VALORIZATION OF URBAN WASTEWATER IN AGRICULTURE

From waste to sustainable resource

Bruno Sousa, **Cristiano Soares** and Fernanda Fidalgo

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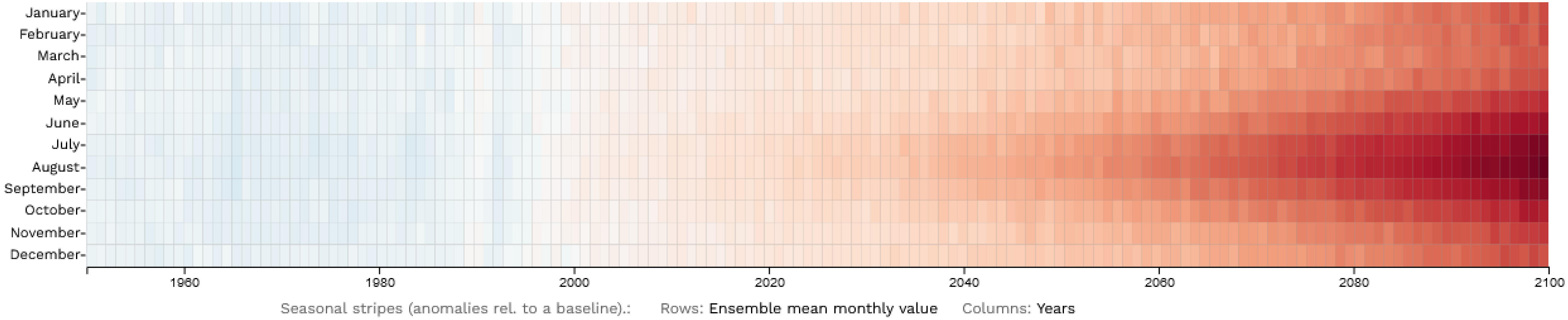
GREENUPORTO · inov4agro · U.PORTO FC FACULDADE DE CIÊNCIAS UNIVERSIDADE DO PORTO · Plant Stress lab · Interreg España - Portugal · bluewater

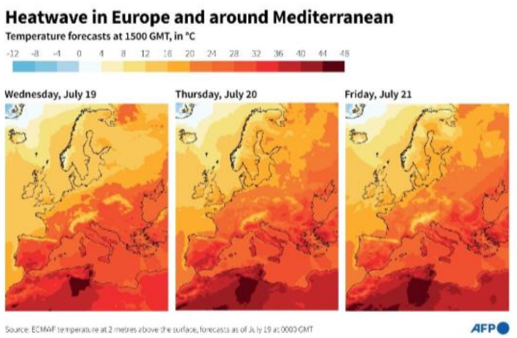
CLIMATE CHANGE

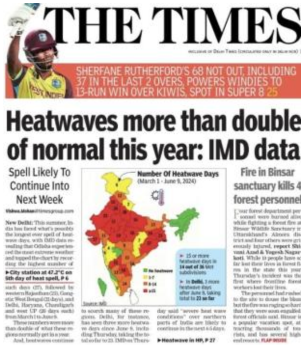
Projected **temperature increase** for the **Mediterranean region** (IPCC 2021)

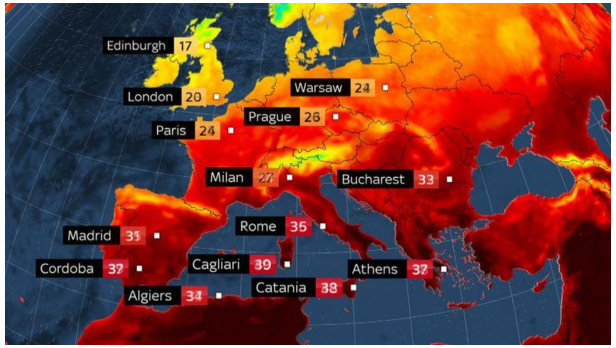


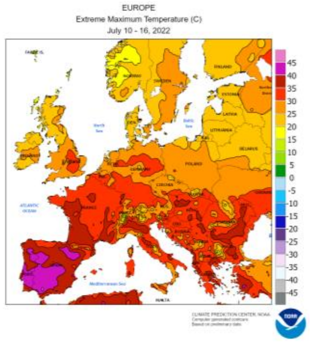
“There’s one issue that will **define the contours of this century** more dramatically than any other, and that is the **urgent and growing threat of a changing climate**.”

@Barack Obama – United Nations Climate Change Summit (2014)







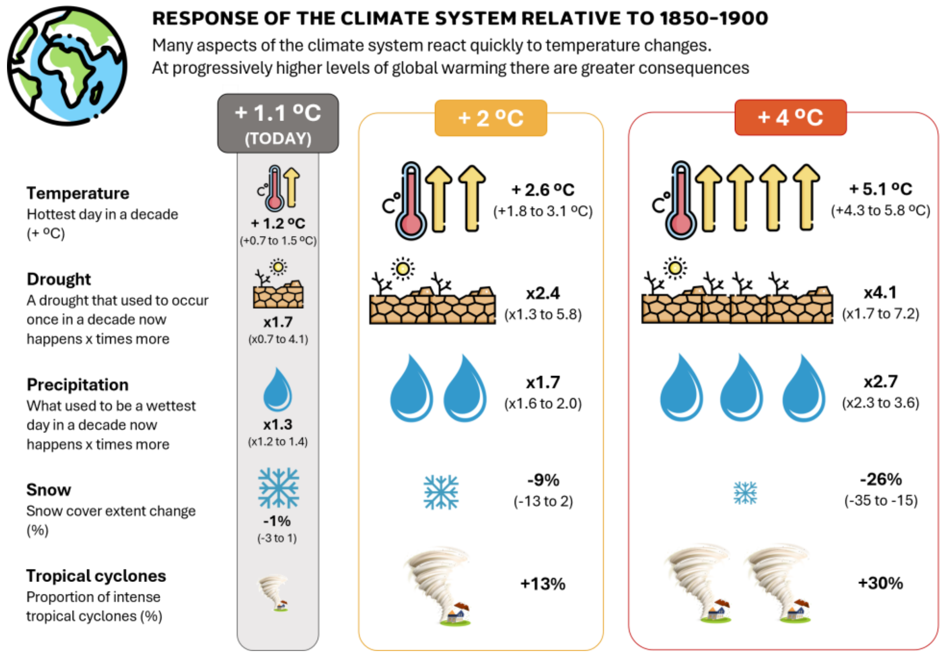


CLIMATE CHANGE

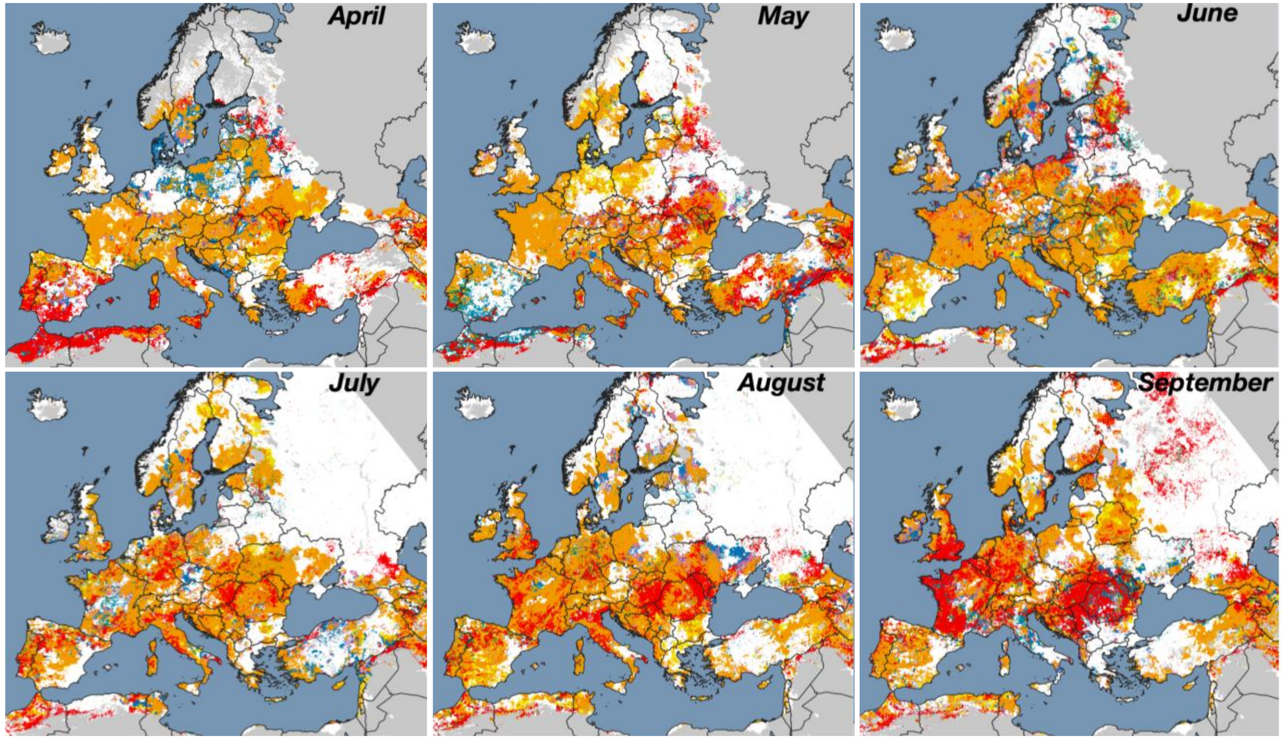
As population **increases**, food production must **DOUBLE** by **2050** to ensure human needs...

...but can agriculture cope under the **present climatic instability?**

HEAT



DROUGHT



Copernicus Climate Change Service
European State of the Climate | 2022

PROGRAMME OF THE EUROPEAN UNION

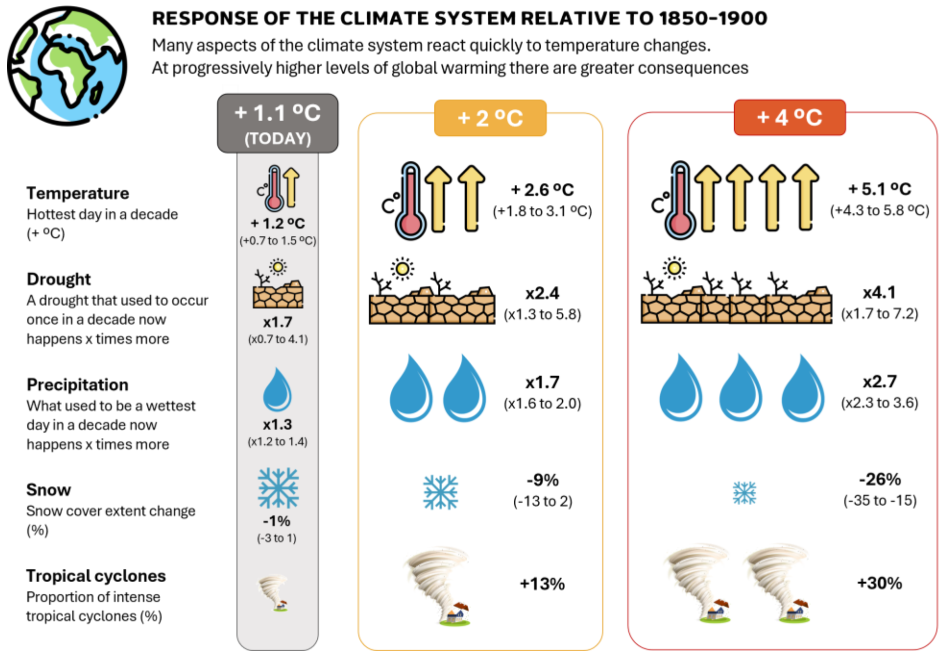
- Watch
- Warning
- Alert
- Full Recovery
- Temporary Soil Moisture Recovery
- Temporary fAPAR Recovery
- No Data

CLIMATE CHANGE

As population **increases**, food production must **DOUBLE** by **2050** to ensure human needs...

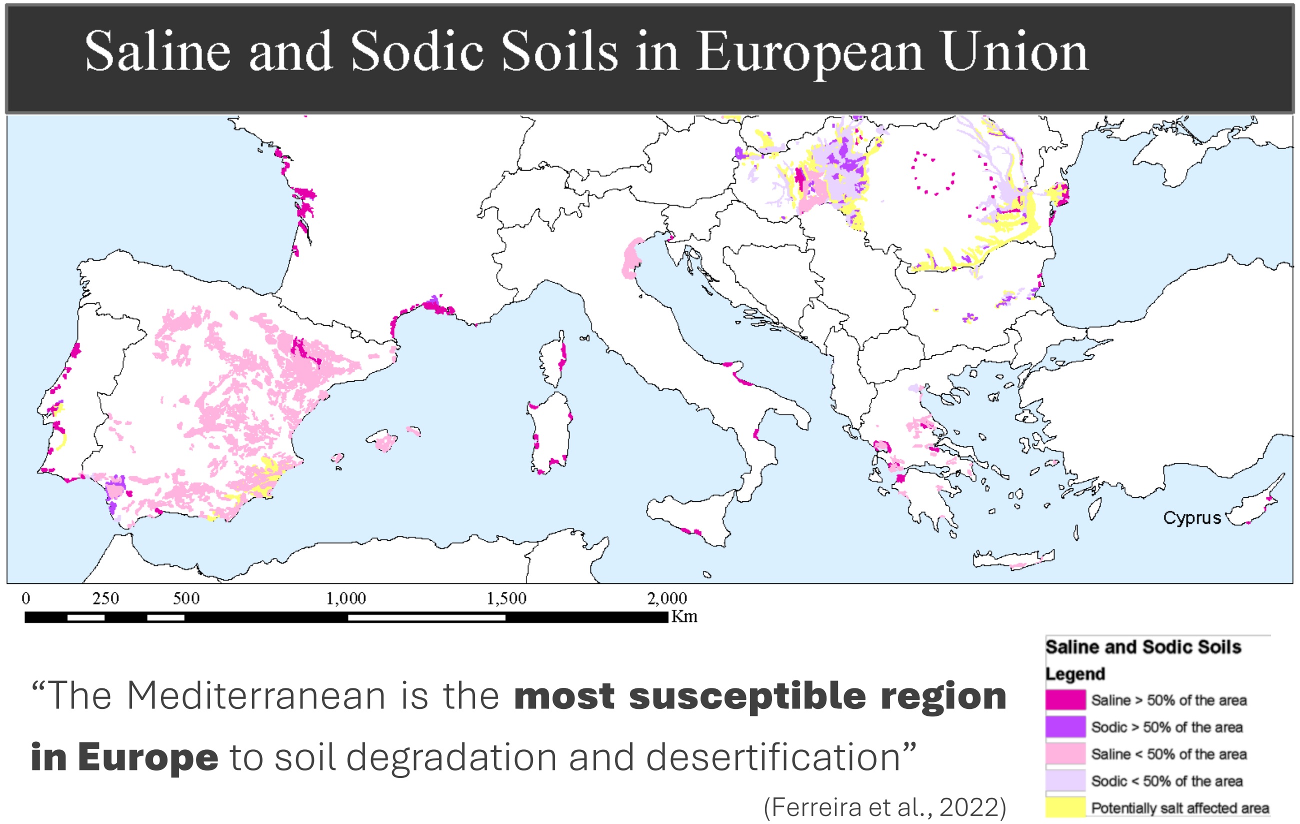
...but can agriculture cope under the **present climatic instability?**

HEAT



DROUGHT

SALINITY



"The Mediterranean is the **most susceptible region in Europe** to soil degradation and desertification"

(Ferreira et al., 2022)

WASTEWATER MANAGEMENT

"**70-90%** of the water in the world is reportedly utilized for agriculture, with ~ **70%** of the water being sourced from **freshwater sources**, including rivers and groundwater"

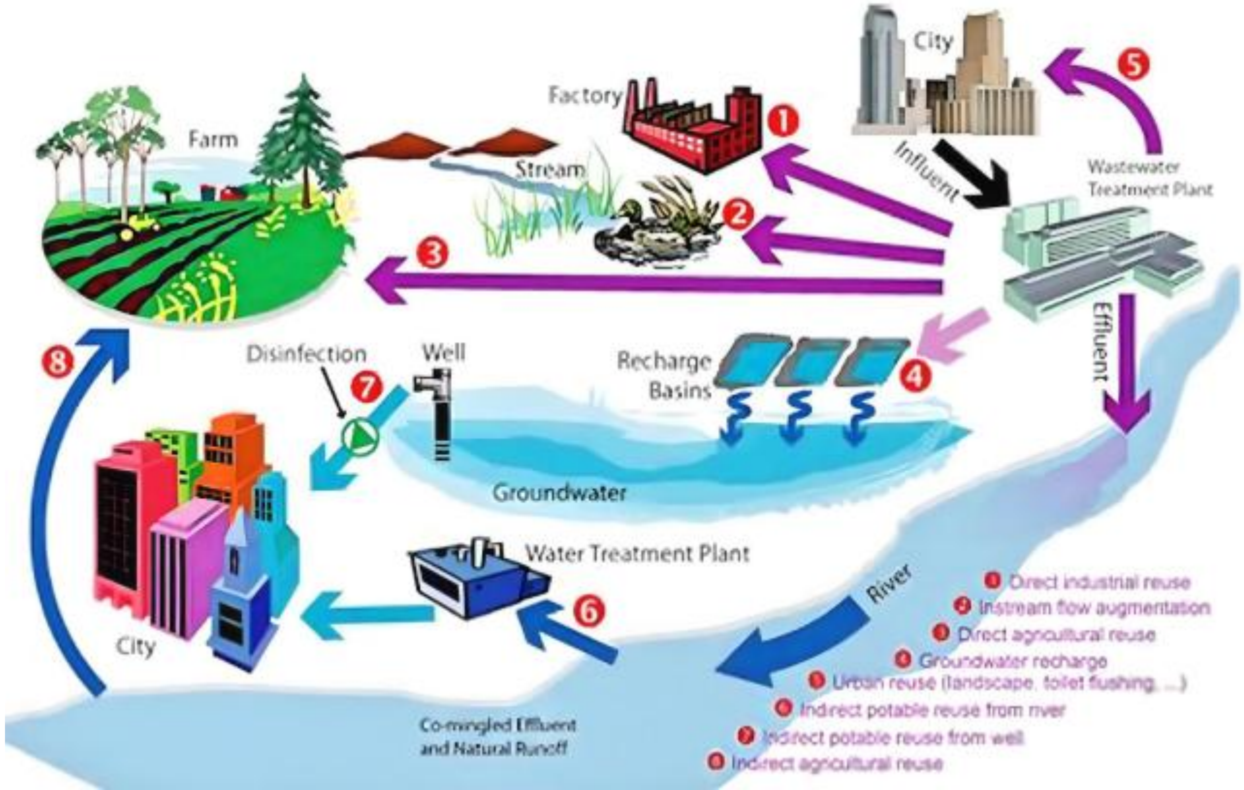
Wastewater Treatment

- **Reduces water abstraction** – relieving demand for freshwater resources
- **Reduces water pollution** – lower discharge of effluent into water bodies
- **Higher content of organic carbon/matter** than groundwater
- **Higher nutrient content**

WASTEWATER MANAGEMENT

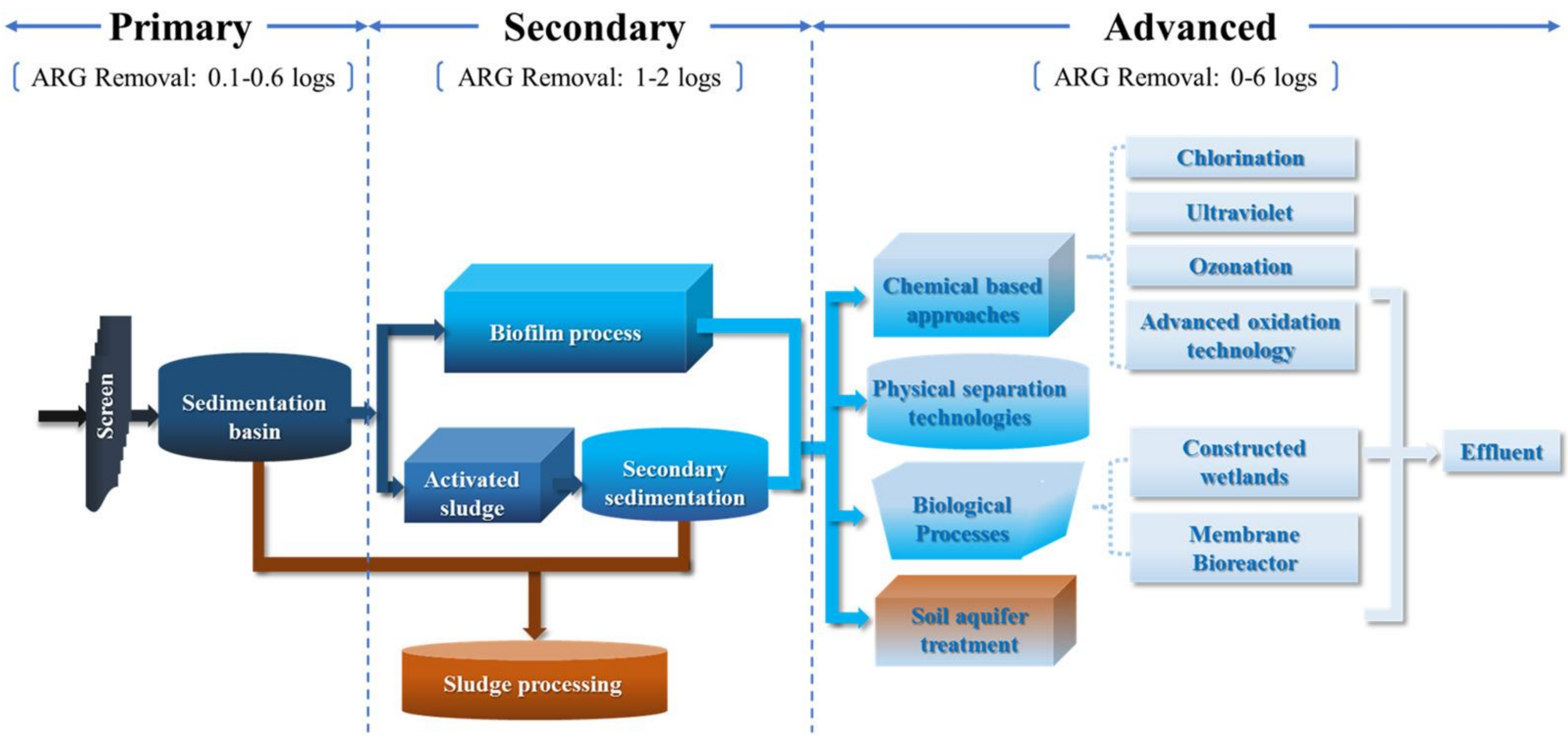
The use of wastewater for irrigation dates back several decades.

In the early 20th century, cities in Europe were using wastewater for irrigation (sewage farms).



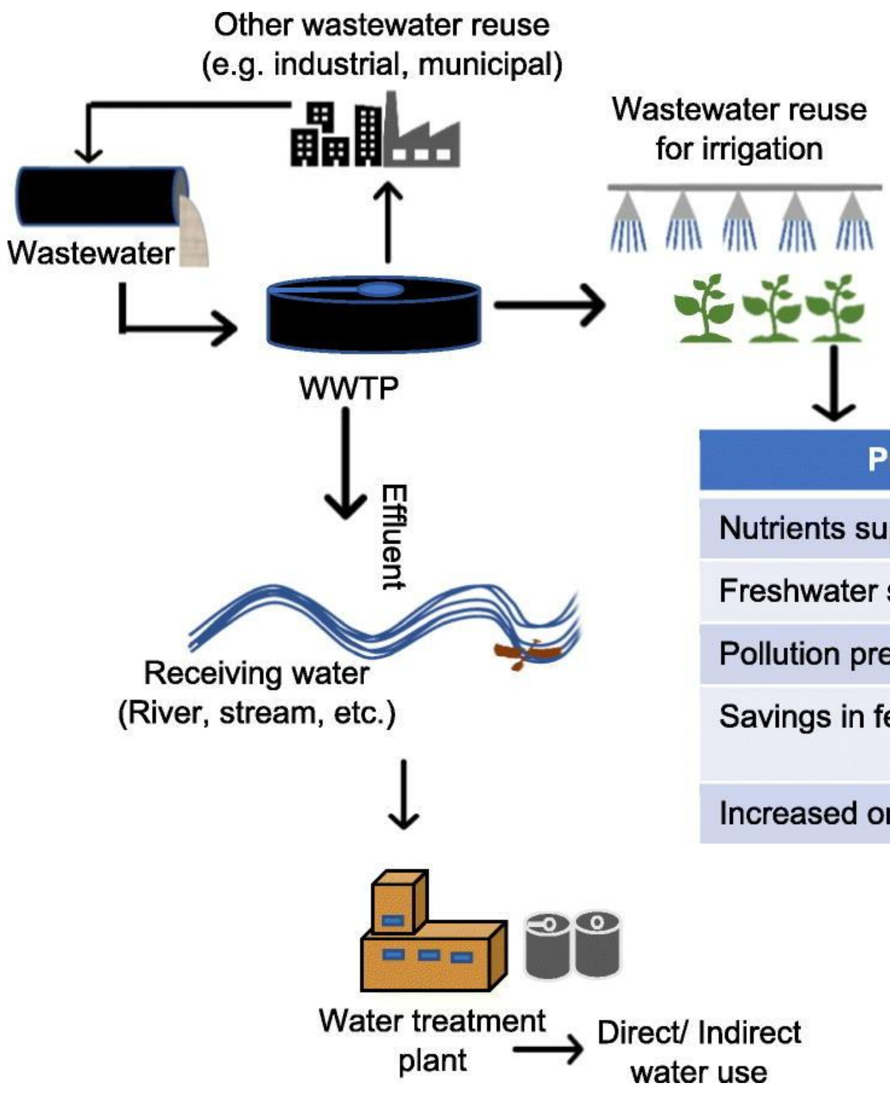
This promoted agriculture but later became an environmental and health issue.

WASTEWATER MANAGEMENT

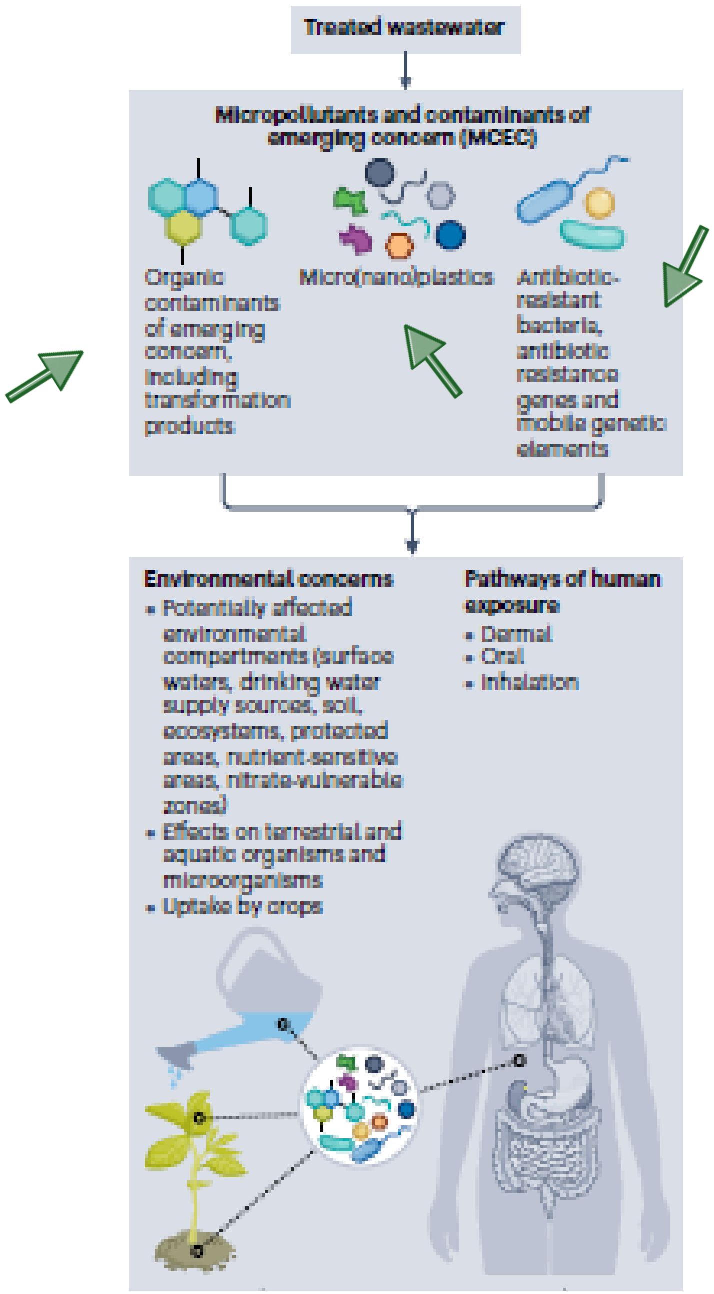


Most of the negative environmental impacts were associated with secondary treated wastewater. This is so because, secondary effluent has higher nutrients, salts and other contaminants than tertiary effluent.

WASTEWATER MANAGEMENT



Pros	Cons
Nutrients supply	Soil salinization
Freshwater savings	Groundwater pollution
Pollution prevention	Public health risk
Savings in fertilizer cost	Increased sodium adsorption ratio (soil)
Increased organic carbon	



WHERE SHOULD WE LOOK AT?

PUBLIC HEALTH

ECONOMICS

PLANTS

- Vegetative growth
- Physiological status
- Bio accumulation patterns
- Yield

MICROBIOME

- Microbial activity
- Diversity indexes
- Population dynamics

SOIL

- Nutrient content
- Contaminant and salinization levels
- Soil functions assessment

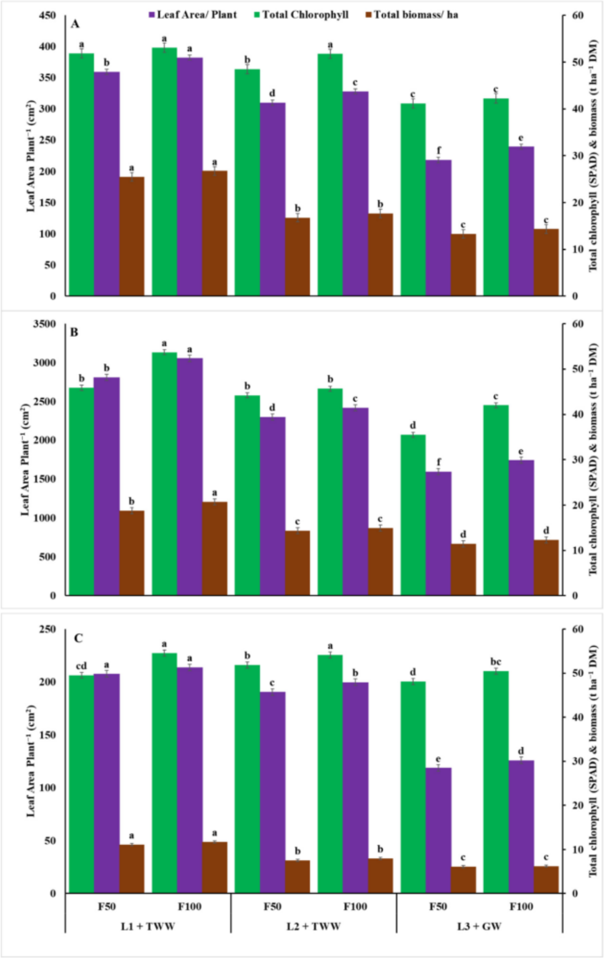
WATER

- < Water abstraction
- Assess water pollution

SOME PRACTICAL EXAMPLES

Case studies of **successful implementation** of treated wastewater for agricultural practices

Old soil + Wastewater | Virgin soil + Wastewater | Virgin soil + Groundwater



agronomy MDPI

Article

Integrative Effects of Treated Wastewater and Synthetic Fertilizers on Productivity, Energy Characteristics, and Elements Uptake of Potential Energy Crops in an Arid Agro-Ecosystem

Nasser Al-Suhaibani [1], Mahmoud F. Seleiman [1,2,*], Salah El-Hendawy [1,3], Kamel Abdella [1], Majed Alotaibi [1] and Ali Alderfasi [1]

energies MDPI

Article

Impacts of Long- and Short-Term of Irrigation with Treated Wastewater and Synthetic Fertilizers on the Growth, Biomass, Heavy Metal Content, and Energy Traits of Three Potential Bioenergy Crops in Arid Regions

Mahmoud F. Seleiman [1,2,*], Nasser Al-Suhaibani [1], Salah El-Hendawy [1,3], Kamel Abdella [1], Majed Alotaibi [1] and Ali Alderfasi [1]

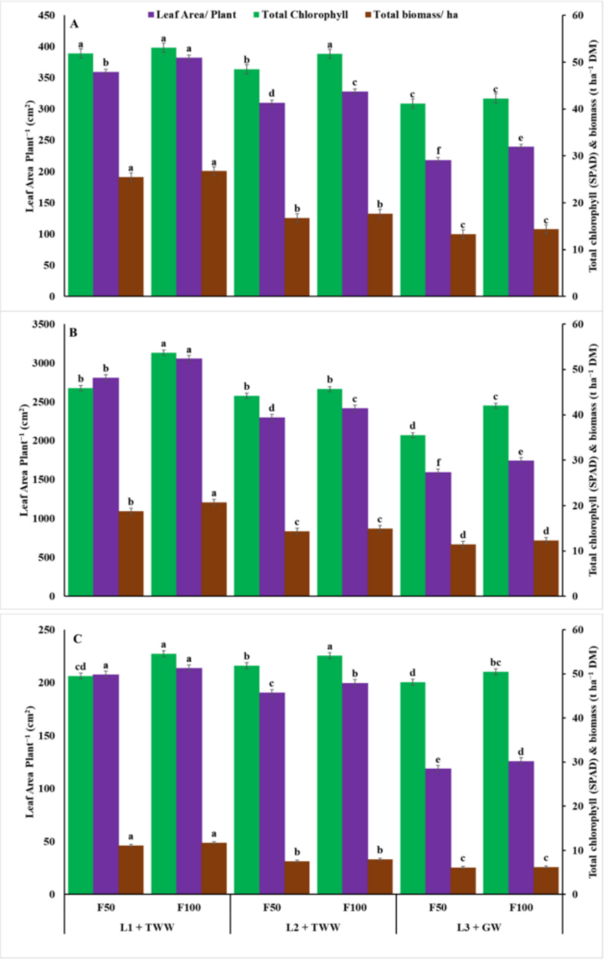
Use of treated wastewater + 50% NPK is **more effective** than the use of the recommended (100%) NPK dosage

- Increased plant biomass, chlorophyll, leaf area
- Increased gross energy
- Improved NPK content in plants, as well as other minerals

SOME PRACTICAL EXAMPLES

Case studies of **successful implementation** of treated wastewater for agricultural practices

Old soil + Wastewater	Virgin soil + Wastewater	Virgin soil + Groundwater



Studies show a **45-90%** lower dependency on chemical fertilizers in various plant species

280€/ha in savings, using wastewater irrigation on tomato cultivation

DRAWBACKS?

MINERAL COMPOSITION

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Industrial Crops and Products
journal homepage: www.elsevier.com/locate/indcrop
ELSEVIER

Effects of treated municipal wastewater irrigation on soil properties, switchgrass biomass production and quality under arid climate

Girisha Ganjegunte[a,*], April Ulery[b], Genhua Niu[a], Yanqi Wu[c]

Table 2
Selected chemical properties of the irrigation waters used in the study.

Parameters	Tap water	Treated Wastewater
Electrical Conductivity EC_e ($dS\,m^{-1}$)	1.4 ± 0.4	2.6 ± 0.3
pH	7.1 ± 0.4	7.3 ± 0.4
SAR ($mmol^{1/2}\,L^{-1/2}$)	4 ± 1	9.3 ± 0.4
Ca ($mg\,L^{-1}$)	54 ± 21	66 ± 10
Mg ($mg\,L^{-1}$)	13 ± 4	17 ± 4
Na ($mg\,L^{-1}$)	127 ± 14	328 ± 14
K ($mg\,L^{-1}$)	12 ± 2	32 ± 5
B ($mg\,L^{-1}$)	0.08 ± 0.10	0.26 ± 0.13
Cl ($mg\,L^{-1}$)	164 ± 93	465 ± 22
NH_4 ($mg\,L^{-1}$)	–	3.86 ± 2.39
NO_3 ($mg\,L^{-1}$)	6 ± 3	18.1 ± 5.1
SO_4 ($mg\,L^{-1}$)	101 ± 51	201 ± 33
BOD 5 ($mg\,L^{-1}$)	–	3.22 ± 0.86
Fecal Coliform (CFU/100 mL)	–	3.29 ± 2.62

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journal homepage: www.elsevier.com/locate/jenvman
ELSEVIER

Effect of irrigation with treated wastewater on soil chemical properties and infiltration rate

Saida Bedbabis[a,*], Béchir Ben Rouina[b], Makki Boukhris[a], Giuseppe Ferrara[c]

Table 1
Chemical characteristics of the irrigation waters used in the experiment.

Characteristics	WW	TWW	Tunisian limits
pH	7.95 ± 0.10	7.60 ± 0.11	6.50–8.50
EC ($dS\,m^{-1}$)	4.70 ± 0.02	6.30 ± 0.03	7.00
TDS ($g\,L^{-1}$)	1.51 ± 0.02	1.82 ± 0.01	2.00
HCO_3^- ($mg\,L^{-1}$)	288.50 ± 0.3	370.00 ± 0.20	600.00
SO_4^{2-} ($mg\,L^{-1}$)	87.50 ± 0.8	363.00 ± 1.50	1000
N total ($mg\,L^{-1}$)	–	58.80 ± 1.20	30.00
$N{-}NO_3^-$ ($mg\,L^{-1}$)	1.11 ± 0.01	15.90 ± 0.05	
$N{-}NH_4^+$ ($mg\,L^{-1}$)	2.24 ± 0.01	37.90 ± 0.01	
$N{-}NO_2^-$ ($mg\,L^{-1}$)	0.08 ± 0.02	5.00 ± 0.01	
P total ($mg\,L^{-1}$)	0.80 ± 0.11	10.30 ± 0.01	0.05
K^+ ($mg\,L^{-1}$)	30.00 ± 0.09	38.00 ± 0.02	50.00
Na^+ ($mg\,L^{-1}$)	355.00 ± 0.01	470.00 ± 0.02	300.00
Cl^- ($mg\,L^{-1}$)	1580 ± 0.04	1999.00 ± 0.04	600.00
Ca^{2+} ($mg\,L^{-1}$)	184.50 ± 0.01	95.80 ± 0.03	
Mg^{2+} ($mg\,L^{-1}$)	126.20 ± 0.01	83.80 ± 0.02	
Pb^{2+} ($mg\,L^{-1}$)	0	<0.004	0.10
Cd^{2+} ($mg\,L^{-1}$)	0	<0.004	0.005
Zn^{2+} ($mg\,L^{-1}$)	0.10 ± 0.01	0.42 ± 0.01	5.00
Mn^{2+} ($mg\,L^{-1}$)	0.19 ± 0.01	0.50 ± 0.01	
SM ($mg\,L^{-1}$)	4.30 ± 0.02	13.40 ± 0.03	
COD ($mg\,L^{-1}$)	0	73.00 ± 0.11	90.00
BOD ($mg\,L^{-1}$)	0	22.00 ± 0.04	30.00

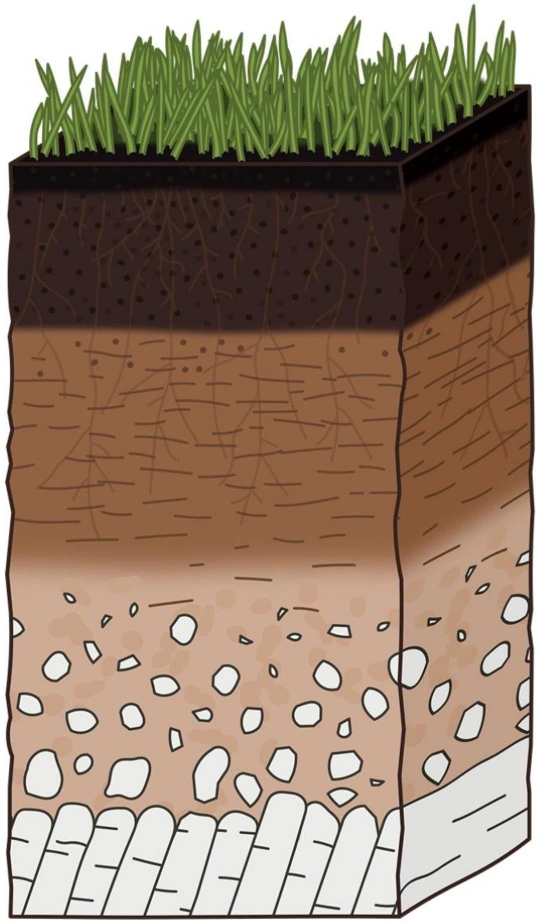
Data represents mean values ± standard deviation.
EC: electrical conductivity; TDS: total dissolved solids; SM: suspended matter; COD: chemical oxygen demand; BOD: biological oxygen demand; WW: well water; TWW: treated wastewater.

✓ **Source of macro and micronutrients** important for plant growth and development

✗ **Possibly contribute for soil salinization** and **contamination**, impacting crop growth

SOIL STRUCTURE AND MICROBIOME

Several studies research the impacts on soil structure over long periods, but results were not always positive



Lower porosity and increased salts accumulation overtime
Lower hydraulic conductivity, sorptivity and cumulative infiltration

Associated with:
- Accumulation of sodium and bicarbonates
- Increased pH
- Dissolution of organic matter

Increased microbial activity (although there are exceptions)
- Higher dehydrogenase, urease, protease, β-glucosidase, and alkaline phosphatase activities
- Increased microbial abundance
- Higher release of growth regulators
- Possibly associated with higher carbon and mineral content of wastewater

HOW TO ACHIEVE A BALANCE?

- What kind of treatments should be done?
- What analyses should be carried out to ensure no drawbacks?
- How to implement this strategy as a long-term net gain?

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blue water

Plant Stress lab

MAIN TOPICS ADDRESSED

How do plants coordinate their metabolism in response to stresses?

What are the main consequences of plant exposure to stressful conditions?

To explore redox homeostasis and antioxidant metabolism

To develop new efficient tools to enhance plant stress tolerance

The study of **PLANT STRESS PHYSIOLOGY**, with particular interest in exploring the **ENVIRONMENTAL IMPACTS** in **PLANT STRESS RESILIENCE**

OUR PARTICIPATION IN THE CONSORTIUM OF blue water

TREATMENTS

- Tap water as control
- Effluent after secondary treatment
- Effluent after tertiary/quaternary treatment

TWO PLANT MODELS

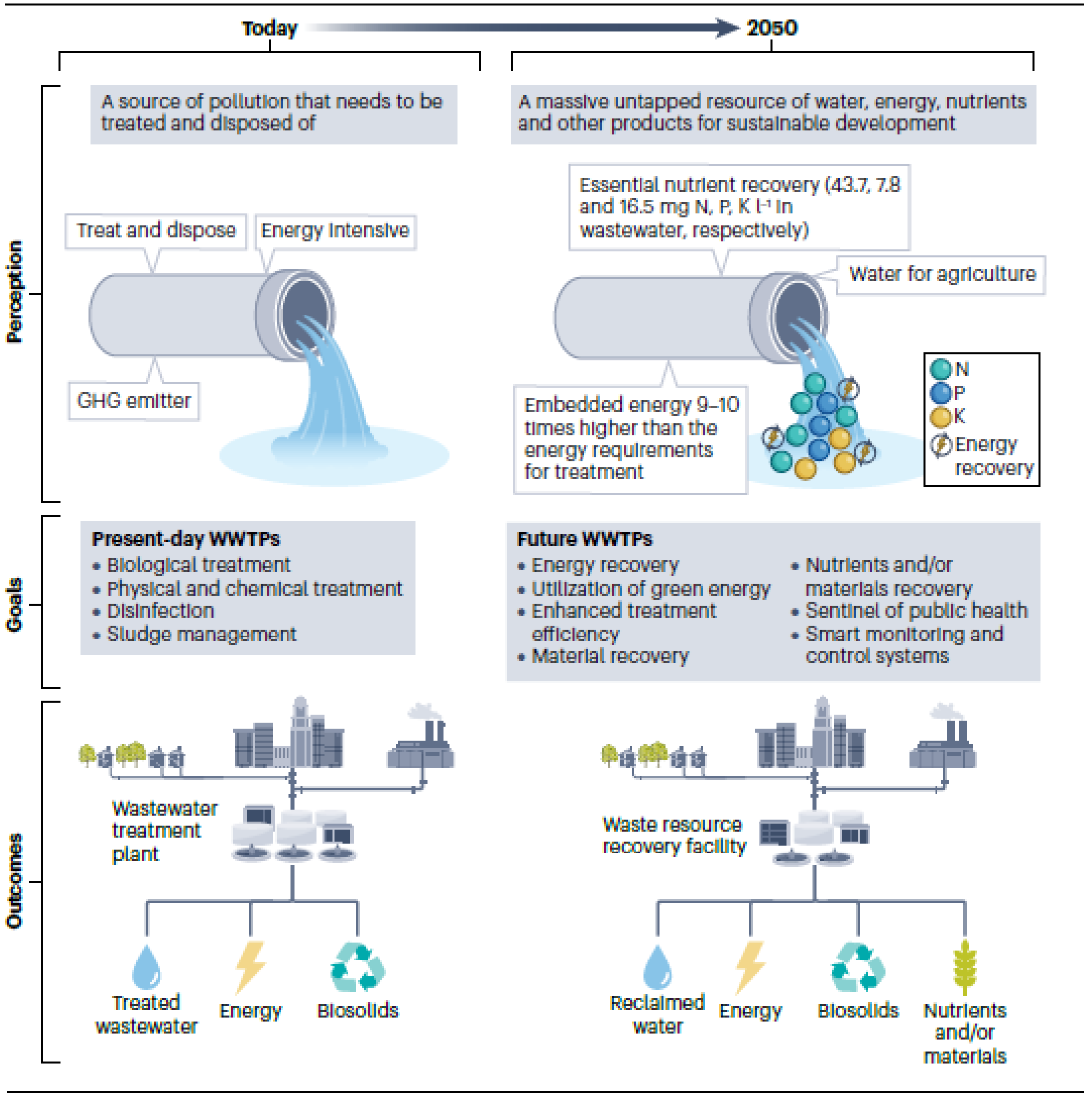
Maize
(*Zea mays* L.)

Lettuce
(*Lactuca sativa* L.)

EVALUATIONS

- **Biometry**
- **Oxidative stress markers**
- **Mineral analysis**
- **Soil analysis**
- **Chlorophylls and protein**

OUTLOOK AND FUTURE DIRECTIONS



The priority of wastewater irrigation should be water recovery and not nutrient supply

Public perception around the safety of wastewater use for irrigation needs to change

Implementation of increasingly efficient advanced treatments is key

Large scale pilot testing and field validation

- Provide useful information on potential challenges, environmental and health impacts
- Assess the economic feasibility

The high cost of transporting treated wastewater can be an issue

- Sitting future wastewater treatment plants closer to arable lands

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Plant Stress lab

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Thank You

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