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Large Scale Irrigation Management Tools for Sustainable Water Management in Rural Areas and Protection of Receiving Aquatic Ecosystems

https://www.interregir2ma.eu/

Eco-efficiency of agricultural systems in the Mediterranean contexts: Evidence from Consorzio per la Bonifica della Capitanata (Southern Italy).

Dr. Andi Mehmeti (CIHEAM Bari)

Sustainable irrigation management in southern Mediterranean agriculture: Opportunities and Challenges

24 June 2021

WEB event | Organisation: CIHEAM Bari

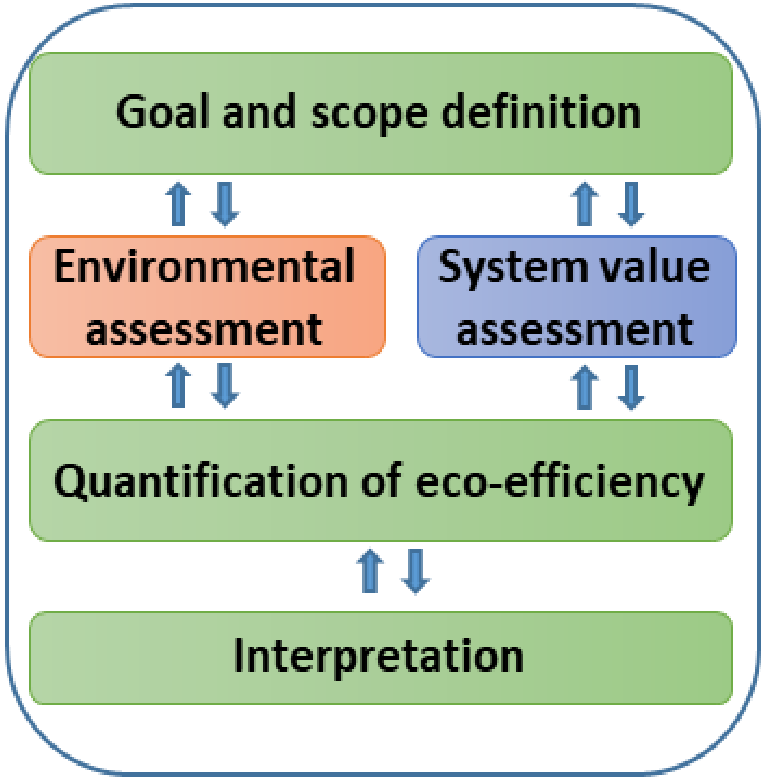
Eco-efficiency

- The concept of eco-efficiency (EE) is proposed as a tool to analyze farm sustainability, i.e., to relate economic value of an activity to its impact on the environment (Rüdenauer et al., 2005).

$$EEI = \frac{\text{Total value added}}{\text{Environmental impact}}$$

$$EEI = \frac{1}{\text{LCA} \times LCC}$$

- Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) are appropriate methodologies to investigate the eco efficiency product/services.



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Why eco-efficiency?

Incorporation of life cycle principles

Reduction of waste and pollution levels

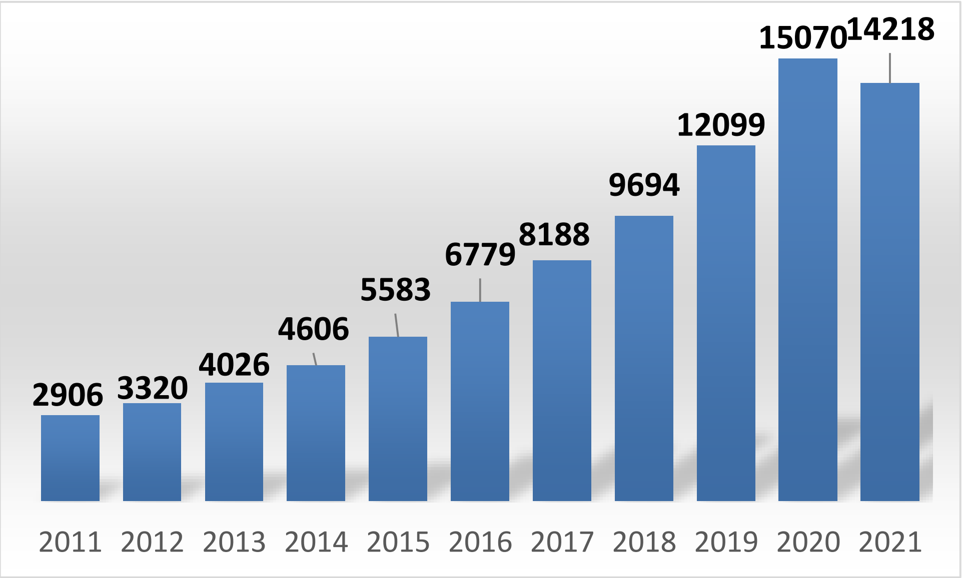
Generates more value through technology and process changes whilst reducing resource use and environmental impact throughout the product

Increasing product or service values

Identify opportunities for improve systems

Address Tradeoff between Economic Output and Environmental Protection

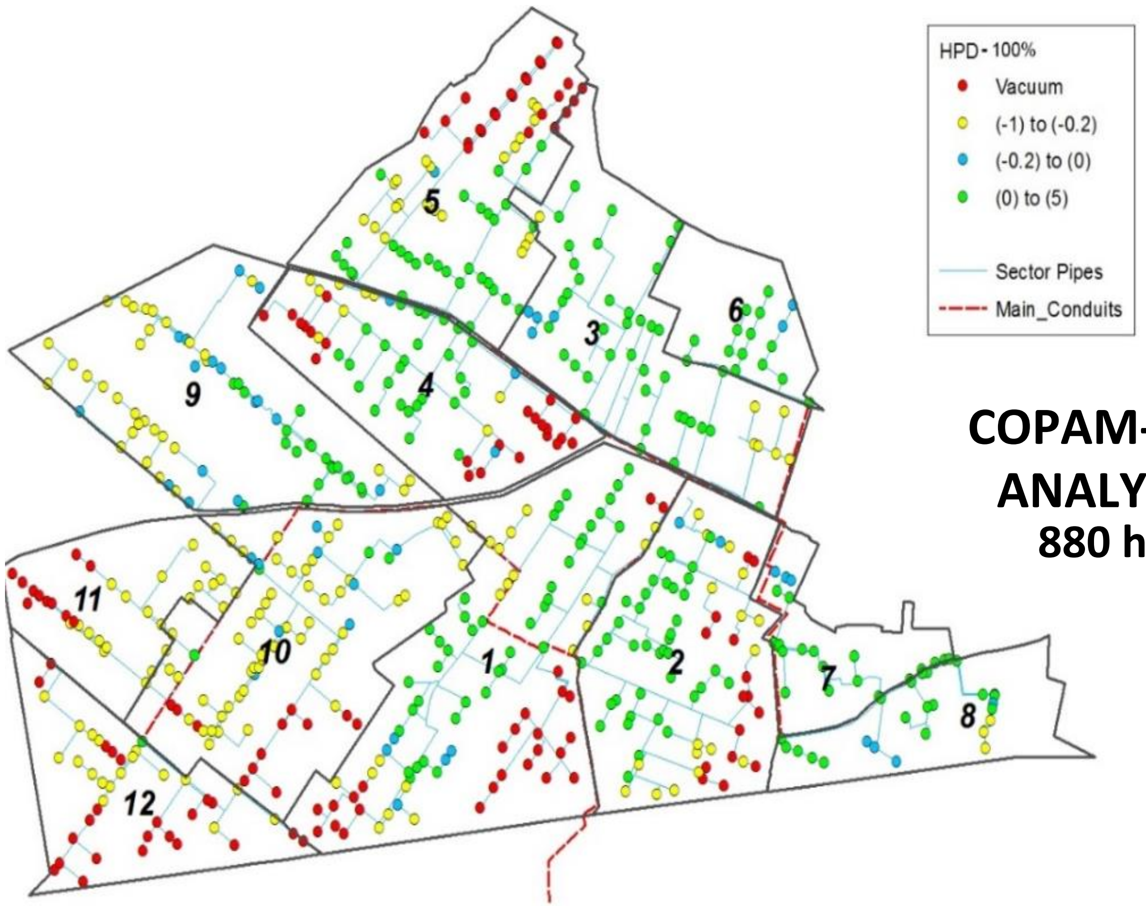
Support sustainability



Fonte: Sciencedirect, accesso 22/06/2021

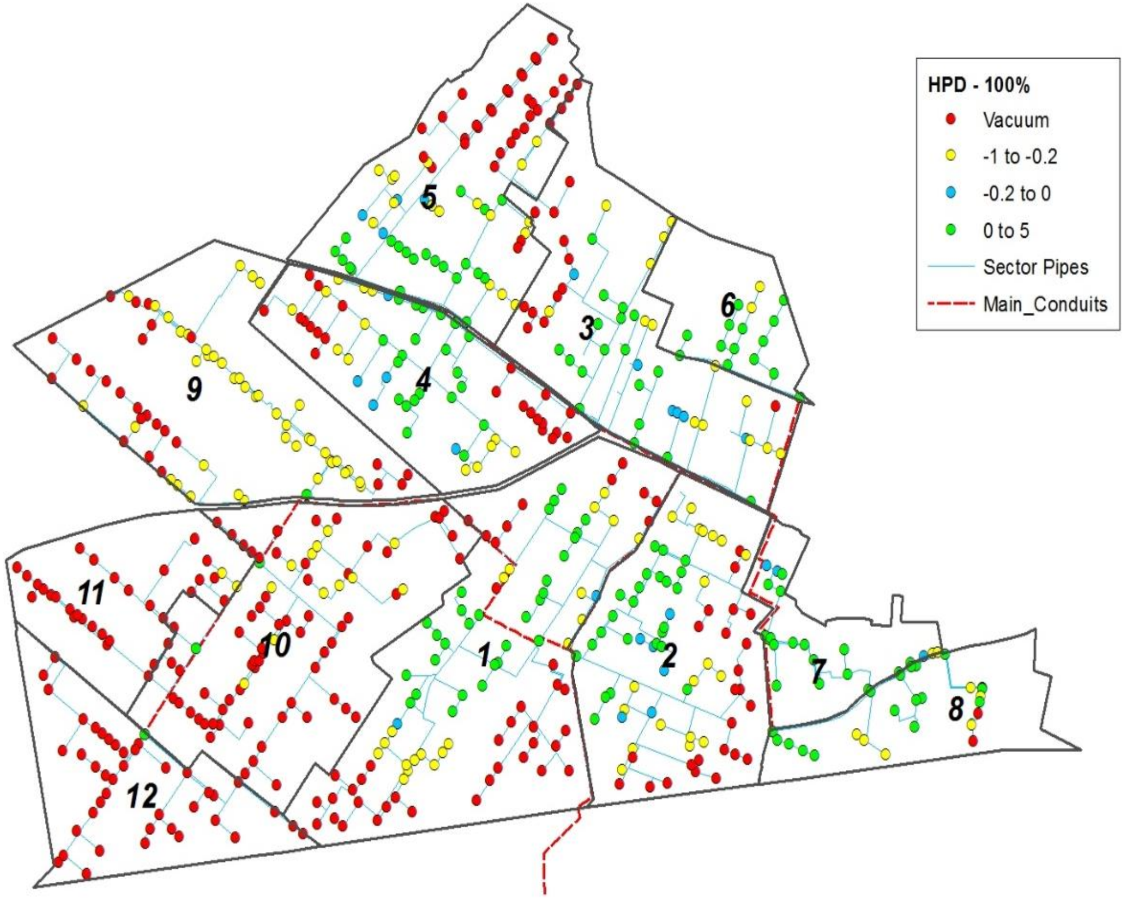
Hydraulic (eco)-efficiency of the irrigation district

Hydraulic performance and sustainability are interlinked in large-scale irrigation schemes.



NORMAL HYDROLOGICAL YEAR

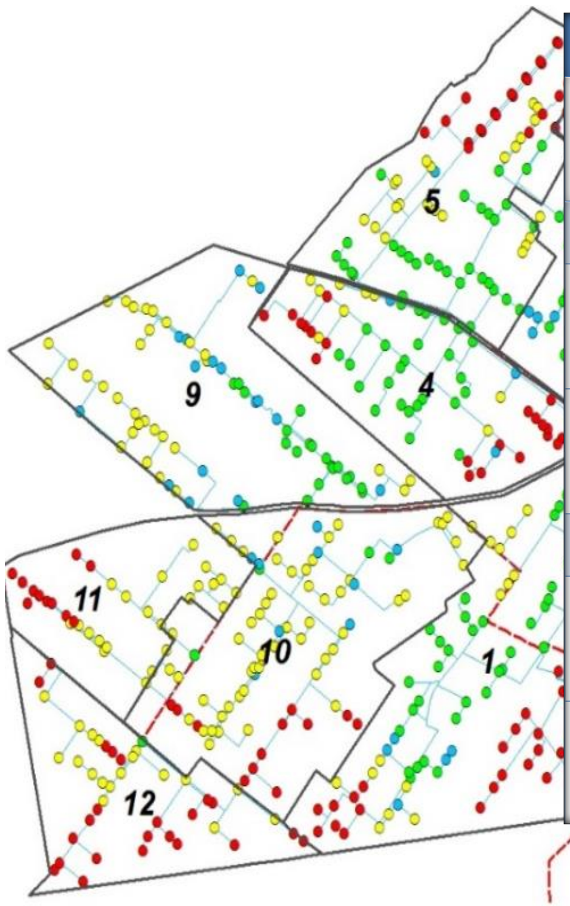
COPAM-GIS ANALYSIS
880 ha



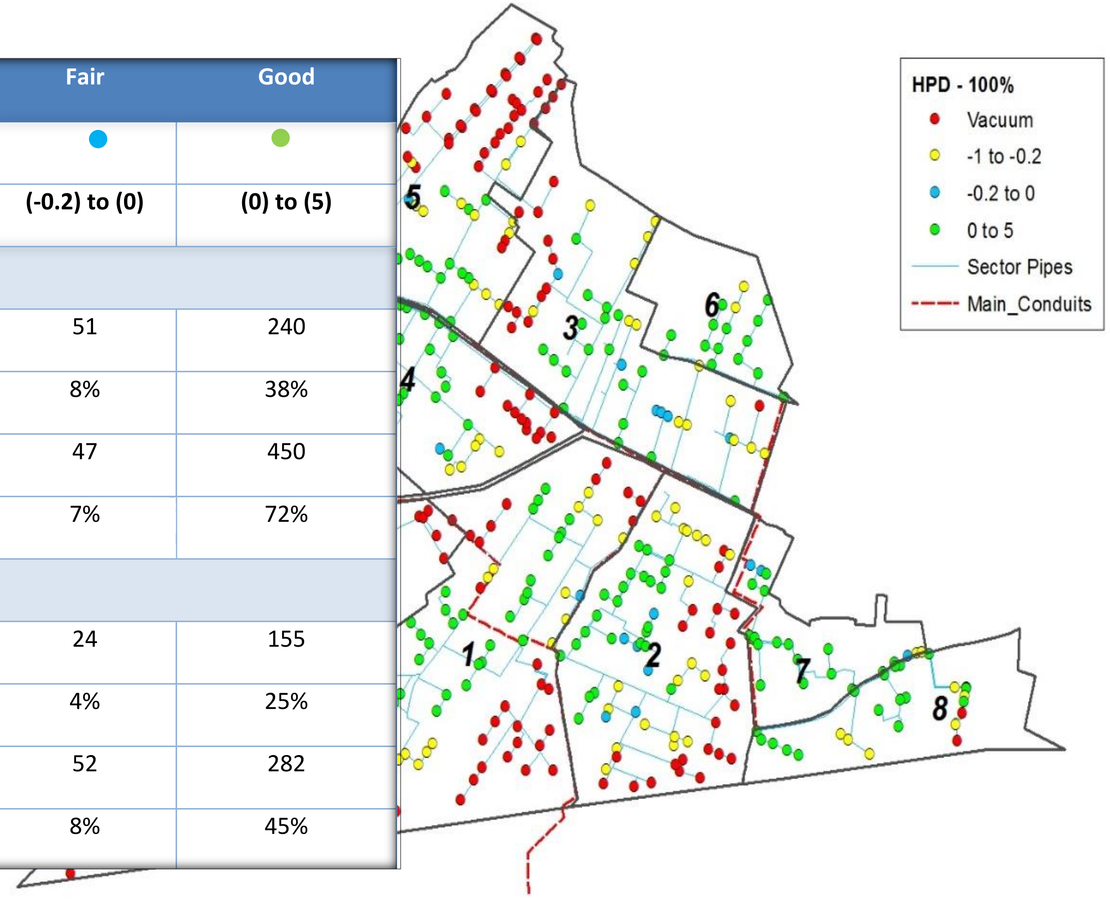
DRY HYDROLOGICAL YEAR

Hydraulic (eco)-efficiency of the system

Hydraulic performance and sustainability are interlinked in large-scale irrigation schemes.



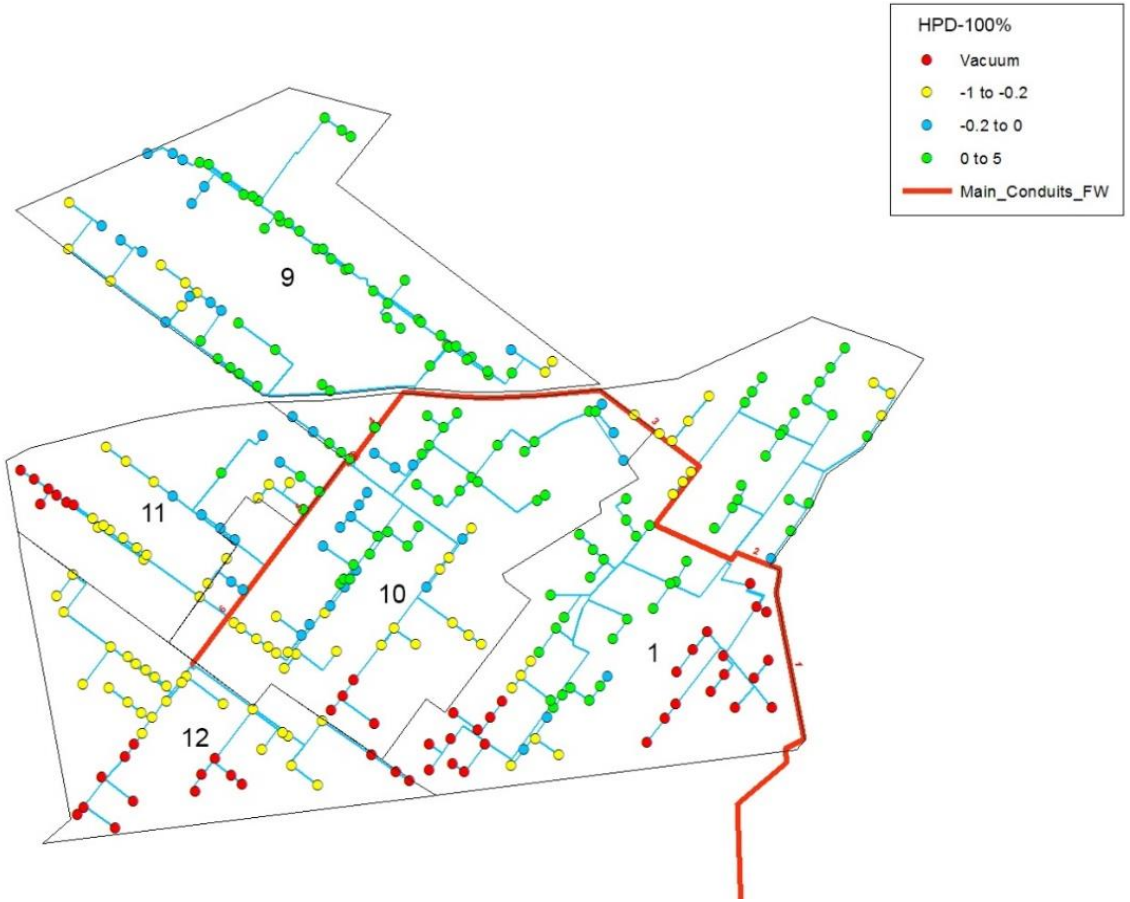
Class	Bad	Poor	Fair	Good
Pressure deficit class	🔴	🟡	🔵	🟢
	(-5) to (-1)	**(-1) to (-0.2)**	**(-0.2) to (0)**	**(0) to (5)**
Average Year				
100 % HPD	133	204	51	240
	21%	32%	8%	38%
90 % HPD	23	108	47	450
	4%	17%	7%	72%
Dry Year				
100 % HPD	288	150	24	155
	46%	24%	4%	25%
90 % HPD	101	193	52	282
	16%	31%	8%	45%

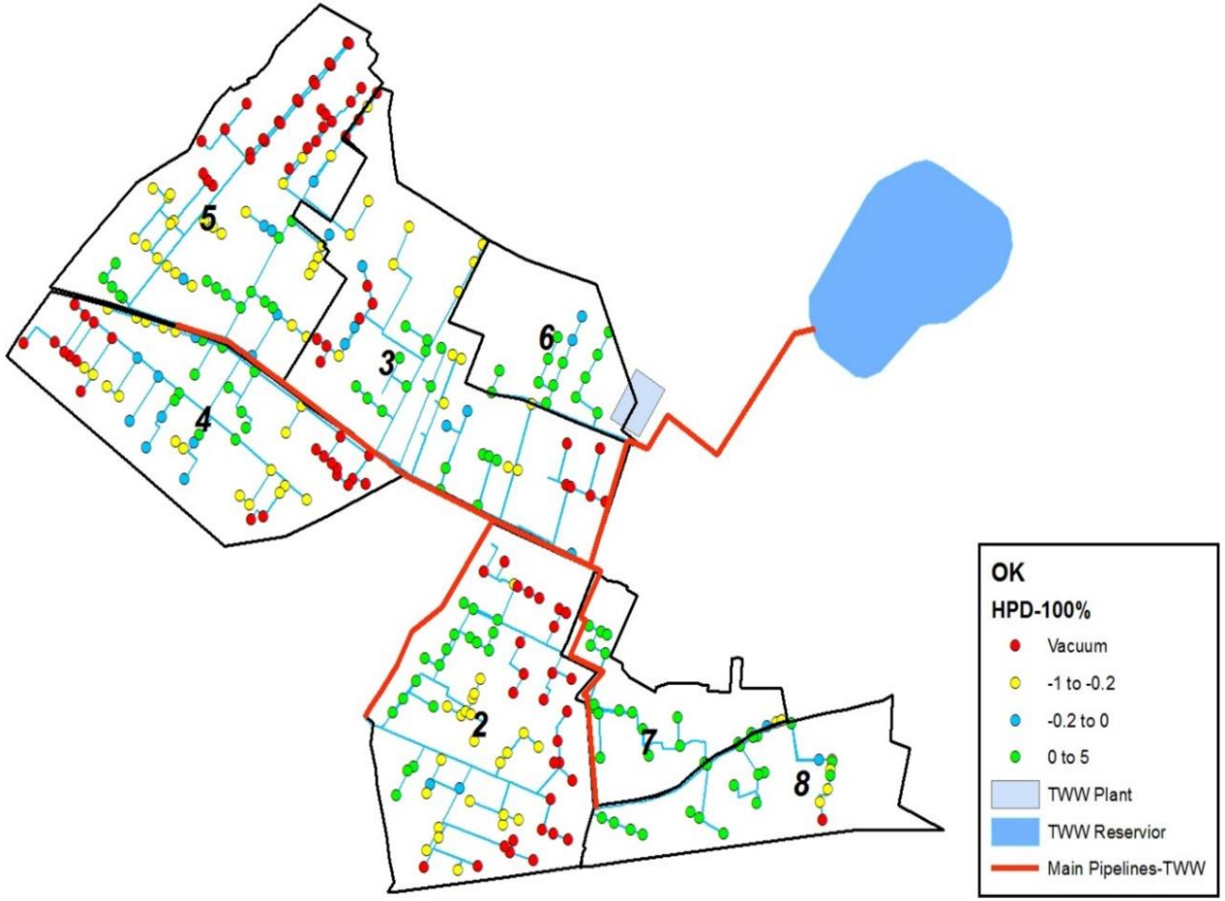


NORMAL HYDROLOGICAL YEAR

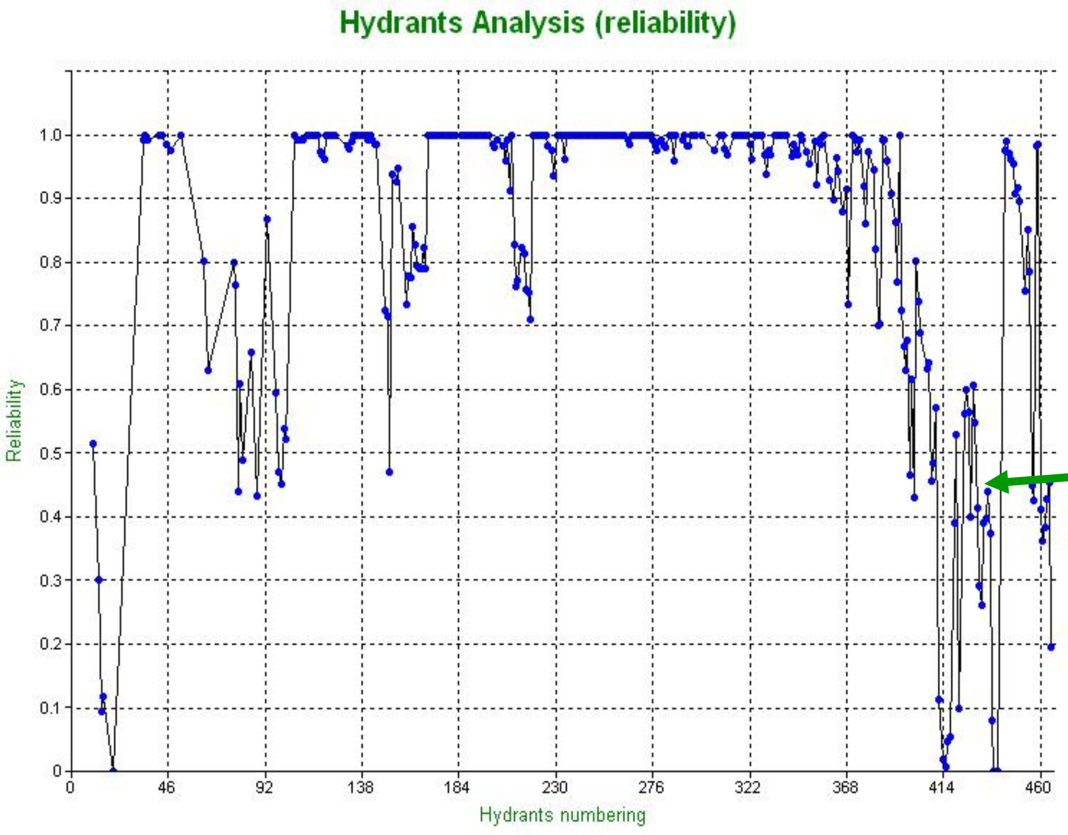
DRY HYDROLOGICAL YEAR

Network sectoring with freshwater and treated wastewater sources.

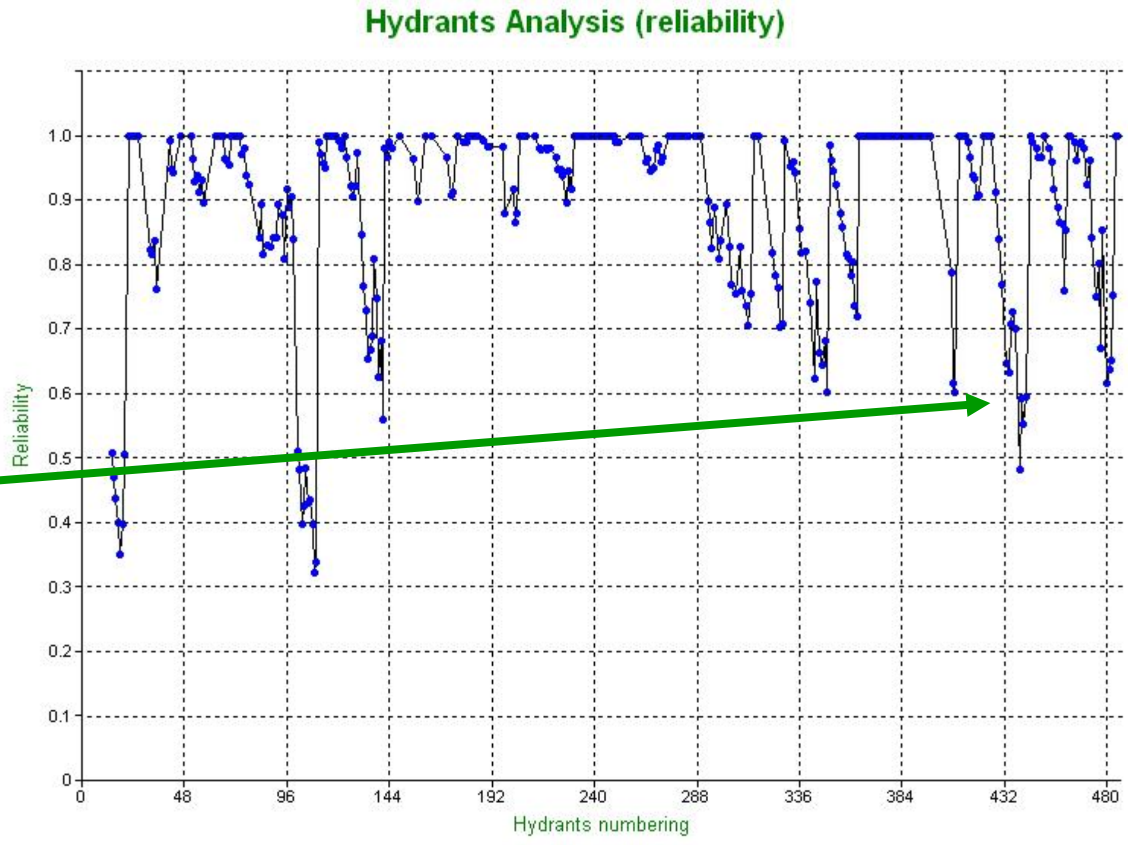




Network sectoring with freshwater and TWW sources.



Freshwater



Treated wastewater

Network sectoring with freshwater and treated wastewater sources.

Class	Bad	Poor	Fair	Good
Pressure deficit class	🔴	🟡	🔵	🟢
	(-5) to (-1)	(-1) to (-0.2)	(-0.2) to (0)	(0) to (5)
Sub-network 1 (freshwater)				
100 % HPD	51	89	45	125
	16%	29%	15%	40%
90 % HPD	12	69	21	208
	4%	22%	7%	67%
Sub-network 2 (TWW)				
100 % HPD	95	88	27	108
	31%	28%	9%	35%
90 % HPD	18	62	36	202
	6%	20%	12%	65%

	Realibility indicator		
Class	Bad	Fair	Good
Pressure deficit class	🔴	🔵	🟢
	<0.5	0.5-0.8	0.8-1.0
Sub-network 1 (Freshwater)	40	45	226
	13%	15%	73%
Sub-network 2 (TWW)	197	89	343
	31%	14%	55%

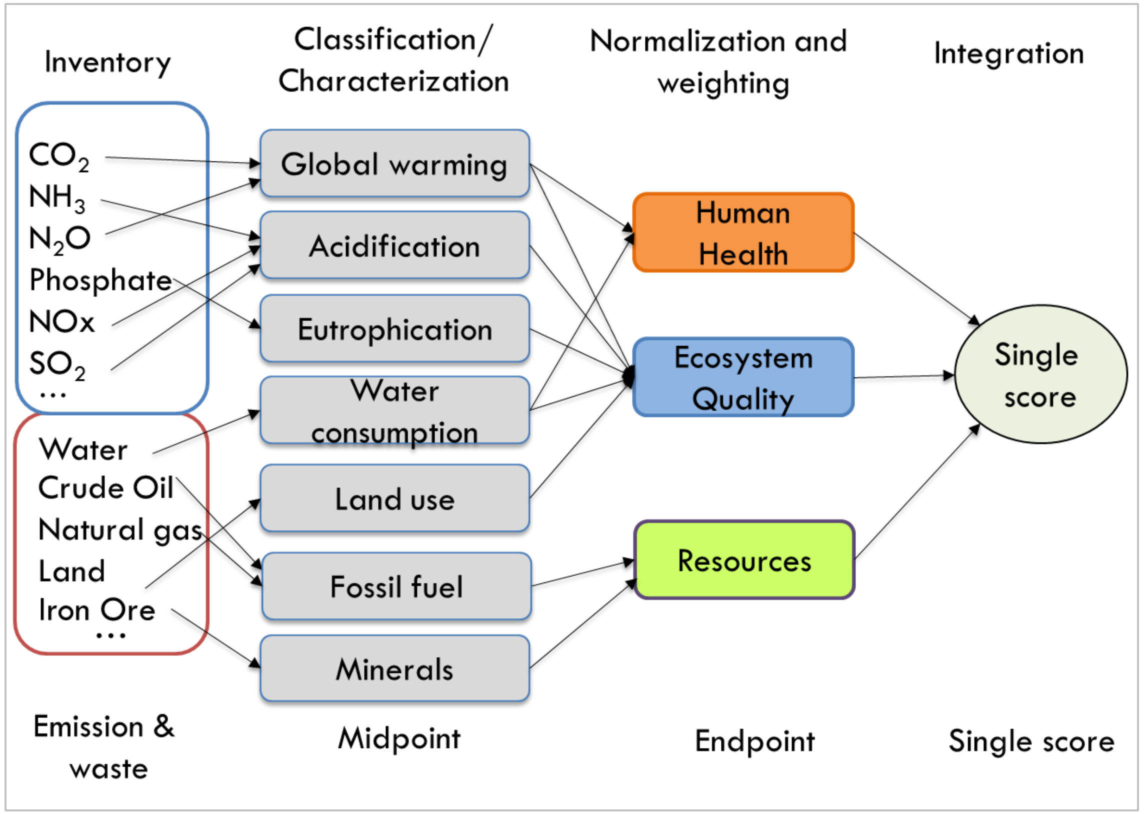
TWW for irrigation of crops would contribute in saving 498,000 m^3 and 520,000 m^3

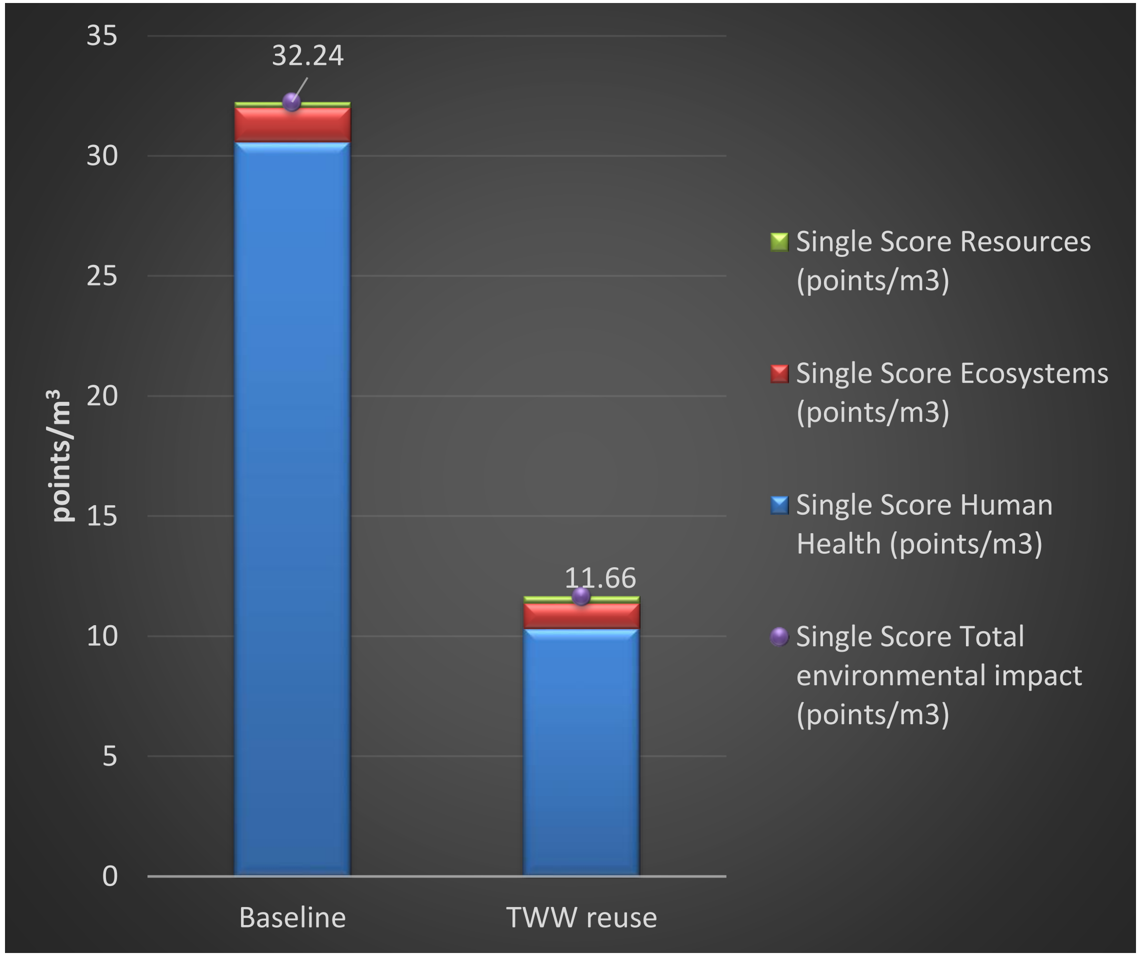
Environmental performance via LCA

Indicator	Unit	TWW REUSE	BASELINE
ReCiPe 2016 (H) midpoint			
Fine particulate matter formation (PMPF)	kg PM2.5-eq	6.77E-04	1.02E-03
Fossil resource scarcity (FFP)	kg oil-eq	0.12	0.07
Freshwater ecotoxicity (FETP)	kg 1,4-DCB-eq	7.58E-03	1.21E-03
Freshwater eutrophication (FEP)	kg P-eq	1.14E-03	9.55E-04
Global warming (GWP)	kg CO_2-eq	0.41	0.21
Human carcinogenic toxicity (HTP_c)	kg 1,4-DCB-eq	8.71E-03	3.88E-03
Human non-carcinogenic toxicity (HTP_{nc})	kg 1,4-DCB-eq	1.60E-01	3.29E-02
Ionising radiation (IRP)	kBq Co-60-eq	6.68E-02	6.79E-03
Land use (LU)	m^2a crop-eq	0.007	0.0009
Marine ecotoxicity (METP)	kg 1,4-DCB-eq	1.03E-02	1.90E-03
Marine eutrophication (MEP)	kg N-eq	3.18E-03	2.73E-02
Mineral resource scarcity (SOP)	kg Cu-eq	1.55E-03	6.32E-04
Human health ozone formation (HOFP)	kg NOx-eq	8.60E-04	2.68E-03
Ecosystem Ozone Formation (EOFP)	kg NOx-eq	1.99E-03	6.22E-03
Stratospheric ozone depletion (ODP)	kg CFC11-eq	2.40E-07	1.21E-07
Terrestrial acidification (TAP)	kg SO_2-eq	2.04E-03	1.97E-03
Terrestrial ecotoxicity (TETP)	kg 1,4-DCB-eq	0.63	0.22
Water consumption (WCP)	m^3 consumed	-0.18	0.38

Canaj et al., (2021).

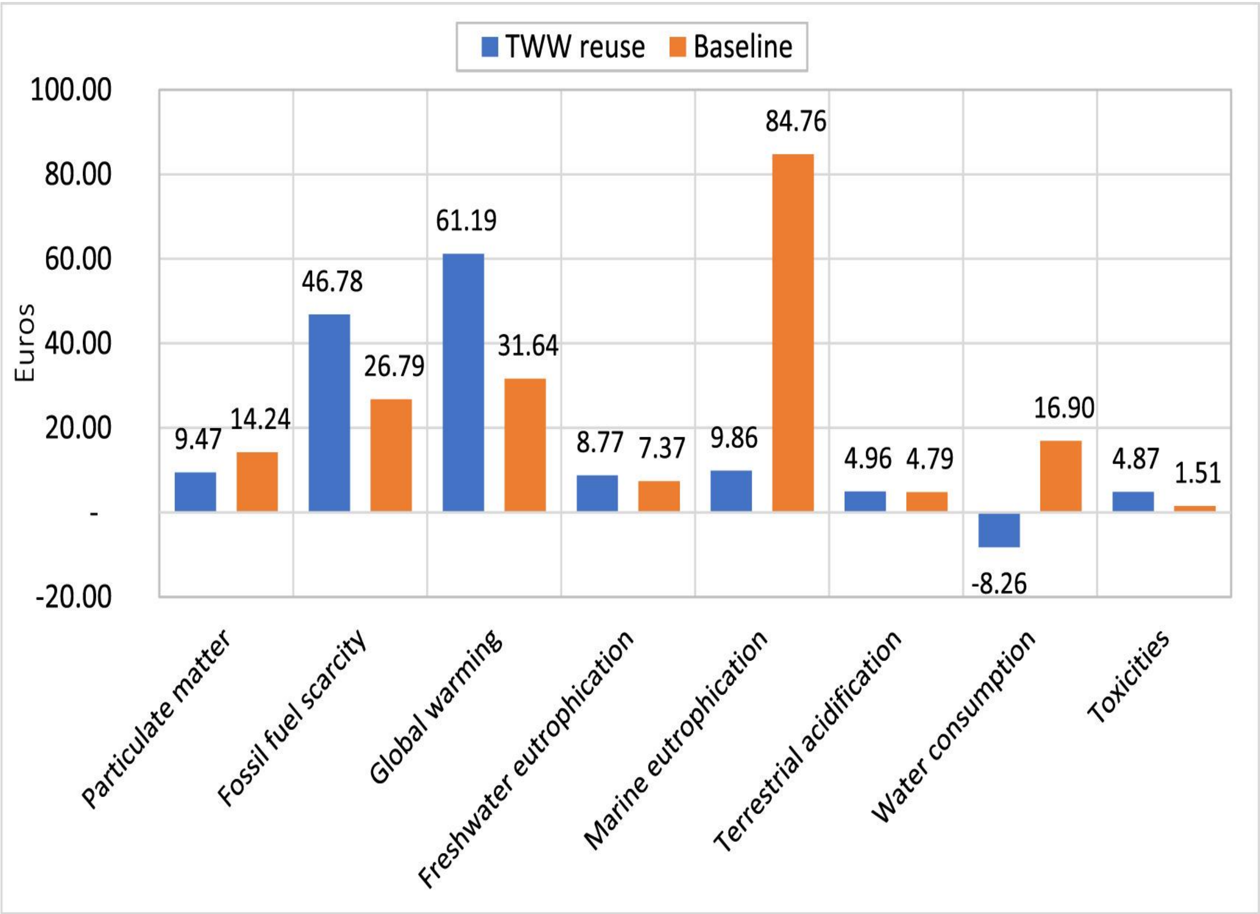
Synthesis of LCA performance

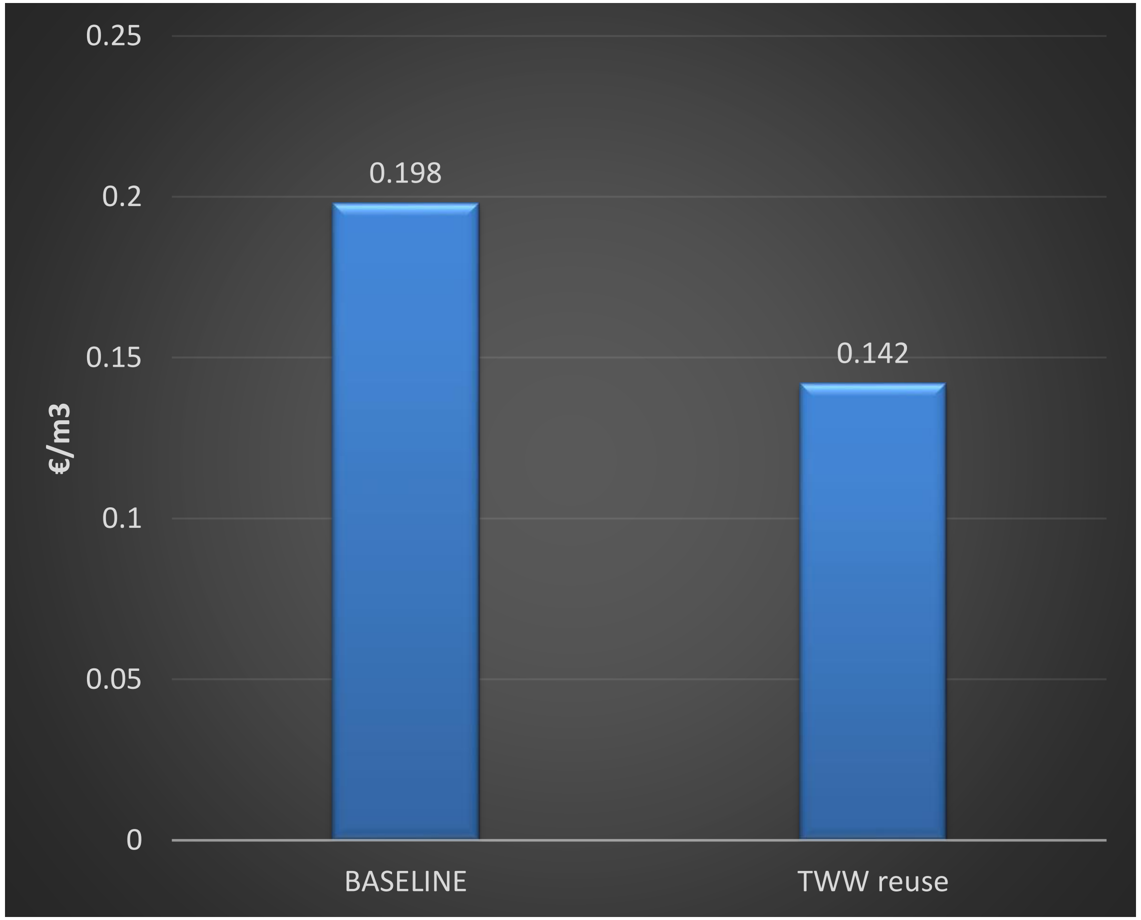




Canaj et al., (2021).

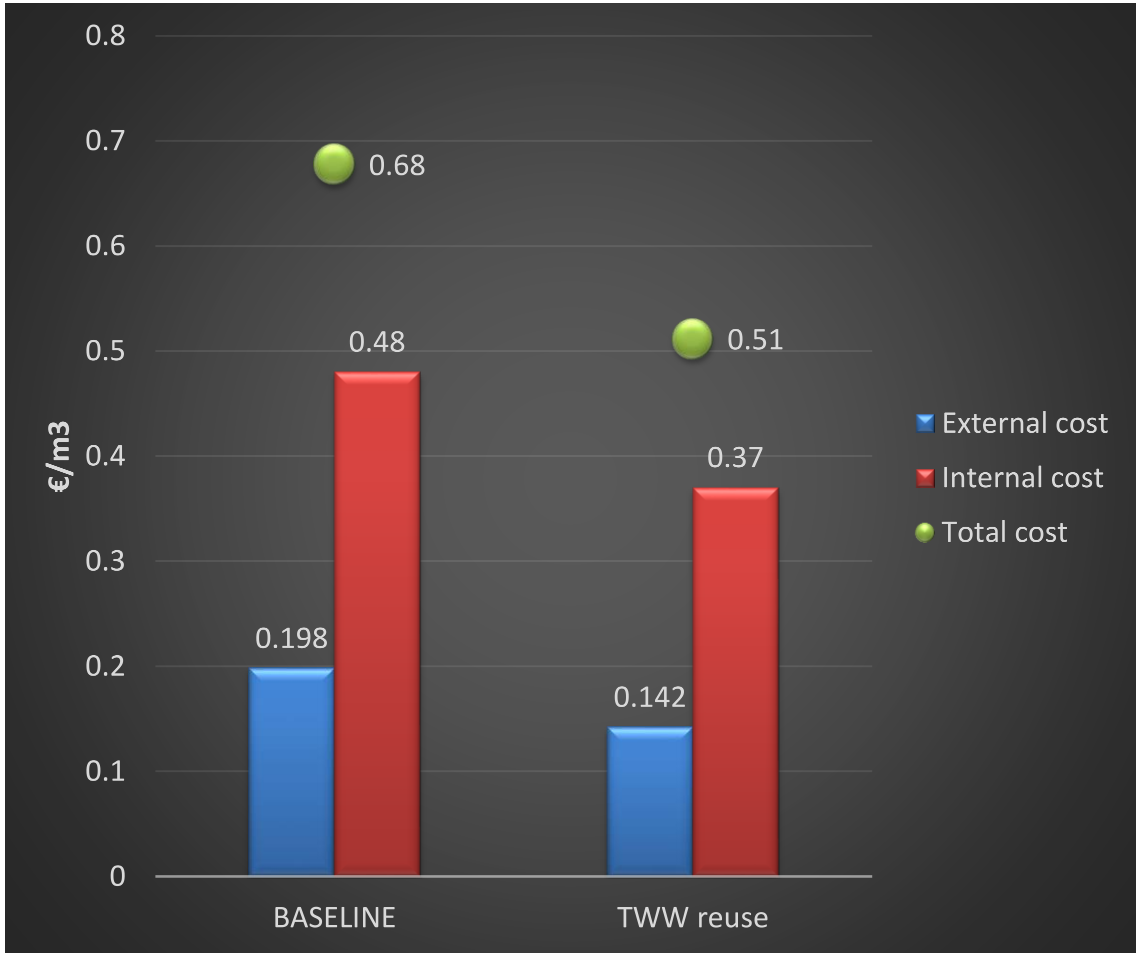
External cost analysis

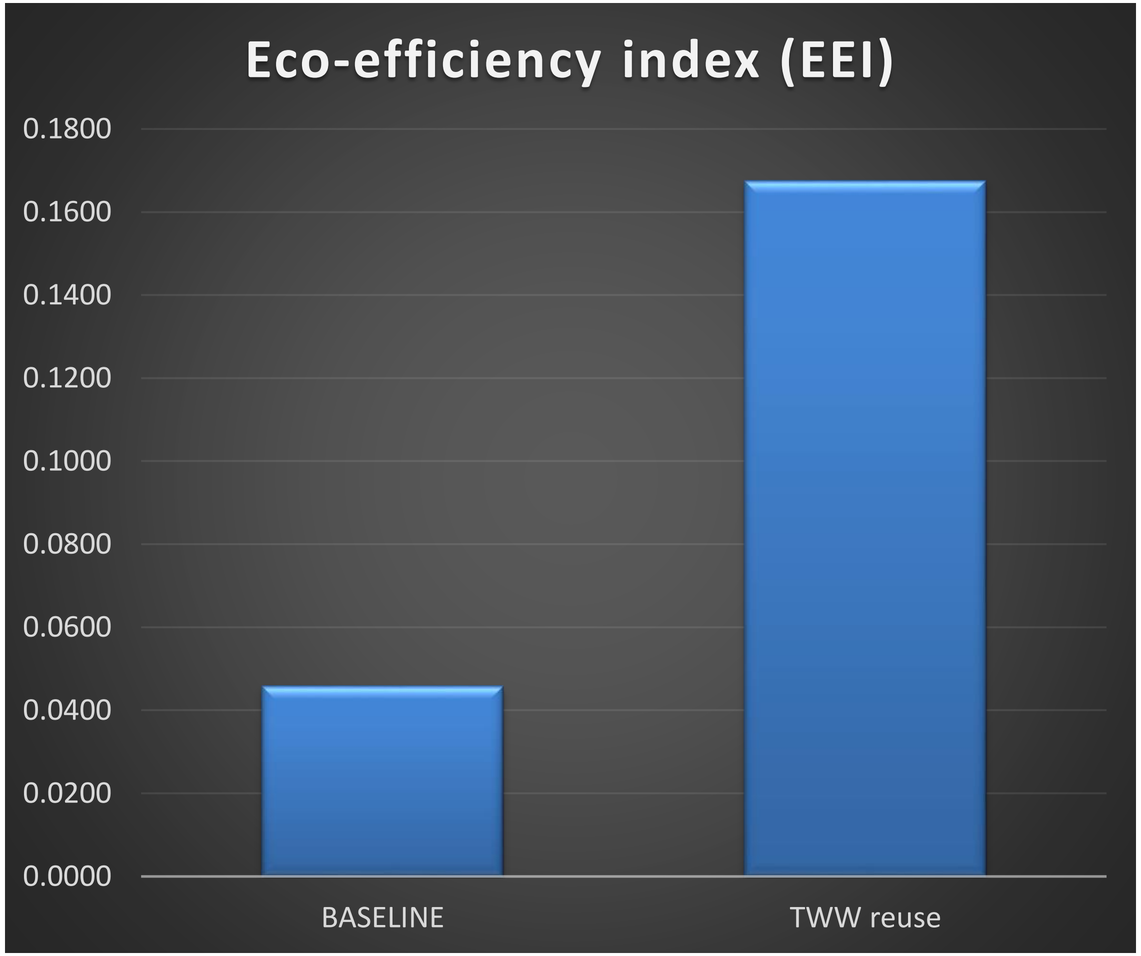




Canaj et al., (2021).

Life cycle total cost and eco-efficiency

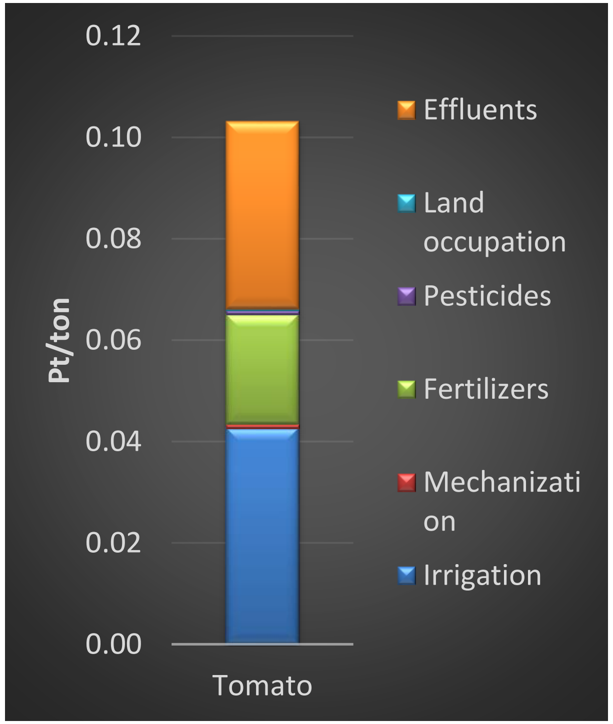


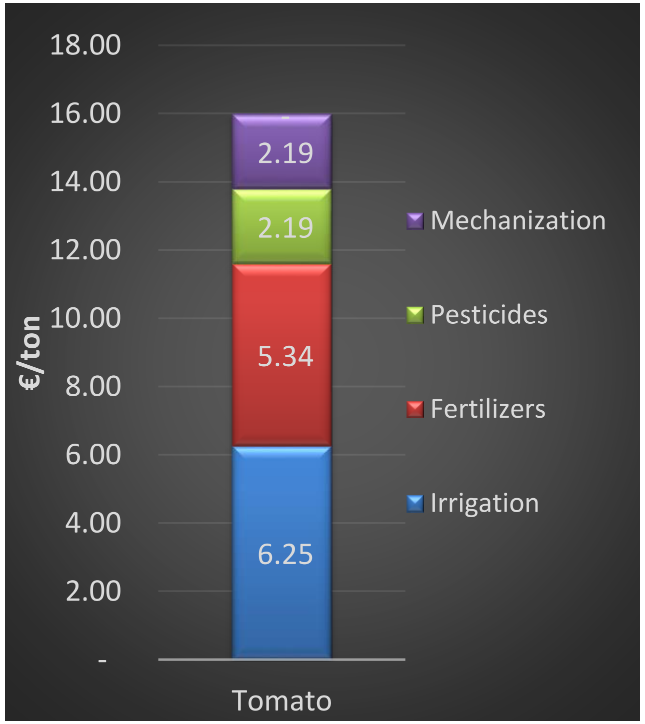


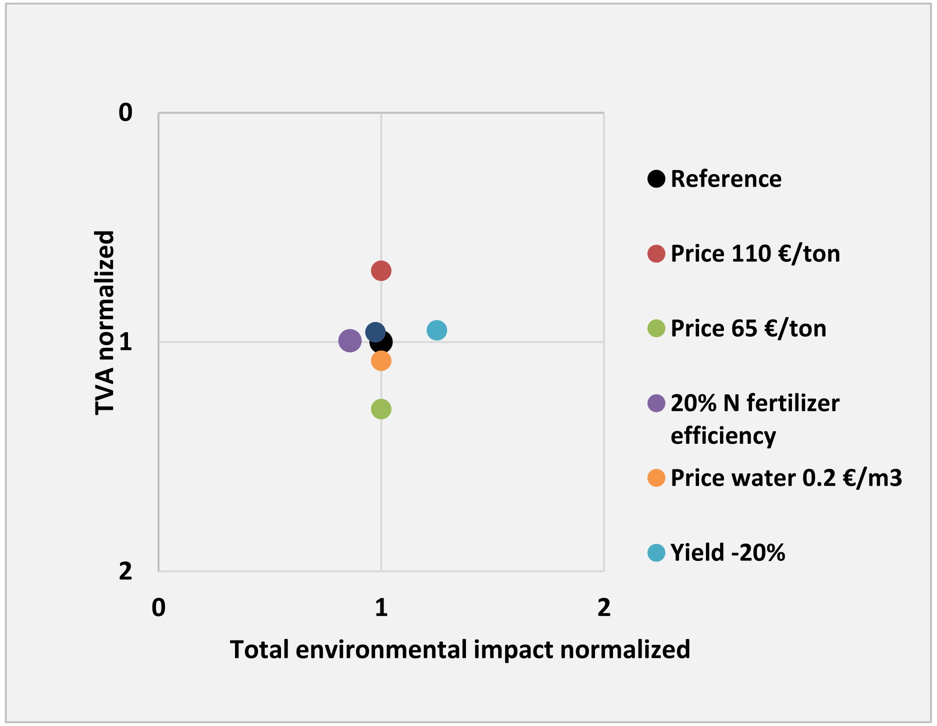
S2. Single crop eco-efficiency

Tomato eco-efficiency open-field

Tomato Crop	Input	Price/Cost
Yield	100 ton/ha	80 €/ton
GIR	500 mm/ha	0.1 €/m^3
Energy irrigation	1046.83 kWh	0.12 €/kWh
N	150 kg N/ha	1.35 €/kg
P_2O_5	100 kg P_2O_5/ha	0.75 €/kg
K_2O	150 kg K_2O /ha	1.5 €/kg
Pesticides	5 kg/ha	35 €/kg
Fuel	50 kg/ha	1 €/kg
Tractor	10 h/ha	25 €/h

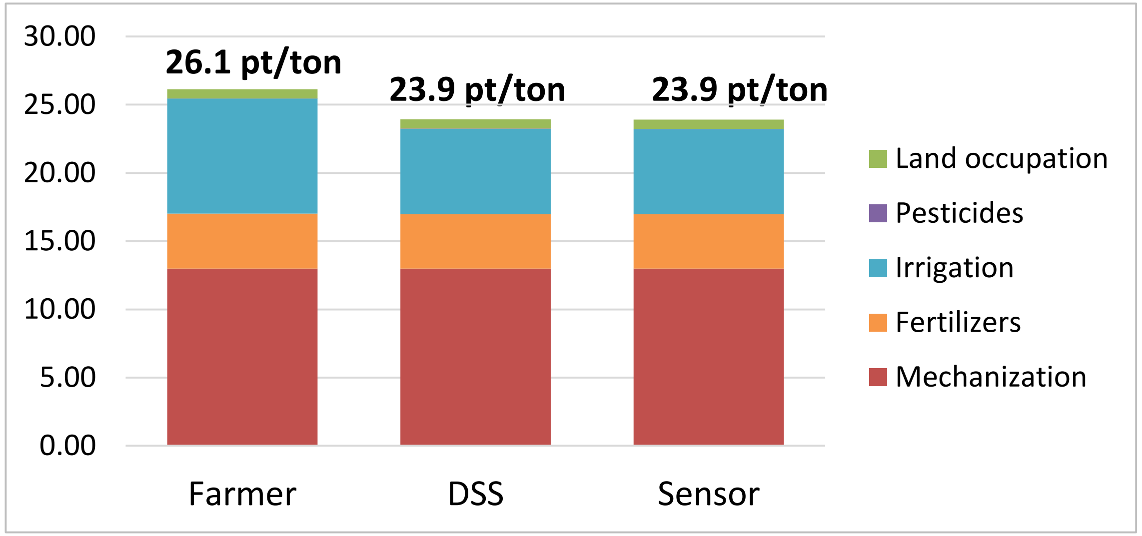


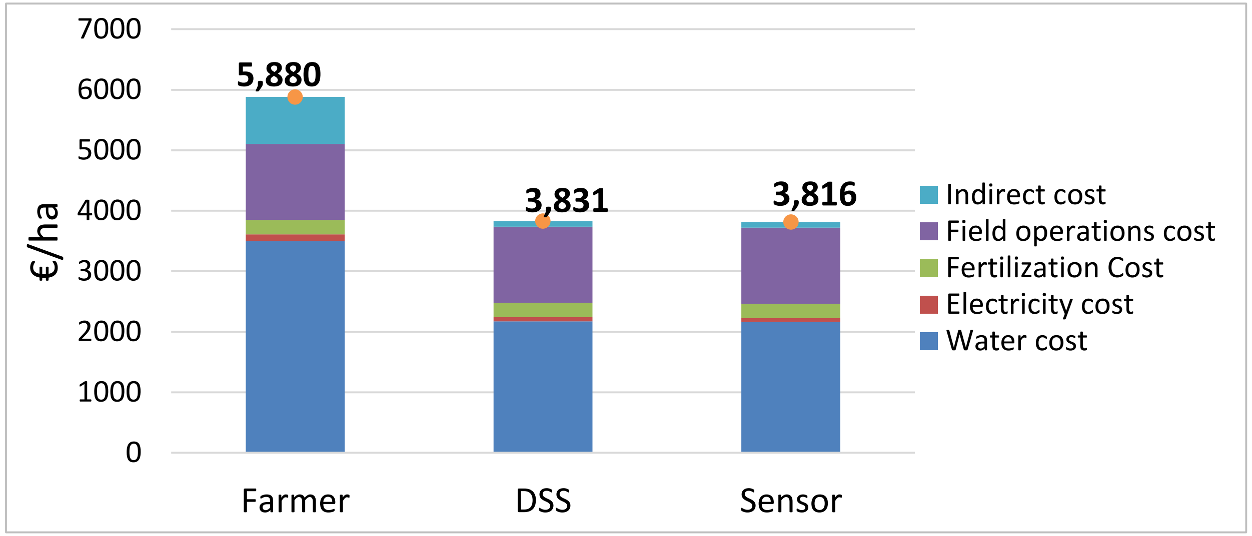


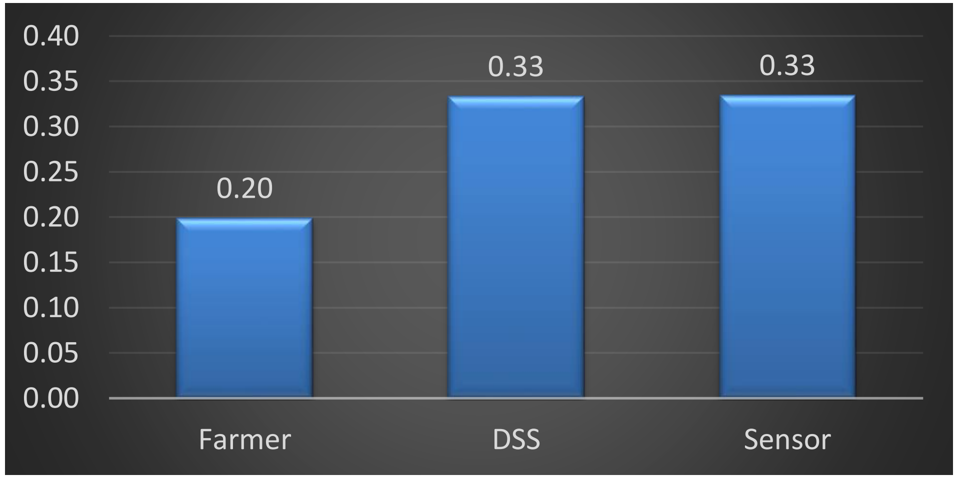


Eco-efficiency pathway

The case of Zucchini production (Greenhouse)



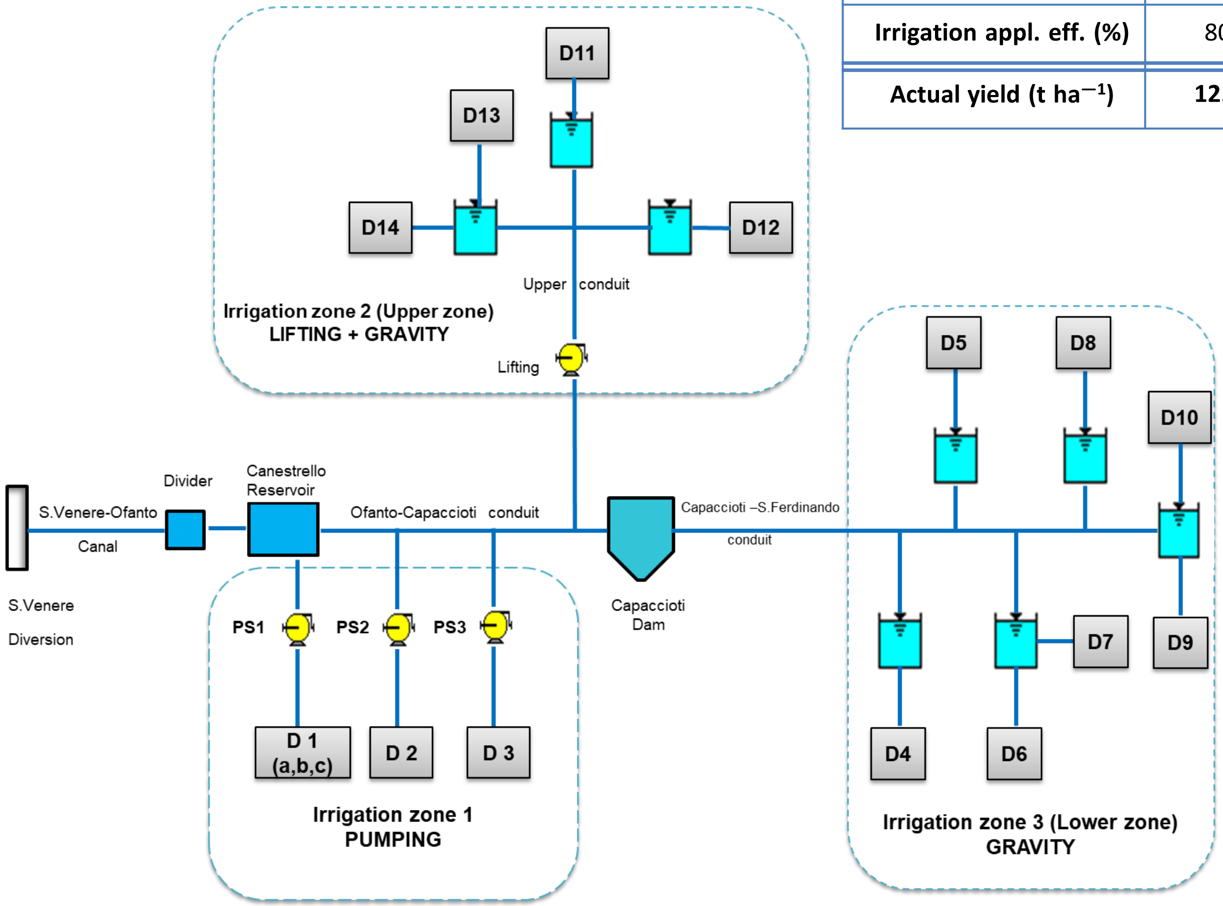




S3. Irrigation system and associated districts.

Eco-efficiency of the system

Parameter/Crops	Artichoke	Asparagus	Olives	Orchards	Sugarbeet	Tablegrape	Tomato	Vegetables	Wheat	Winegrape
Zone 1 (ha)	43	102	60	67	3	0	218	47	2218	**98**
Zone 2 (ha)	20	0	3656	13	0	41	63	215	2604	**3793**
Zone 3 (ha)	506	5	3619	3147	25	3233	90	483	1943	**7338**
NIR (m^3 ha^{-1})	3880	4850	2430	4860	3630	4510	4240	2800	1560	**3550**
N_input (kg ha^{-1})	200	160	90	110	110	170	150	180	110	**170**
P_input (kg ha^{-1})	100	60	45	60	85	95	110	80	33	**90**
Machine power (kW)	80	80	80	60	80	45	80	80	80	**45**
Machine hours (hr ha^{-1})	26.5	25.5	14	17	11	27.5	16	13.5	6	**25.5**
Irrigation appl. eff. (%)	80	90	80	80	90	90	90	90	90	**90**
Actual yield (t ha^{-1})	**12.4**	**8**	**5.56**	**25.1**	**38.7**	**35**	**90**	**27**	**4.05**	**23**



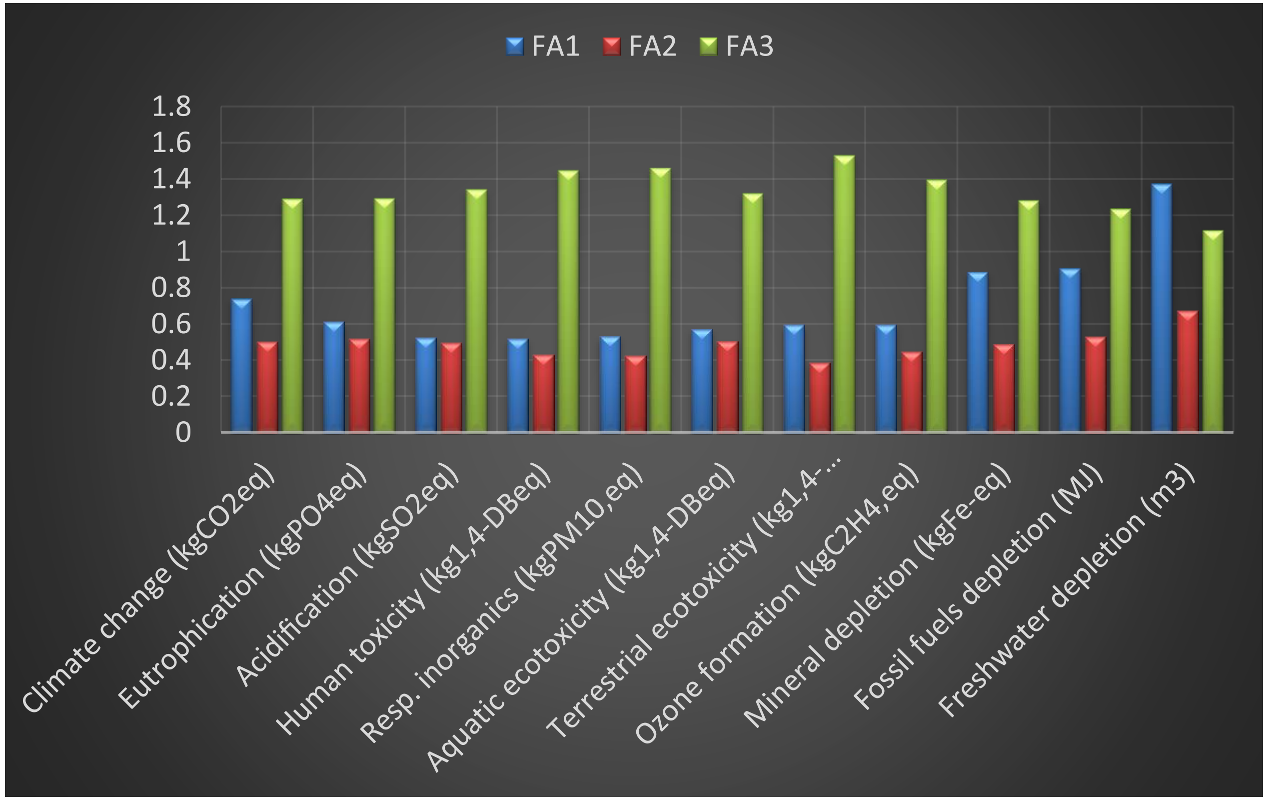
Overall system eco-efficiency

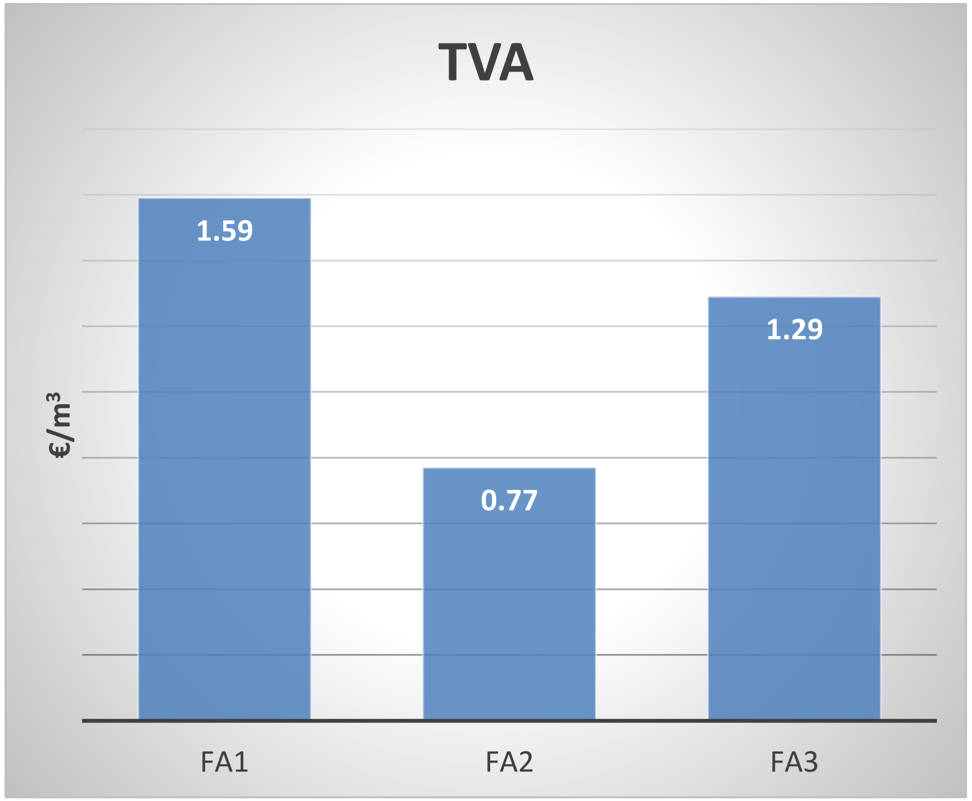
Environmental Impacts of the Sinistra Ofanto irrigation scheme considering foreground and background processes and environmental impacts per unit of product and per m^3 of water used

Impact Categories	Value	Foreground	Background	Indicator (per kg product)	Indicator (per m^3 water) used)
Climate change (kg CO_2eq)	86,768,284	64,410,903	22,357,381	0.14842	1.03856
Eutrophication (kg PO_4eq)	942,070	929,699	12,371	0.00161	0.01128
Acidification (kg SO_2eq)	1,024,001	861,077	162,924	0.00175	0.01226
Human toxicity (kg 1,4-DBeq)	3,912,171	e	3,912,171	0.00669	0.04683
Resp. inorganics (kgPM10,eq)	22,145	e	22,145	0.00004	0.00027
Aquatic ecotoxicity (kg1,4-DBeq)	1,100,716	e	1,100,716	0.00188	0.01317
Terrestrial ecotoxicity (kg1,4-DBeq)	19,150		19,150	0.00003	0.00023
Ozone formation (kgC_2H_4,eq)	8688	32	8656	0.00001	0.00010
Mineral depletion (kgFe-eq)	12,503	e	12,503	0.00002	0.00015
Fossil fuels depletion (MJ)	21,291,625	e	21,291,625	0.03642	0.25485
Freshwater depletion (m^3)	13,752,563	13,752,563	0	0.02352	0.16461

Todorovic et al., 2016

Eco-efficiency of irrigated districts





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Eco-efficiency of innovative management strategies

Impact categories	**Baseline**	**Subsurface drip irrigation**	**Solar pumping**	**Smart precision technologies**
Climate Change (kgCO_2eq)	89,296,134	88,430,503	72,315,546	86,704,855
Fossil Fuels Depletion (MJ)	19,565,510	19,292,766	14,215,247	18,954,837
Freshwater Depletion (m^3)	13,753,846	13,715,395	13,753,846	13,158,292
Eutrophication (kgPO43−eq)	885,676	885,635	884,869	856,848
Human Toxicity (kg1,4-DBeq)	4,849,440	4,840,804	4,680,024	4,730,869
Acidification (kgSO_2eq)	1,168,306	1,167,719	1,156,794	1,133,382
Aquatic Eco-toxicity (kg1,4-DBeq)	1,295,962	1,295,286	1,282,703	1,255,822
Terrestrial Eco-toxicity (kg1,4-DB eq)	24,968	24,737	20,443	24,499
Respiratory Inorganics (kgPM10,eq)	32,099	32,019	30,531	31,293
Photochemical Oxidation (kgC_2H_4,eq)	11,469	11,416	10,438	11,168
Mineral Depletion (kgFe-eq)	12,146	11,954	8,383	11,822

TOTAL VALUE ADDED (Million Euro)	96,541,994	97,241,483	99,289,657	95,718,773

The way forward

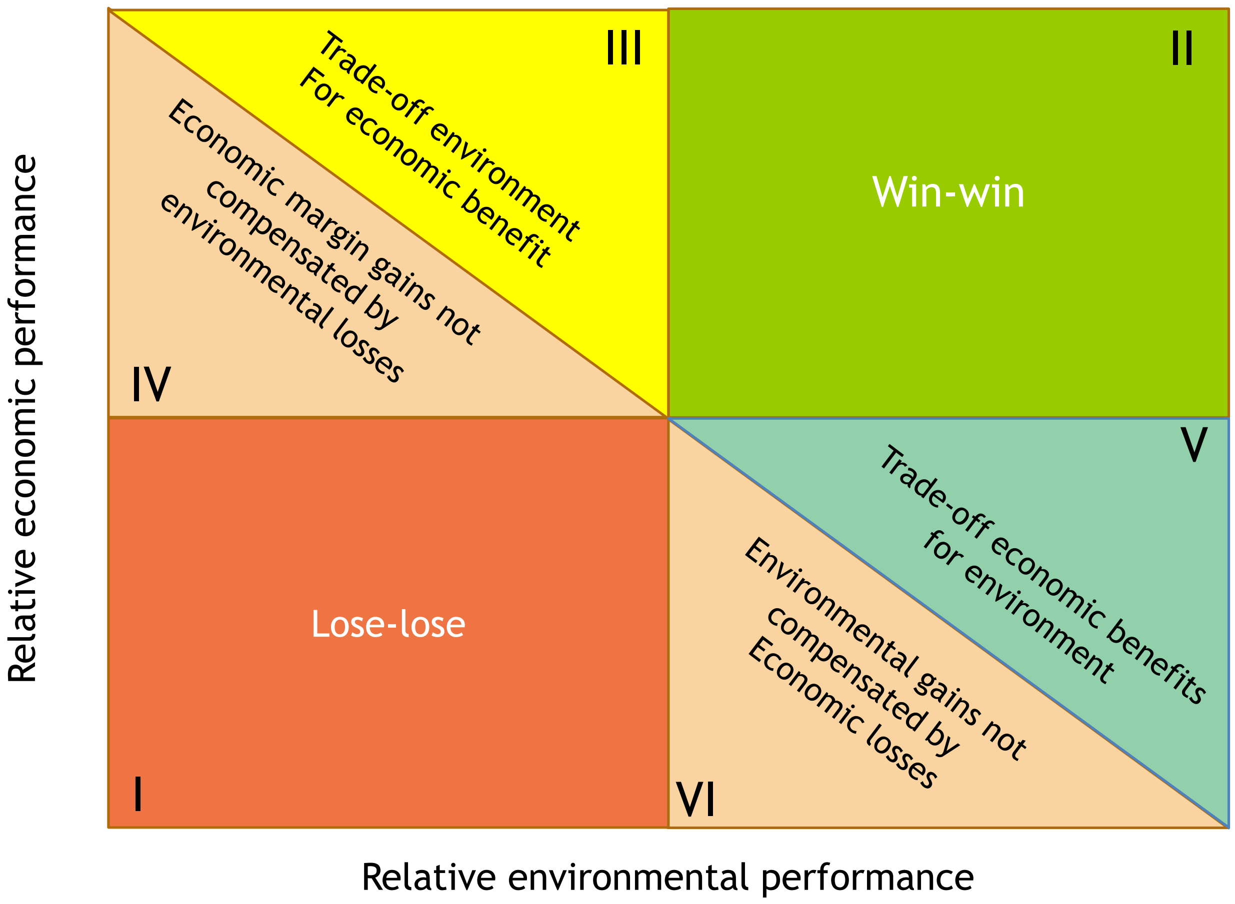
Eco-efficiency is a key concept of proper indicators which can help toward sustainable agriculture.

It is helpful

- 1. Knowledge development
- 2. Decision support
- 3. Information exchange/ communication

The preparation of an eco-efficiency requires time, skill and money. It also requires LCA methodologies, a great deal of data, and software to manipulate the data.

Eco-efficiency quadrants



https://www.mdpi.com/journal/resources/special_issues/wastewater_LCA

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24 June 2021

WEB event | Organisation: CIHEAM Bari