



Istituto di Ricerca Sulle Acque (Water Research Institute)



Consiglio Nazionale delle Ricerche (National Research Council)

Planning Agricultural Reuse: A case study from Italy on treated wastewater and crops quality

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27th April 2012
Limassol - Cyprus



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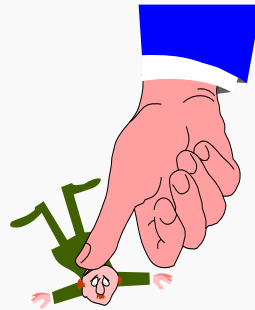


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Wastewater Reuse

- A key option for mitigating water resources scarcity-

Main Drivers



Water shortage
(quantitative and/or qualitative)

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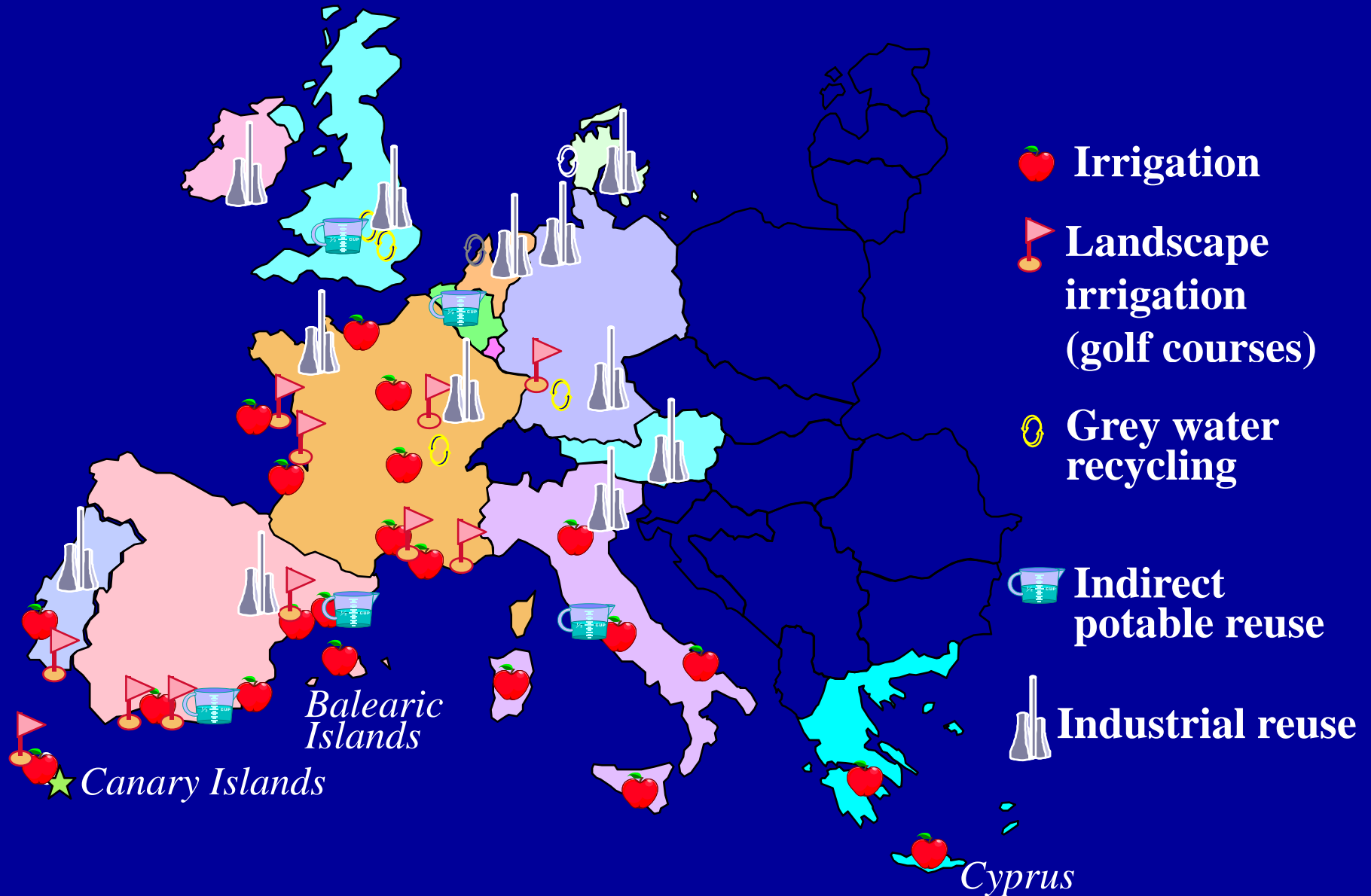
More and more stringent regulations

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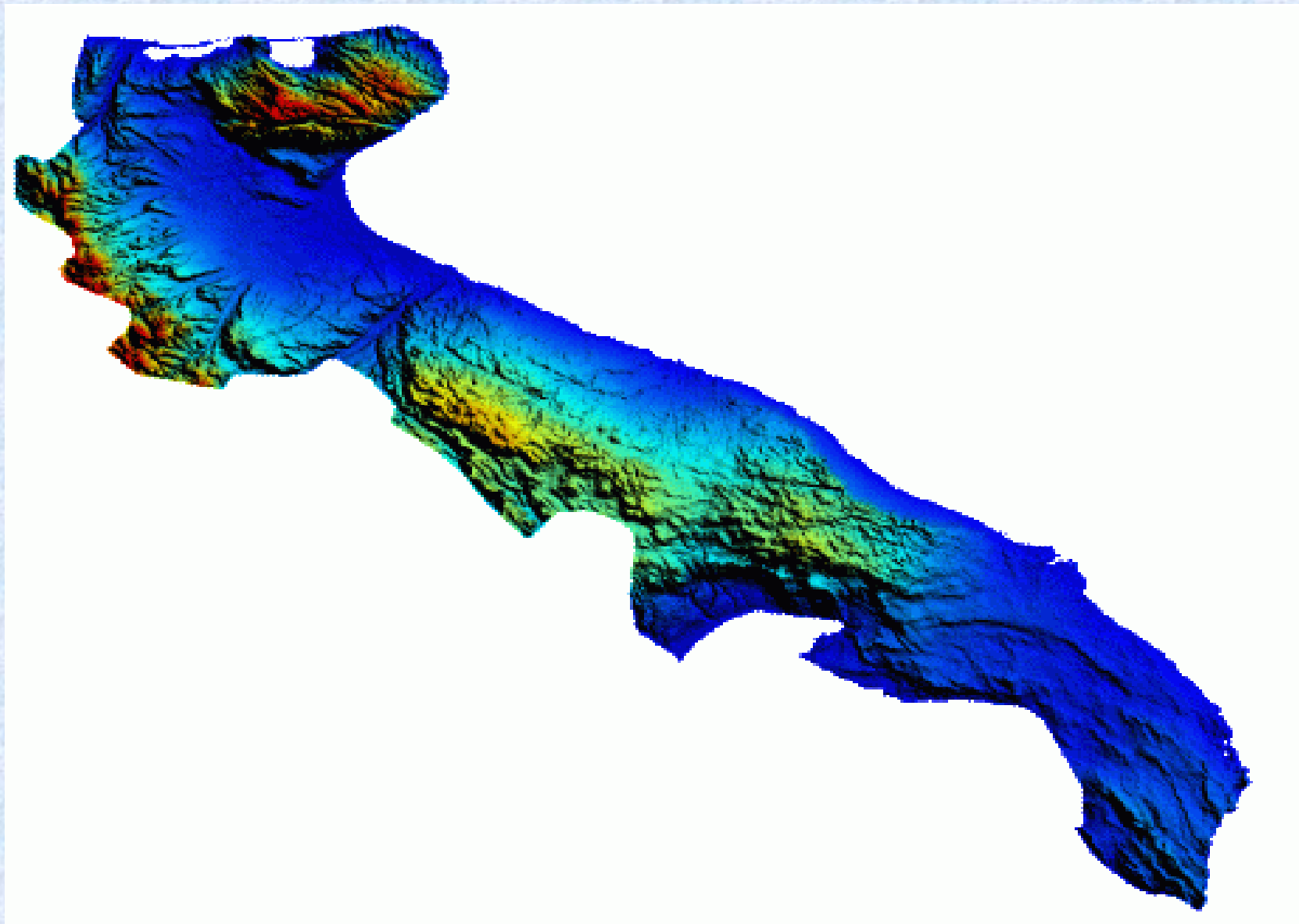
Social, Political and Market pressure

Water reuse in EU Countries

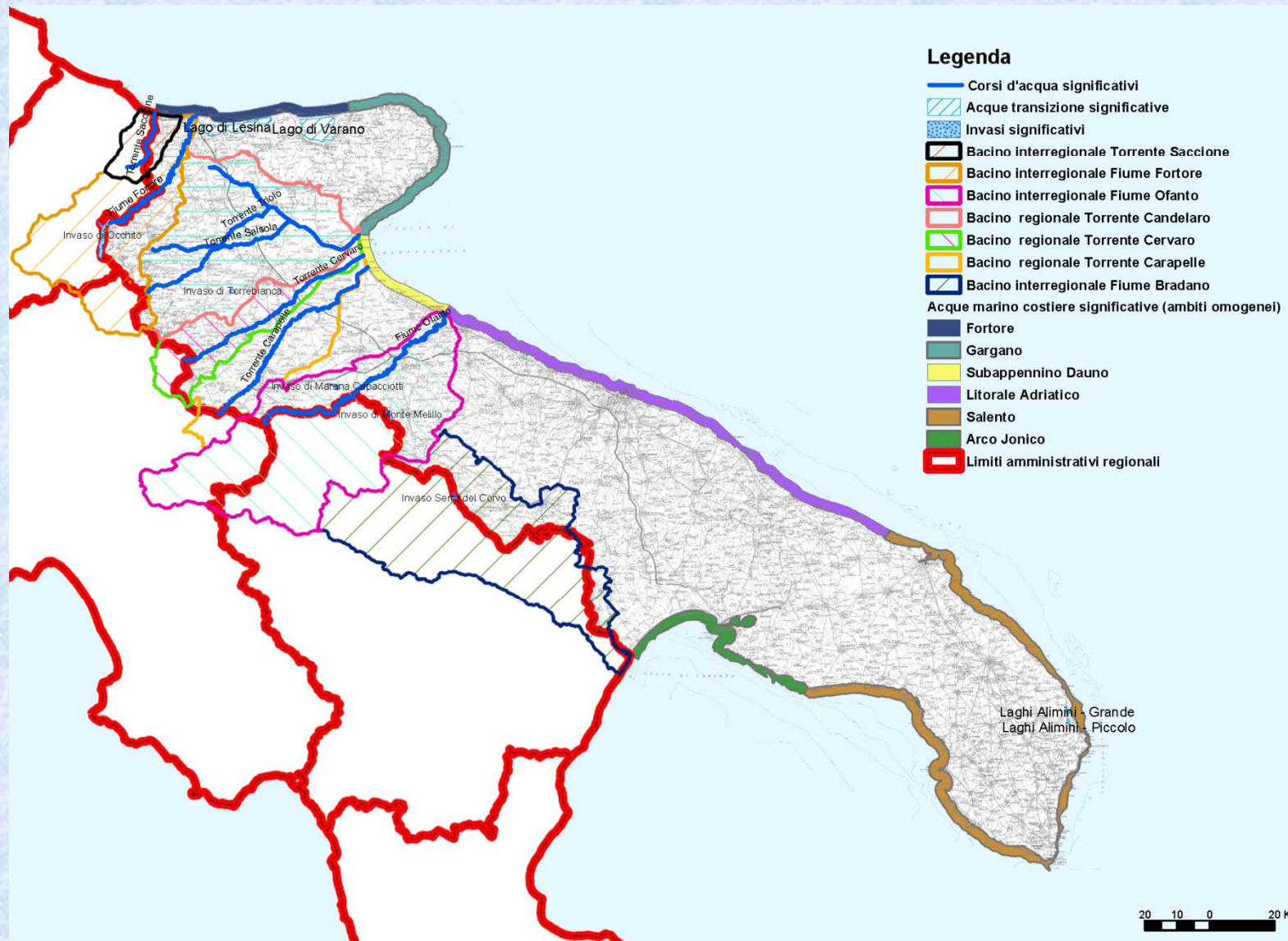
Diversification of types of reuse



Orography of Apulia Region



Hydrography of Apulia Region





APULIA

Population: 4,500,000 M

Area: 19,000 km²

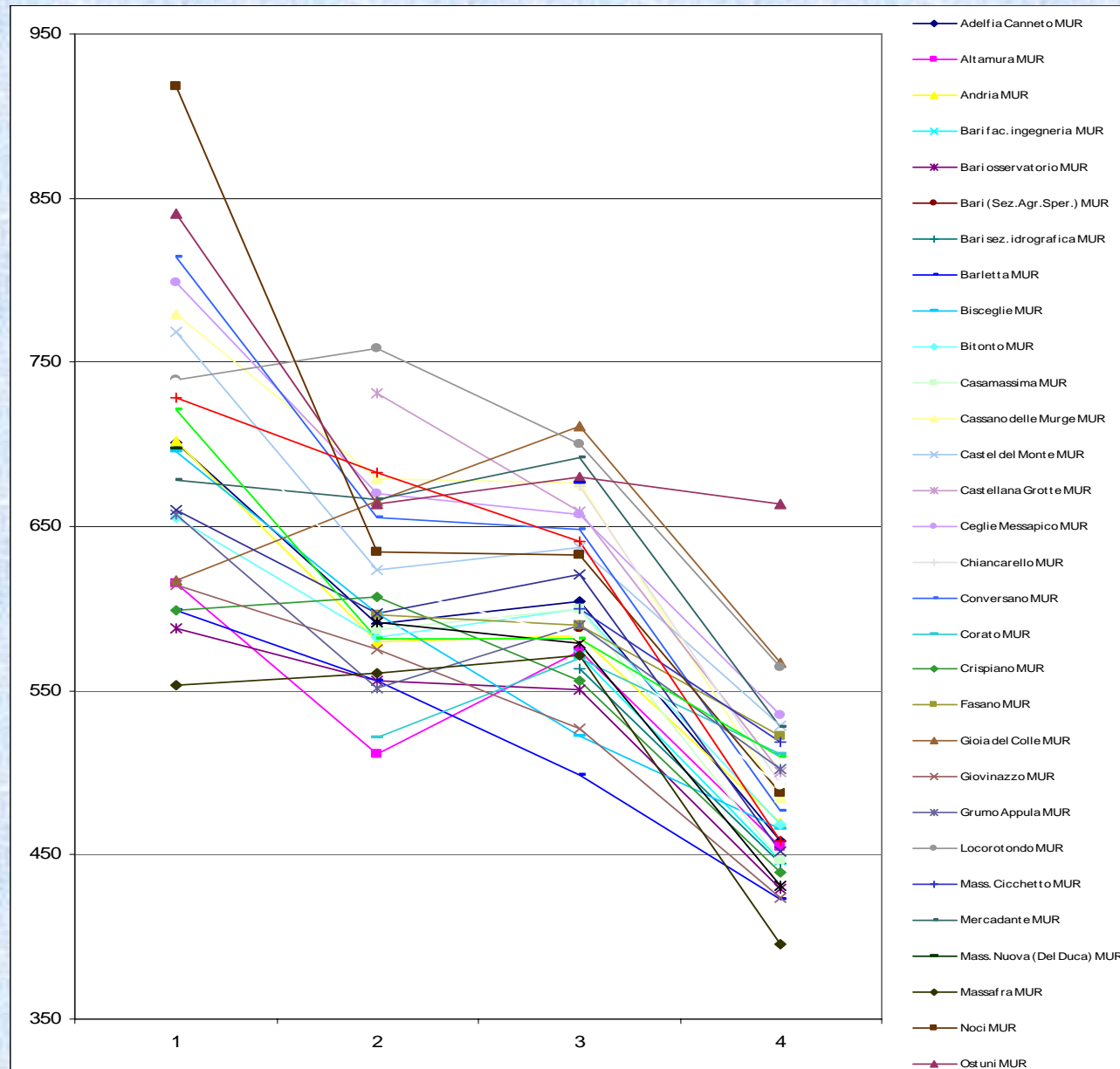
Coasts length: 800 km

Inflows and Outflows average yearly values of the main Italian regional water basins (1965-2005)

Main regional water basins	INFLOWS		OUTFLOWS		OUTFLOWS COEFFICIENTS
	mm	10 ⁹ m ³	mm	10 ⁹ m ³	
Po	1070	71.8	670	47.0	0.62
Veneto	1160	42.8	810	30.0	0.70
Liguria	1340	6.4	990	4.8	0.74
Romagna + Marche	940	20.6	460	10.1	0.49
Toscana	1010	20.9	470	9.7	0.47
Lazio	1020	24.1	440	10.3	0.43
Abruzzo + Molise	900	11.9	490	6.5	0.54
Campania	1200	23.2	670	12.9	0.56
Puglia (APULIA)	660	13.2	150	2.9	(150/660) = 0.23
Basilicata	800	7.9	200	2.0	0.25
Calabria	1170	16.1	560	7.8	0.48
Sicilia	730	18.8	190	4.9	0.26
Sardegna	780	18.3	250	6.1	0.33
ITALY	990	296.0	510	15.5	0.52

Rainfalls trends in Apulia during the period 1965-2005

(Ten years average values measured at selected rainfall stations)



Yearly sectorial water needs in Apulia

INDUSTRY

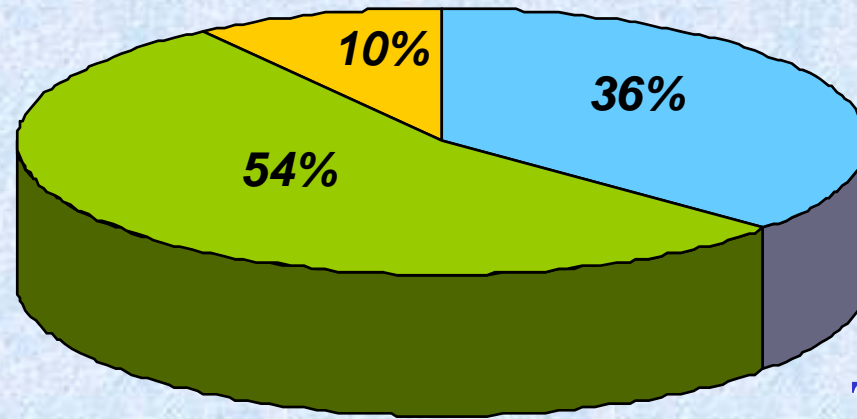
(142 Mmc)

AGRICULTURE

(812 Mmc)

POTABLE

(546 Mmc)

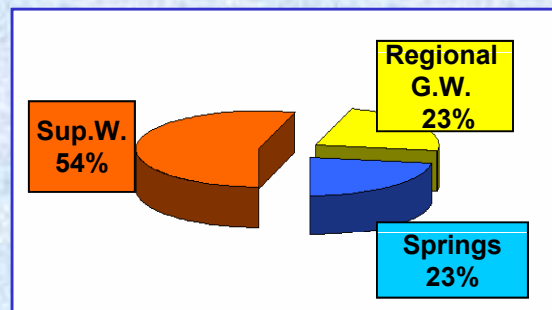


TOTAL=1500 Mmc

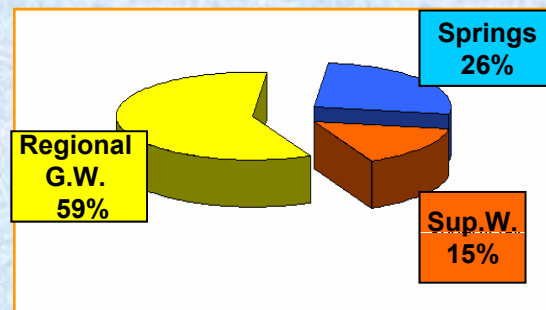
- 55% coming from regional groundwater [~ 150,000 wells]
- 45% coming from out of Region sources (11% from springs and 34% from superficial water bodies)

Sectorial water-sources contribution (%)

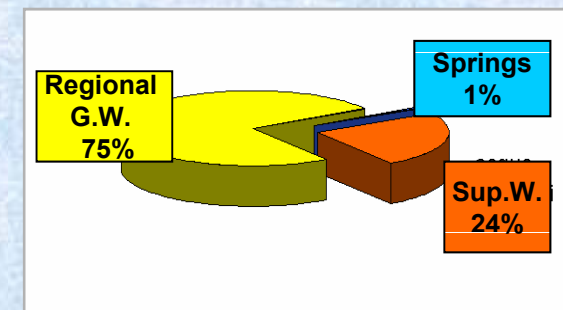
POTABLE



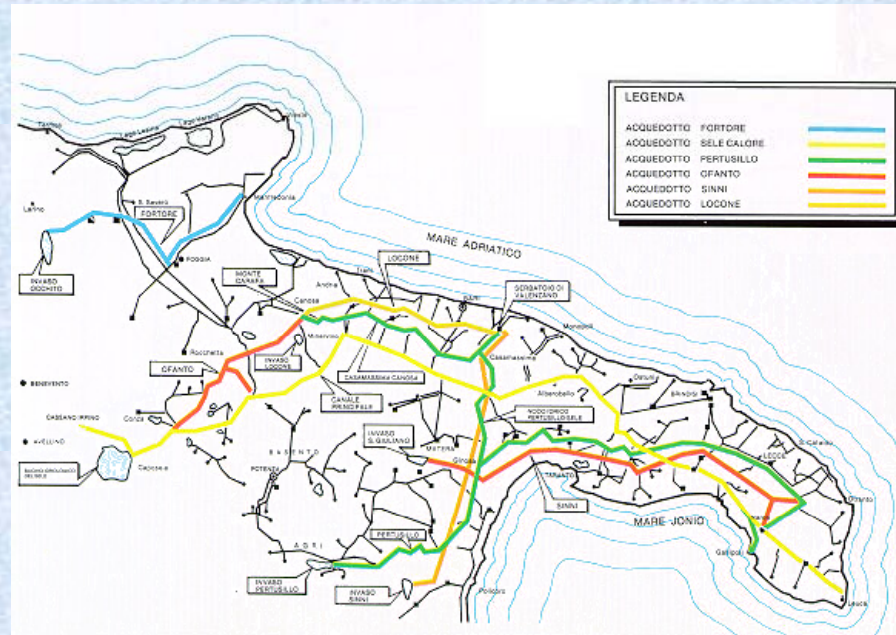
INDUSTRY



AGRICULTURE



In Apulia potable needs are satisfied by the Apulian Aqueduct (AQP): the largest in Europe – the third in the World

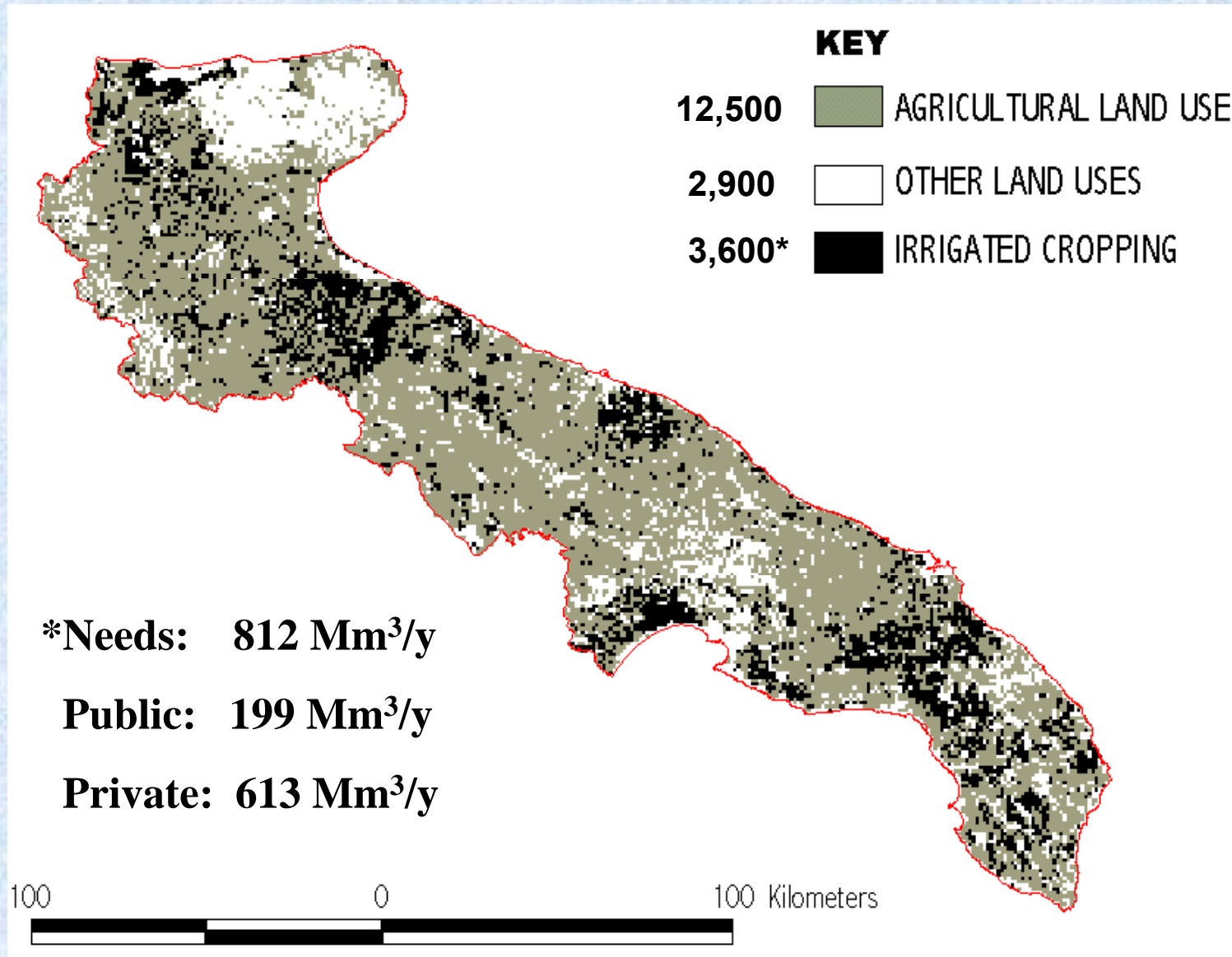


Main figures

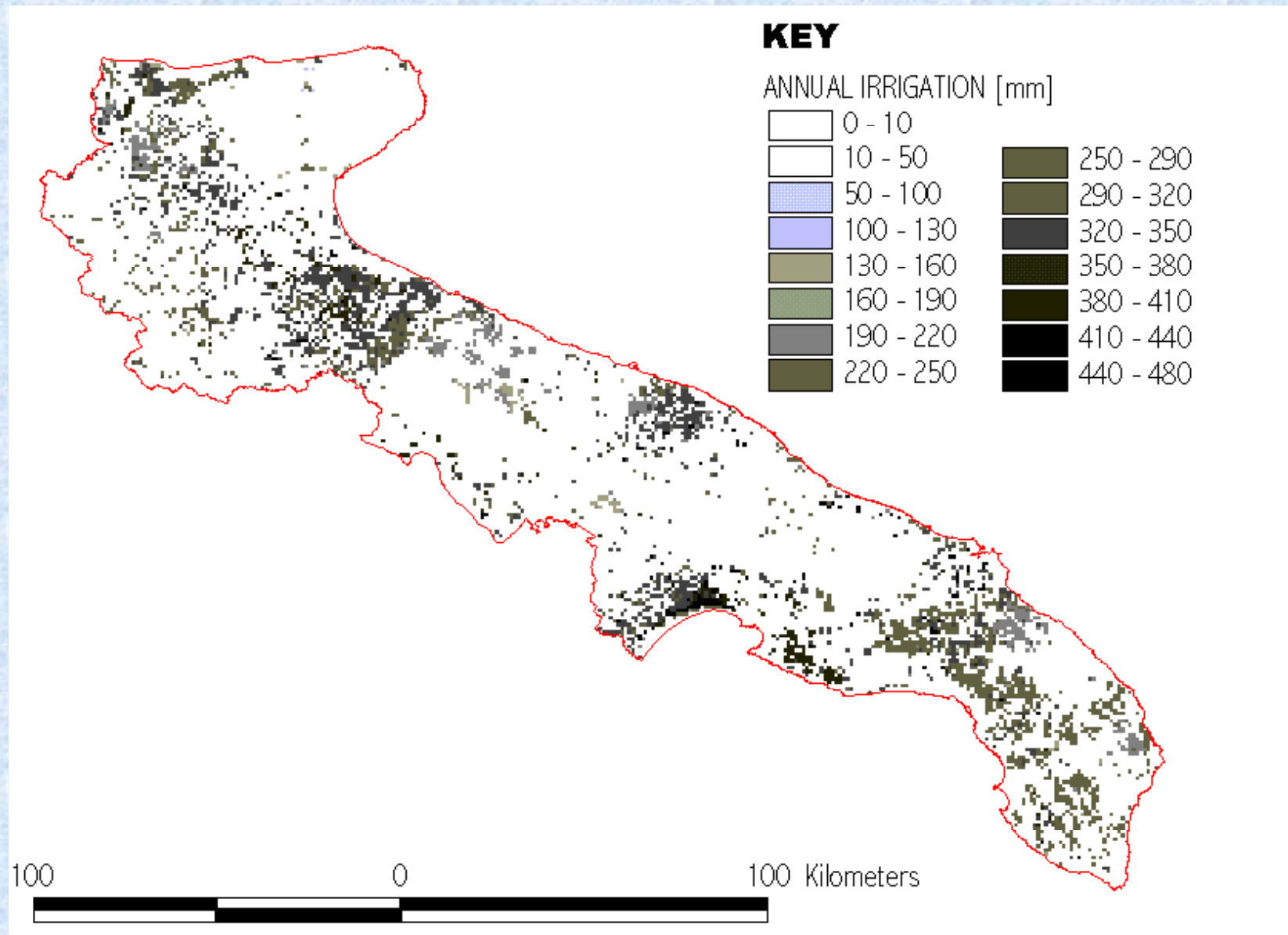
- ✓ 250 (municipalities served)
- ✓ 4,000,000 (inhabitants)
- ✓ SERVICES PROVIDED - water: treatment, supply and distribution - wastewater: collection and treatment
- ✓ 20,000 Km² (territory served)
- ✓ 20,000 Km (distribution pipelines)
- ✓ 550,000,000 m³/y (distributed water)

23% Regional GW
77% Bordering Regions

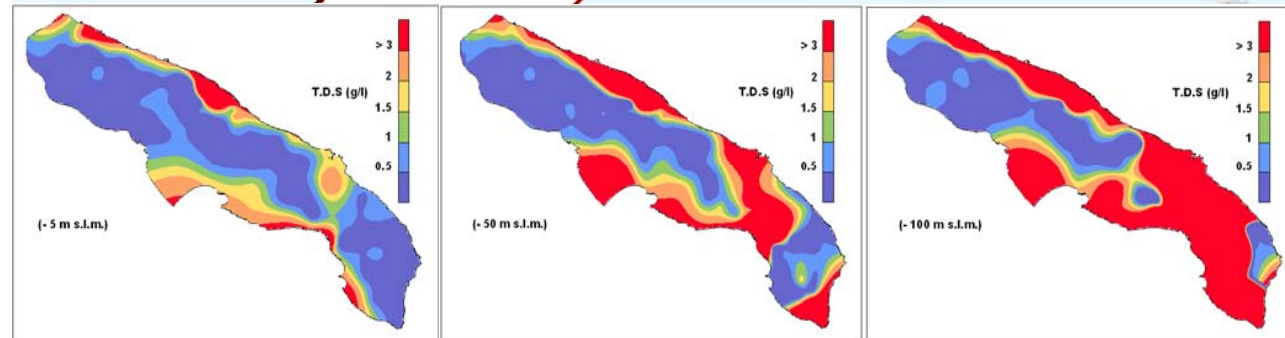
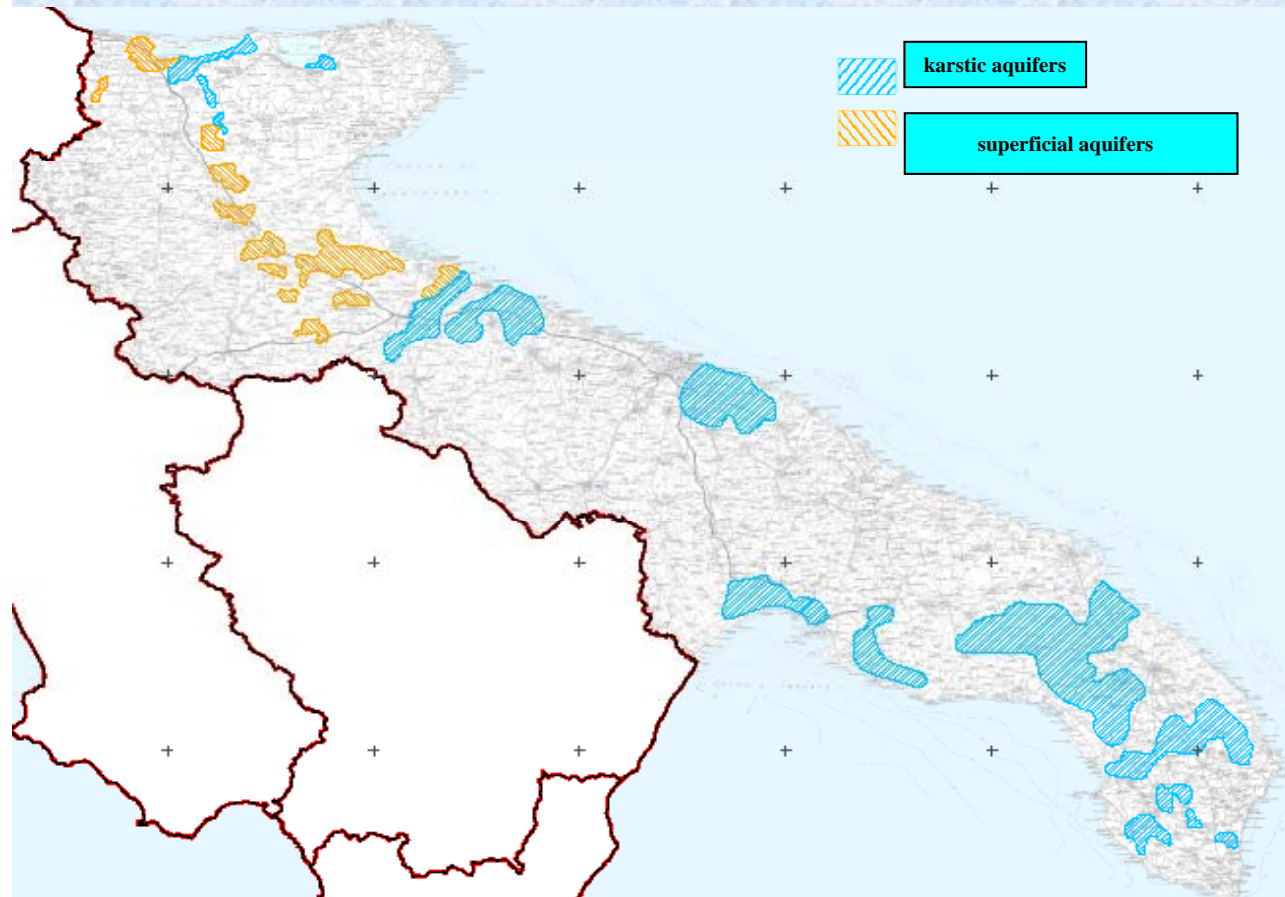
Land use in Apulia (Regional Total Area: 19,000 km²)



Groundwater withdrawals for irrigation purposes in Apulia (mm/y)

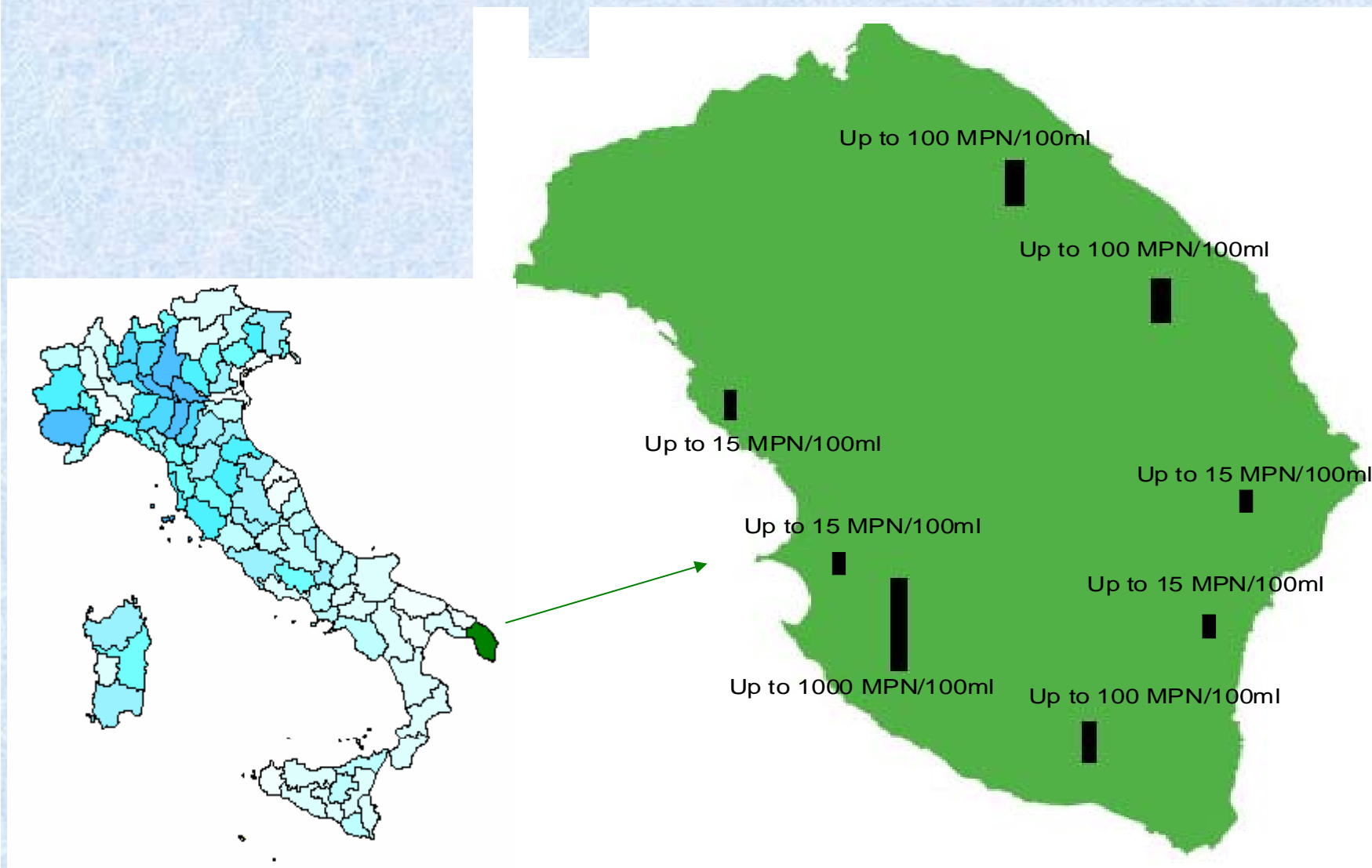


Apulian areas affected by groundwater overexploitation



**SALT
INTRUSION
PHENOMENA**

Occurrence of faecal coliforms in Apulian groundwater samples



Sampling period: 1996-2003

The Apulian Water Protection Master Plan

”Piano di Tutela delle Acque (PTA)”

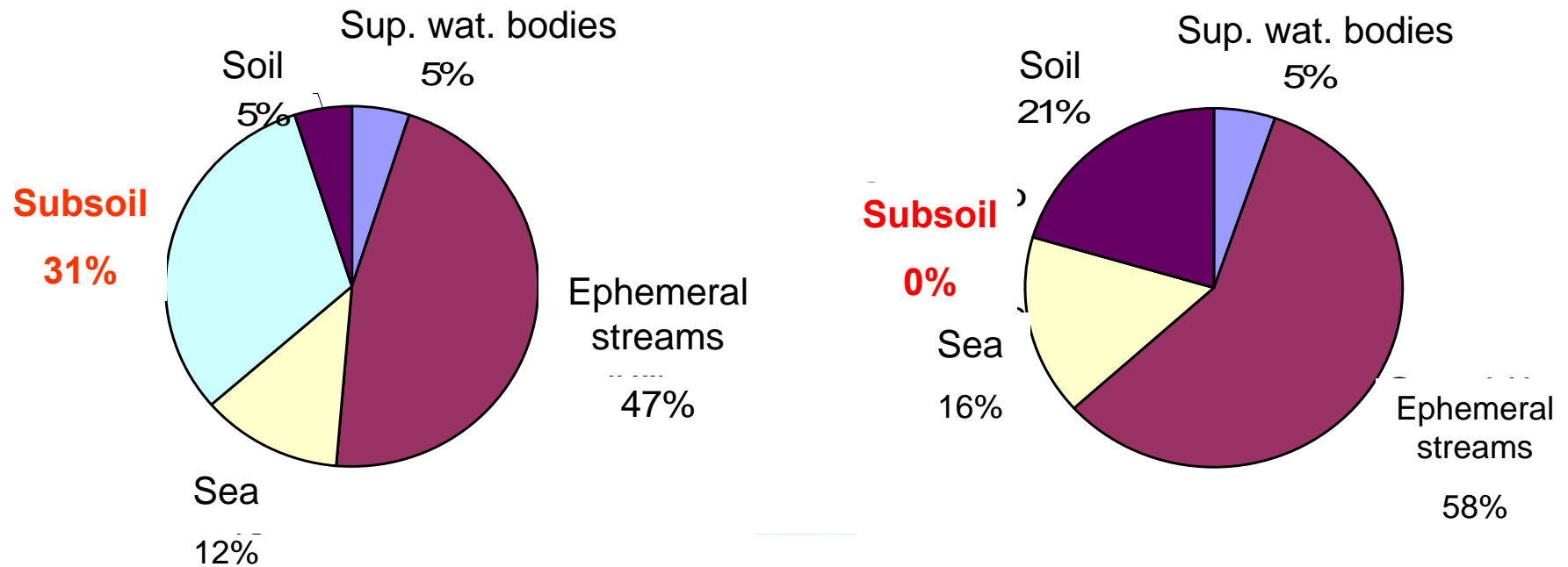
(definitively issued on 20th/October/2009)

Aim:

**assessing the quality state of regional water resources and
planning the implementation of the necessary measures for
preventing their quali-quantitative worsening**

One of the main goals of the Apulian PTA:

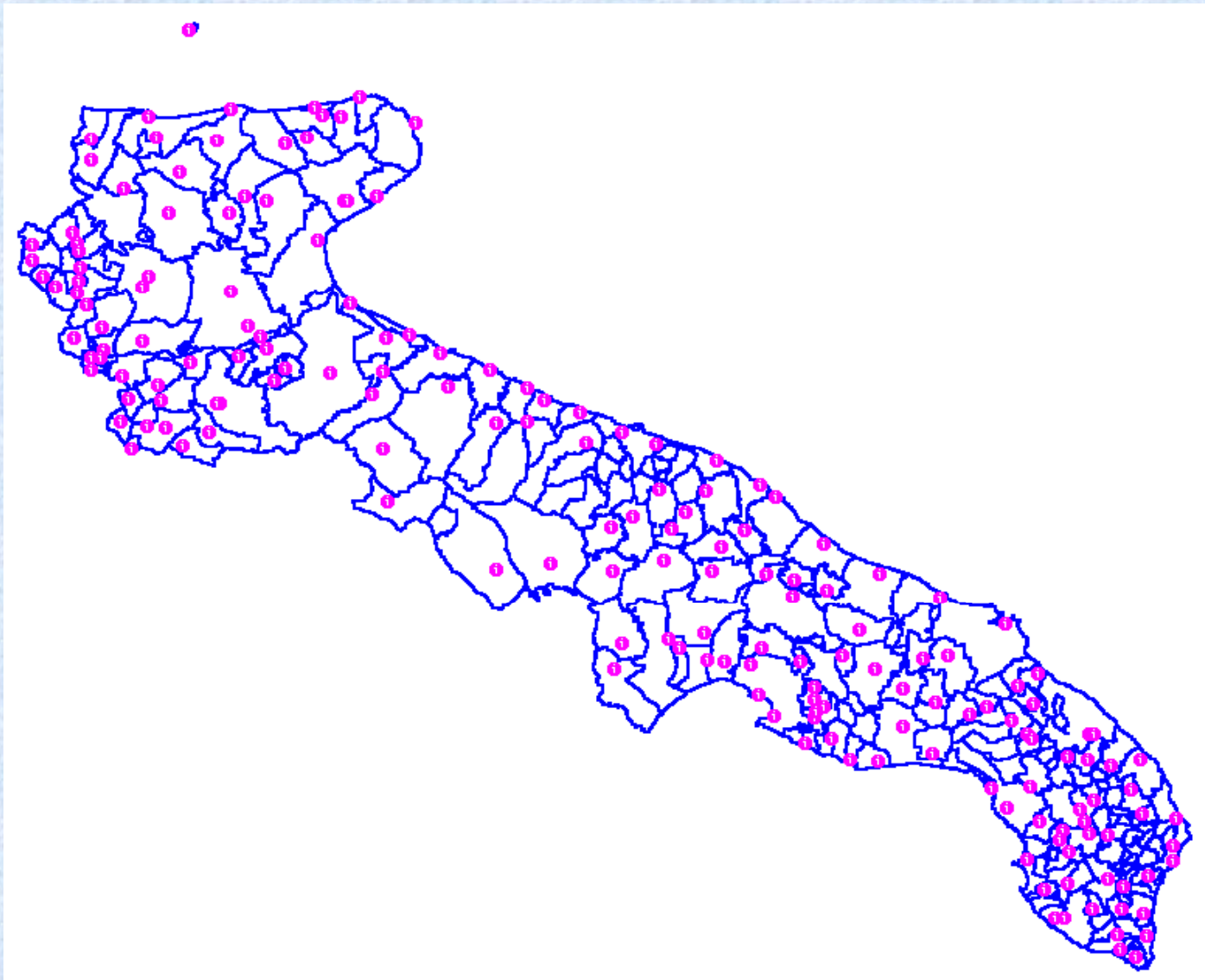
STOP DISCHARGING TREATED MWW INTO GROUNDWATER !



Situation: before PTA

expected after PTA implementation

Geographical distribution of Apulian MWWTPs (182)



Criteria used for planning MWW Reuse in Apulia

Selection of areas and WWTPs

AREAS

- **Possibility to storage the treated water in natural reservoirs**
- **Severe sea water intrusion and groundwater pollution phenomena**
- **Scarcity of superficial water bodies**
- **Presence of users**

MWWTPs

- **Plants technologically ready to produce effluents having the required quality**
- **Plants whose technological upgrading can be rapidly achieved**
- **Plants that can be easily connected to the infrastructures necessary to distribute the treated effluents**

NB - In case all the above criteria were satisfied but the local water demand was lower than the wastewater production, the WW reuse was excluded.

Apulian PTA goals: IMPLEMENTING MWW REUSE

Volumes of reusable municipal wastewater in Apulia according to the PTA

1st phase

VOLUMES REUSABLE FROM THE POLISHING TREATMENT PLANTS **ALREADY**

- EXITING **or**
- UNDER CONSTRUCTION **or**
- FINANCED

POTENZIALITA' DISPONIBILE		
PROVINCIA		POTENZIALITA'
BARI	mc/anno	22.690.000
BRINDISI	mc/anno	4.480.000
FOGGIA	mc/anno	12.090.000
LECCE	mc/anno	12.080.000
TARANTO	mc/anno	41.058.000
TOTALE	mc/anno	92.398.000

92 Mm³/y

2nd phase

VOLUMES THAT WILL BE REUSED WHEN **ALL** THE APULIAN WASTEWATER TREATMENT PLANTS WILL BE EQUIPPED WITH A POLISHING STEP

POTENZIALITA' TOTALE		
PROVINCIA		POTENZIALITA'
BARI	mc/anno	42.473.510
BRINDISI	mc/anno	9.392.619
FOGGIA	mc/anno	16.780.644
LECCE	mc/anno	29.752.337
TARANTO	mc/anno	49.219.631
TOTALE	mc/anno	147.618.741

NOTE THAT THIS IS JUST THE VOLUME PRESENTLY REQUIRED BY THE WHOLE APULIAN INDUSTRIAL SECTOR



147 Mm³/y

Regulations: Last step!

REGOLAMENTO REGIONALE

Norme e misure per il riutilizzo delle acque reflue depurate

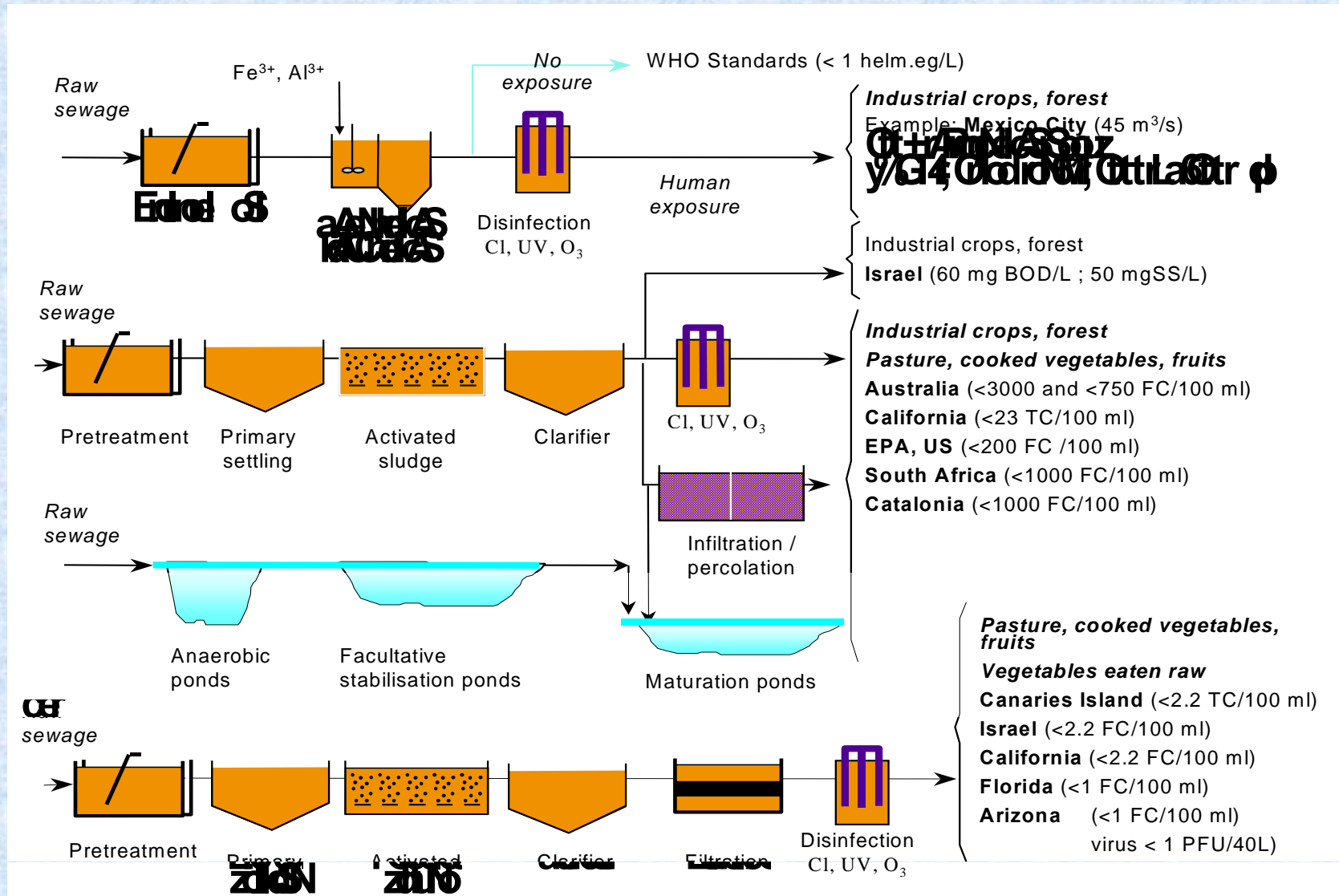
Art. 99, comma 2, TITOLO III, CAPO II, D.Lgs. n. 152/2006 e

Legge della Regione Puglia n. 27 del 21 Ottobre 2008, art. 1, lettera b

First draft issued on January 2011

Definitive issued on March 2012

Typical treatment schemes used to achieve different water quality objectives for agricultural irrigation



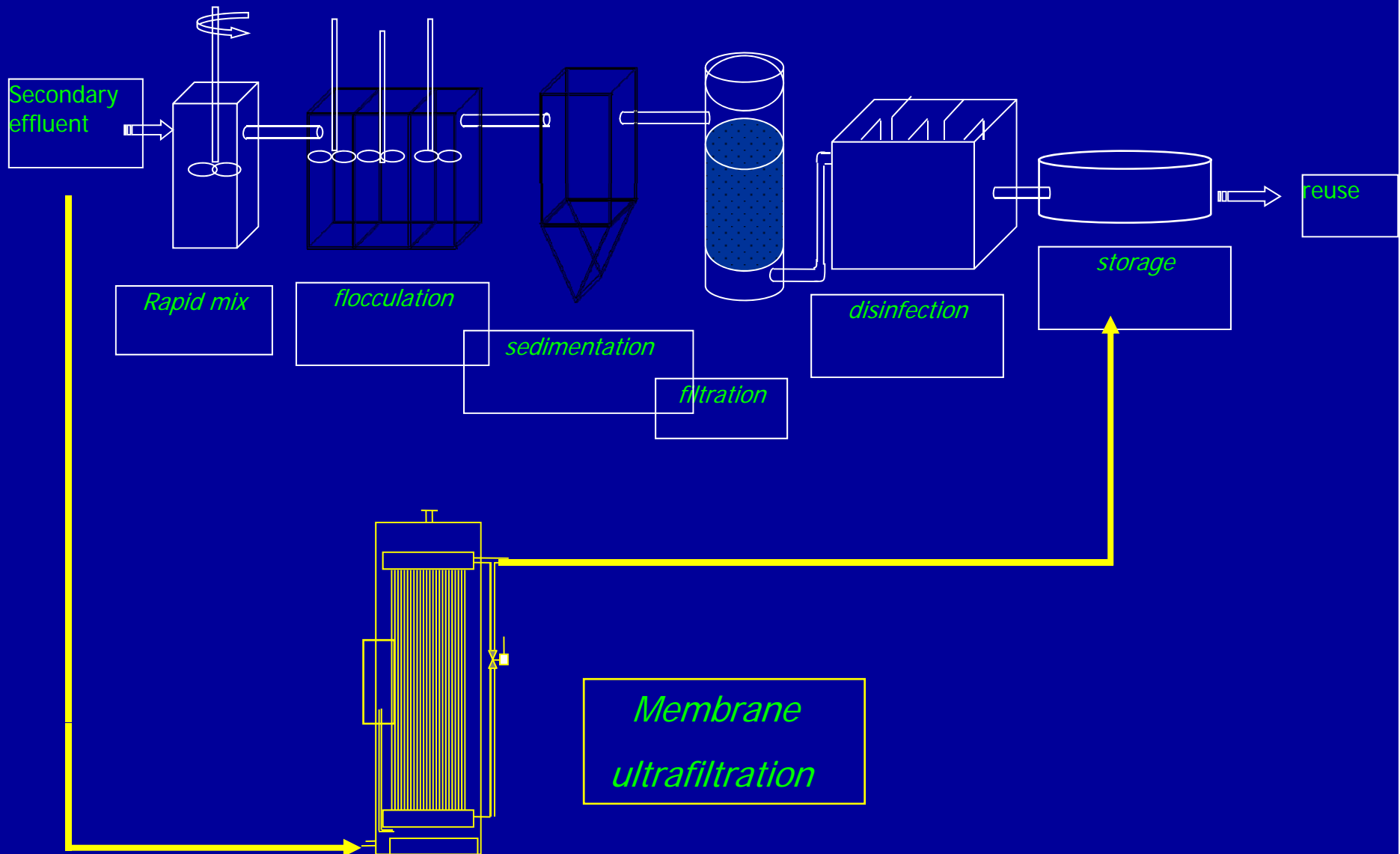
Main quality parameters fixed by the in force Italian law (D.Lgs n. 185/03) for agricultural reuse of municipal wastewater.

(*) = Exceptions possible in Apulia.

PARAMETER	VALUE	PARAMETER	VALUE
pH	6-9.5	Total Phosphorus(mg/L)	10
Coarse solids (mg/L)	absent	Total Nitrogen (mg/L)	35
TSS (mg/L)	10	Grease and Oil (mg/L)	10
COD (mg/L)	100- (50)*	Aldehydes (mg/L)	0.5
BOD ₅ (mg/L)	20 - (10)*	Surfactants	0.5
Boron (mg/L)	1.0- (2.0)*	Chlorinated Pesticides	0.0001
Chlorides (mg/L)	250-(500)*	Escherichia coli (CFU/100ml)	10
Sulphates (mg/L)	500	Salmonella (CFU/100ml)	absent
Electrical Conductivity (µS/cm)	3,000	Sodium Adsorption Ratio	10

Notes: In addition to B even Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Si, Th, V, Zn, THM, CN, SO₃, Benzene, Benzo(a)pyrene and other organics are considered.

Conventional polishing treatment train used to achieve the quality standards fixed for agricultural reuse of municipal wastewater



Membrane Filtration pilot plant at CERIGNOLA (FG)

[Zee Weed 250]

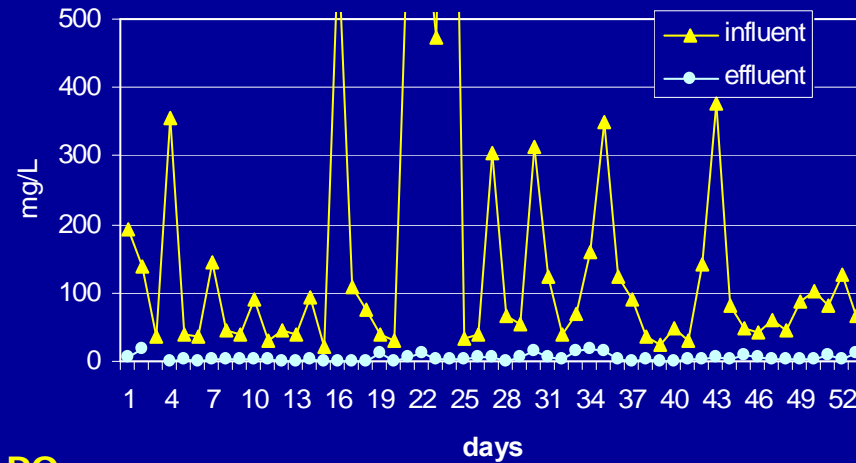


Total membrane surface area **23.5 m²**

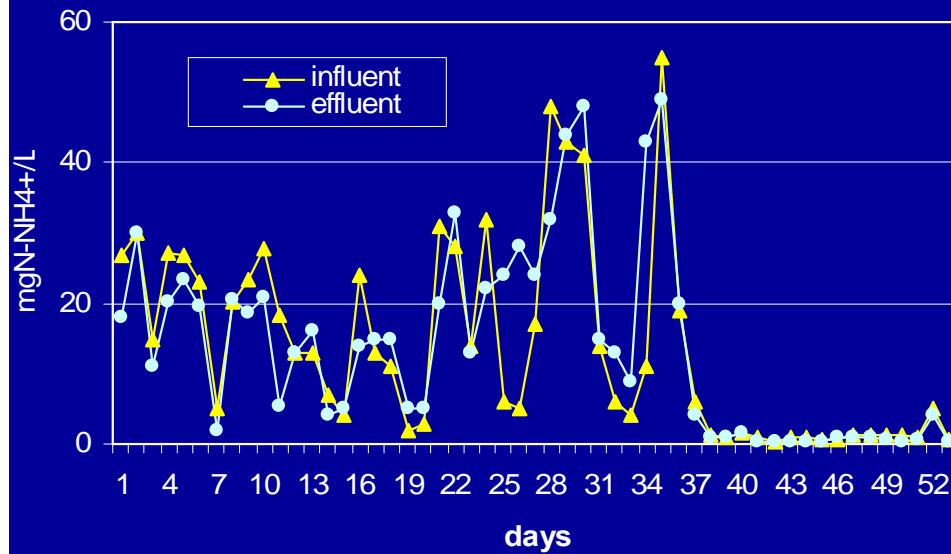
Ø ext. **1.9 mm**
Ø int. **1.0 mm**
Ø pores: **0.03 µm**
Material: **Polyethylene**
Surface: **Hydrophilic**

Municipal wastewater membrane filtration at CERIGNOLA plant: some performances

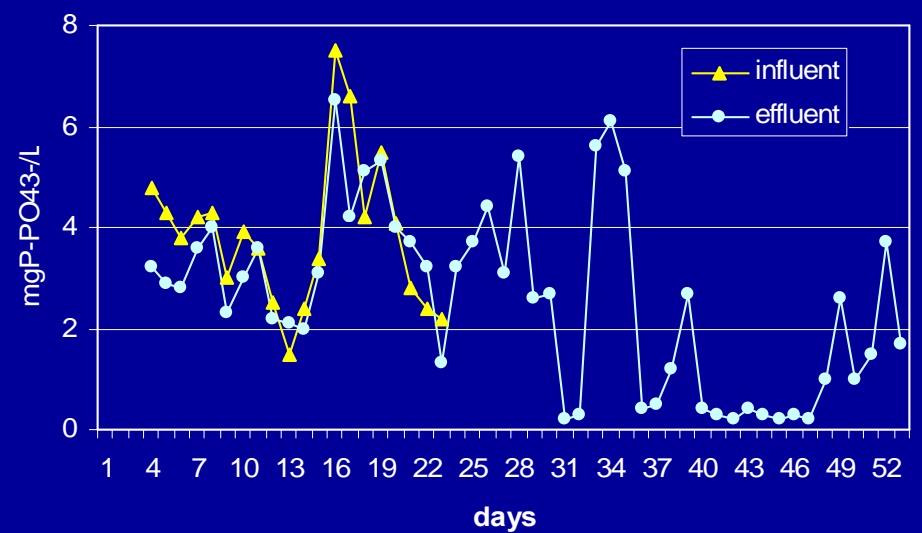
TOTAL SUSPENDED SOLIDS



P-PO₄



N-NH₄

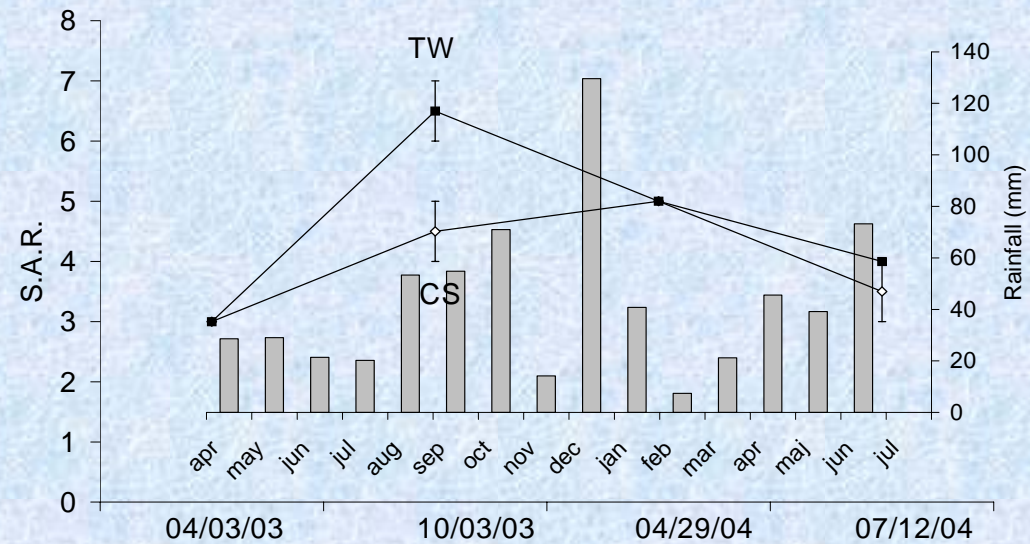
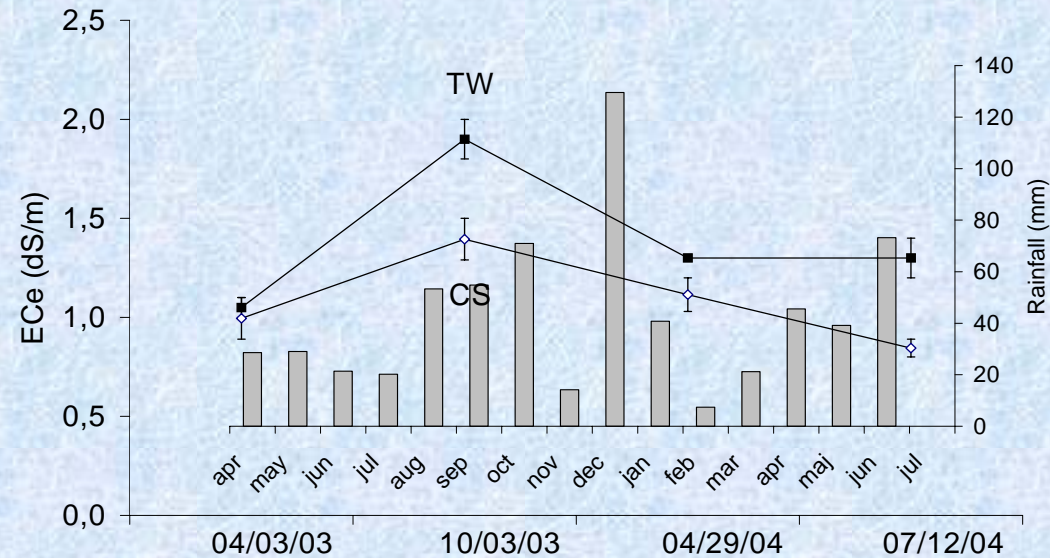


Quality of membrane filtered wastewater compared with conventional well water and regional quality limits

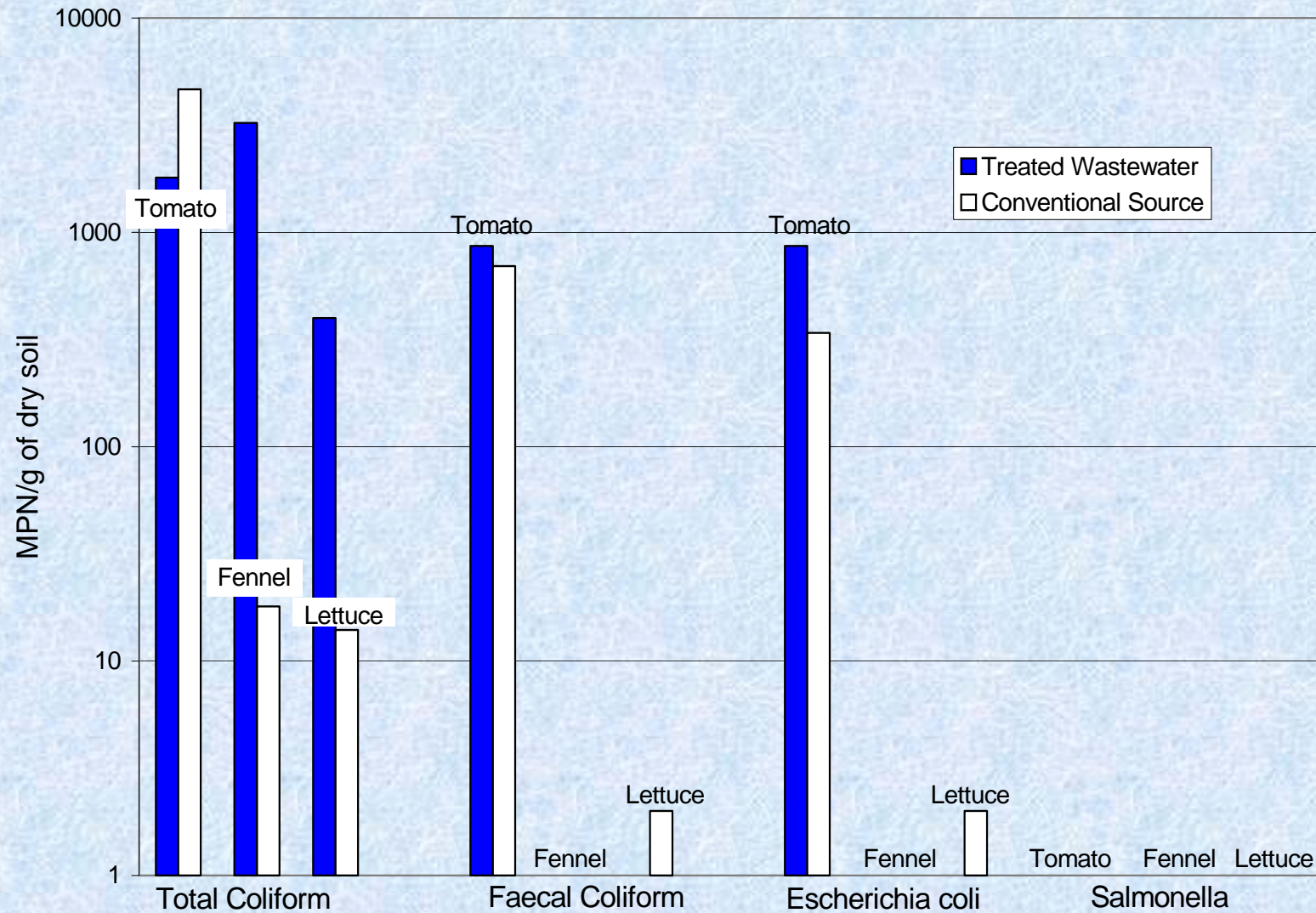
Parameter	Unit	Treated Wastewater	Conventional Source	Regional limits (*)
TSS	mg/L	< d.l.	< d.l.	10
COD	mgO ₂ /L	43	32	50
N-NH ₄ ⁺	mg/L	1.0	0.3	2
NO ₃ ⁻	mg/L	9.5	5.8	
P-PO ₄ ⁻	mg/L	2.3	2.3	10
Na ⁺	mg/L	329	124	
Ca ⁺⁺	mg/L	45	44	
Mg ⁺⁺	mg/L	27	51	
Cl ⁻	mg/L	460	256	500
K ⁺	mg/L	30	18	
B	mg/L	1.0	0.1	2.0
Fe	mg/L	0.0	0.0	2.0
Mn	mg/L	0.0	0.0	0.2
ECw	dS/m	2.4	1.5	3.0
S.A.R.		13	4	10
Total coliforms	Cfu/100mL	146	293	
Faecal coliforms	Cfu/100mL	38	73	
Escherichia Coli	Cfu/100mL	8	13	10
Salmonellae	Cfu/100mL	0	0	0

(*) Limits established by Apulia Region for unrestricted reuse of municipal wastewater in agriculture.

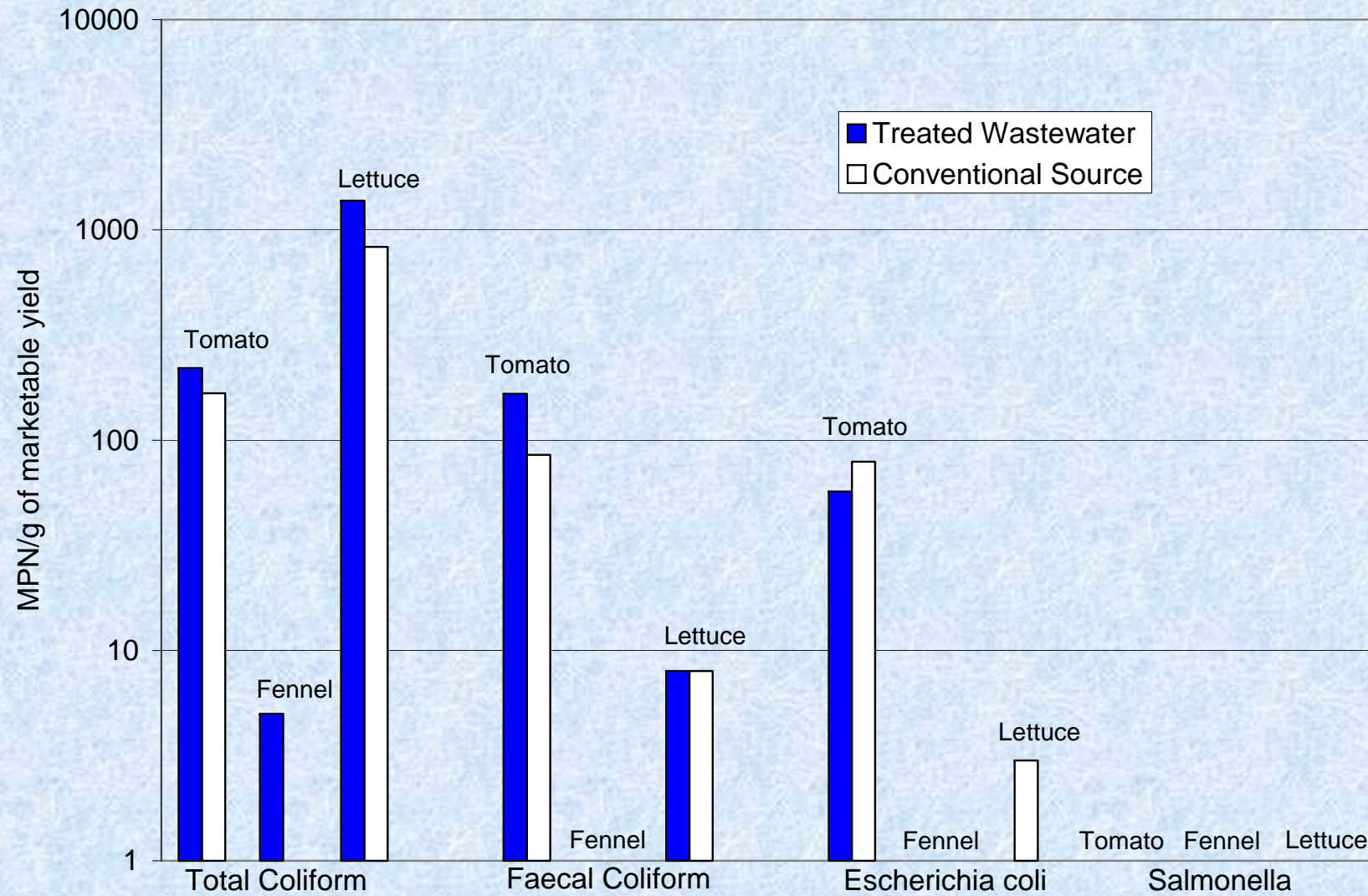
Trends of soil electrical conductivity (ECe) and SAR and comparison with monthly rainfall



Microbiological parameters measured in soil samples on harvesting time



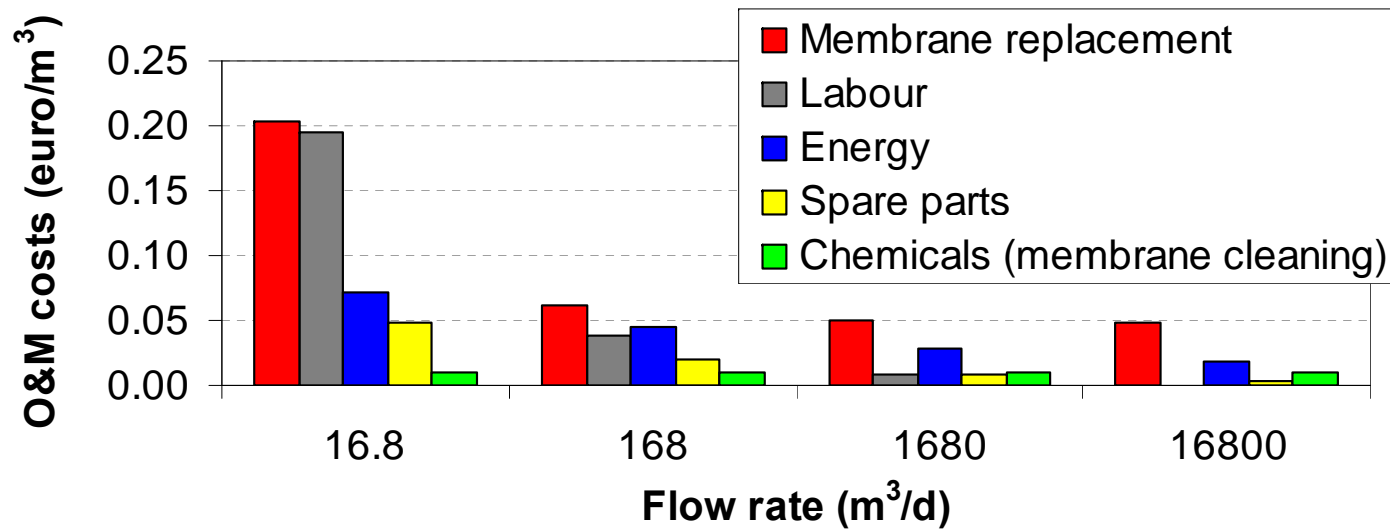
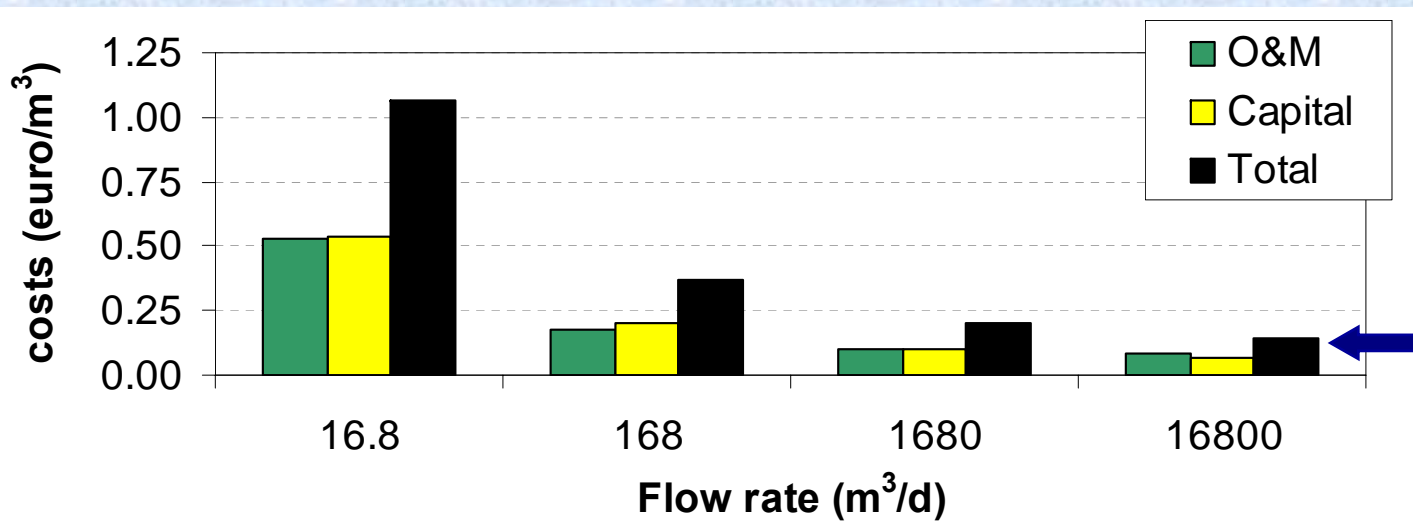
Microbiological parameters measured in tomato fruits, fennel heads and lettuce leaves on harvesting time



Average concentrations of heavy metals in crops irrigated with conventional well water (CS) and membrane filtered wastewater (TW)

Metal	Unit	Tomato fruits		Fennel heads		Lettuce leaves		Common range	Toxic range
		CS	TW	CS	TW	CS	TW		
Fe	mg/kg	12	13			5	10	30-300	
Al	mg/kg	4.0	1.2					7-75	75
Cu	mg/kg	0	0			3	4	3-20	25-40
Zn	mg/kg	0.4	2.0	9	10	6	6	15-150	500-1500
Pb	mg/kg	0	0	0	0	0	0	2-5	400-200
Mn	mg/kg	0	0	92	101	90	48	15-150	

Wastewater Membrane Filtration: Costs Estimation



Equivalent Inhabitants

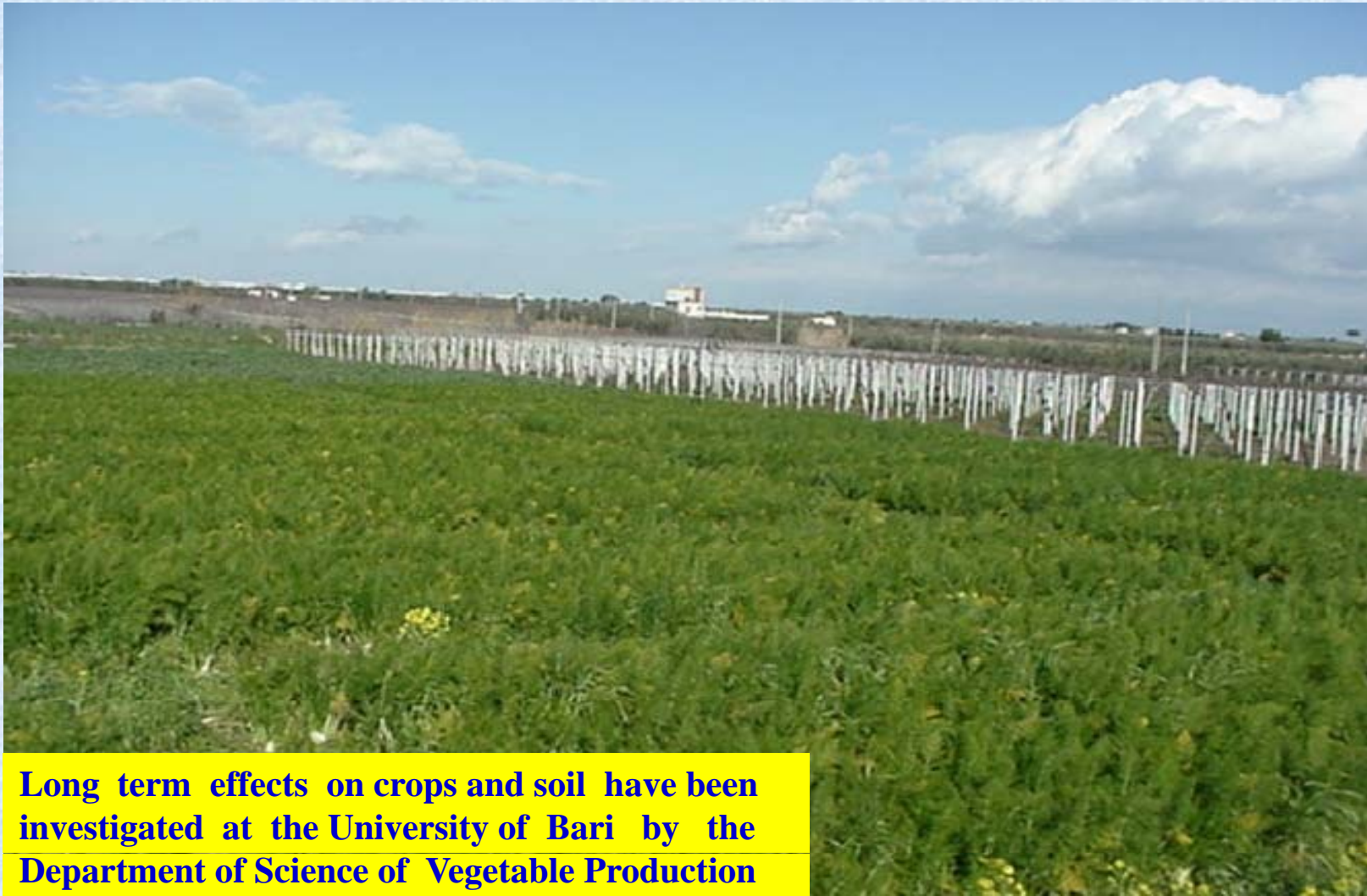
50

500

5000

50000

Field of fennels irrigated with membrane filtered municipal wastewater at CERIGNOLA (FG)



Long term effects on crops and soil have been investigated at the University of Bari by the Department of Science of Vegetable Production

*Thank you
for your attention*