

Desarrollo de capacidades para la resiliencia hídrica: IA participativa y responsable para la toma de decisiones en el Nexo WEFE

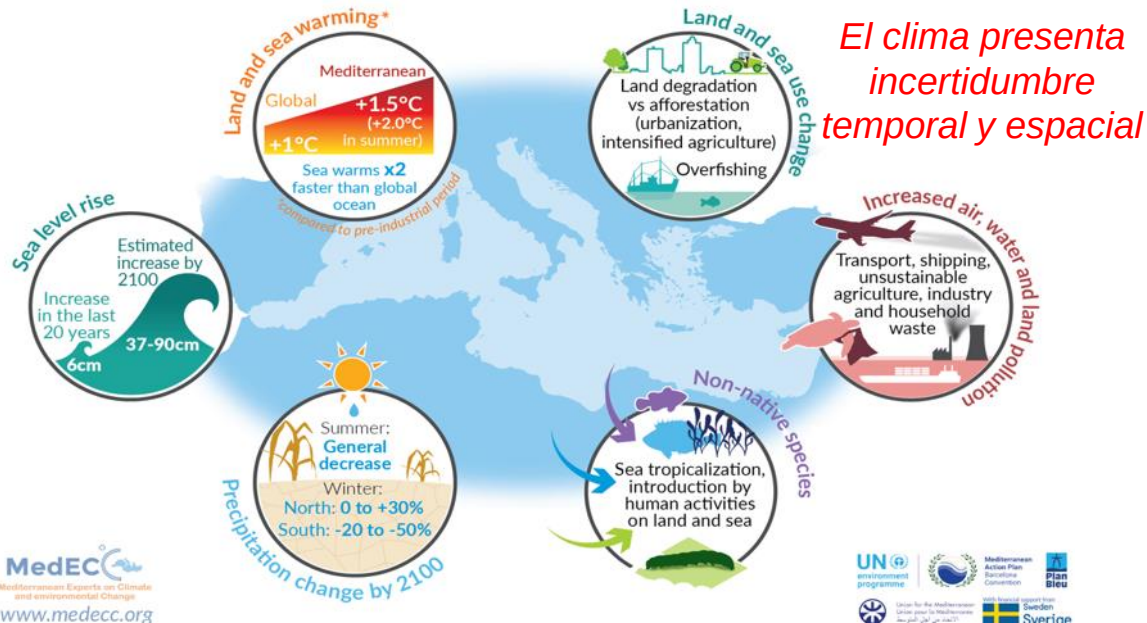
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Cátedra UNESCO de Sostenibilidad & INLAB* - Universitat Politècnica de Catalunya

Reto 1-2. Realidad climática – Conflictos por los recursos

Existe una realidad climática que está provocando una emergencia social.

1st Mediterranean Assessment Report (MAR1) published by MedECC

The Mediterranean Basin: main drivers of environmental change



PLANETARY LIMITS

6 / 9

planetary boundaries are transgressed, indicating that Earth is beyond the assessed safe operating space for humanity.

Richardson et al. (2023)



WATER SCARCITY

**4.0 billion
0.5 billion**

people experience severe water scarcity at least 1 month per year; around 0.5 billion face it year-round.

Mekonnen & Hoekstra (2016)



WATER SECURITY AND BIODIVERSITY

**~80%
65%**

of the global population is exposed to high threat to human water security; habitats associated with 65% of continental discharge are moderately to highly threatened.

Vörösmarty et al. (2010)



FOOD-WATER DEPENDENCE

>70%

of global freshwater withdrawals are used by agriculture, highlighting the central role of food production in water demand.

FAO (2025)



Resource pressures are interconnected: water scarcity, food production, energy demand and ecosystem integrity cannot be assessed independently.

Selected data sources: Richardson et al. (2023); Mekonnen & Hoekstra (2016); Vörösmarty et al. (2010); FAO (2025).

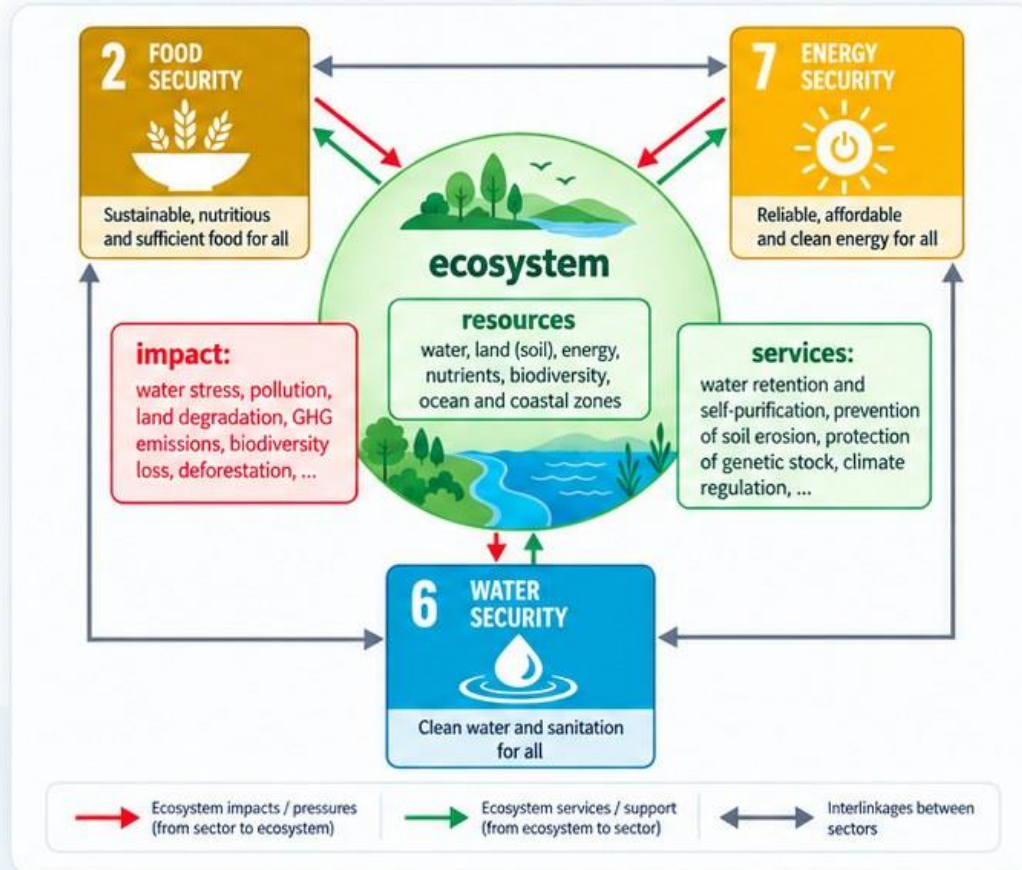
La realidad climática conduce a una **menor productividad agrícola**, tanto en cantidad como en la calidad organoléptica de los productos.

Understanding Complexity Before Building Capacity



“We can never fully understand our world, not in the way our reductionistic science has led us to expect.”

— Donella Meadows, *Dancing with Systems* (2001)



Water–Energy–Food–Environment (WEFE) Nexus



- 1 Before developing capacity, we need to **understand complexity** of the systems in which people make decisions.



- 2 Water, energy, food and ecosystems **cannot be understood in isolation.** Their interactions involve multiple sectors, scales, actors and competing objectives.



- 3 The challenge is therefore not to simplify complexity away, but to **make it understandable.**

Beyond the Fear: AI as a Tool for Understanding and Learning



AI can help us connect data, knowledge and stakeholder perspectives, **making complex interactions visible** and **turning them into shared learning**.

This allows capacity development to move beyond training individuals — to spreading understanding across sectors, institutions and communities.



AI can help us make **complexity understandable** — and **learning scalable**.

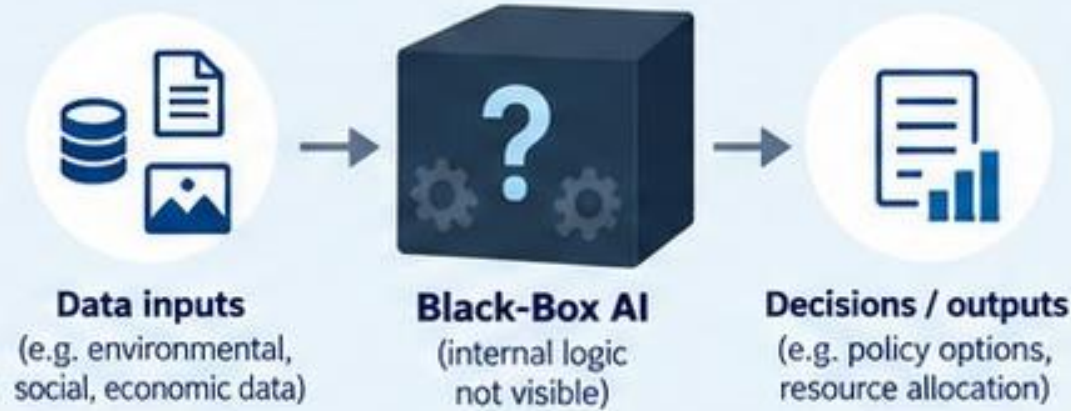


The challenge is not to ignore the fears surrounding AI, but to move **from fear to responsible use** — using AI to understand complexity, support collective learning and strengthen decision-making.

Reto 3. IA de caja negra

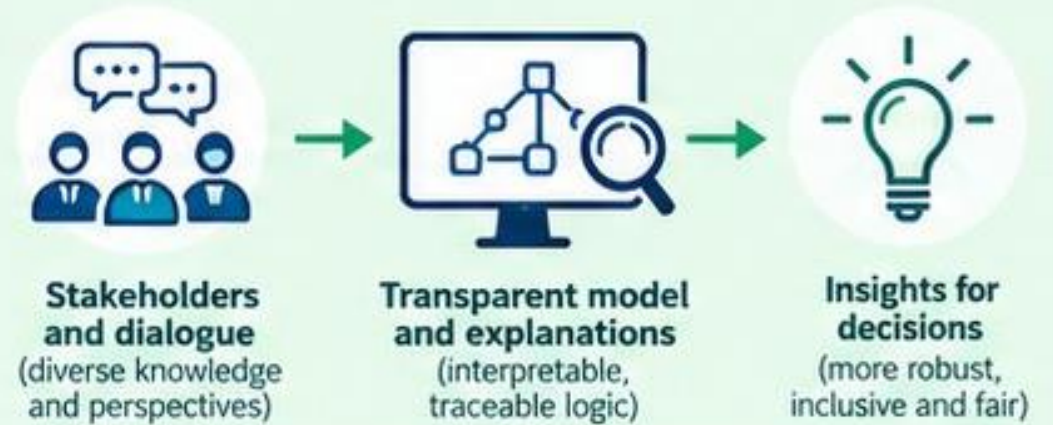
Why avoid Black-Box AI?

Black-Box AI (opaque, non-transparent)



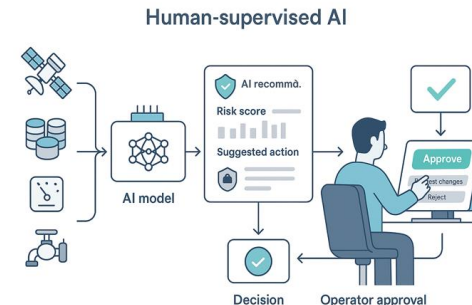
! When AI remains a black box, stakeholders may struggle to understand, trust or replicate its recommendations.

Participatory & Explainable AI



✓ Transparency supports trust, learning and responsible decision-making.

Las decisiones las toma un **sistema de IA supervisado por personas** con la aprobación del operador



Ensuring fair WEFE NEXUS transition for Climate Change Adaptation and Sustainable Development implementation, based on coupled Nature-based Systems and Bioeconomy



Desplegar **soluciones innovadoras a pequeña escala como demostradores de sistemas socioecológicos y técnicos (SET)** basadas en:

1. Soluciones de bioeconomía (BES)

2. Soluciones basadas en la naturaleza (NbS)

para el **NEXO WEFE**, y evaluar su **productividad y valor para la comunidad local**.



**SURE
NEXUS**



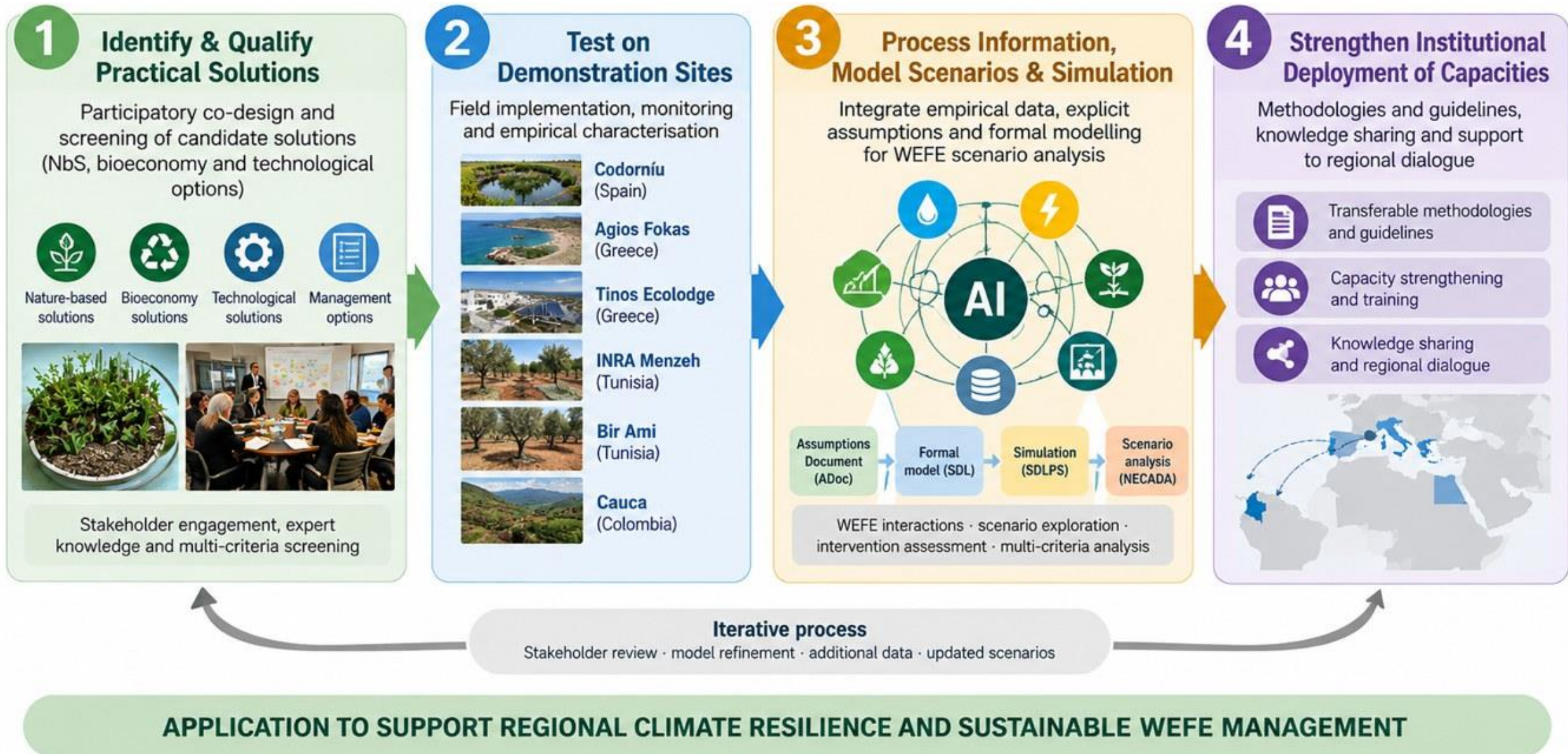
**7 countries / 15 institutions
7 países / 15 instituciones**



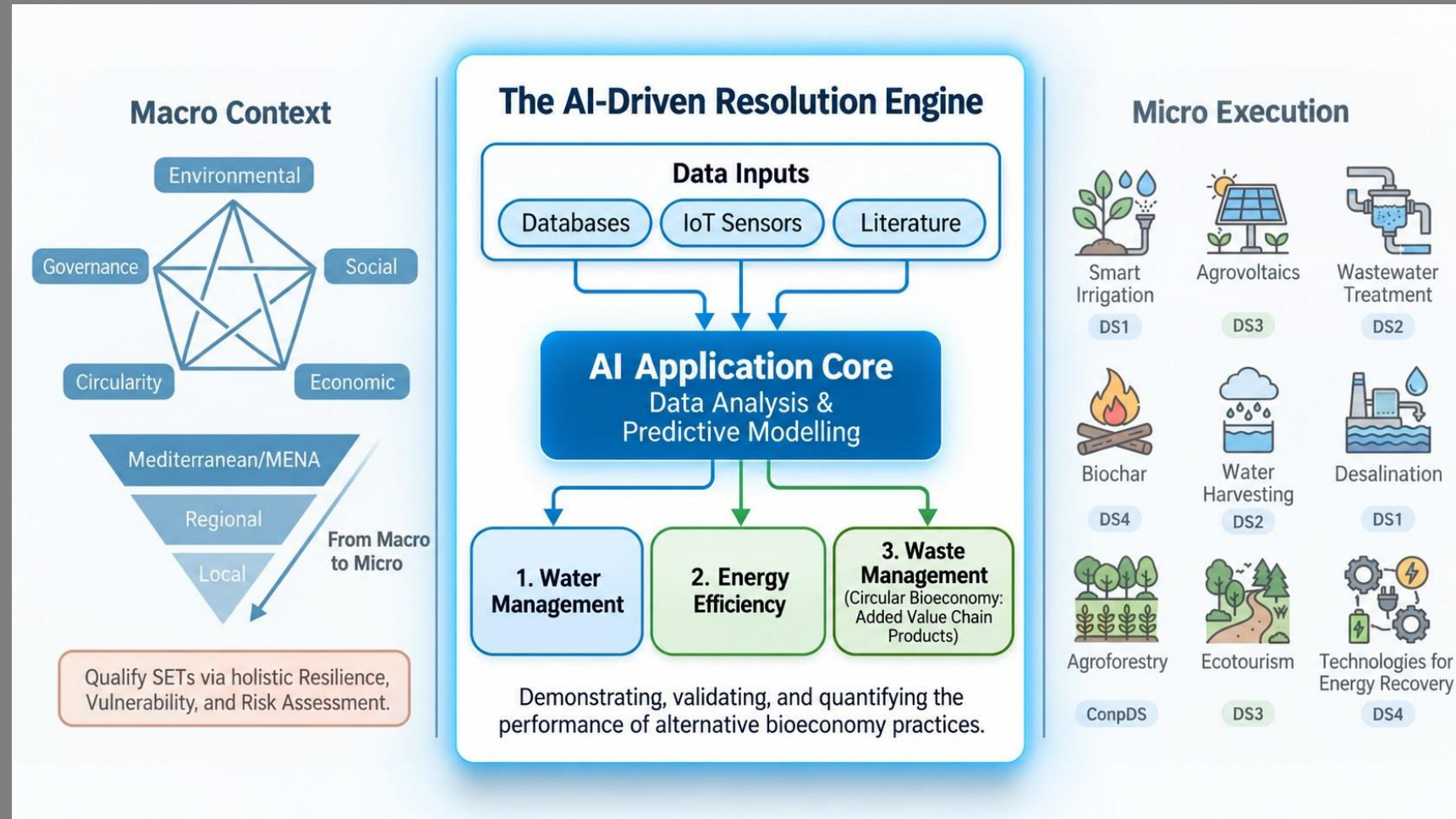
UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH
UNESCO Chair on Sustainability



Estrategias integradas de resiliencia climática regional



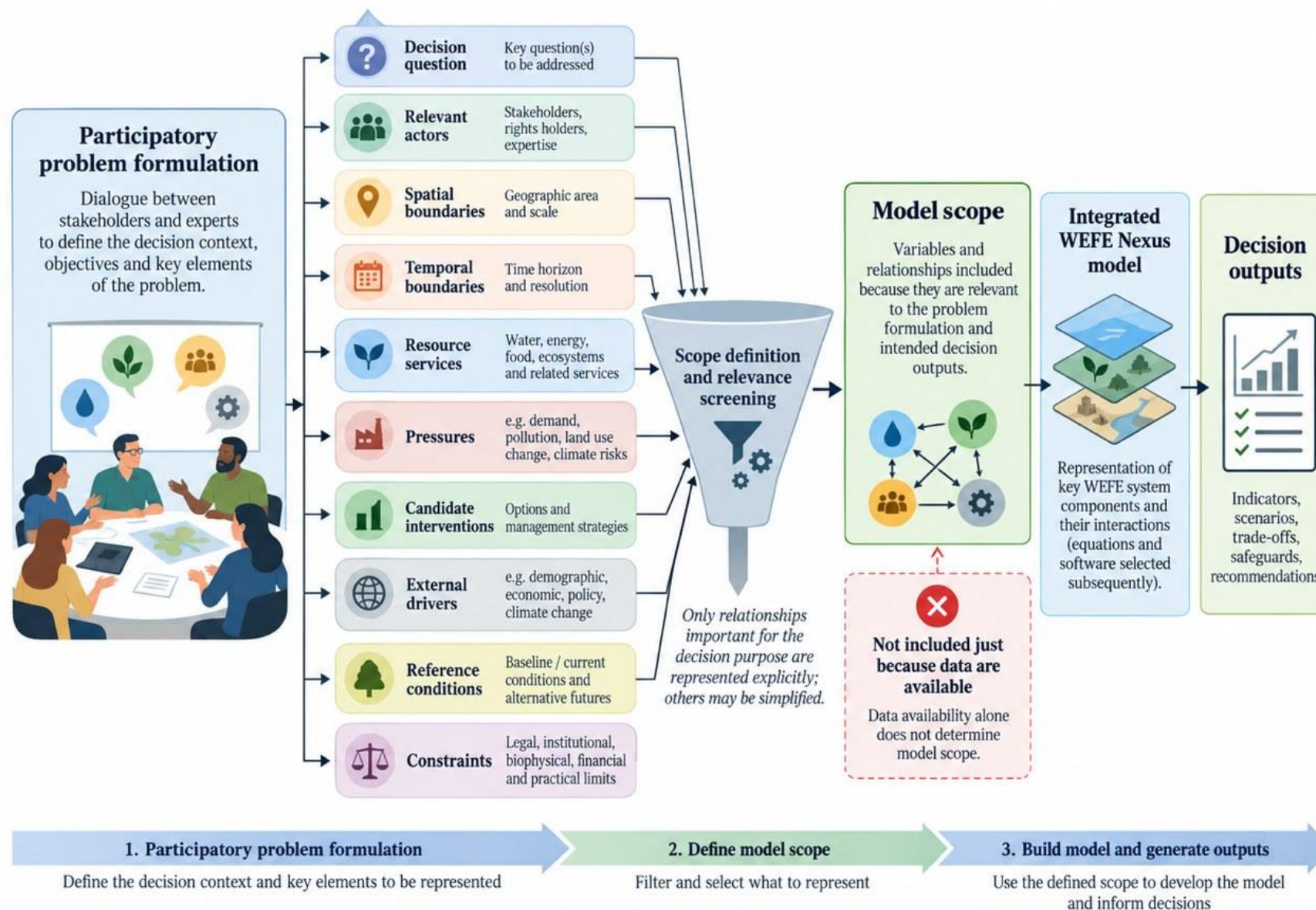
MARCO PARA ESCALAR SOLUCIONES PRÁCTICAS



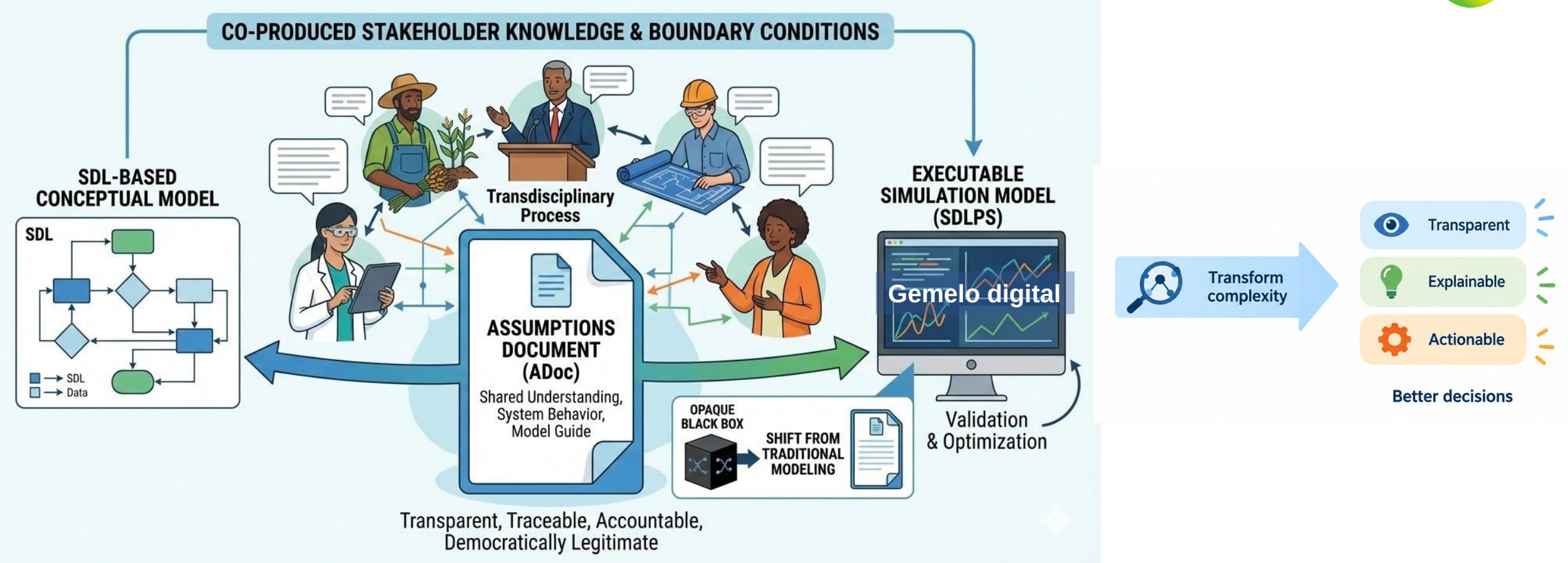
EN CONDICIONES DE EMERGENCIA CLIMÁTICA EXTREMA Y ESCASEZ DE AGUA

Reto 4. De la teoría del WEF E Nexus a la Acción

Marco de IA participativa SURENEXUS para la evaluación WEFE



THE AI WEFE NEXUS: CO-DESIGNING THE ASSUMPTIONS DOCUMENT (ADoc)



SDL: Specification and Description Language

Enfoque transdisciplinar para elaborar el documento de supuestos (ADoc) del modelo y un gemelo digital gráfico en SDL que representa visualmente el sistema real y fomenta el trabajo en equipo.

Marco participativo SURENEXUS para la evaluación WEFE

22



Participatory Workshops

934



Total Participants

7



Countries

2023–2025

Engagement Horizon

Acceleration of the Participatory Process



Global Footprint & Local Context



Three-Pillar Strategic Framework



Capacity Building

Training on WEFE nexus modelling, AI courses.



On-the-Ground Action

Regional workshops across demo-sites, sector-focused workshops in citrus and olive oil, site visits, permaculture workshops, and agrivoltaics platform sessions.



Strategic Alignment

Policy dialogue, international conferences, and executive stakeholder meetings.

Comp DS: RIEGO SUBTERRÁNEO PARA EL CULTIVO DEL OLIVO (Bir Ami, Túnez)



**Innovación
tunecina
Patentada**



Riego por goteo convencional



Riego subterráneo



Subsurface irrigation used ~83–85% less water,
while production decreased only **12.8%**, resulting in **5.7× higher water productivity.**

Subsurface Irrigation

Water use  **83% less water (model)**
84.6% less water (observed)  **~84% less**

Olive production **11.34 ± 0.46 kg tree⁻¹**
n = 25 trees  **12.8% lower**

Water productivity **1.98 kg m⁻³**
  **≈ 5.7-fold increase**

Oil quality indicators

	Surface Drip	Subsurface	Change
Free acidity	0.60%	0.30%	↓ -50.0%
Peroxide index	11 meq kg ⁻¹	7 meq kg ⁻¹	↓ -36.4%
Polyphenols	180 mg kg ⁻¹	280 mg kg ⁻¹	↑ +55.6%
Fruity sensory score	4/10	7/10	↑ +75.0%

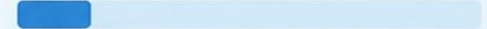
Soil ecosystem indicators

	Surface Drip	Subsurface	Change
Organic matter	0.8%	1.3%	↑ +62.5%
Enzymatic activity	1.2 µg TPF g ⁻¹ d ⁻¹	3.6 µg TPF g ⁻¹ d ⁻¹	↑ +200%
Soil electrical conductivity	2.8 dS m ⁻¹	1.9 dS m ⁻¹	↓ -32.1%
Water retention	15%	20%	↑ +33.3%

Surface Drip Irrigation (reference)

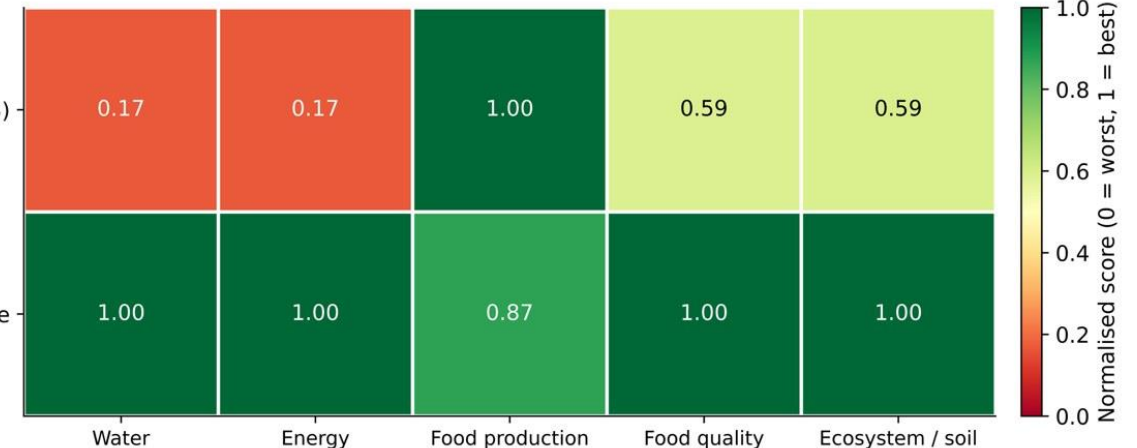
Water use  **Higher water use**
(reference)

Olive production **13.00 ± 0.94 kg tree⁻¹**
n = 32 trees

Water productivity **0.35 kg m⁻³**


Surface Drip (mean S1-S3)

Subsurface



MCDA y deltaheatmap para seleccionar intervenciones

Citricultura de precisión



Sustainability and profitability enhancement of citrus sector by leveraging advanced techniques, advances in biotechnology, computing and sensing infrastructure.

KENITRA, MARRUECOS



El modelo AI WEFE Nexus se utiliza para modelar la **necesidad bruta de riego (GIR)**, la **necesidad neta de riego (NIR)**, la **cosecha** y los indicadores de eficiencia derivados para cada combinación de variedad y factor de acolchado.



Modelo de
evapotranspiración
FAO Penman–Monteith

Escenario	GIR (mm/año)	Agua ahorrada vs suelo desnudo
Mulching fuerte (0.7)	282.3	43%
Mulching moderado (0.8)	322.6	35%
Mulching débil (0.9)	362.9	27%
Suelo desnudo (1.0)	496.5	0%





CO₂ (-72%) 5681 kg/año EVITADOS
NO_x (-65%) 5.16 kg/año EVITADOS
CH₄ (-95%) 1965 kg/año EVITADOS



- 80% GEI



- 70%
contaminantes



52370 m³/año



85 t/año



56 kg/año



0 t/año DE LODOS

- 90%



53880 kWh/año



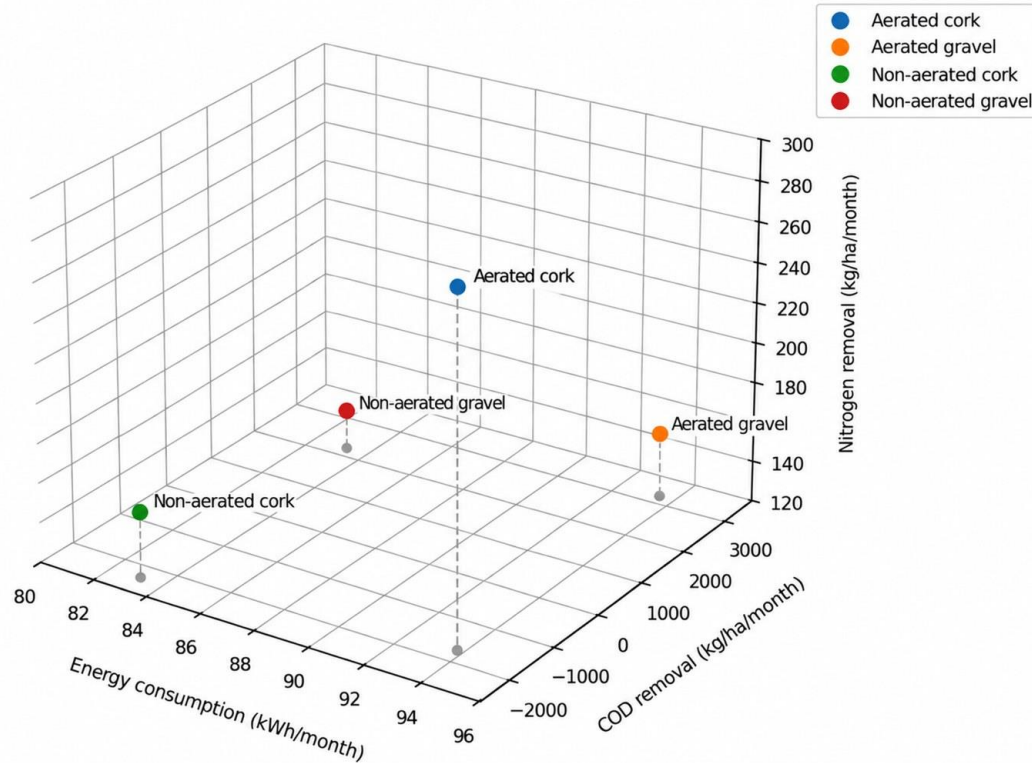
48440 m³/año – AGUA TRATADA



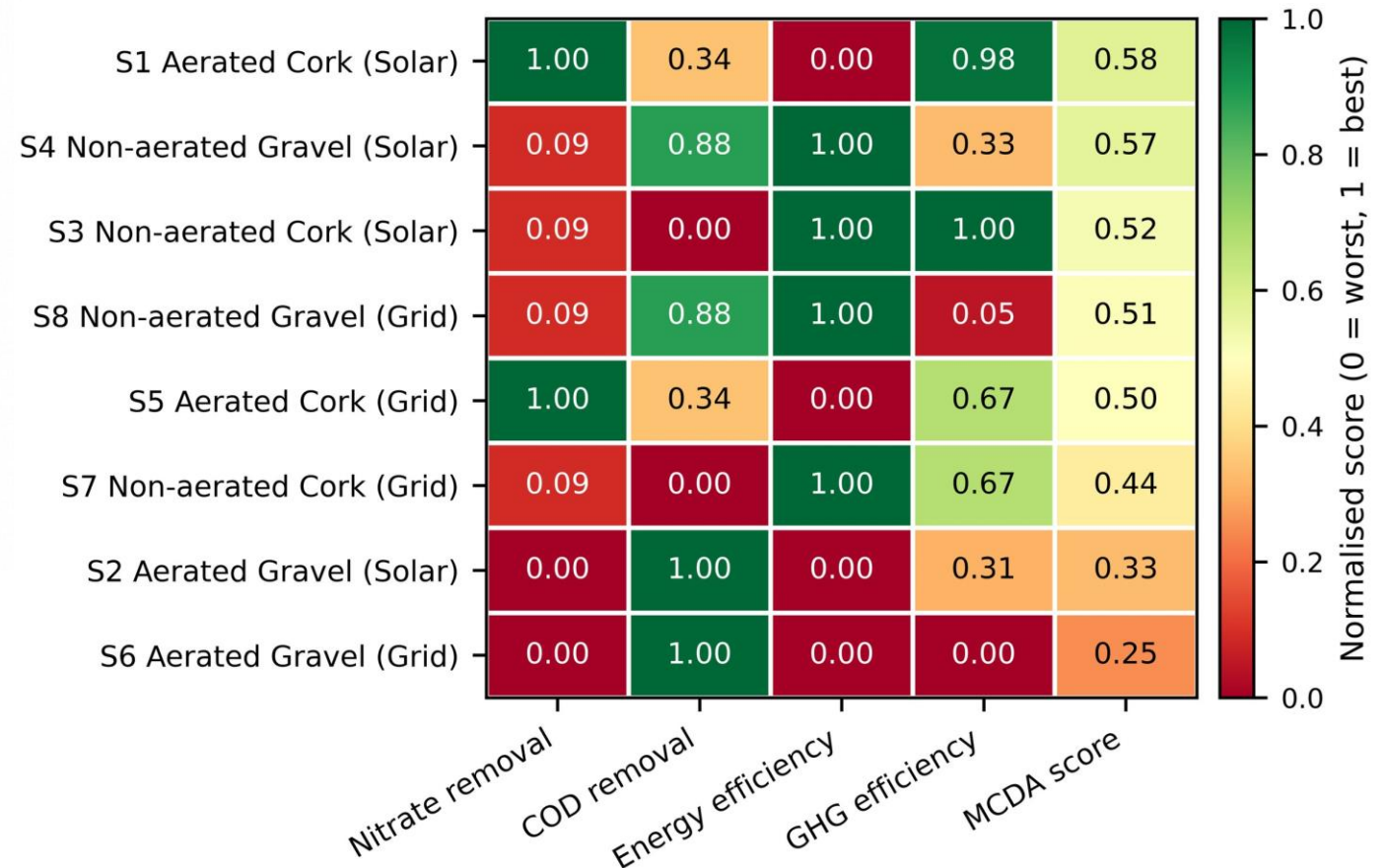
DBO (-95%) – 4242 kg/año
SDT (-15%) – 157524 kg/año
N total – 50 kg/año
N-NO₃ – 0 kg/año
Metalaxil (-85%) – 2612 kg/año

3% de los
residuos de
corcho de
Cataluña
reciclados

Análisis de trade-offs AI WEFE Nexus



MCDA y mapas de calor para seleccionar intervenciones



Apoyo a la decisión

Los sistemas expertos de apoyo a la decisión basados en IA ofrecen herramientas para gestionar las demandas en competencia del Nexo WEFE

Optimización multiobjetivo

Identificar estrategias que equilibren las compensaciones entre sectores, como las necesidades de riego frente a la generación hidroeléctrica.

Recomendación de soluciones y prácticas

Orientar a los actores hacia estrategias cooperativas con beneficios mutuos, a partir de datos históricos y simulaciones.

Detección de prácticas insostenibles

Identifica anomalías en los patrones de uso, como la sobreexplotación de acuíferos compartidos entre países.



Modelización predictiva y análisis de escenarios

Los modelos de IA ayudan a entender las complejas interdependencias entre agua, energía, alimentos y ecosistemas (Nexo WEFE)

Simulación de escenarios

Anticipa los efectos de cambios en la asignación de agua, en los rendimientos agrícolas o en la producción de energía bajo distintas condiciones climáticas o políticas.

Optimización de recursos

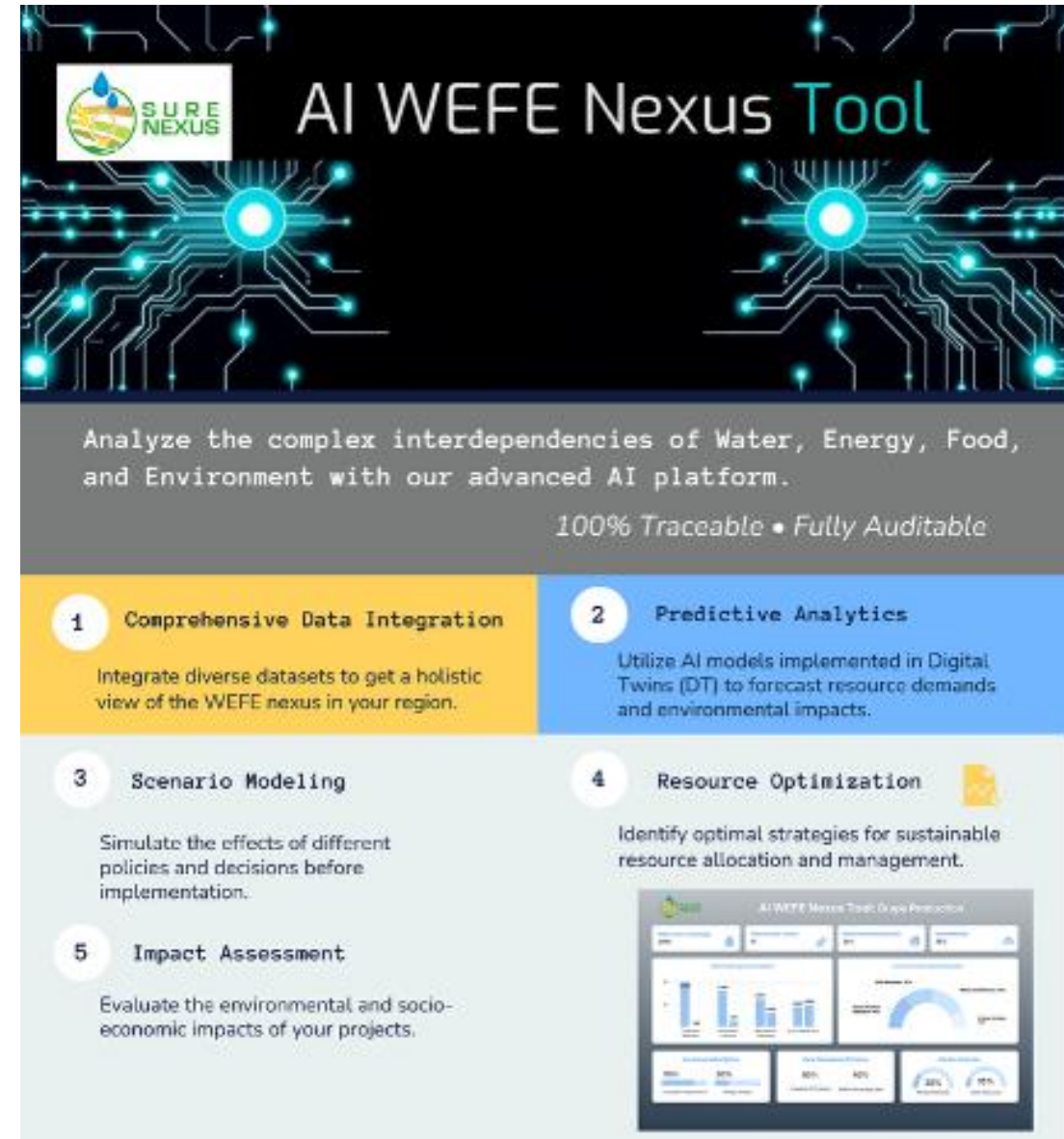
Identificar estrategias óptimas para una asignación y una gestión sostenibles.

Evaluación de impactos

Evalúa los impactos ambientales y socioeconómicos de cualquier proyecto.

Facilitación del diálogo

Proporciona una base objetiva para el diálogo sobre las compensaciones compartidas entre países, facilitando la toma de decisiones colaborativa



Reto 6. De las Barreras de Gobernanza al Desarrollo de Capacidades



AI is not a substitute for governance. It becomes valuable when institutions and stakeholders have the **capacity** to **understand**, **use** and **govern** it.

1



Policy barriers

fragmented rules,
limited coordination,
low trust

2



Participatory & explainable AI

transparent models,
evidence, shared
understanding

3



Capacity development

skills, institutions,
stakeholder
engagement

4



Better governance

transparency,
accountability,
adaptive decisions

5



Replication & scaling

cross-sector uptake
and transferability



Technical capacity

- Interpret AI outputs
- Use data and tools
- Support evidence-based decisions



Institutional capacity

- Coordinate across sectors
- Embed AI in governance processes
- Adapt policies over time



Social capacity

- Build trust and participation
- Enable co-learning
- Strengthen legitimacy and ownership



Capacity development is the bridge that turns AI-enabled transparency into effective governance and long-term replication.

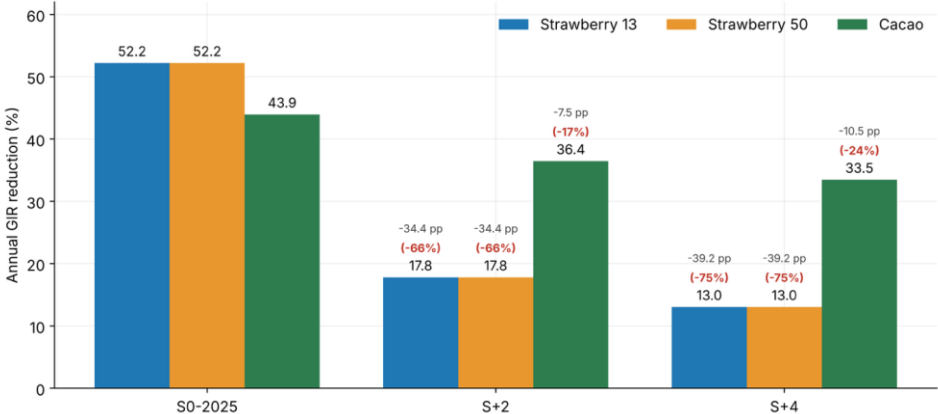
Reto 7. Del Desarrollo de capacidades a la Replicación y Escalamiento



El Niño stress and water-management adaptations in cacao and strawberry production: An AI-enabled Water–Food Nexus assessment in the Tropical Andes

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14 h
total contact time

8
live sessions

~2
working weeks

Online
live + recorded

Responsible AI for Water Resilience and WEFE Nexus Capacity Development

A practice-oriented programme connecting responsible AI, WEFE Nexus assessment and water policy.

PROGRAMME AT A GLANCE

1

Public lecture

Why responsible AI matters for water resilience and the WEFE Nexus.

1 h

OPEN TO ALL IWRA MEMBERS

2

Workshop 1
Responsible AI for WEFE Nexus Assessment

Frame decisions, build scenarios, interpret MCDA/KPIs and apply responsible AI safeguards.

3 × 2 h

6 HOURS · HANDS-ON

3

Workshop 2
AI for Water Policy

Translate AI-supported evidence into transparent policy, governance and investment pathways.

3 × 2 h

6 HOURS · CASE-BASED

4

Wrap-up & synthesis

Cross-cutting Q&A, consolidation, certificates and next steps.

1 h

FULL FACULTY

LEARNING PATHWAY

WEFE framing

AI-supported scenarios

Decision support

Policy action

IWRA certificate of completion
SURENEXUS cases & tools

AIWARE: Driving Responsible AI for Water Resilience & WEFE Nexus Capacity Development UN-Water SDG 6 CDI Pilot

The Mediterranean Pilot Basins Matrix		
Spain (Júcar River Basin) Irrigation, reuse and drought resilience. Focus: AI-supported scenarios for irrigation modernisation, wastewater reuse, and energy in water services under drought conditions. Lead Anchors: MITECO, Confederación Hidrográfica del Júcar (CHJ), UPV, and UNESCO Chair UPC.	Tunisia (Oued Souhil / Nabeul-Hammamet) Wastewater reuse and aquifer recharge. Focus: Advanced tertiary treatment using constructed wetlands and biochar, with reuse and managed aquifer recharge potential. Lead Anchors: ISSBAT, University of Tunis El Manar, with relevant UN-Water members.	Albania (Drin / Vjosa / Lake Ohrid) Transboundary cooperation and trade-offs. Focus: AI-supported scenarios for hydropower–irrigation–environment trade-offs, ecosystem services, and tourism-linked water demand. Lead Anchors: AMBU and Ministry of Environment, with UNECE for transboundary cooperation.

```
graph LR; A[Capacity-Needs Diagnostic  
Identifying specific IWRM and WEFE gaps.] --> B[Data Readiness & Governance  
Assessing ADoc, core assumptions, and data governance.]; B --> C[Scenario Co-Design  
Developing 2–3 targeted scenarios supported by MCDA and KPI dashboards.]; C --> D[In-Country Mission  
Executing the NECADA clinic and facilitating stakeholder dialogue.]; D --> E[Policy Uptake  
Final institutionalisation and integration into the CDI repository.];
```

Más información sobre el simulador SDLPS: <https://sdlps.com>

Más información sobre el modelo SureNexus en SDLPS:

<https://sdlps.com/Experiments/ModelDocsPng/3039>

Información general sobre NECADA DT: <https://necada.com>

Necada DT: <https://necada.com/home/dashboard>

Contacto: jordi.morato@upc.edu ; pau.fonseca@upc.edu (INLAB_FIB)



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Jose Luis Martin Bordes



Pau Fonseca i Casas



Olga Lucía Sánchez



Javier Collado



Brent Villanueva