Infrastructuring and governing agricultural water network: the key to achieve resilience to recurrent extreme climate impacts.

Adriano Battilani

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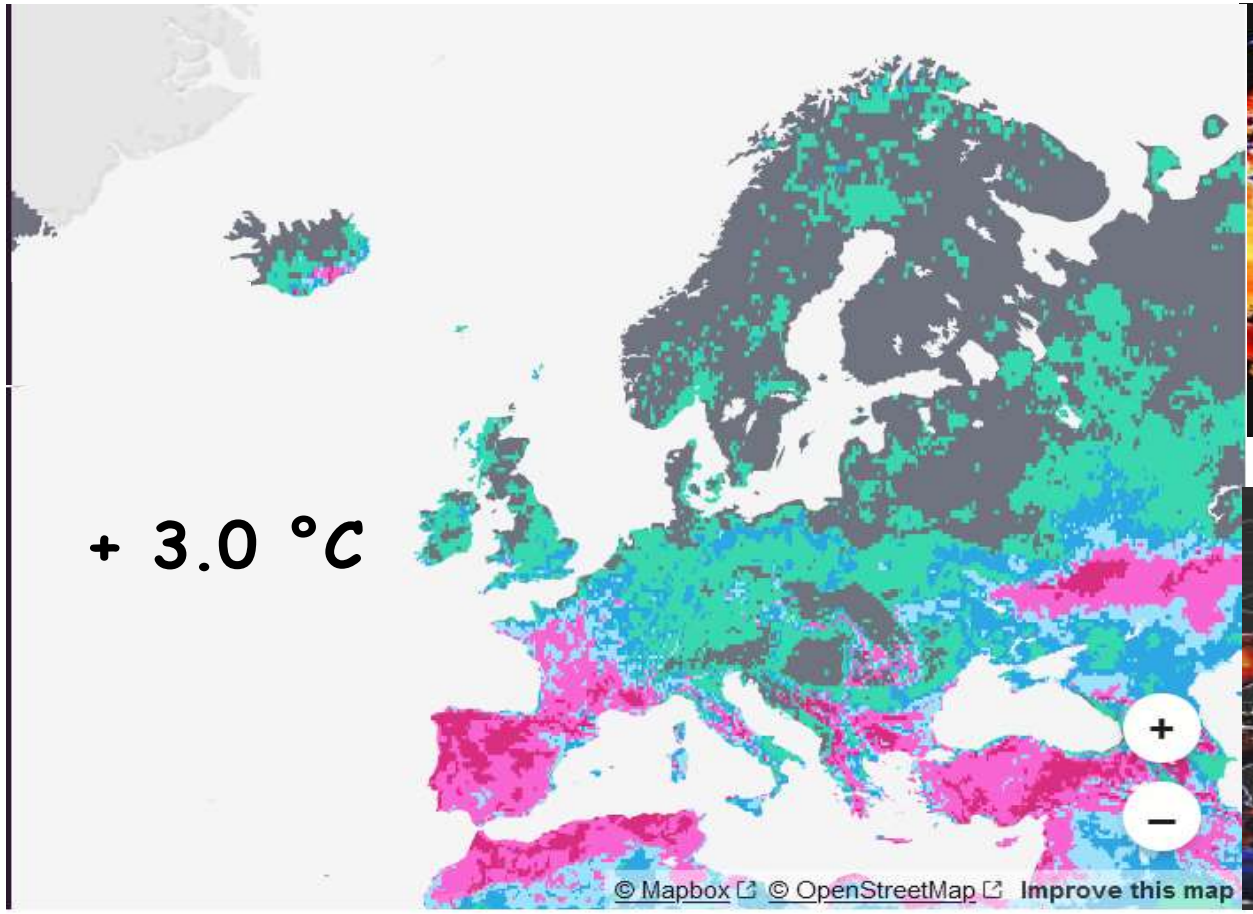
Todi, 26th July 2024

THE CONTEXT

EXTREME DROUGHT AND FLOODS PROBABILITY

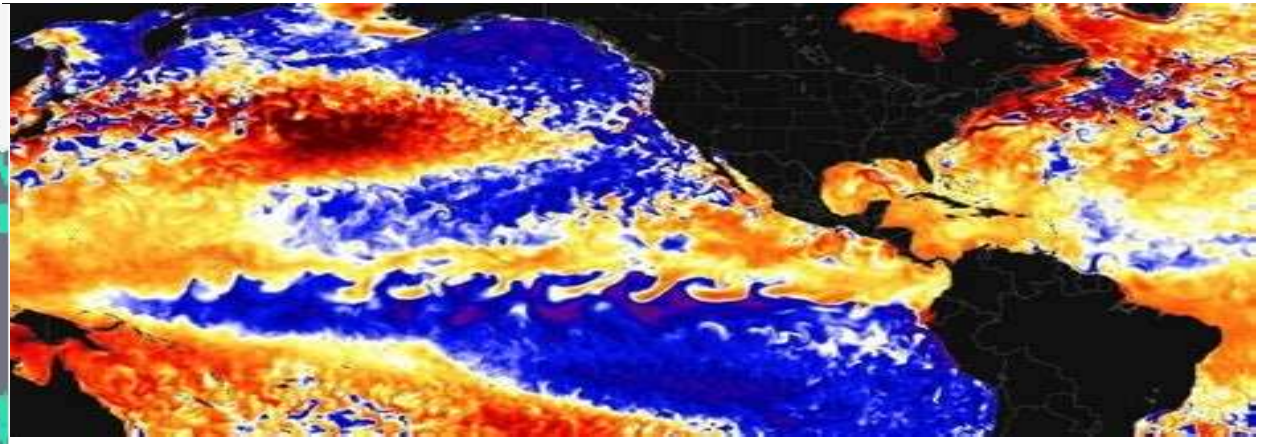
Over 6 months with precipitation and soil moisture at levels equal to present probability in the area of 0,1% (1 year out of 1000).



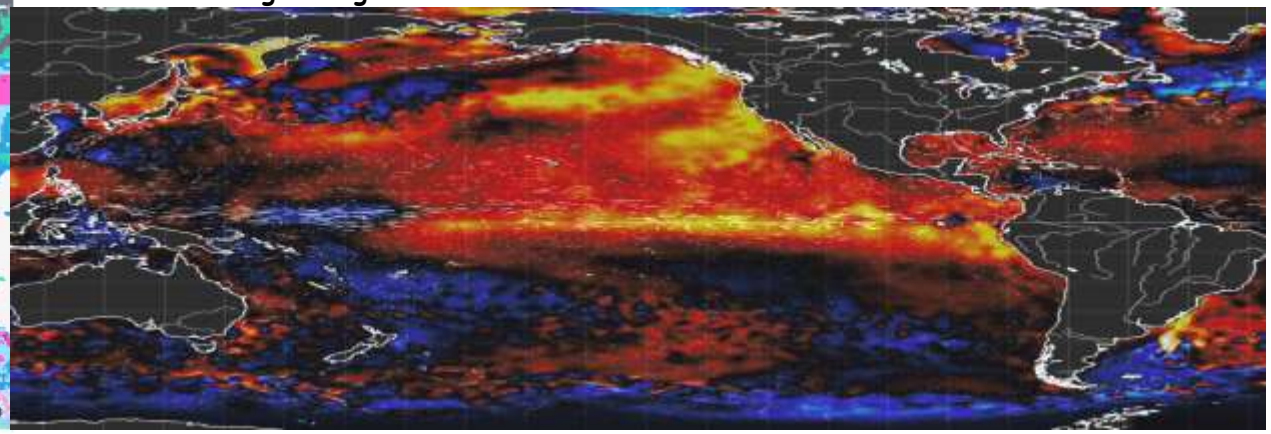
CORDEX-CORE ensemble (REMO 2015 and RegCM4). Processed by Woodwell Climate Research Center, 2021

Annual likelihood (%)

0-10 | 11-33 | 34-50 | 51-66 | 67-90 | 91-100



La NINA – Lasting strong over three winters



El NINO – Getting stronger in 2023

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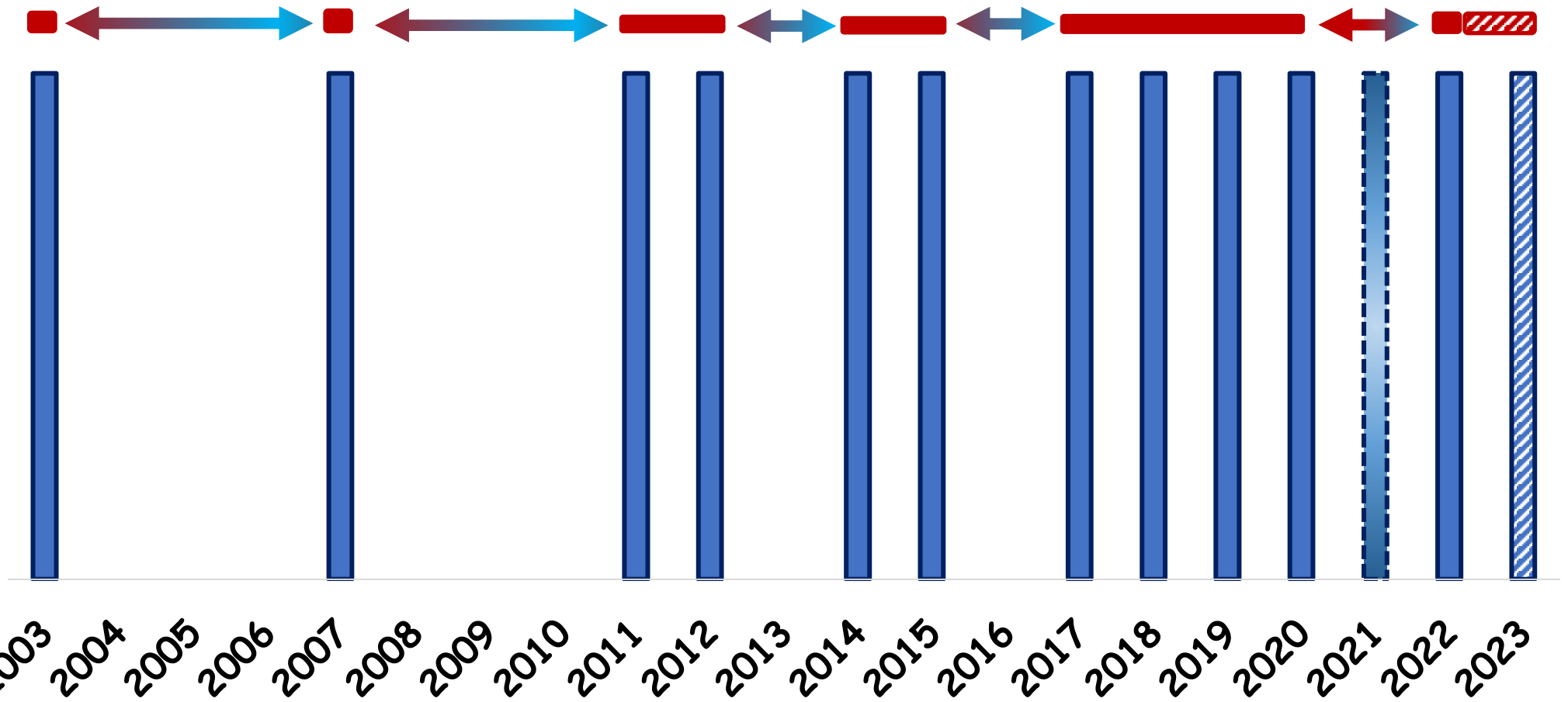
DROUGHT OCCURRENCE IN EUROPE



HIGHER FREQUENCY, LONGER DURATION, ALTERNATE WITH WATER SCARCITY

OVERALL SYSTEM RESILIENCE FAST DECREASING

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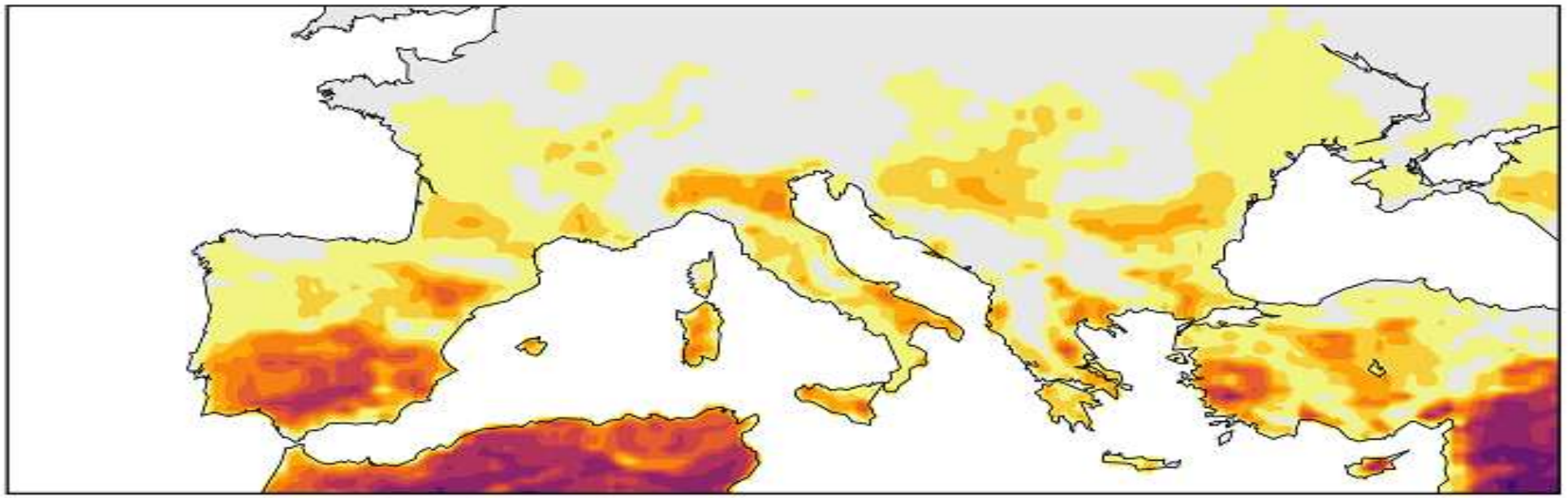
HEAT STRESS DAYS

Number of days during extended summer (JJAS) 2023 with 'very strong heat stress'

Data: ERA5-HEAT daily maximum Universal Thermal Climate Index (UTCI) • Credit: ECMWF/C3S



Copernicus Climate Change Service
European State of the Climate | 2023

PROGRAMME OF THE EUROPEAN UNION

Copernicus

ECMWF

Number of days that experienced 'very strong heat stress' (UTCI between 38°C and 46°C) during June, July, August and September 2023. Heat stress indices represent the effect of the environment on the human body. Data source: ERA5-HEAT. Credit: C3S/ECMWF.

SALINE INTRUSION

2003 = 23 Km (high tide historical max)

2022 = 41 Km

Potabilization plants stop
Portable desalinisation (reverse osmosis) stop

Soil and crops with salt damages up to 10 m from canal's banks

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EXPOSURE TO FLOOD RISK

Country	Population At High Flood Risk x 1000
Germany	13670
France	11632
Italy	8504
Spain	5859
Poland	5280
Romania	6548
Netherlands	10100
Belgium	2070
Sweden	978
Czech Republic	1500

FLOODS & LANDSLIDES OCCURENCE IN ITALY

PERIOD	Floods Number	Floods per year
1861-1946	14	0,16
1947-1999	39	0,74
2000-2023	58	2,42

ONLY 10,7% OF THE RECORDED FLOODS REPORT NO CASUALTIES, THEREBY THE PROBABILITY OF HUMAN LIVES LOSSES ASSOCIATED TO A FLOOD EVENT IS OF ABOUT 90%

PERIOD	Landslides Number	Landslides per year
2017-2021	829	166
2022	91	91
2023	>1200	>1200

THE LOWEST OCCURENCE OF LANDSLIDES WAS IN 2022, THE DRIEST YEAR IN CENTURIES, AND THE HIGHER IN A SHORT PERIODS OF 2023 WHEN RAIN RETURNED ABUNDANT ALTHOUGH NOT PARTICULARLY INTENSE

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INCREASING FLOODED AREA EXTENSION

MULTI-YEAR LOSSES OF CROPS PRODUCTIVITY, CROPLAND AND ESSENTIAL INFRASTRUCTURES. IMPACTING ON FOOD SUPPLY CHAINS AND INSURANCES.

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INCREASING RAINFALL INTENSITY & FLOODS ENERGY

Irrigants d'Europe

Before **After**

Source: Google Earth/@BezRegKoeln

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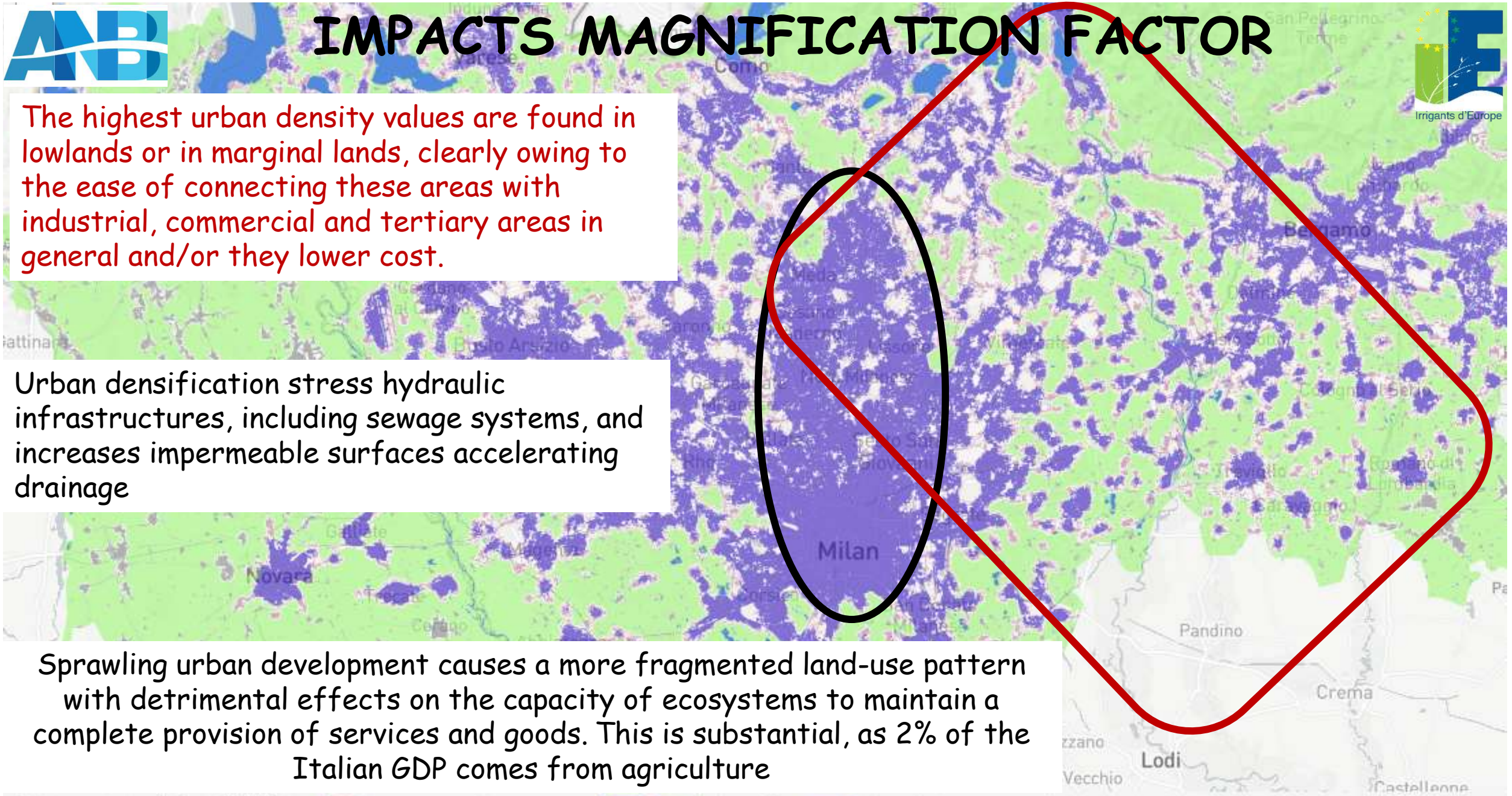
IMPACTS MAGNIFICATION FACTOR

The highest urban density values are found in lowlands or in marginal lands, clearly owing to the ease of connecting these areas with industrial, commercial and tertiary areas in general and/or they lower cost.

Urban densification stress hydraulic infrastructures, including sewage systems, and increases impermeable surfaces accelerating drainage



Sprawling urban development causes a more fragmented land-use pattern with detrimental effects on the capacity of ecosystems to maintain a complete provision of services and goods. This is substantial, as 2% of the Italian GDP comes from agriculture

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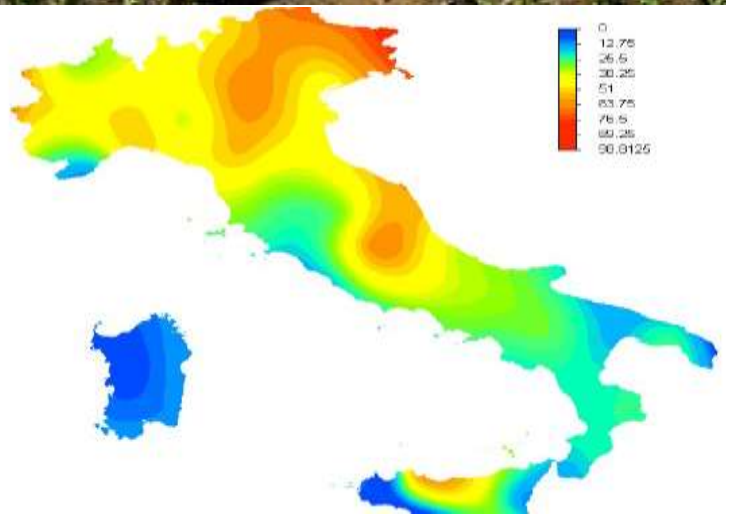
SOIL DEFENSE AND CONTRAST TO EROSION



"Among European countries, Italy pays the highest bill with an annual loss of 619 million euros and 33% of its total agricultural area affected by serious erosion. The damage due to the loss of habitats and biodiversity cannot be assessed"

Infrastructures are needed for the defense of the territory.

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HIGH INTENSITY RAINFALLS INEFECTIVENESS

California had 3 years of drought, and many reservoirs and lakes were dry.

Snowfall in the mountains in January 2023 was 174% of the historical average for this time of year. Colorado snows were also hitting high records, with the Upper Colorado River Basin snowpack standing at 142% of the last three decade median.

Officials say that while the storm is giving the drought-stricken state hope for a moist 2023, several more storms will be needed to refill reservoirs.

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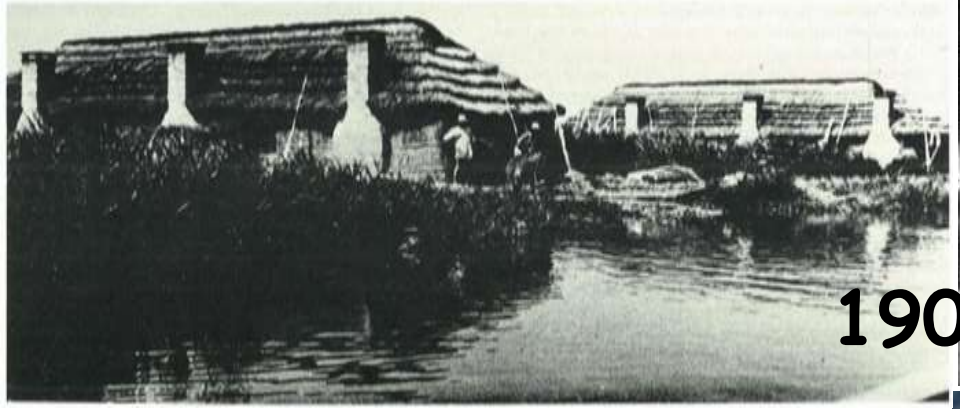
THE LEGACY INFRASTRUCTURE

HEAVILY MODIFIED TERRITORIES

1908


1900

1930

2022

A PRODUCTIVE, SAFE AND SUSTAINABLE AGROECOSYSTEM WHERE HAD INSISTED MARSHES AND MALARIC FEVERS

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LAND RECLAMATION AND IRRIGATION CONSORTIA MISSION

- SAFEGUARD THE HYDROGEOLOGICAL STABILITY OF THE TERRITORIES
- REGULATE DRAINAGE
- GOVERNANCE OF WATER IN AGRICULTURE
- SUPPORT FOOD PRODUCTION PROVIDING IRRIGATION
- PROTECT FROM FLOODING
- DRAINING METEORIC WATER FROM URBAN AGGLOMERATION
- RECEIVE TREATED WASTE WATERS.

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ANBI INFRASTRUCTURES

ANBI operate over an area of 19.230.649 hectares involving nearly the totality of the most productive agricultural and industrial areas.

The main water infrastructures are as follows:

- 231.044 km of canals;
- 16.686 km of river and sea banks;
- 22.839 weirs and barrages for flood lamination;
- 960 hydro-geological defense waterworks (with a total flow rate of 4949 mc/sec.)

The drainage area is of 9.592.611 ha (8.094.837 ha gravity; 1.497.774 ha mechanical lift).

- 2,244 irrigation works (576 barrages; 1,668 pumping stations)
- 914 irrigation storage basins and reservoirs
- 54 dams (with a total capacity of about 980,000,000 m3) converted to multipurpose uses (irrigation, civil, industrial, hydroelectric, etc.).
- 161,411 ha irrigated with reclaimed water.

The area served by irrigation works is of 3.500.000 ha (1.741.891 ha open canals; 1.422.033 ha pressurized networks).

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INFRASTRUCTURES' MODERNISATION

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We were used to manage a relatively stable environment, we must now adapt our infrastructures to the rapid and frequent transition between extreme opposites. Flexible, dynamic, forecast-based, scalable management, are the keywords of the future.

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CAPTURE AND HOLD PRECIOUS WATER ON THE TERRITORIES

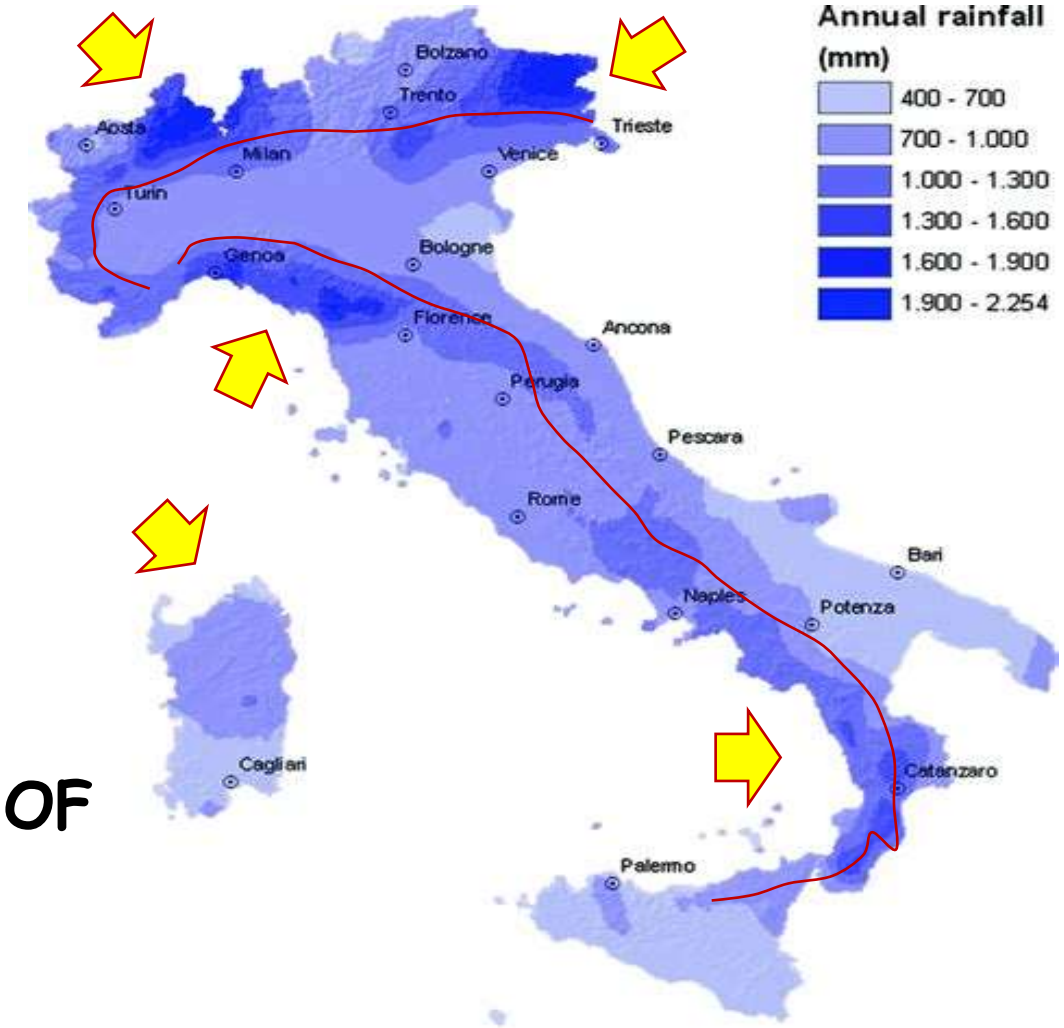
STORAGE 1 - SNOWPACK

STORAGE 2 – LAKES & STORAGE BASINS

STORAGE 3 – SOIL MOISTURE

STORAGE 4 – SHALLOW WATERTABLE & AQUIFERS

STORAGE 5 – IN SEASON INFILTRATION OF PRECIPITATIONS



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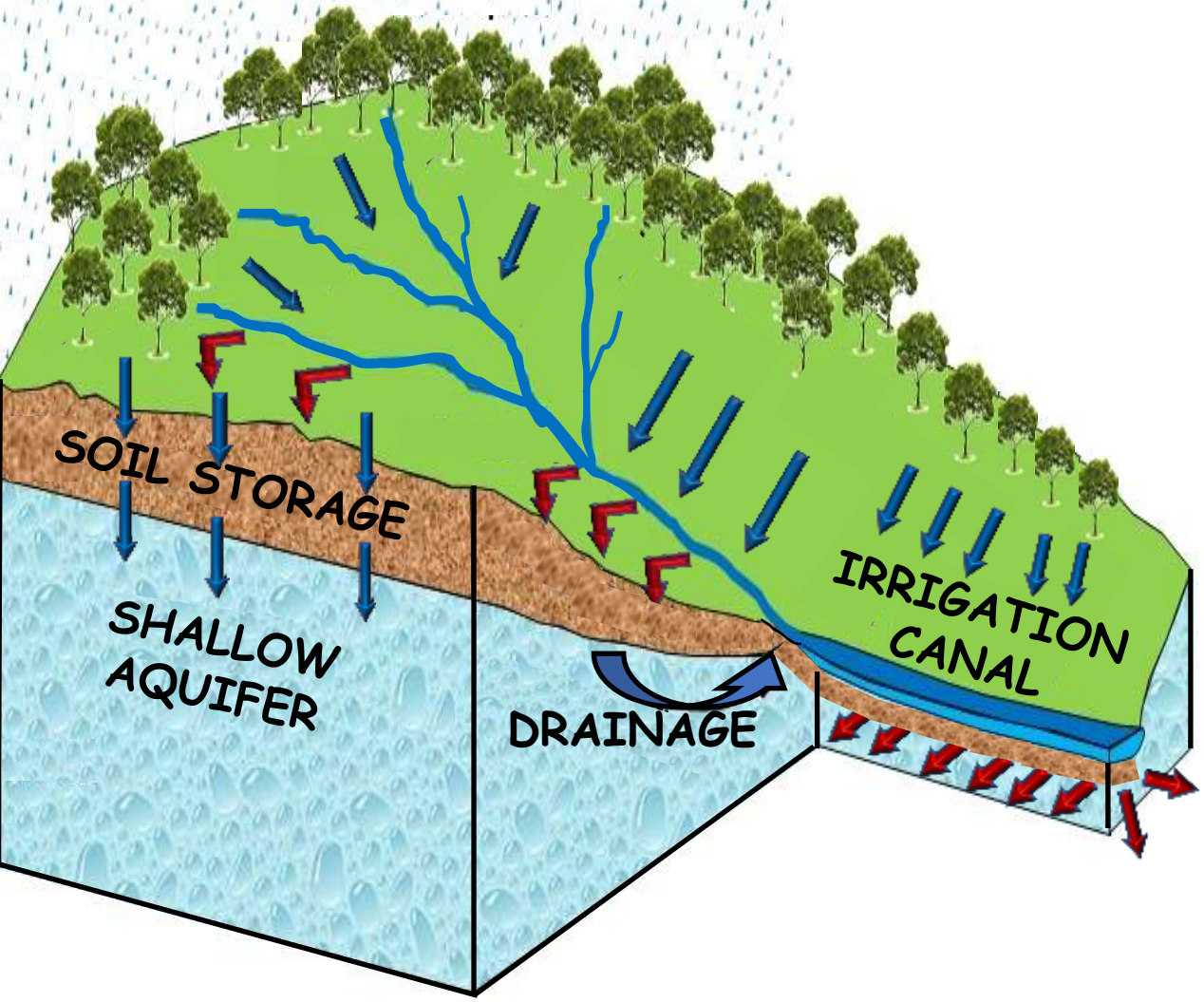
HOLD WATER AS LONG AS POSSIBLE



STORING WATER INTO THE SOILS AND SHALLOW WATER TABLES ALLOWS FOR MORE IN SEASON INFILTRATION OF RAINFALLS MAKING USE OF THE LARGEST AVAILABLE STORAGE BASINS

IT ALLOWS FOR DIFFUSED RAIN HARVEST AND AQUIFERS RECHARGE

CHANNEL STORAGE OR DIVERTING WATER INTO AGRICULTURAL WATERWORKS WHEN AVAILABLE AND IN VIEW OF A DROUGHT SPELL IS EFFECTIVELY HOLDING WATER ON THE TERRITORIES.

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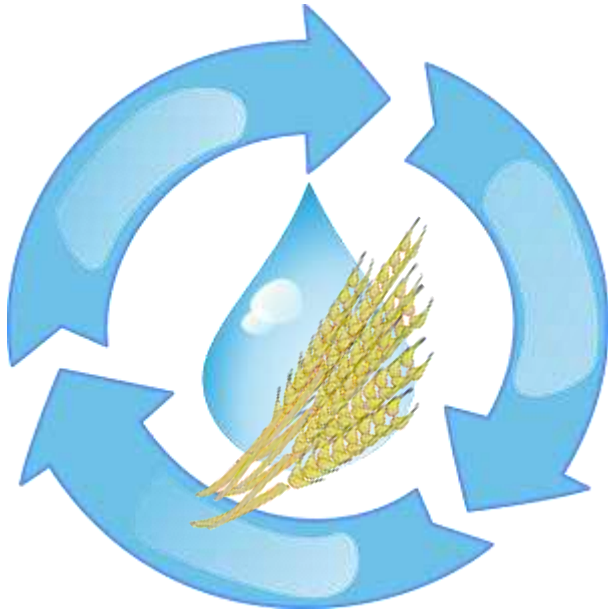
WATER REMOVAL OF URBAN AND INDUSTRIAL AGGLOMERATIONS AND THE CHALLENGE OF REUSE

The increasingly close interconnection between cities and countryside stress the hydraulic network created to remove rainwater from the fields and not to dispose continuous flow rates from sealed soils and urban areas.



Networks modernization, monitoring and defense against pollution, is of the utmost urgency to make water reuse for irrigation a widespread reality,.

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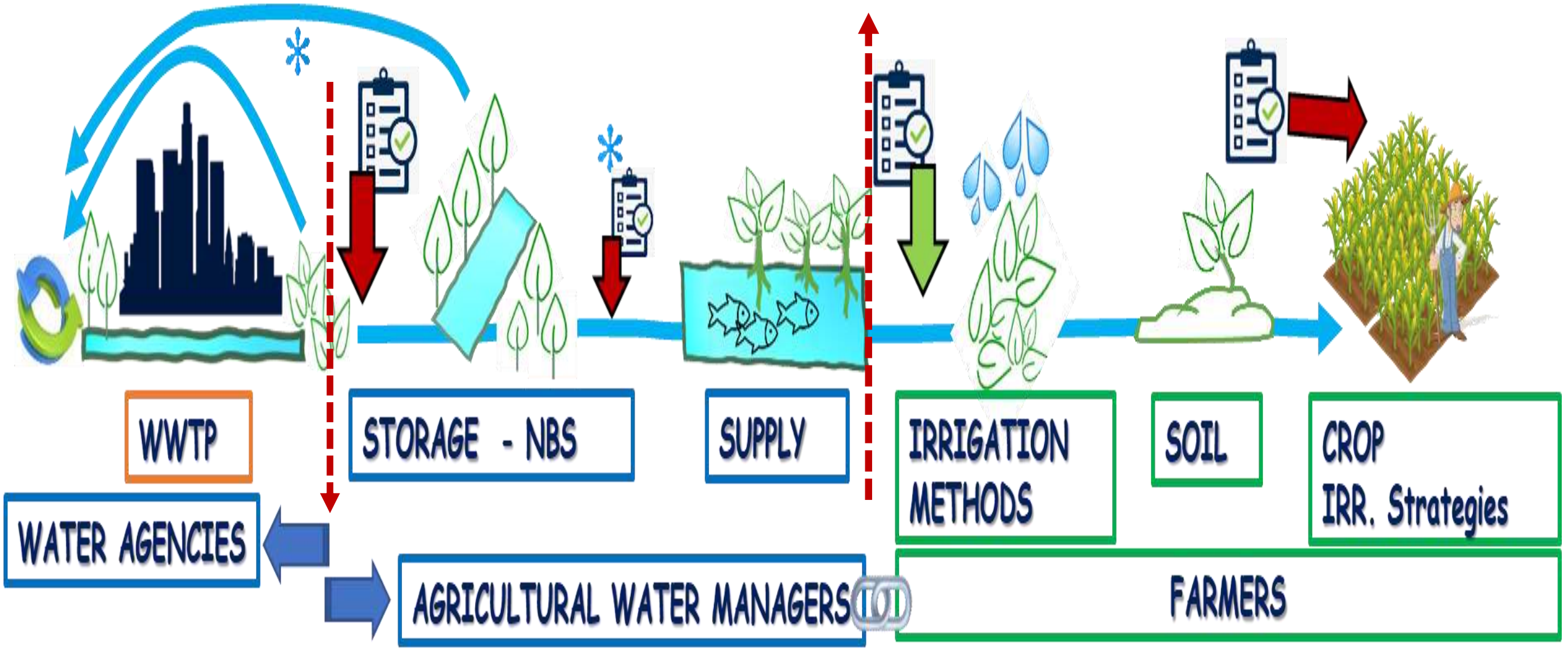
Infrastructure enabling Water Scarcity management in irrigation/water reuse schemas



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UPGRADE STORAGE AND AGRI WATER INFRASTRUCTURES

Irrigants d'Europe

Agricultural water networks will have to act as buffers and adequate storage will have to be incorporated and interconnected in order to cope with intense, jeopardized precipitations.

Infrastructure modernization can also be combined with multifunctional Nature Based Solutions (NBS) with low or no energy impact or with novel solutions offering new business opportunities.

PRODUCTION OF SPIRULINA ALGAE IN STORAGE PONDS

BUFFERING WATER TO SUSTAIN ECO FLOWS

PHOTOTROPIC PURPLE BACTERIA CULTIVATED TO RECOVER PHA

NUTRIENTS RECOVERY

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NATURE BASED SOLUTIONS

NBS are defined by the European Commission as "living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to simultaneously provide economic, social, and environmental benefits"

NBS is an umbrella concept

- Increasingly adopted in EU and global policy
- Applied at multiple scales and across multiple sectors
- Requires Multifunctionality and stakeholder involvement
- Dedicated evaluation frameworks
- Need Overarching strategic planning and evaluation

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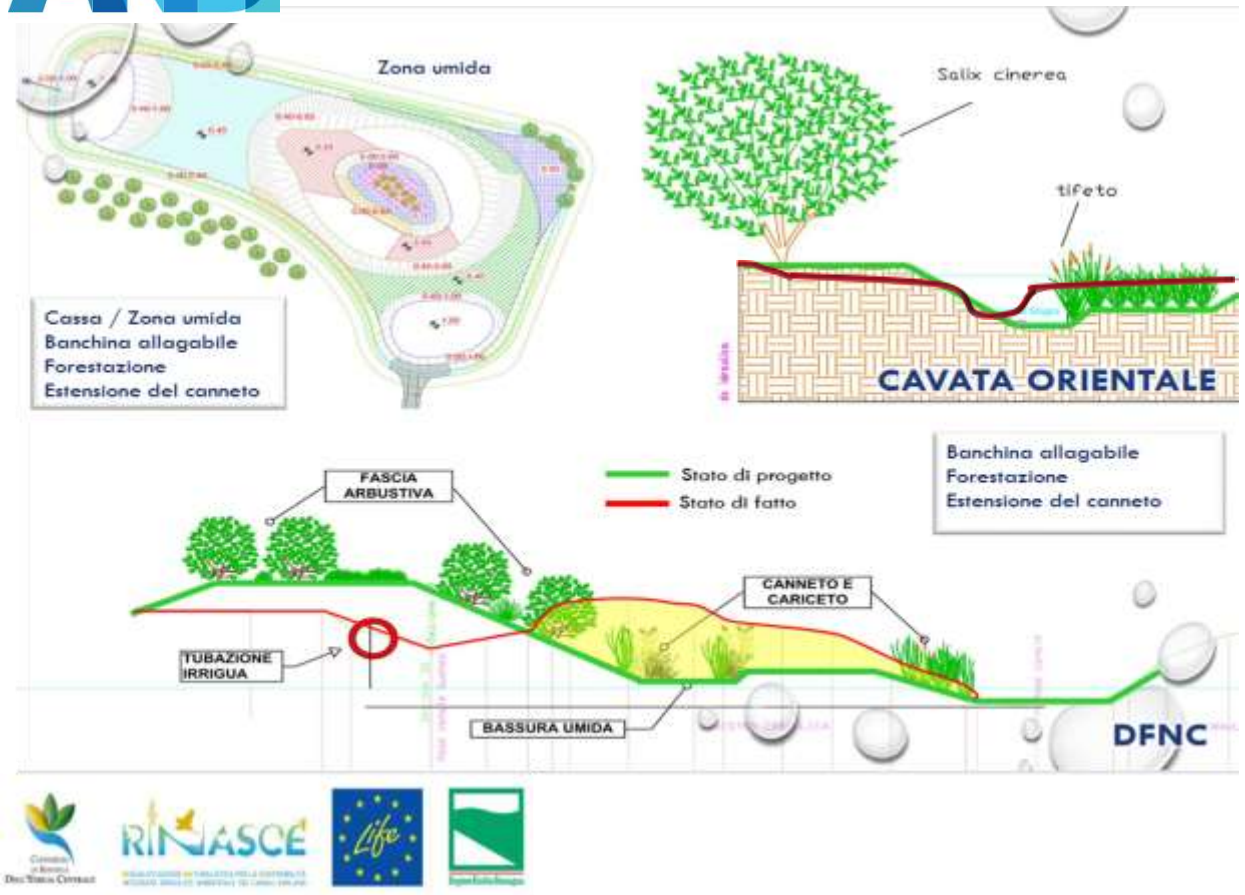
NATURAL WATER RETENTION MEASURES



Are not limited to ponds or artificial wetlands. Rigenerative Agriculture, Soil Carbon Storage, Aquifer Infiltration, Irrigation canals governance, Soil Water Storage are NWRM.

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	"slow down the waters" during flood events : • to increase the rolling capacity of canals and poorly urbanized areas, • to avoid dangerous flooding in the areas located downstream and identified as sites to protect, • to maintain or introduce morphological diversification processes and areas with different current speed depth The natural-like section enlargements allow an increase in the volumes available to accommodate and laminate the floods and an overall improvement of the ecosystem of the canal.
Pedo-climatic / geographical	Mediterranean Temperate and Sub-Oceanic - Mediterranean semi-arid - Sub-Oceanic / Several areas in Veneto, Lazio and Emilia-Romagna regions (Italy)- In total 35 NBS identified
Economic benefits	• Direct benefits: agricultural water networks OPEX and extraordinary **maintenance costs reduction**; • Indirect benefits: **water storage capability**, possible Eco-flow dynamic management, support to F2F compliance
Environmental benefits	Restored and increased biodiversity; reduced water pollution; higher water quality; higher resilience of the natural/artificial watercourses facing extreme climatic events
Social benefits	Landscape restoration; Various ecosystem services; Flood protection of urban areas
Success factors	Proactive engagement of the Agricultural Water Boards. Local/Regional administrations support; effective Private Public Partnership
Limitations and drawbacks	Need of ***capacity building***, training and specific skills and in some cases equipment. ***Land*** use for non productive goals. ***Financing*** difficulties
Involved actors	ANBI Regional Agencies, local Consortia, local administrations

	"river/ canal restoration": • Vegetation is restored by using techniques of "living" naturalistic engineering; • Techniques are based on the prevalent use of live plant materials (trees, shrubs, herbaceous plants). The self-purification capacity of the rivers/canals is enhanced by hydro-morphological interventions aimed at diversifying, as far as possible, section and flows regimes
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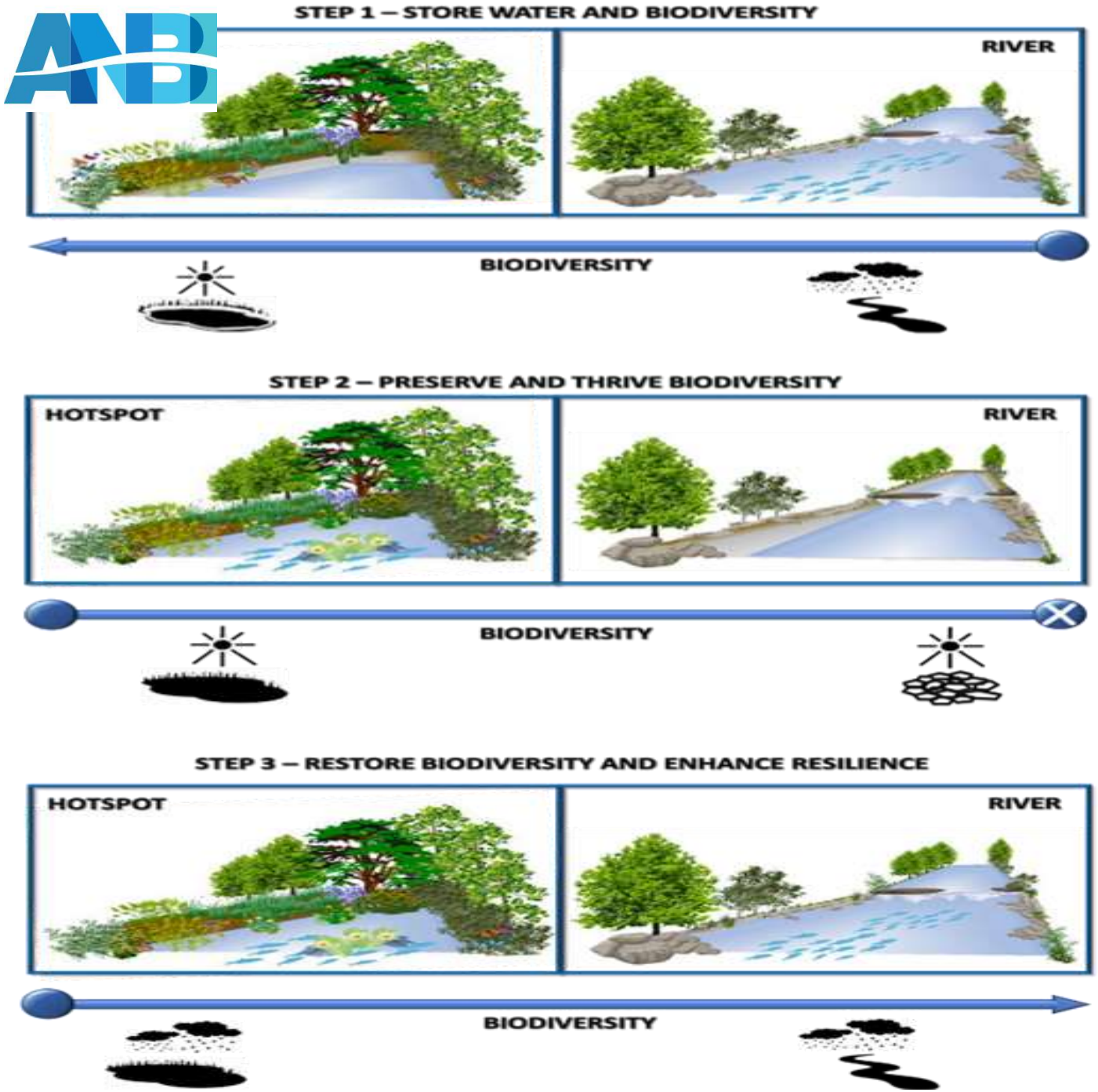
	"farm constructed wetland": • Farm constructed wetland aims to enhance water retention as well as to promote pollutant removal/retention (e.g., pesticides, herbicides, nutrients, etc.) and nutrient recovery (mainly nitrogen and phosphorous) from agricultural drainage water ; • Can act as a natural reservoir to store surface water runoff and agriculture drainage water for use at later date; • Can allow nutrient recovery , i.e. accumulate nutrients from agricultural drainage water, can be harvested and composted and then used as a soil conditioner or organic fertilizer.
Pedo-climatic / geographical	Site has a humid subtropical climate that is mild with no dry season, constantly moist, with year-round rainfall. Summers are hot and muggy with thunderstorms. Winters are mild.
Economic benefits	• Simple maintenance and easy and ***low-cost operation***; • Possibility to produce biomass and recover nutrients and water.
Environmental benefits	• Mitigation of runoff impacts during intensive meteo events.; • Regulation of crop water supply. Water pollution control. Environmental requalification and biodiversity protection.
Social benefits	• Opportunities for recreation, education and research activities.
Success factors	• Farm constructed wetlands are a ***sustainable and resilient solution*** in the context of climate change; • Can preserve freshwater quantity and quality, ensuring food security and environmental health.
Limitations and drawbacks	• Require large spaces of ***land.***
Involved actors	Farmers; water/soil/air conservation authorities; irrigation consortia; research institutes; community.

	" Local measures to increase groundwater recharge": • Searching for water resources for groundwater infiltration to increase groundwater availability for irrigation, two farmers in the northern German landscape Lüneburger Heide (between Hamburg and Hannover) developed the idea to stop leading this drainage water into nearby ditches or natural watercourses. • Leading the ***drainage water into newly created seepage ponds*** at a sandy bottom. • Nitrate contained in the drainage water, will be reduced to nitrogen gas due to the anaerobic conditions ot the seepage pond with organic material from surrounding shrubs on its bottom.
Pedo-climatic / geographical	Maritime-Subcontinental-Northern German Lowlands / Northern Germany but it can be transferred to other glacial landscapes with nearby alternation of sandy and loamy soils.
Economic benefits	• At the moment none
Environmental benefits	• Increased ***groundwater supply*** for groundwater dependant ecosystems like waterbodies or wetlands
Social benefits	• no obvious ones, but see econ. and env. benefits.
Success factors	• ***Reduced nitrate*** contents in drainage water; • Active information ,organisation of the planning, of geological research and additional financial means for material (supplementing farmers volunteer works) during a project; ***no running costs***!
Limitations and drawbacks	• expenses for material and planning work -***could be compensated,*** if the involved farmers would be rewarded by additionally permitted groundwater abstraction quota; • this rewarding system only functions physically, if the additional groundwater from the seepage pond is indeed flowing towards the involved farmers irrigation wells.
Involved actors	• For repetition on basis of an ecosystem service-scheme, farmers, hydrogeology experts and water authority need to be involved. The described pilot was done as part of a larger project.

	"Non-Coventional Water Resources in Agriculture": • Use of natural systems (constructed wetlands and lagoons) for the treatment and reuse of municipal wastewater as non-conventionsl water resource (***NbSs Type III***); • Deployment of resource efficient agricultural practices in greenhouse aquaponics and in organic farm plots, where the reclaimed water will be applied for irrigation. Including: precision/deficit irrigation techniques, composting and agroforestry (***NbSs Type II);*** • Conservation of natural wetlands that exist in the area (e.g. improvement of water balance and wet buffer zones), as well as environmental interpretation measures (***NbSs Type I***).
Pedo-climatic / geographical	MDN-Mediterranean North / Local.
Economic benefits	• Reduced water treatment and ***farming cost;*** • Reliable and ***constant water source*** for the irrigation of dynamic crops; • potential source of nutriens (depenting of the water quality and treatment level).
Environmental benefits	• ***Efficient use of water resources***, conservation of natural water reserves and aquifers; • Reduced agricultural pollution, contribution to the conservation status of natural wetlands and ***biodiversity enhancement.***
Social benefits	• Increase awareness about sustainable farming and natural resources conservation, cooperation opportunities between farmers and authorities responsible for municipal wastewater treatment.
Success factors	• The wastewater ***problem turns into a reliable water source*** for crop production • Integration of Non-Conventional Water Resources ***into sustainable farming practices***.
Limitations and drawbacks	• Minor landscape interventions may be necessary to regulate water flow; • ***Social perception*** regarding crops irrigated with reclaimed water; • Legislation requirements concerning the wastewater reuse.
Involved actors	• Hellenic Agricultural Organization -Soil and Water Resources Institute (HAO-SWRI) / R&I Project funded by PRIMA H2020



NBS & BIODIVERSITY HOTSPOTS

MULTI-FUNCTIONAL WATER AND BIODIVERSITY STORAGE THROUGH WIDESPREAD IMPLEMENTATION OF NATURE BASED SOLUTIONS

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Small and Medium Basins

N. 116 existing storage basins for a total volume of 1.095.527.200 m³

n. 245 small/medium basins to be built for a total volume of capacità totale 686.787.021 m³, and an investiment of € 3.641.646.916

Job Creation: 17.464 new permanent positions

Preventing hydrogeological risks

Increasing water availability for civil uses

Agricolture

245 new storage basins allow to collect +65% rainwater

+ 452.099 hectares made available to crop high value cash crops (fruits and veggies)

Landscape and biodiversity

Sustainable Tourism

New wetlands

Green Energy:

- Reducing emissions of about 630.000 tonnes/year CO_2 equivalent, comparable to more than 1.300 hectares of forest

Green Energy

FLOATING PHOTOVOLTAIC

n. 361 new installations producing 1,306 mln di MWh with a basin's surface coverage of 30%

HYDROELECTRIC

n. 80 plants producing yearly 7.620 MWh

Of about 1,314 mln di MWh/year can be produced per year.

Satisfying the needs of 1864000 persons, equal to 466.000 families.

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Rendering, Solar AquaGrid

YouTube– REC Solar panels over canals in India

WATER ENERGY NEXUS

REC solar panels suspended by cables above canals are saving 73 million liters of water which are channeled to local farms, while generating 8.4 million kW of energy annually since 2017.

8400 km of suspended solar panels can produce 13 GigaWatts, of about 5% of the Italian agricultural canal network can provide energy to over 1 million of houses

DECARBONIZE WATER SUPPLY AND IRRIGATION

OVER 400 RENEWABLE ENERGY PLANTS

600.000.000 KWh PRODUCED PER YEAR

CARBON FARMING: Hydraulic infrastructures at the core of renewables energy production to offset consumption, and acting as enabler for regenerative irrigated agriculture to produce more biomasses, increase and preserve soil organic matter and the storage of CO2

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NOVEL LOW ENERGY IRRIGATION TECHS

Plants release root exudates in response to their changing environment (temperature, wind, rain). In response to the root signals, tube releases water and nutrients. Their interior surface is infused with a **hydrophilic polymer** creating a chemical bond that attracts water molecules, enabling the movement of the water molecules and soluble amendments through the micropores along the tube's surface. Because plants control their own consumption, the irrigation flows in different rates, automatically 24 hours, 7 days a week. Water savings up to 40% have been observed in arid climates.

RDI RESPONSIVE DRIP IRRIGATION **GrowStream™**

Zero Energy input, low pressure, low rate, anticlogging, no-filter, drip irrigation system

N-Drip

N-Drip™ Gravity-Powered Micro-Irrigation

N-Drip enables farmers to move from flood to gravity-powered micro-irrigation, using existing infrastructure and the force of gravity - No pumps, No filters

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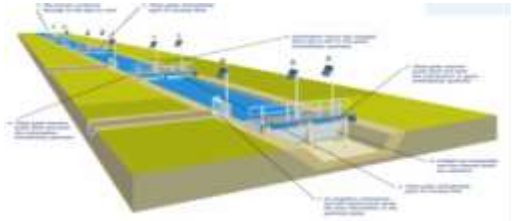
SOFT INFRASTRUCTURES

TAILORING INNOVATION ON THE TERRITORIES

Irrigants d'Europe



SMART GOVERNANCE

GREEN ENGINEERING

BIOREMEDIATION
& FITODEPURATION

SAFEGUARD AND RESTORATION
OF NATURAL AREAS

HYDROMORPHOLOGY
RESTORATION

14 EU PROJECTS

27 NATIONAL,REGIONAL, ETC. PROJECTS

COLLABORATIONS WITH NATIONAL AND INTERNATIONAL UNIVERSITIES AND RESEARCH CENTERS

APPLIED INNOVATION: HUNDREDS OF INFRASTRUCTURE IMPROVEMENT / MODERNIZATION PROJECTS

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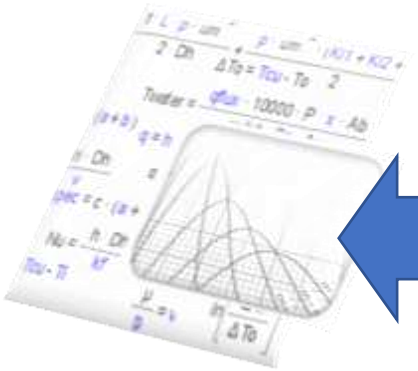
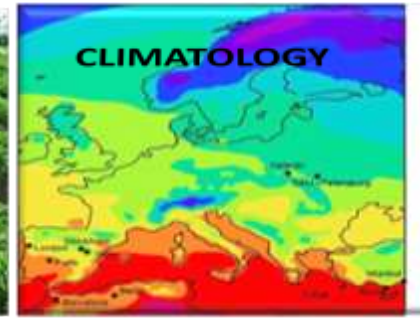
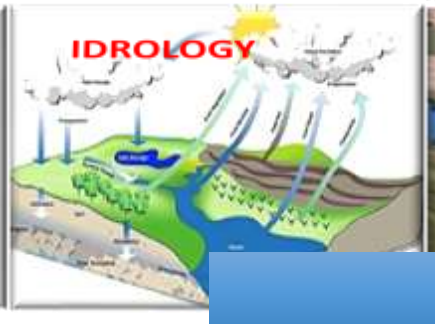


MATH & MODELLING





MULTIDISCIPLINARITY

RISK/ TRADE-OFF BASED FARMER' DECISIONS

CROP WATER MAMANGEMENT

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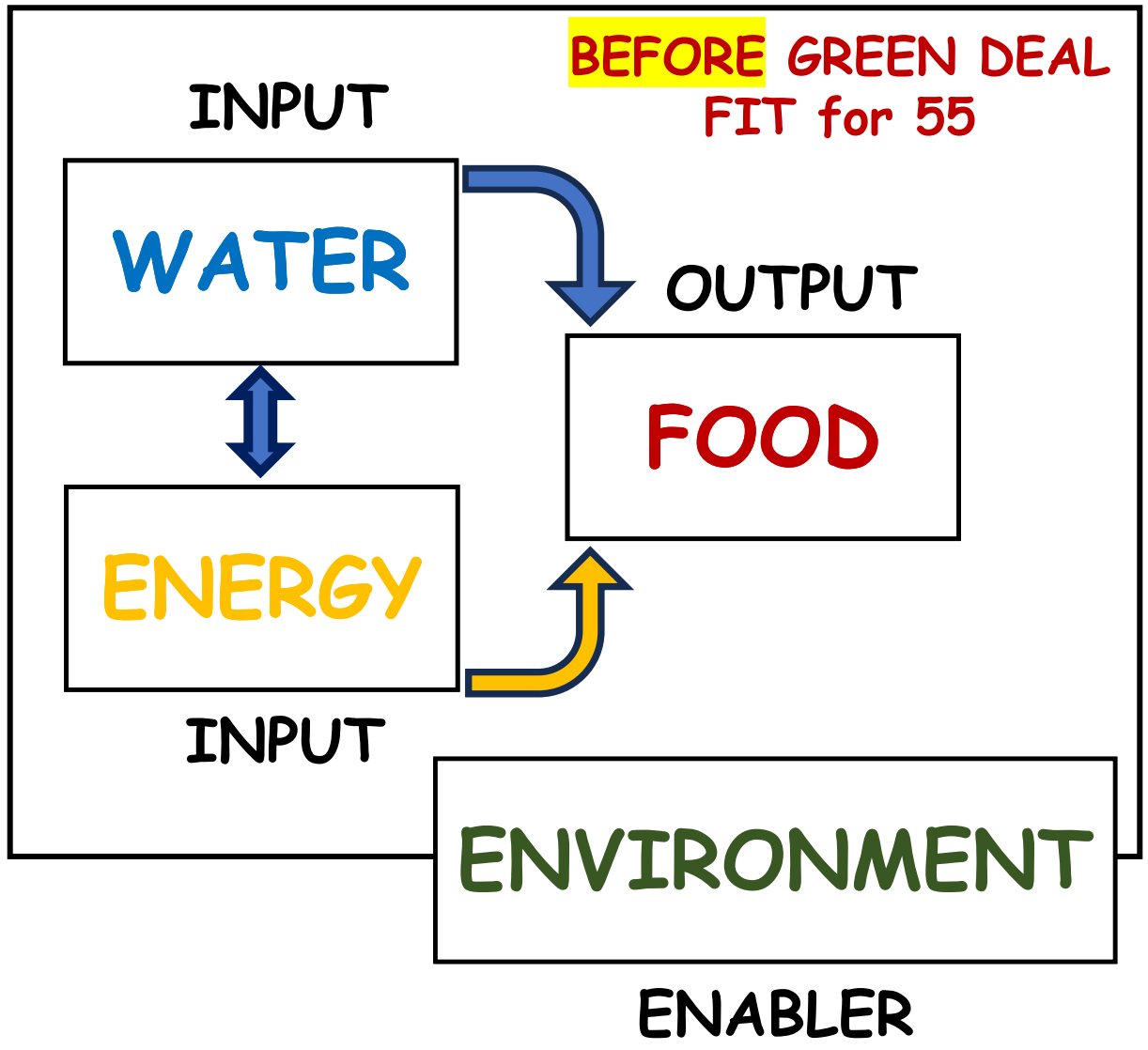
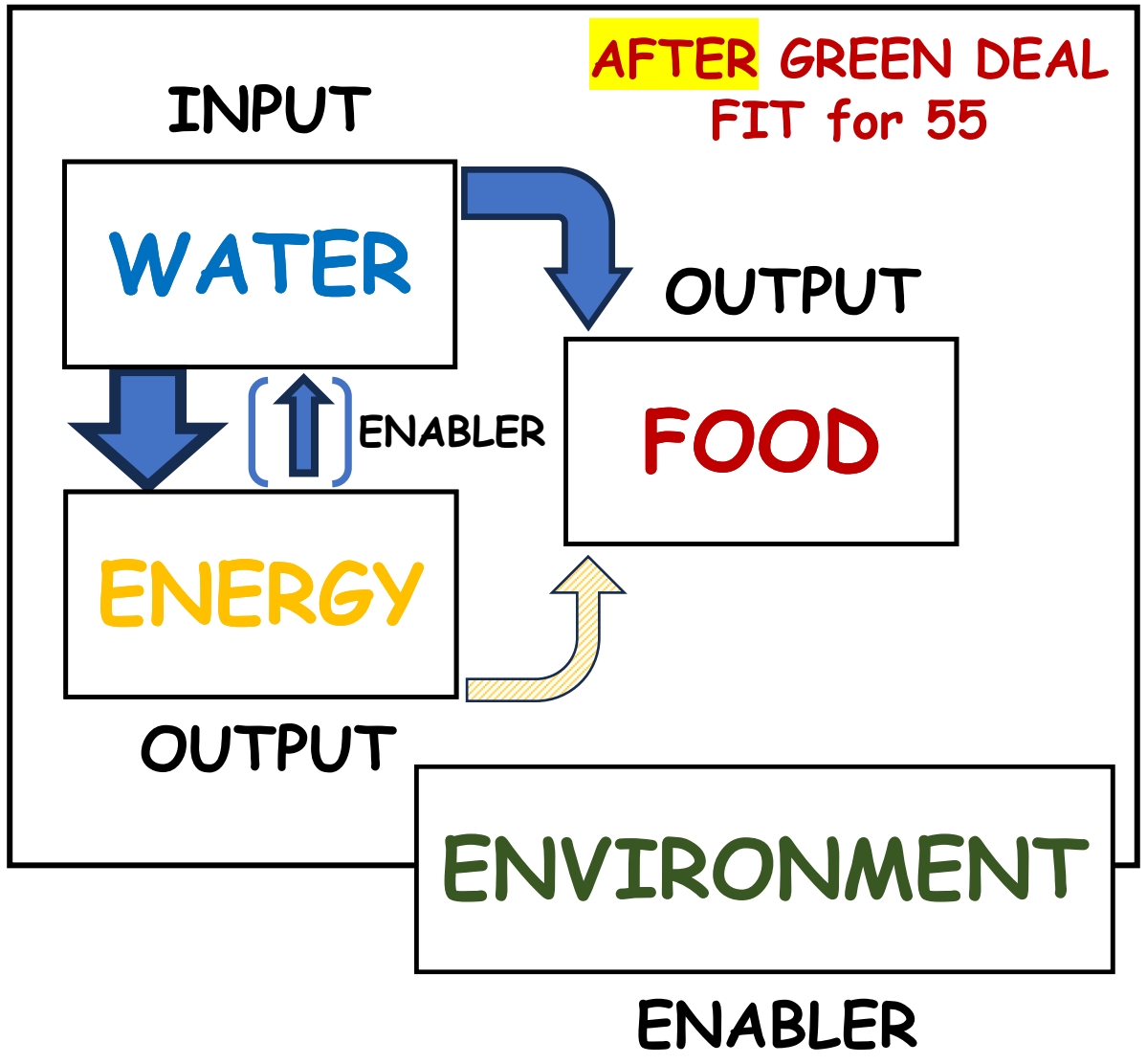
TAKE HOME MESSAGE

WATER/ENERGY/FOOD/ENVIRONMENT NEXUS EVOLUTION





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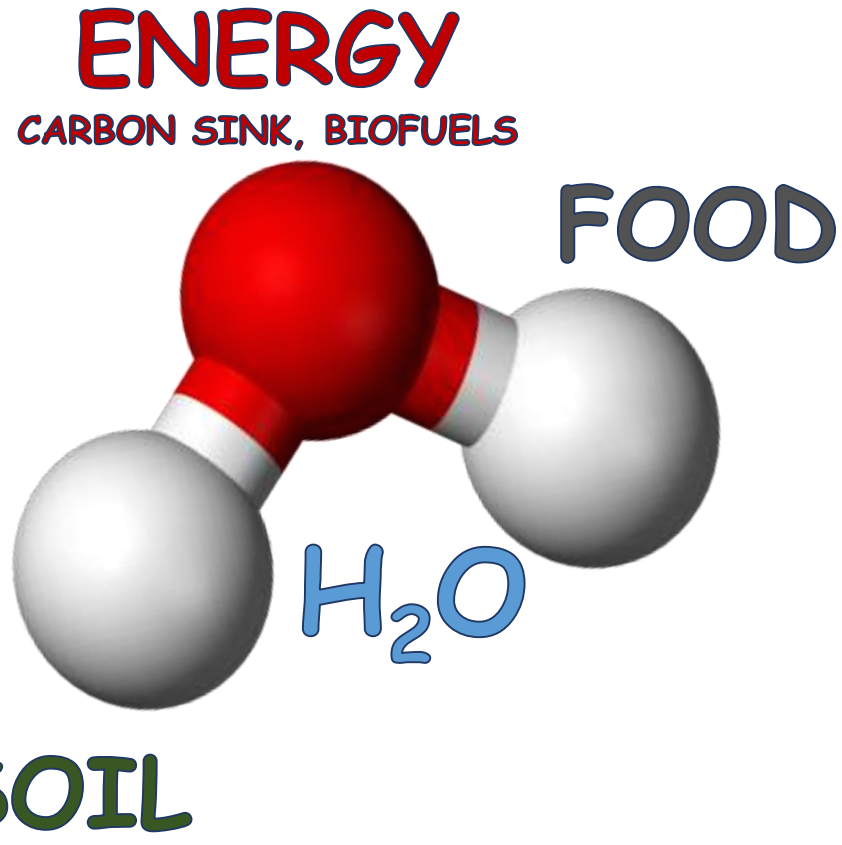
MULTIANNUAL PLAN FOR INFRASTRUCTURE MODERNISATION AND MAINTENANCE



FLOOD & DROUGHT IMPACTS CAN BE AVOIDED ONLY UNDERTAKING PREVENTIVE ACTIONS

PREVENTION PLAN MUST RECOGNIZE SOIL/WATER AND WEFE NEXUS AS A CORNERSTONE OF A BROADER CONSERVATION, ADAPTATION AND MITIGATION WORK

GREEN ENGINEERING AND NATURE-BASED SOLUTIONS MUST BE IMPLEMENTED WHENEVER POSSIBLE

TO SUCCEED MITIGATING HYDROGEOLOGICAL INSTABILITY, FLOOD AND DROUGHT IMPACTS SOIL AND WATER MUST BE A PRIMARY FOCUS OF OUR CLIMATE CHANGE ADAPTATION AND MITIGATION EFFORTS.

INFRASTRUCTURES ARE THE KEY TO ADAPT AND MITIGATE

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Sustainable development must not be hampered by a rewriting of history that retains no memory of poverty, food insecurity, diseases.

Today we need the same innovative courage and vision that left us a legacy of essential infrastructures, but combined with the awareness of a necessary long-term environmental sustainability.

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THANKS FOR YOUR ATTENTION

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