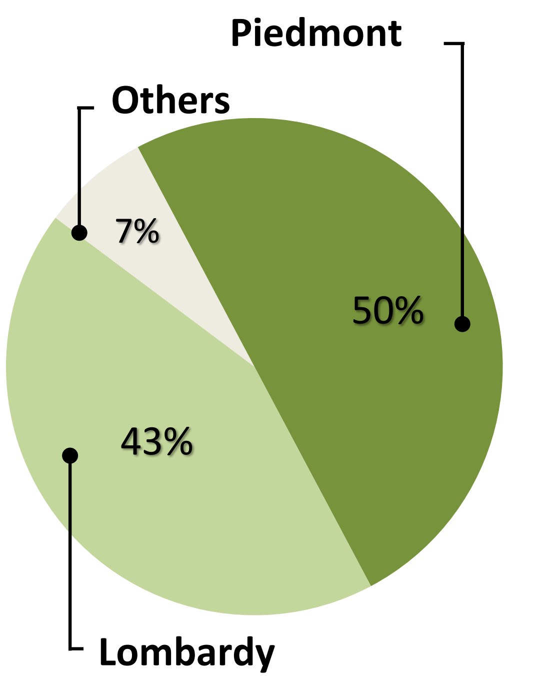
Rice in Italy

220.030 ha

(FAOSTAT, 2019)

1.5 milion tons

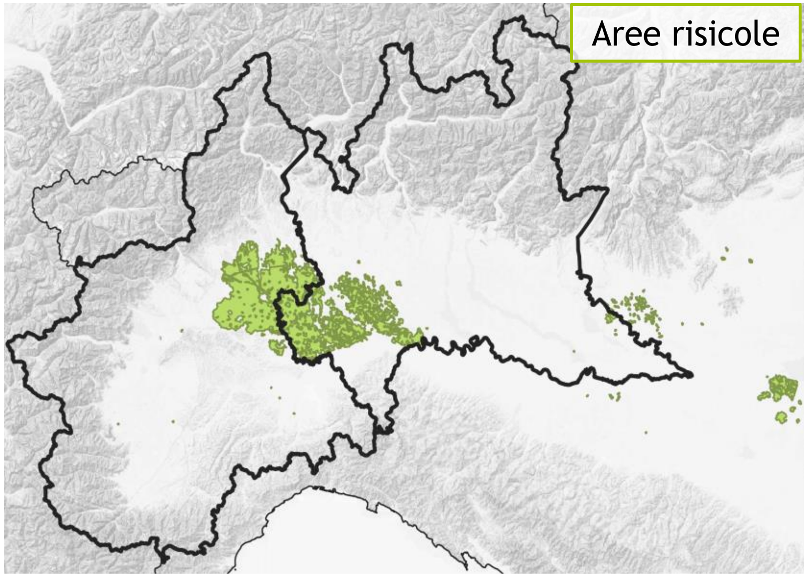
(FAOSTAT, 2019)



(ENR, 2018)

"Water saving" irrigation techniques for rice in Italy

- In Italy, almost the total rice production is concentrated in a large paddy rice area between Lombardy and Piedmont regions (north-western part of the country).
In this area irrigation of rice has been traditionally carried out by wet seeding and continuous flooding (**WFL**),
which requires a huge volume of water, since fields are flooded from before sowing to a few weeks before harvest.



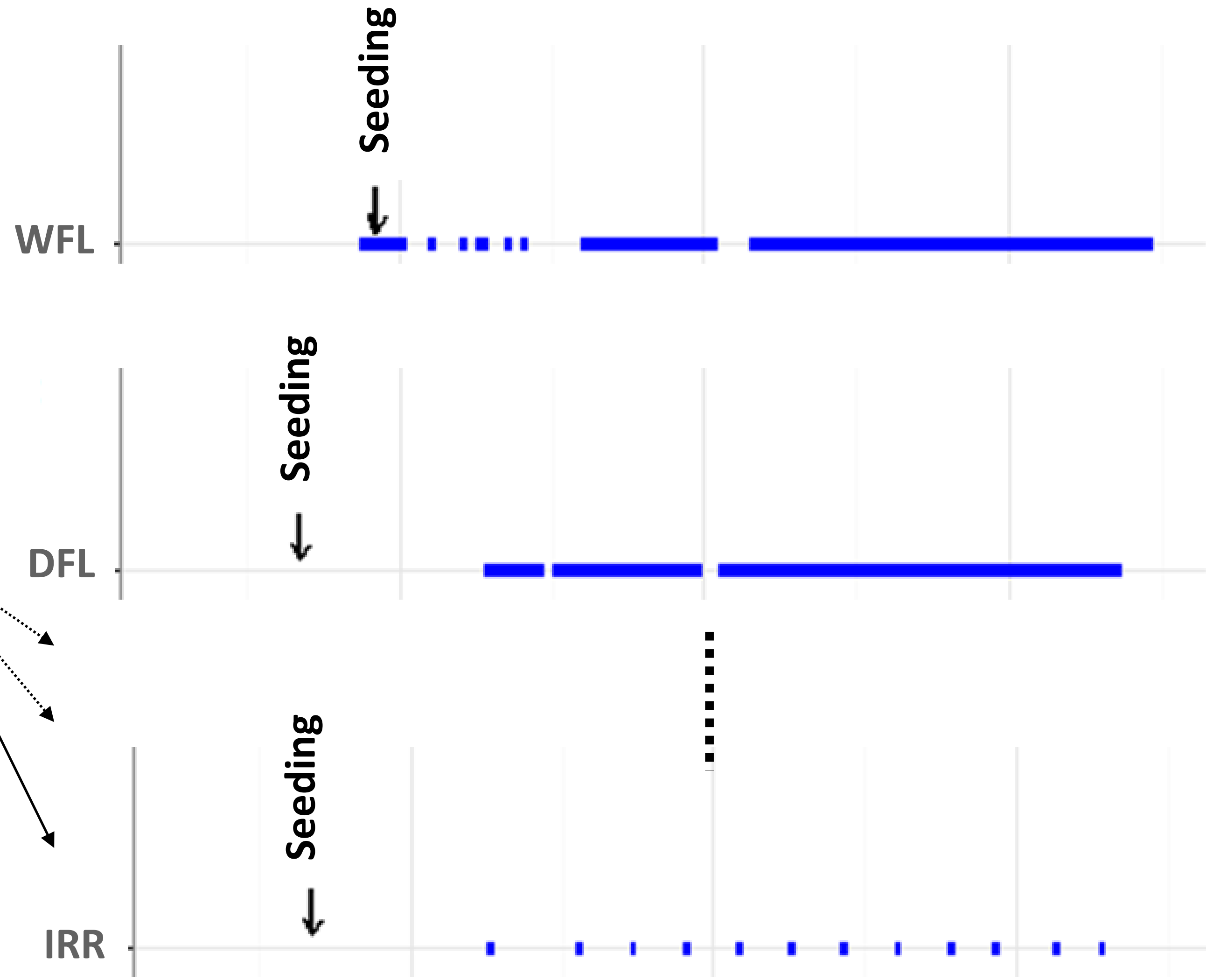
- In recent years, the interest in the adoption of "water saving" techniques has increased, due to a decreased water availability in many areas and to an increased competition between water uses.
In particular: dry seeding and delay flooding (**DFL**) and dry seeding and intermittent irrigation (**IRR**) have been introduced.

- When adopting a new irrigation technique, advantages and disadvantages in terms of:
i) water saving,
ii) yield,
iii) environmental impacts,
must be assessed.

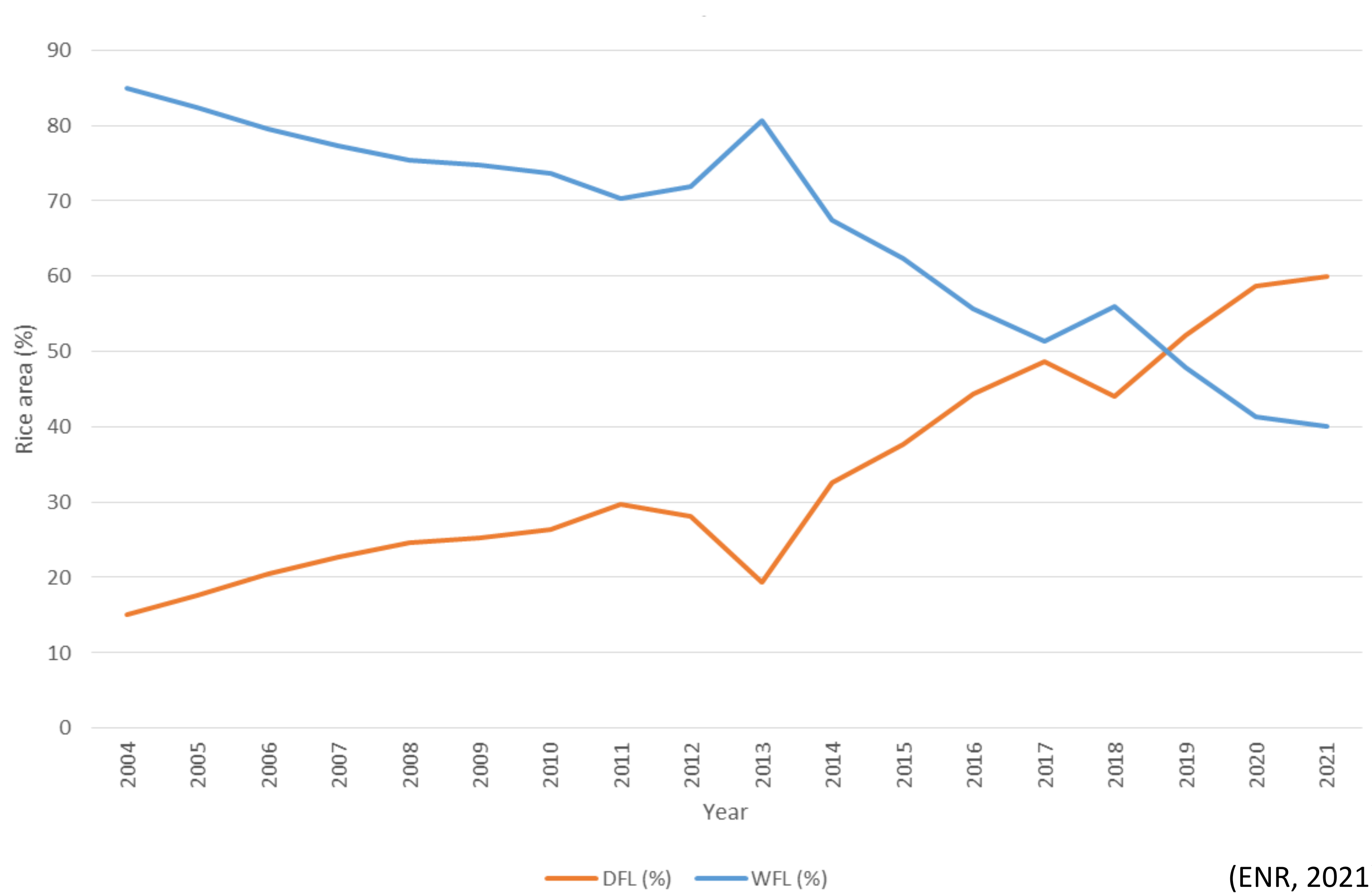
Rice irrigation techniques widespread in Northern Italy

Water seeding and continuous flooding (WFL)

Dry seeding followed by different irrigation options, from:
delayed flooding starting from the 3°/4° leaf stage (DFL),
to:
aerobic rice under intermittent irrigation (IRR)



In northern Italy water seeding is being replaced by dry seeding



(ENR, 2021)

The conversion to dry-seeding is taking place, not everywhere with the same speed, throughout the Lombardy-Piedmont rice area.

AWD - Alternate Wetting and Drying rice irrigation

- AWD is an intermittent irrigation technique that involves alternating dry periods with periods of flooding during the rice cropping cycle. Depending on how long the single dry period is prolonged between one flooding and another (and consequently, on how much the soil water content drops below the saturation), AWD is classified as "safe" or more "severe".

- It is important to set the threshold in term of soil water status at which the dry period must be stopped. Soil water status is usually monitored inside the paddy through hydraulic tensiometers or field water tubes.

Hydraulic tensiometer

- The water tube is a practical way to implement AWD, since it can be self-made. It is a perforated plastic tube having a length of 30-40 cm and a diameter of 10–20 cm, which allows the measurement of the water level “hidden” below the ground surface.

Field water tube

AWD –Alternate Wetting and Drying rice irrigation

- AWD is largely applied in Southeast Asia, China, India, and Japan. It has also been successfully adopted in temperate areas, such as California and Arkansas (USA). It shows advantages in terms of: i) water saving; ii) reduction of GHG emissions; iii) increase in nitrogen use efficiency; and iv) decrease of Arsenic in rice grain.

- The first steps towards the AWD practice in the Mediterranean basin have been moved in the context of the MEDWATERICE project (PRIMA-Section2, 2018).

OBJECTIVES OF THE STUDY

- **As a new rice irrigation technique in Italy, AWD was tested in the context of the MEDWATERICE project in an experimental platform in northern Italy (CRR-ENR, Castello D'Agogna, PV) for years 2019 and 2020. Data collected were used to assess the overall sustainability of rice production under AWD in northern Italy.**

- **Results in term of water saving obtained in the experimental platform are being extrapolated at the irrigation district scale (San Giorgio di Lomellina district, PV) through a semi-distributed agro-hydrological model.**

Field-scale experimental site for AWD (Castello D'Agogna, PV)

In Italy, AWD was tested at the Rice Research Centre of the ENTE NAZIONALE RISI experimental farm (Castello d'Agogna, PV), in the core of the Italian rice area.

In the 2019 and 2020 agricultural seasons the experimentation was conducted in six plots of about 20 m x 70 m each, with two replicates for each of the **three** following **water irrigation techniques**:

1) *Water seeded rice and continuous flooding* (**WFL**);

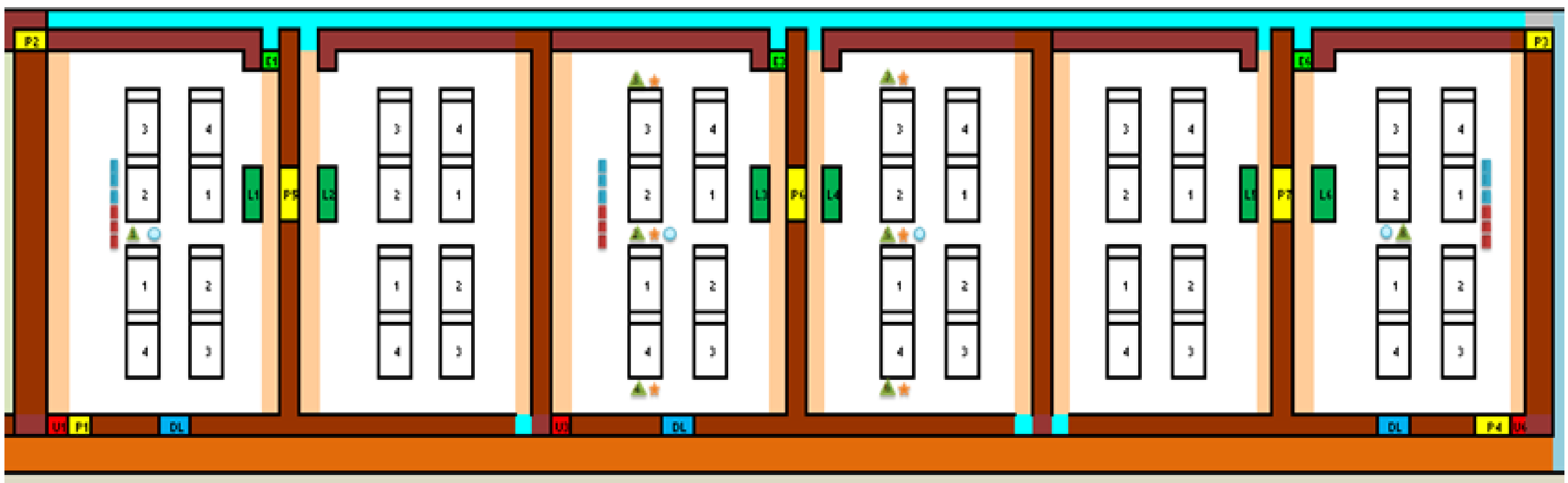
2) *Dry-seeded rice followed by a delayed continuous flooding* from around the 3-leaf stage (**DFL**);

3) *Water seeded rice followed by an Alternate Wetting and Drying* regime from the tillering stage (**AWD**); a "safe" AWD was in particular implemented (soil water status threshold: water level at – 10 cm from the seeding bed observed in water tubes, corresponding to a soil water potential of – 30 hPa measured through tensiometers).

Field-scale experimental site for AWD (Castello D’Agogna, PV)

Experimental setup 2020 (the same design was adopted in 2019, but the position of the WFL and AWD plots in the platform was exchanged)

WFL		AWD		DFL	
FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5	FIELD 6
WATER SEEDING-FLOODING	WATER SEEDING-FLOODING	WATER SEEDING-FLOODING	WATER SEEDING-FLOODING	DRY SEEDING-FLOODING 3-4 LEAF	DRY SEEDING-FLOODING 3-4 LEAF
SIRTAKI (CLOMAZONE) 0,5 L/ha	SIRTAKI (CLOMAZONE) 0,5 L/ha	SIRTAKI (CLOMAZONE) 0,5 L/ha	SIRTAKI (CLOMAZONE) 0,5 L/ha	SIRTAKI (CLOMAZONE) 0,5 L/ha	SIRTAKI (CLOMAZONE) 0,5 L/ha
TRIPIONE E (MCPA) 1 L/ha	TRIPIONE E (MCPA) 1 L/ha	TRIPIONE E (MCPA) 1 L/ha	TRIPIONE E (MCPA) 1 L/ha	TRIPIONE E (MCPA) 1 L/ha	TRIPIONE E (MCPA) 1 L/ha
40-30-30	40-30-30	40-30-30	40-30-30	0-70-30	0-70-30



Sub-plots	
1	0 N
2	100 N
3	160 N
4	160 N NO FUNGICIDE

P1	PIEZOMETRIC WELLS
E1	FLOW METER AT INLET
U1	FLOW METER AT OUTLET
L1	WATER LEVEL SENSOR
DL	DATA LOGGER

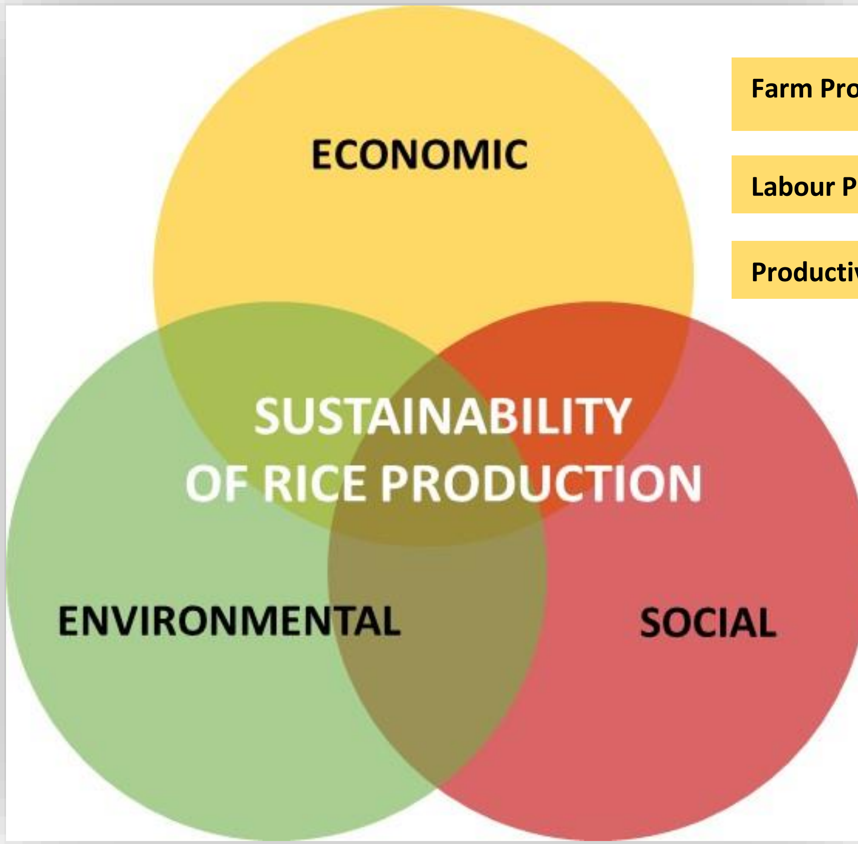
- POROUS CUPS AT 20 CM
- POROUS CUPS AT 70 CM
- FIELD WATER TUBES
- pH and Mv ELECTRODES
- TENSIOMETERS

Field-scale experimental site for AWD (Castello D'Agogna, PV)
MONITORING ACTIVITIES

- Measurement of water balance terms: one out of the two plots irrigated with the same irrigation technique was instrumented with water inflow and outflow meters, water level sensors, tensiometers, water tubes, piezometers.
- A soil survey was conducted before the agricultural season (through an EMI sensor and physico-chemical analysis of collected soil samples).
- Periodic measurements of crop biometric parameters (LAI, crop height, crop rooting depth) were carried out.
- Rice grain yield, rice grain and straw nitrogen uptake, and Arsenic and Cadmium rice grain contents were analyzed.

Indicators for the sustainability assessment of rice production under different irrigation strategies developed in the MEDWATERICE project

- Water Productivity
- Relative Water Supply
- Energy Productivity
- Nutrient (N, P, K) Use Efficiency
- Environmental Potential Risk Indicator for Pesticide
- Percolation To Groundwater
- Greenhouses Gas Emission
- Food Safety



- Farm Profitability (Net income)
- Labour Productivity
- Productivity (Grain yield)
- Social Acceptability of new irrigation technologies/techniques

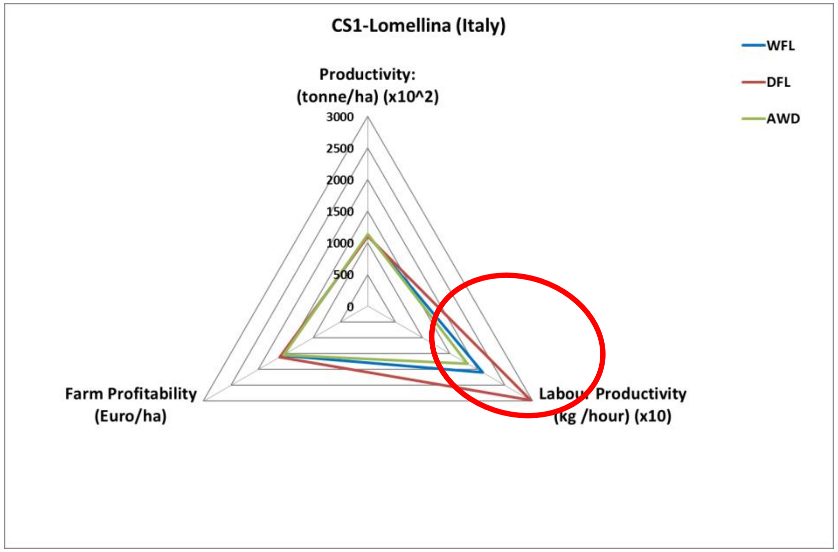
Data needed for the calculation of indicators (and not directly collected in the experiment platform) were obtained through questionnaires and interviews (to researchers, technicians and farmers).

Results: Water balance terms 2019 and 2020

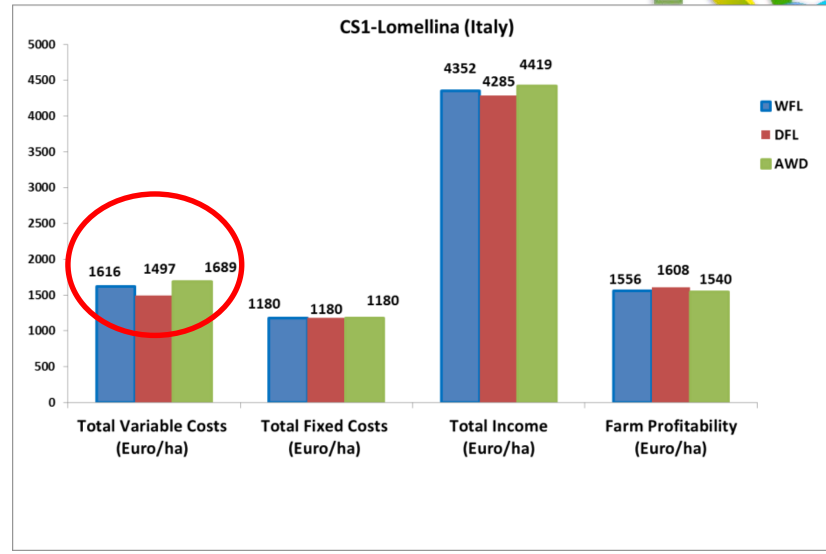
2019	WFL	DFL	AWD
Rainfall (R, mm)	185	200	185
Net surface irrigation (Q_{IN}-Q_{OUT}, mm)	2404	2099	2135
Evapotranspiration (ETc, mm)	654	635	653
Residual term (SP, mm)	1934	1673	1663
Relative Water Supply RWSE (-)	3.96	3.62	3.55
Water productivity (kg/m^3)	0.43	0.48	0.49
Water saving (% compared to WFL)	-	**12.7%**	**11.2%**

2020	WFL	DFL	AWD
Rainfall (R, mm)	357	375	357
Net surface irrigation (Q_{IN}-Q_{OUT}, mm)	2546	2158	1806
Evapotranspiration (ETc, mm)	674	652	659
Residual term (SP, mm)	2167	1815	1474
Relative Water Supply RWSE (-)	4.31	3.88	3.28
Water productivity (kg/m^3)	0.34	0.36	0.47
Water saving (% compared to WFL)	-	**15.2%**	**29.1%**

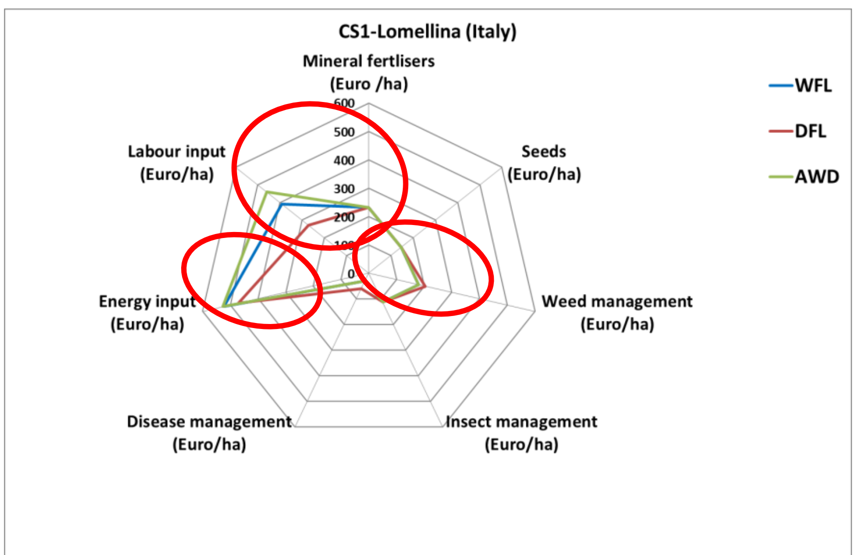
RESULTS: Economic and environmental indicators 2019



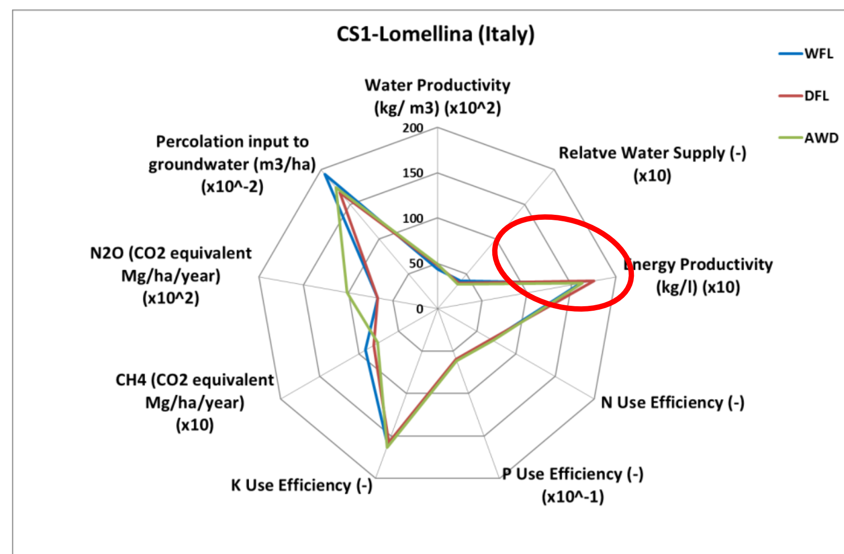
Economic indicators 2019



Farm economic balance components 2019



Variable costs 2019



Environmental indicators 2019

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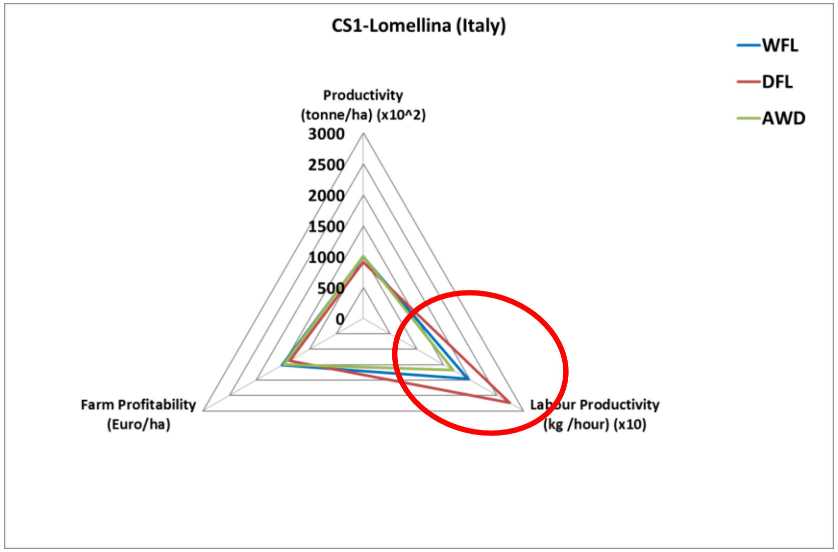
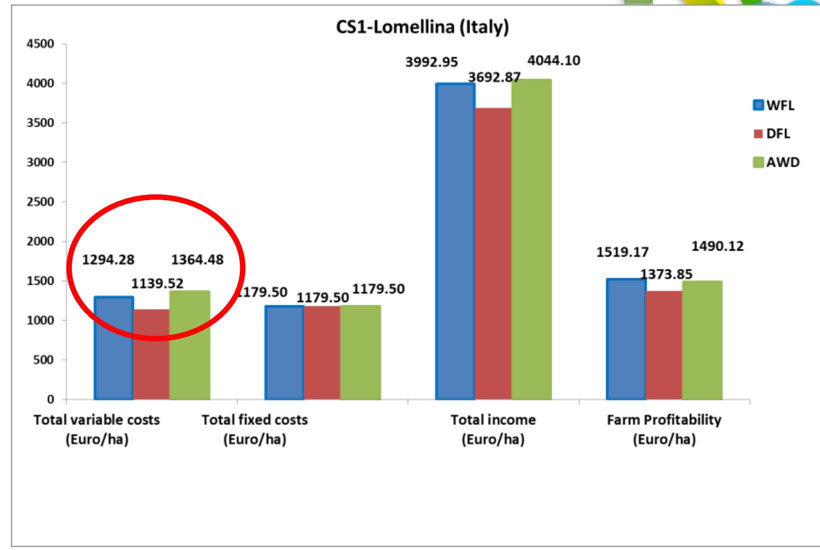
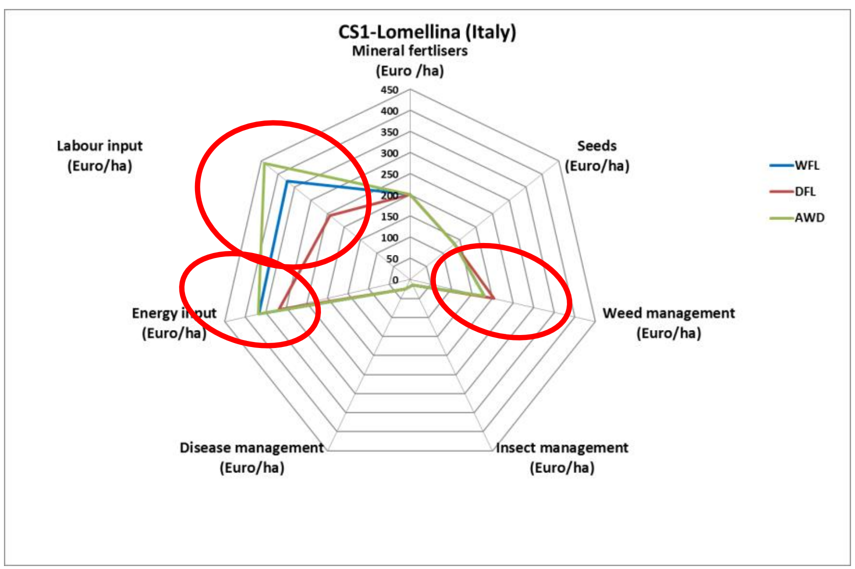
RESULTS: Economic and environmental indicators 2020



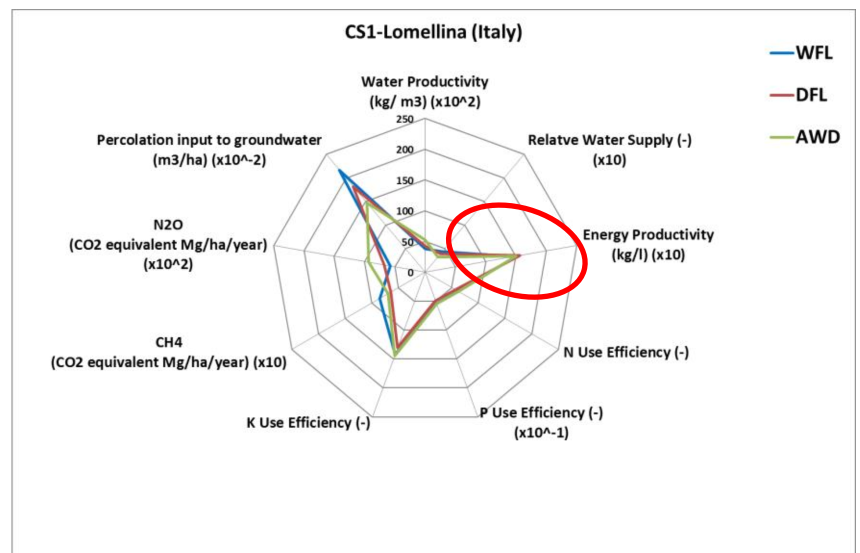
Economic indicators 2020



Farm economic balance components 2020



Variable costs 2020



Environmental indicators 2020

RESULTS: Social Acceptability of AWD

The social acceptability of AWD was evaluated considering a theoretical approach based on the Technology Acceptance Model (TAM) (Davis 1989).

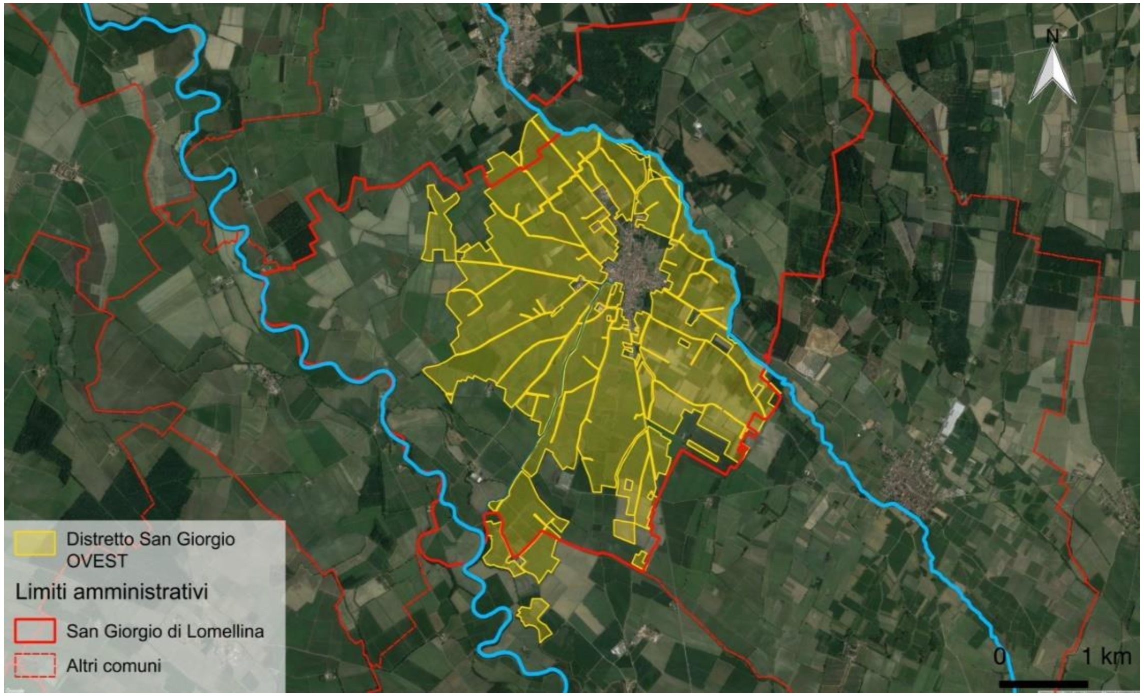
The main messages emerged are the following:

- Concerning the capacity and willingness of farmers of the rice area to adopt innovative irrigation management solutions, their behavior towards AWD was encouraging. In fact, although they didn't know the technique before the interview, they showed interest in its potential.
- However, since AWD requires coming back to the water seeding (all the rice area in the last years switched to the dry seeding - DFL and IRR) they declared their need for both financial and technical support to adopt AWD.
- The experience of rice farmers of the area in adopting technologies is limited, thus, if AWD would require technologies to be implemented, it will be necessary to support them in their use.

Use of a semi-distributed agro-hydrological model to assess the AWD «water saving» potential at the irrigation district scale

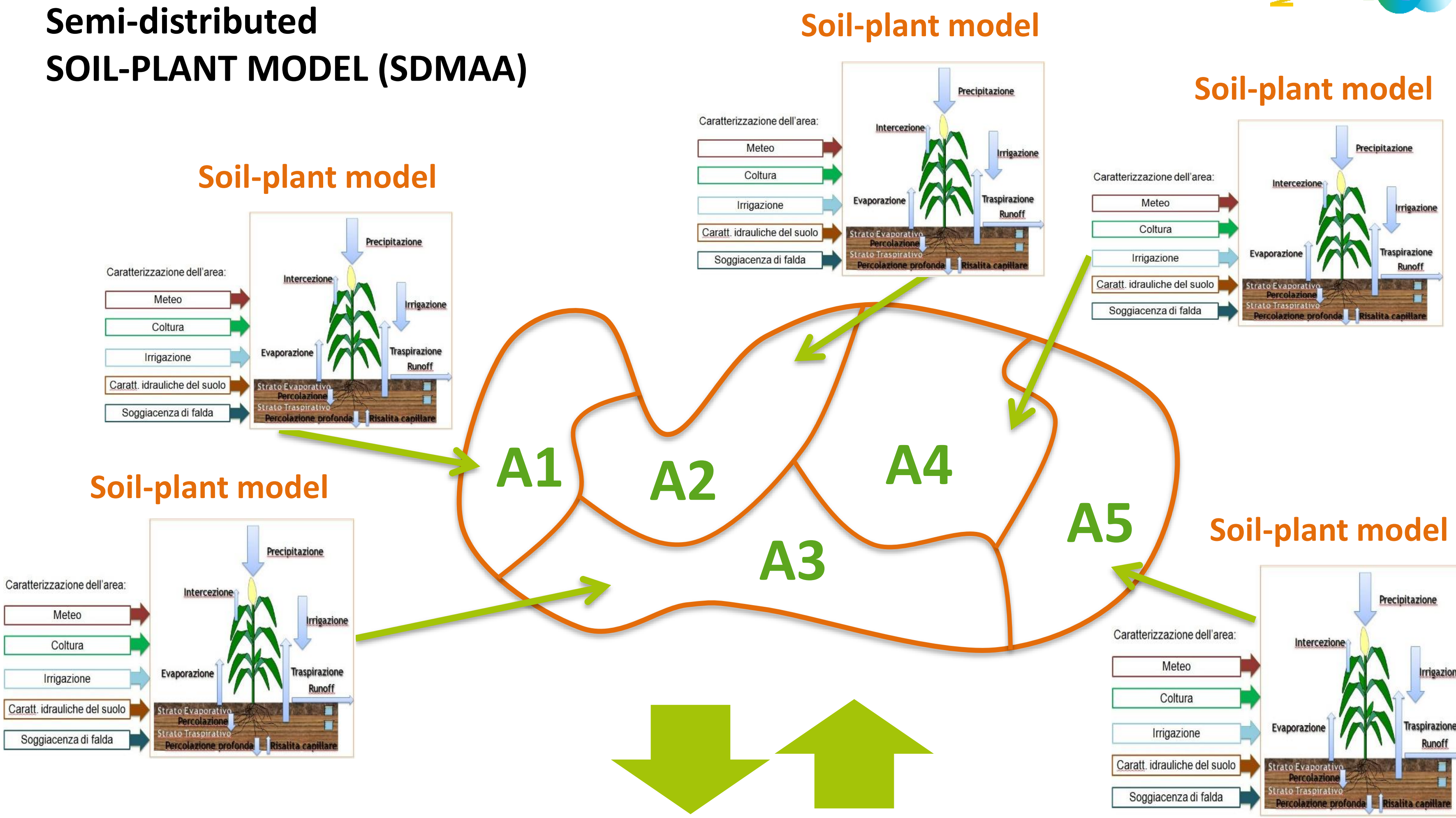
Study area: San Giorgio di Lomellina irrigation district (PV, northern Italy)

- Approximately 1000 ha, rice (85%), maize and poplar (≈15%)
- Simulation period: 2013-2020
- Data needed: temporal data series (irrigation discharges, agro-meteo data, groundwater depths) and maps (land use, topography, soil hydrological properties, irrigation methods)



AGRO-HYDROLOGICAL MODEL STRUCTURE (Overview)

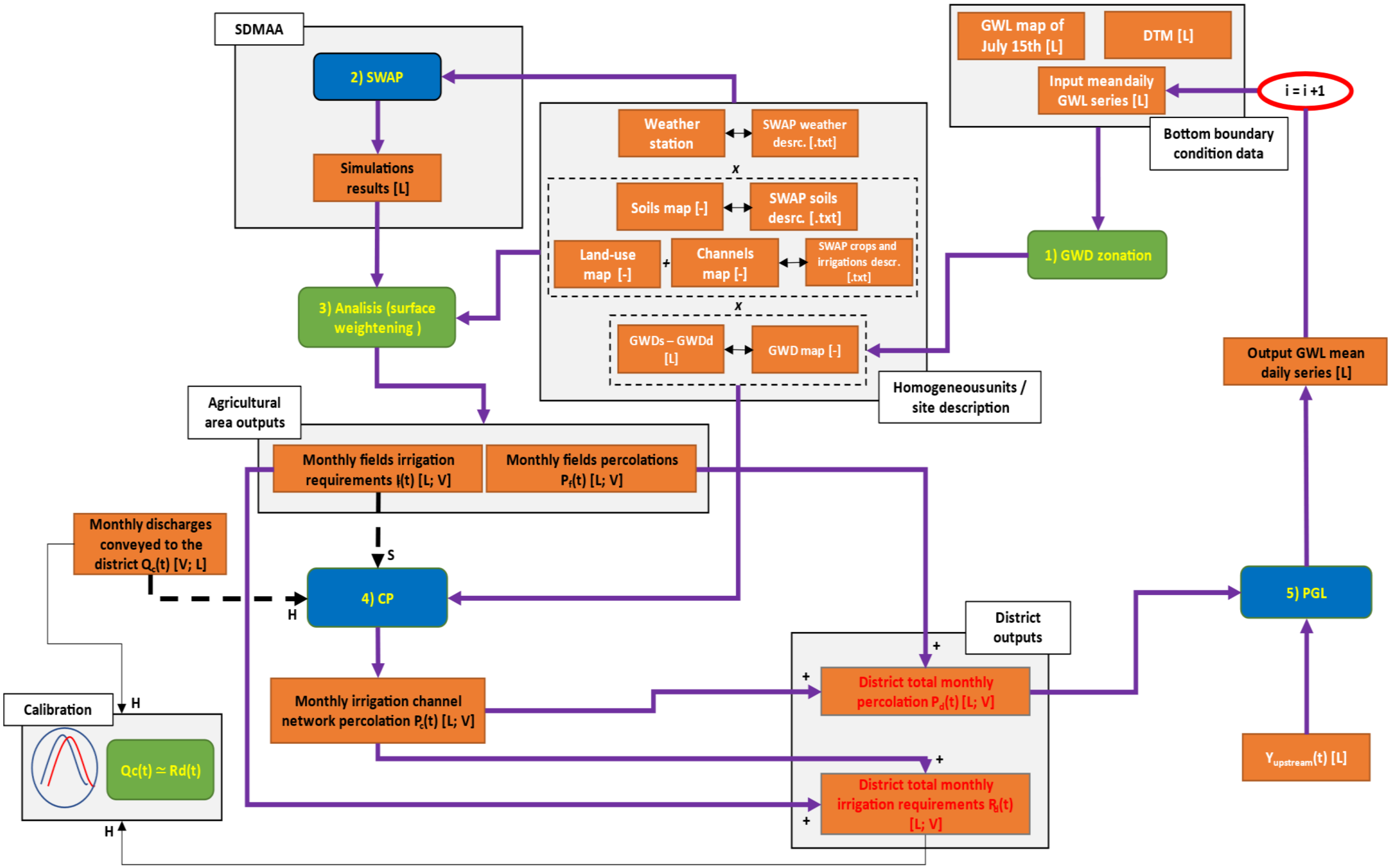
Semi-distributed
SOIL-PLANT MODEL (SDMAA)



Coupled to the following 2 spatially concentrated and empirical models:

- **Channel network percolation (CP MODEL)**
- **Phreatic groundwater dynamic (PGL MODEL)**

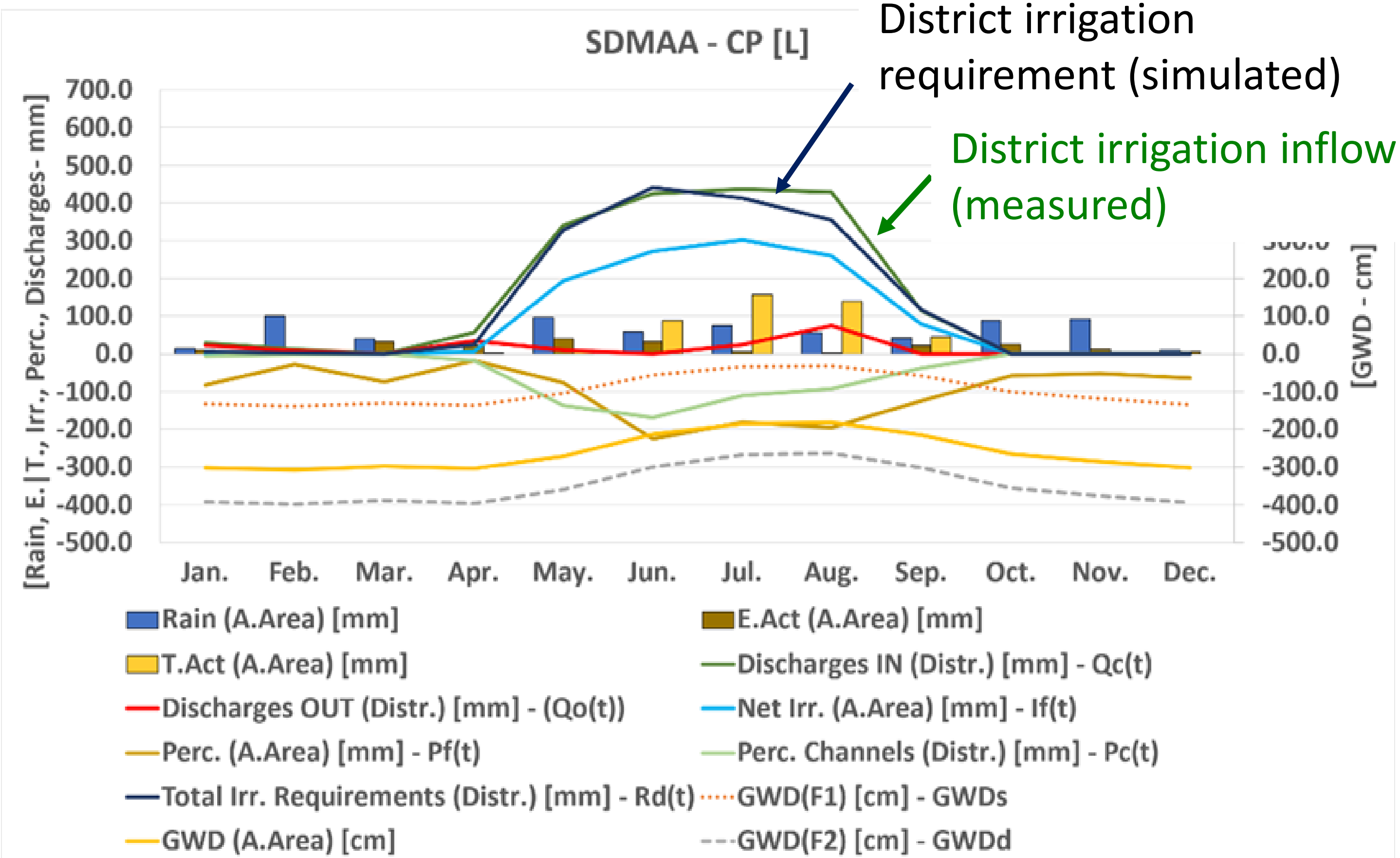
AGRO-HYDROLOGICAL MODEL STRUCTURE (Details)



Flowchart of the model framework showing the interconnections among the three sub-models (SDMAA, CP, PGL)

AGRO-HYDROLOGICAL MODEL CALIBRATION (e.g. 2016)

Water balance components for the whole district (aggregated on a monthly time step)



NEXT STEPS: **use of the calibrated model to simulate the effects of AWD on the water resource system of the irrigation district.**

Conclusive remarks

- AWD-safe is **economically sustainable**: the farm profitability is slightly higher than WFL: farm profitability increases of 22 euro/ha.

- AWD-safe is **agronomically sustainable**: rice grain yield is similar to WFL (≃11 t/ha)

- AWD-safe **saves water** compared to WFL: **net irrigation decreases** of 20%, **WP increases** of 20%, **RWS decreases** of 21.5%, **percolation reduces** of 24%.

- As concerns the other environmental aspects, when compared to WFL, AWD-safe has **similar energy productivity** and **similar nutrient (N, P, K) use efficiency**, **reduces CH4 emissions** (18 %) and **increases N2O emissions** (≃39 %).

- When considering rice grain quality, AWD-safe **decreases the inorganic Arsenic** content in grain; however, rice **Cadmium content increases** although it remains **under the legal limits set in the EU even for baby food.**

- Regarding **social acceptability**, farmers demonstrated their **willingness to adopt AWD-safe**; however, they would **need financial, technical, and technological support**.

- An agro-hydrological model was developed to assess **the impact of AWD-safe on the water resource system** at the irrigation district scale. **The model has been successfully calibrated**. In the **next steps AWD-safe will be implemented** and results will be compared to those obtained in the current situation.


Thanks for your attention!