From waste to worth: Harnessing residual biomass to boost soil quality and carbon sequestration

J.M. de la Rosa[1*], S. Domínguez[2], S. Perez-Dalí[1], Á. Sánchez-Martín[1], J. Márquez-Moreno[1], S. Gutierrez-Patricio[1], A. Moreno[3], B. Cubero[1], P.M. Martín-Sánchez[1], P. Souza[3], A. Merino[3], C. Rodríguez-López[1], H. Knicker[4], P. Campos[1], J.A. González-Pérez[1], and G. Bárcenas[2]

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Gobierno de España, Ministerio de Ciencia, Innovación y Universidades, CSIC Consejo Superior de Investigaciones Científicas

EGU Division Soil System Sciences

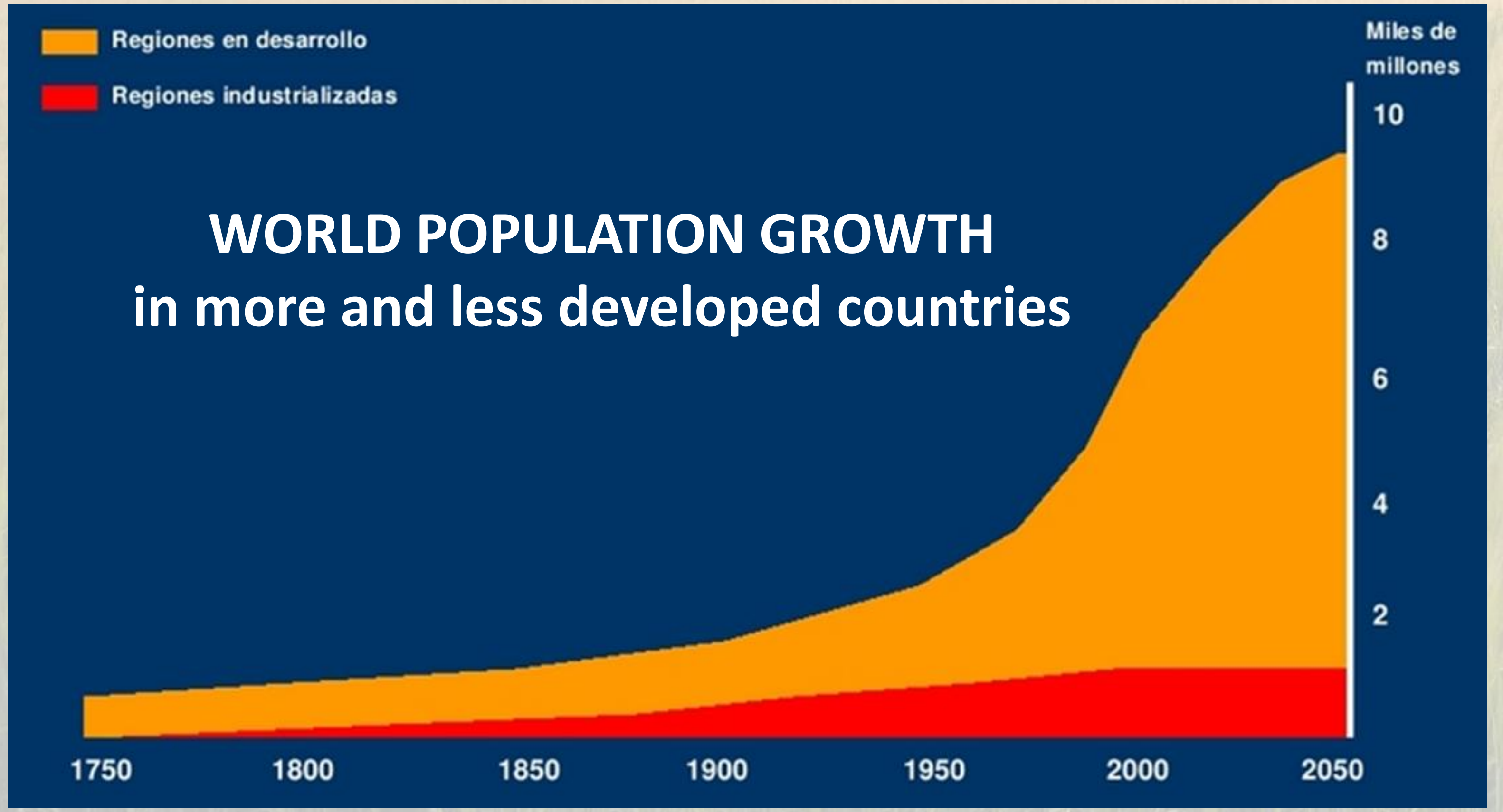
Index

1. Present challenges in agriculture
2. Recovery and valorization of agro-livestock and forestry residues
3. Case studies (Mediterranean climatic conditions)

Key takeaways and conclusions

1

Feeding growing population



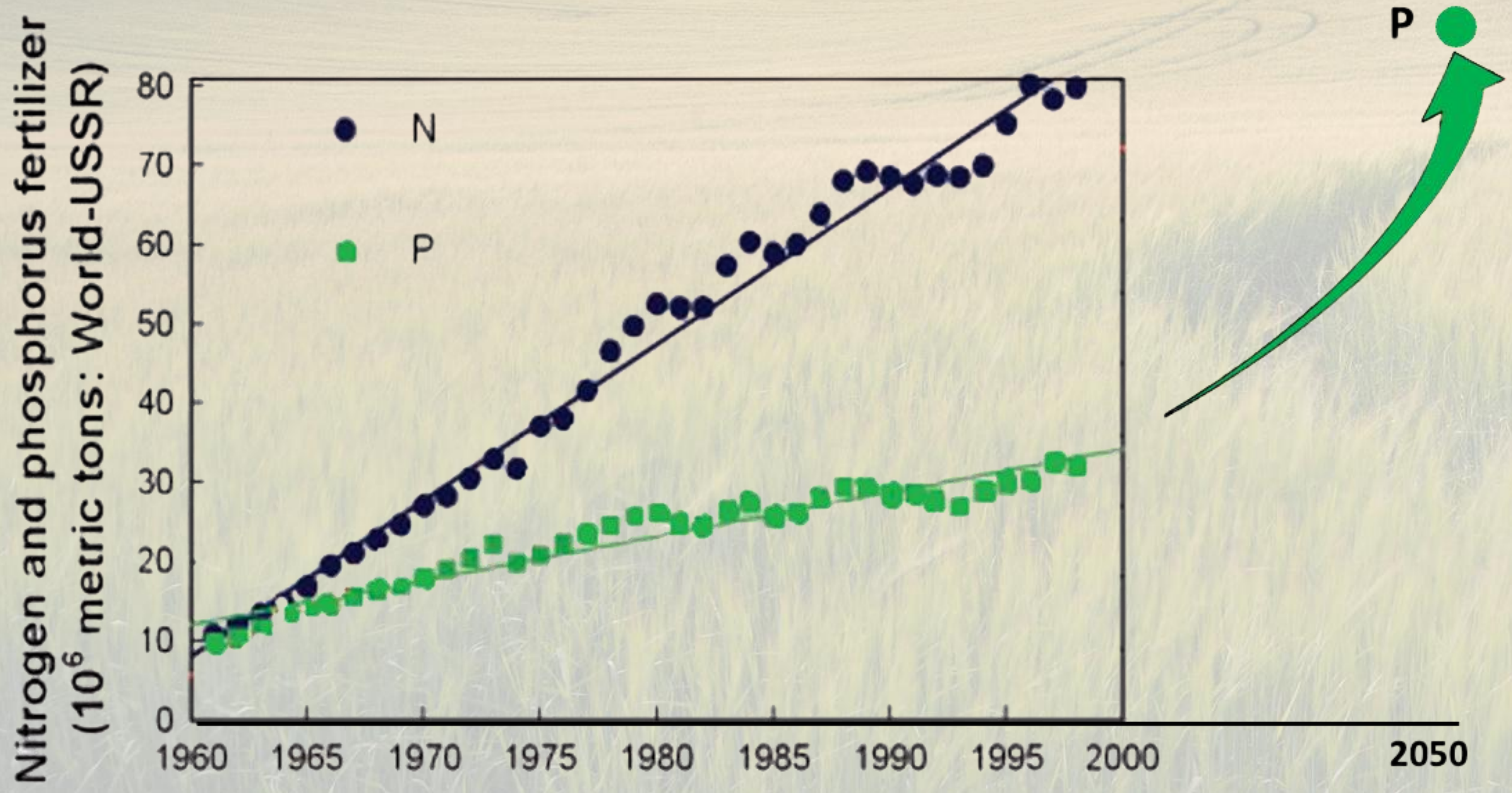
1

7
N
Nitrogen
14.00674

230 mill. ton/yr

15
P
Phosphorus
30.973762

85 mill. ton (P_2O_5)/yr



Feeding growing population

Dependence on mineral fertilizers

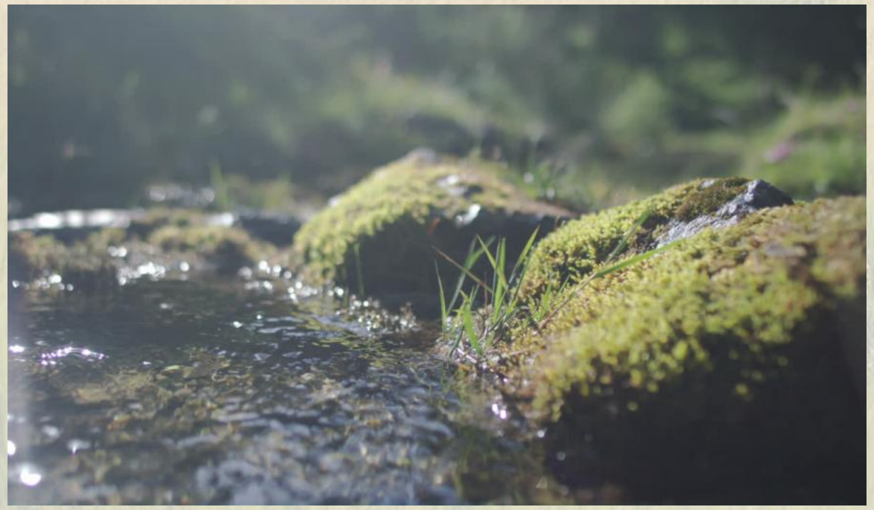
1

Environmental and economic risks

Eutrophication

GHG emissions

Dependence on fossil fuels



Water pollution

Feeding growing population

Dependence on mineral fertilizers

Risk of pollution

1


Over-exploitation and wrong management


Pollution


Erosion


Wildfires

Feeding growing population

Dependence on mineral fertilizers

Risk of pollution

Soil degradation

1

120-140 mill tons/yr bio-organic residues EU
40-50 % agriculture, cattle and forestry

- Feeding growing population
- Dependence on mineral fertilizers
- Risk of pollution
- Soil degradation
- **Waste generation**

1

Mostly used as energy sources in inefficient processes or disposed of in landfills

Feeding growing population

Dependence on mineral fertilizers

Risk of pollution

Soil degradation

Waste generation

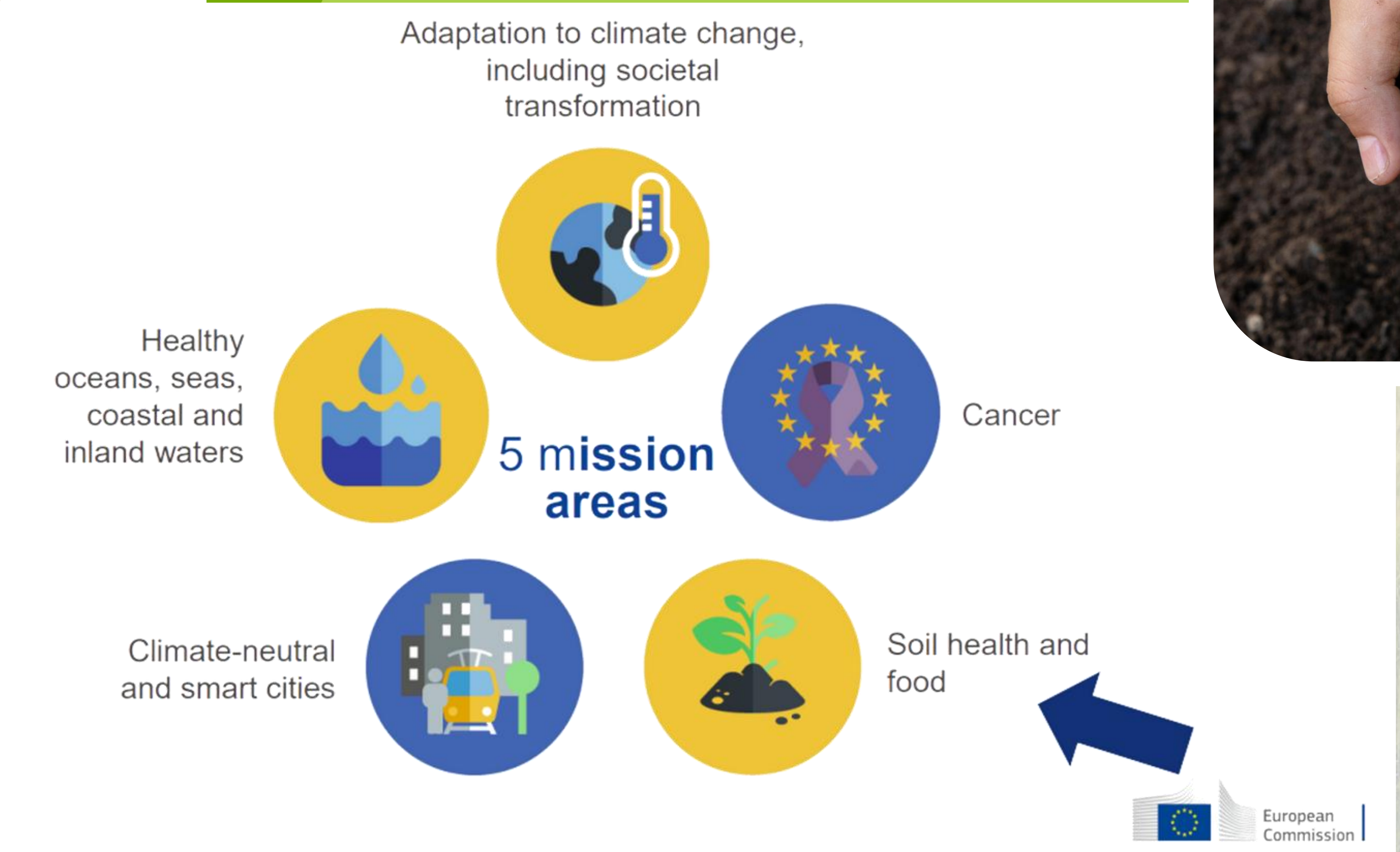
2

Worrying trends Vs. Opportunity

- Technology
- Restoration of degraded soils
- EU policy
- More resilient crops
- Risk reduction
- Waste valorization

2


EUROPEAN UNION
EU
MISSIONS
SOIL DEAL FOR EUROPE
Concrete solutions for our greatest challenges


Adaptation to climate change, including societal transformation
Healthy oceans, seas, coastal and inland waters
5 mission areas
Cancer
Climate-neutral and smart cities
Soil health and food
European Commission

2

Local residual biomass

Legal framework: UE: 2019/1009 27/08/24-RD.

Harvest and pruning residues

Sludge

Forest biomass

Food discards

Separate collection (organic waste)

Biomass ash

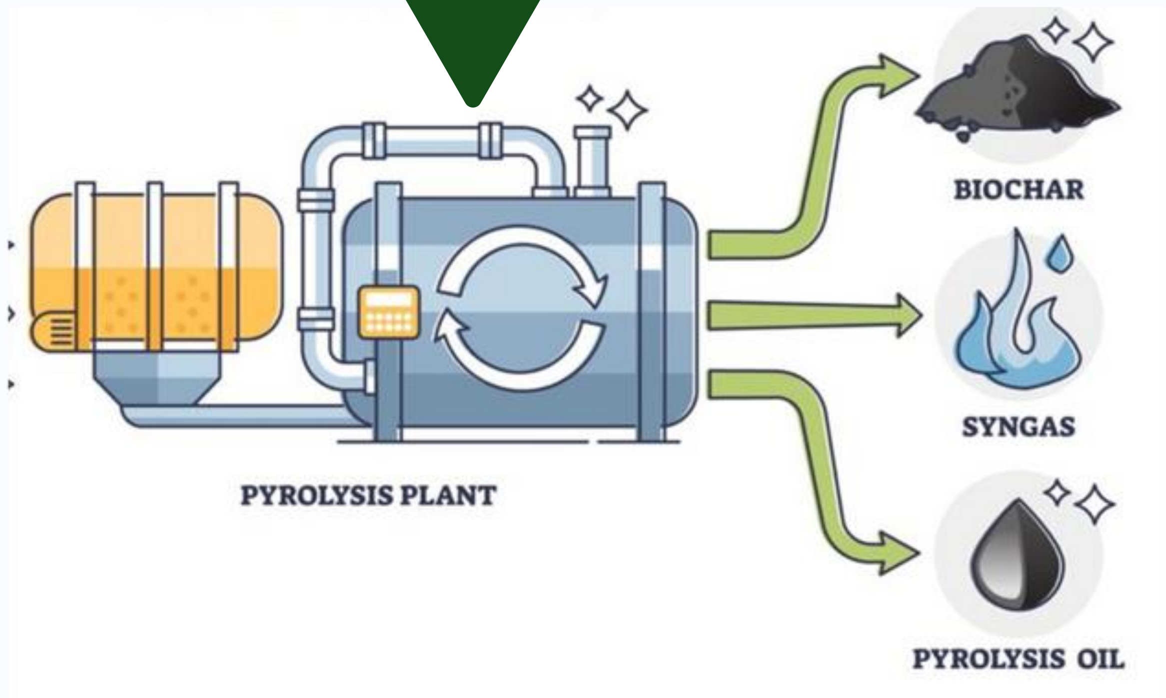
Valorization

Continuous technological evolution

2

Local residual biomass

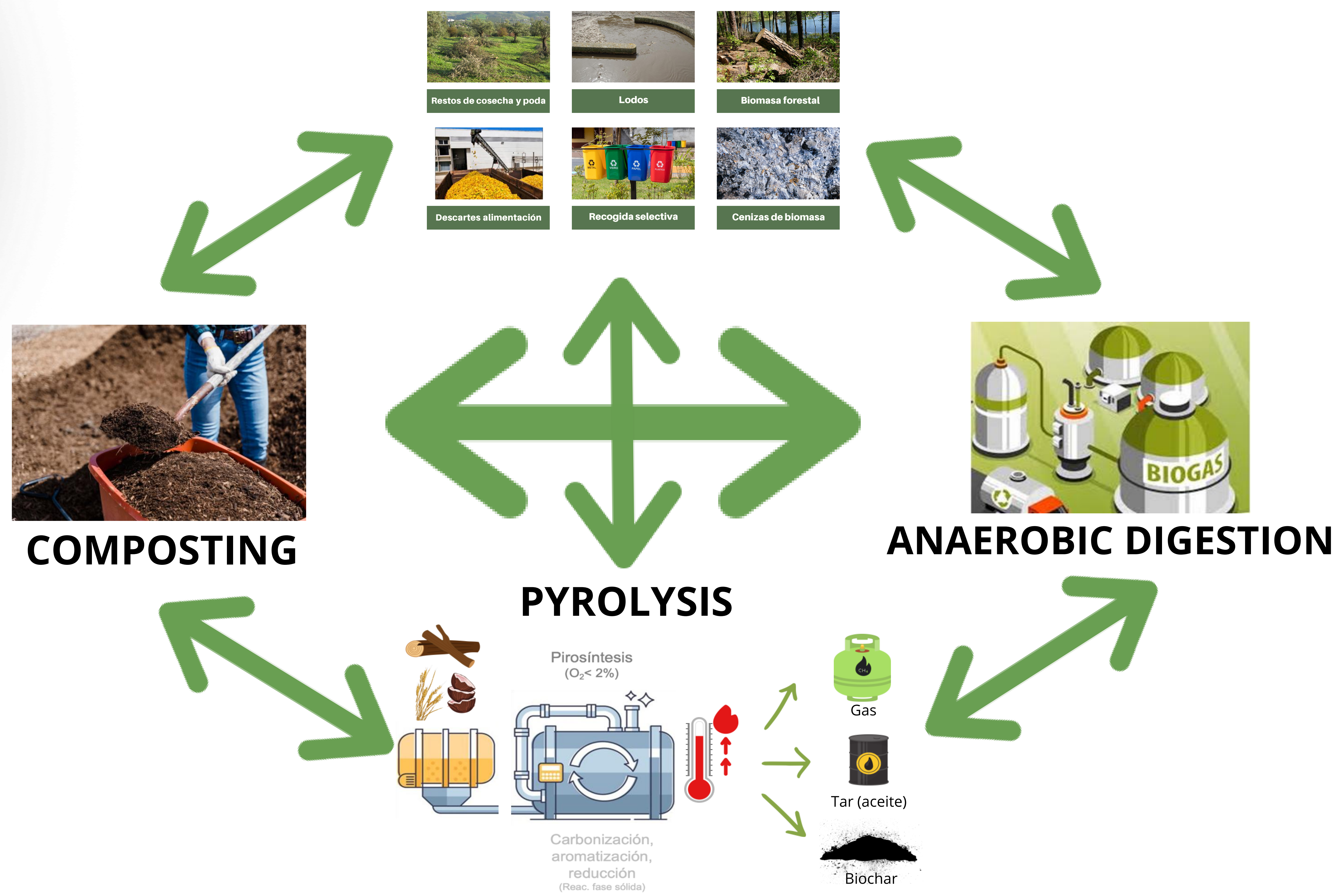
Composting



Pyrolysis

Anaerobic digestion

Valorization of organic residues



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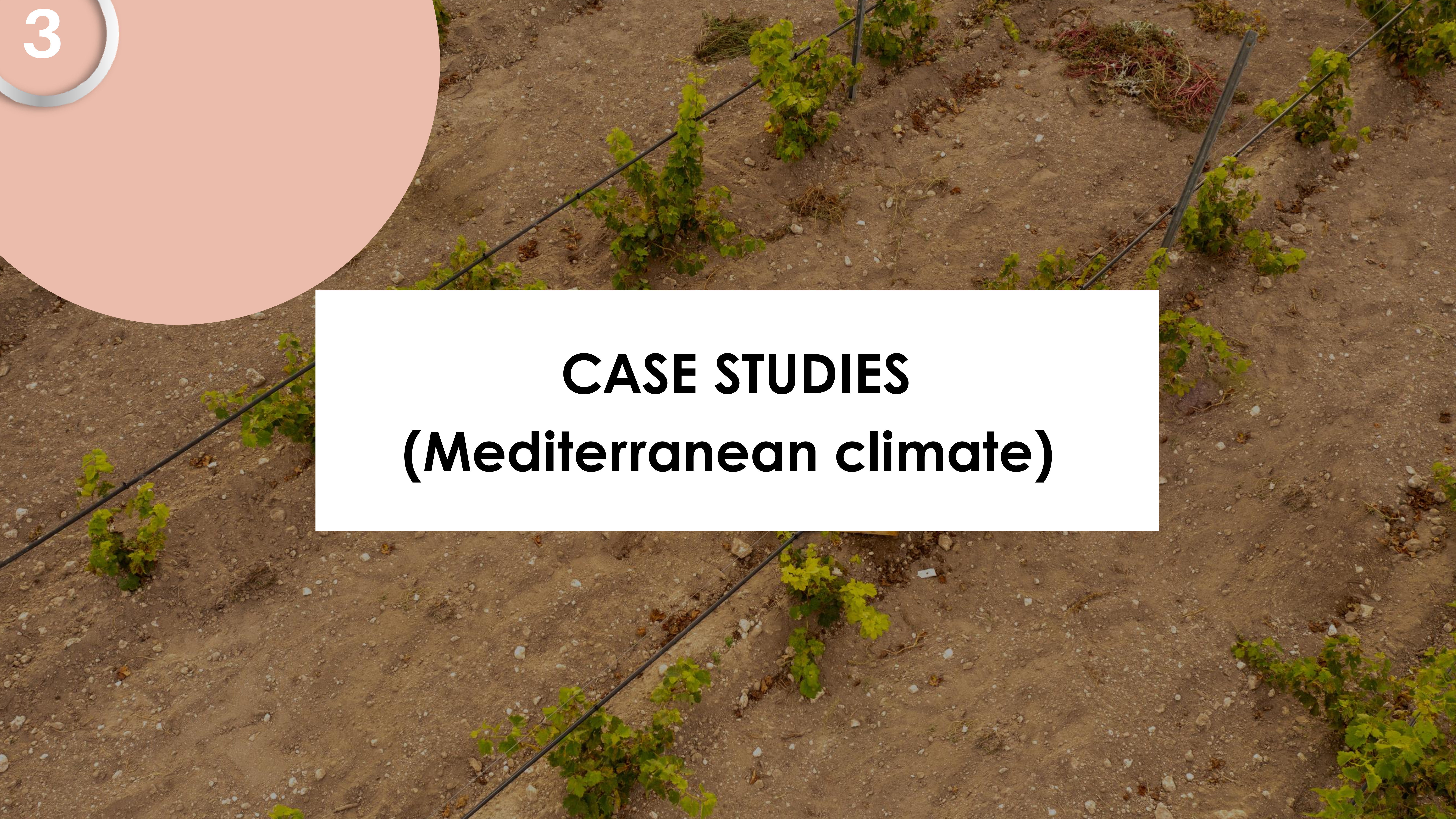
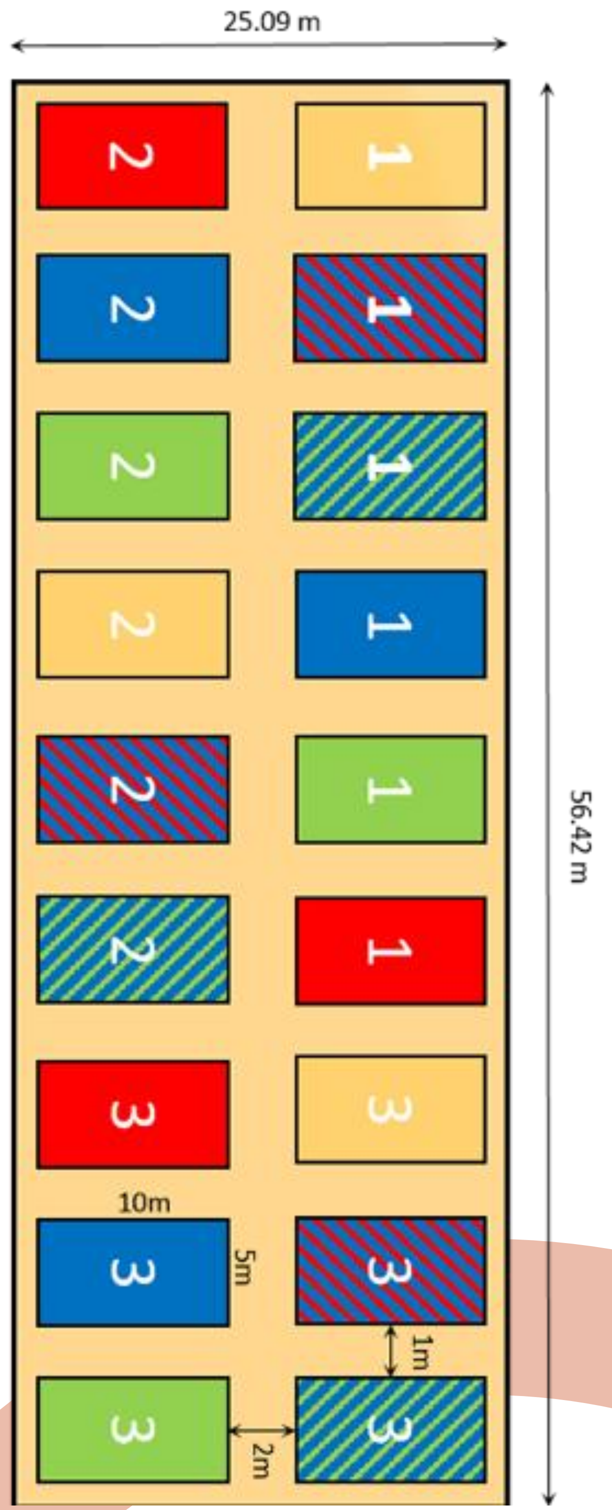


CASE STUDIES
(Mediterranean climate)

3

Case studies

1. Post-activity rehabilitation (sand and gravel pit)



- **Soil: Nonexistent;** bedrock (TOC: 0.3%; TN: 0.05%, pH: 8.4)
- **Location:** Gádor (Almería); arid climate; 240 mm/year
- **Cultivation:** Wild olive, dwarf fan palm, rosemary, thyme
- **Procedure:** Technosols (artificial soil) based on local organic waste

GC
Compost 100% green (harvest and prune residues)

CC
Compost: Greenhouse residues

SS
Sewage sludge (stabilized)

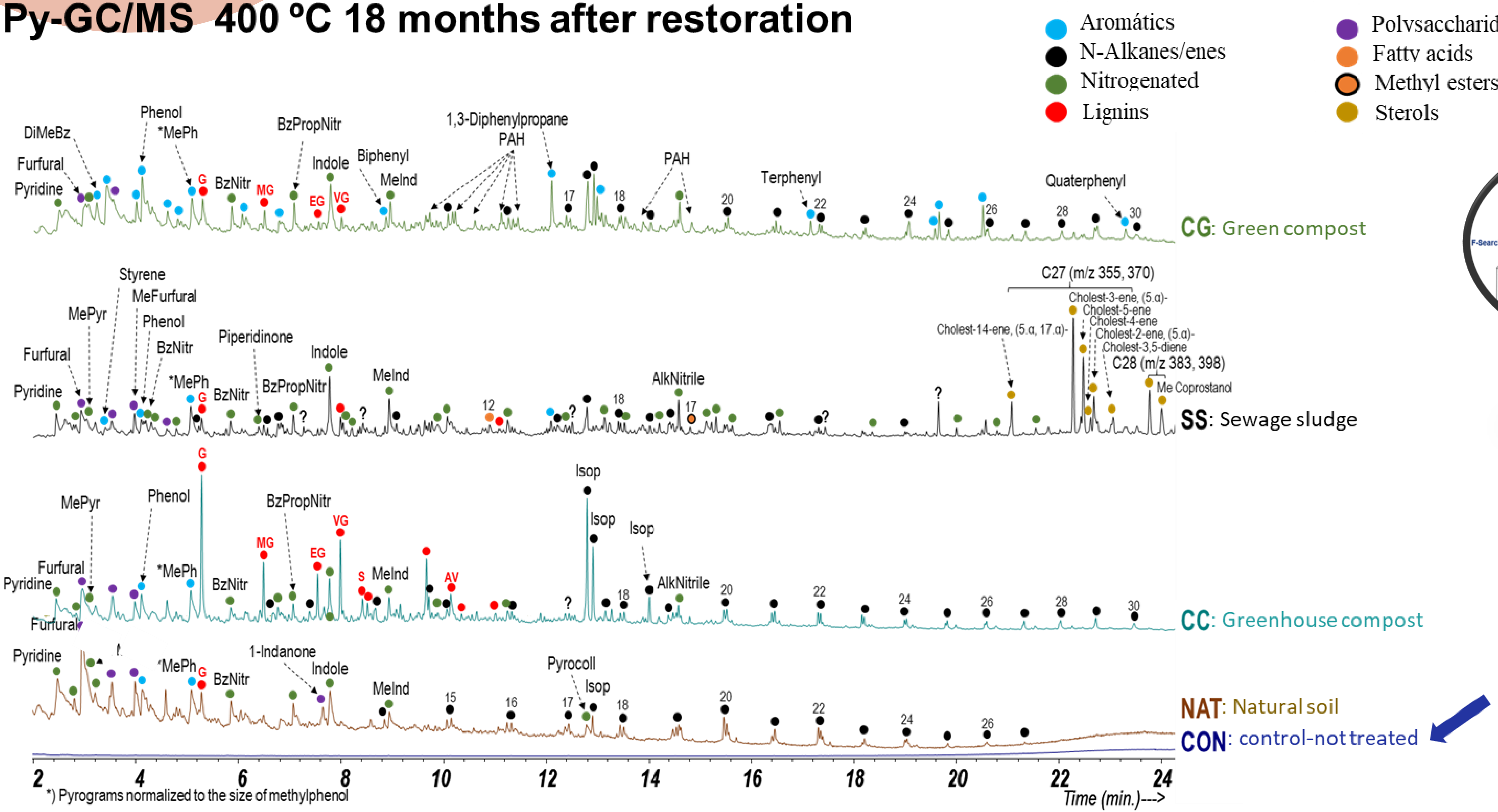
SS-B
Biochar (500ºC; sludge + greenhouse residues)

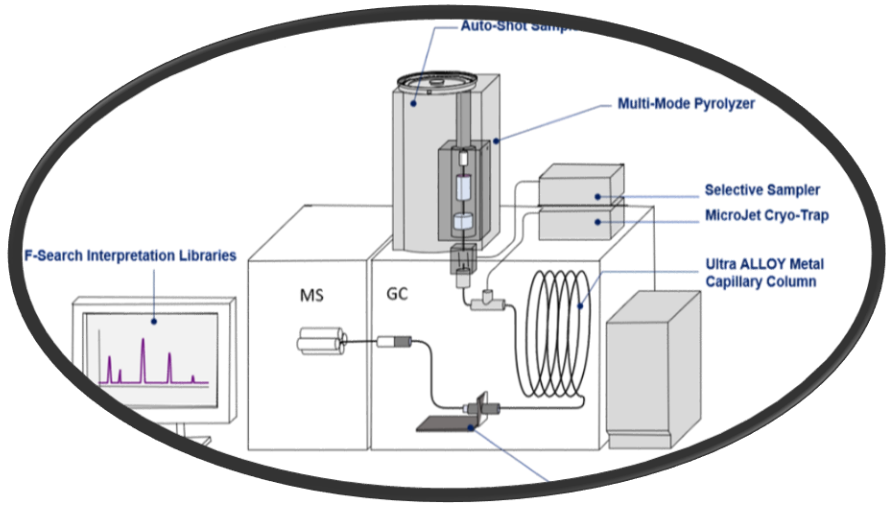
1. Post-activity rehabilitation (sand and gravel pit)

3

1. Post-activity rehabilitation (sand and gravel pit)

Py-GC/MS 400 ºC 18 months after restoration





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1. Post-activity rehabilitation (sand and gravel pit)

June 2018

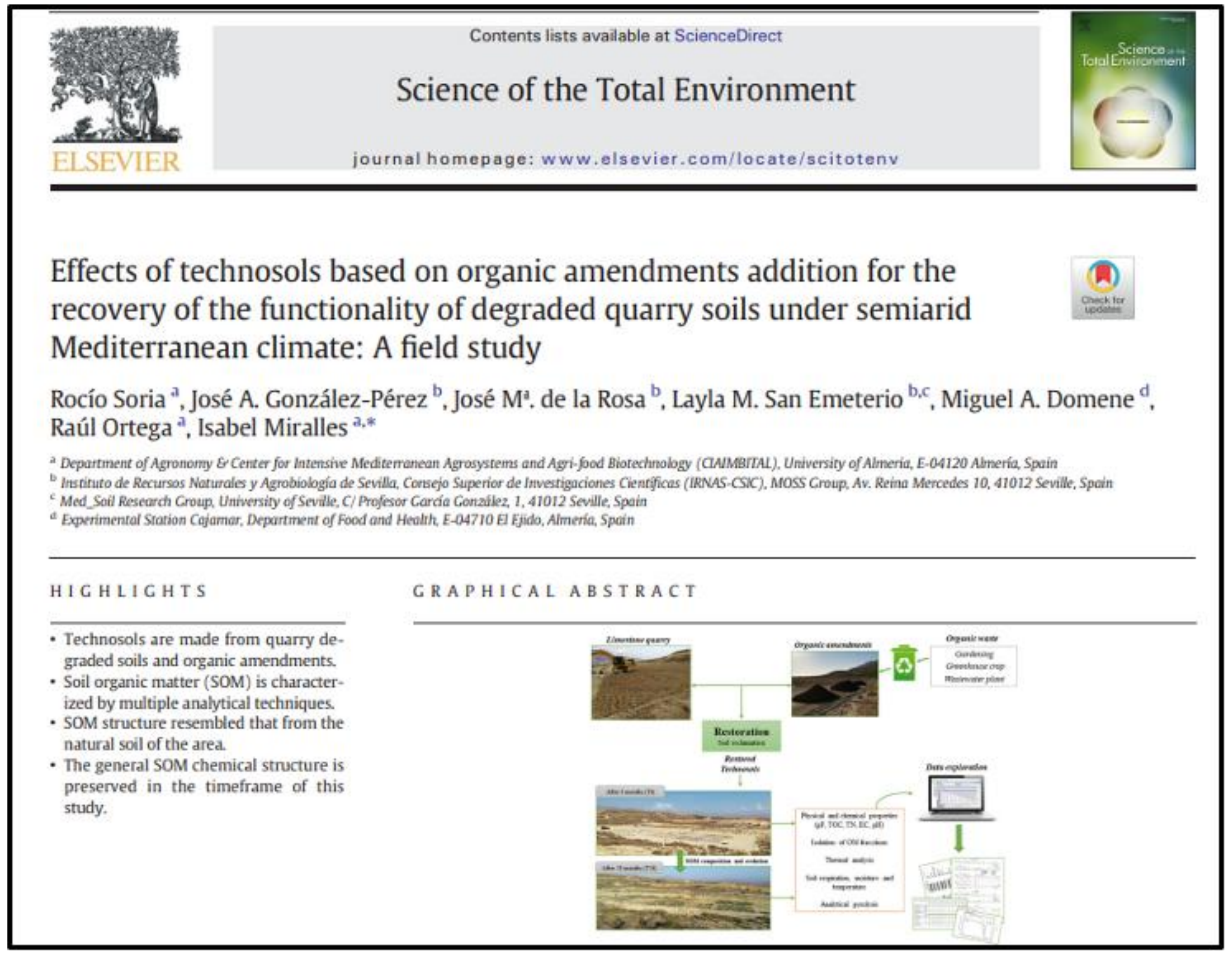
February 2021

Natural soils (NAT)

The application of organic amendments enabled the recovery of soil functionality within 18 months

- **Soil physical properties improved significantly (soil moisture; soil density, WHC,..)**
- **Enzymatic activities, DNA-seq (microbial diversity), SMB (abundance)**

1. Post-activity rehabilitation (sand and gravel pit)



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Effects of technosols based on organic amendments addition for the recovery of the functionality of degraded quarry soils under semiarid Mediterranean climate: A field study

Rocío Soria [a], José A. González-Pérez [b], José Mª. de la Rosa [b], Layla M. San Emeterio [b,c], Miguel A. Domene [d], Raúl Ortega [a], Isabel Miralles [a,*]

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HIGHLIGHTS

- Technosols are made from quarry degraded soils and organic amendments.
- Soil organic matter (SOM) is characterized by multiple analytical techniques.
- SOM structure resembled that from the natural soil of the area.
- The general SOM chemical structure is preserved in the timeframe of this study.

GRAPHICAL ABSTRACT

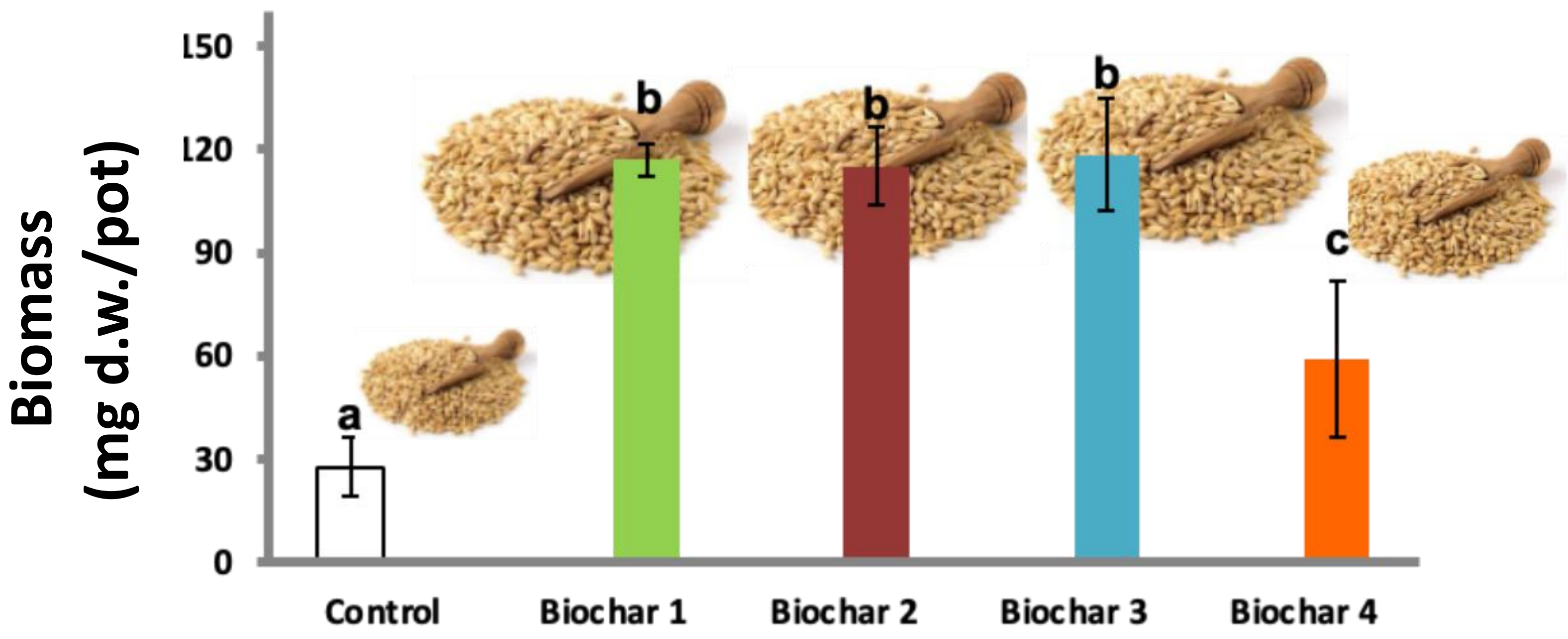
Soria et al. (2022), STOTEN

3

2. Calcic cambisol (alkaline, poor OC; dryland)

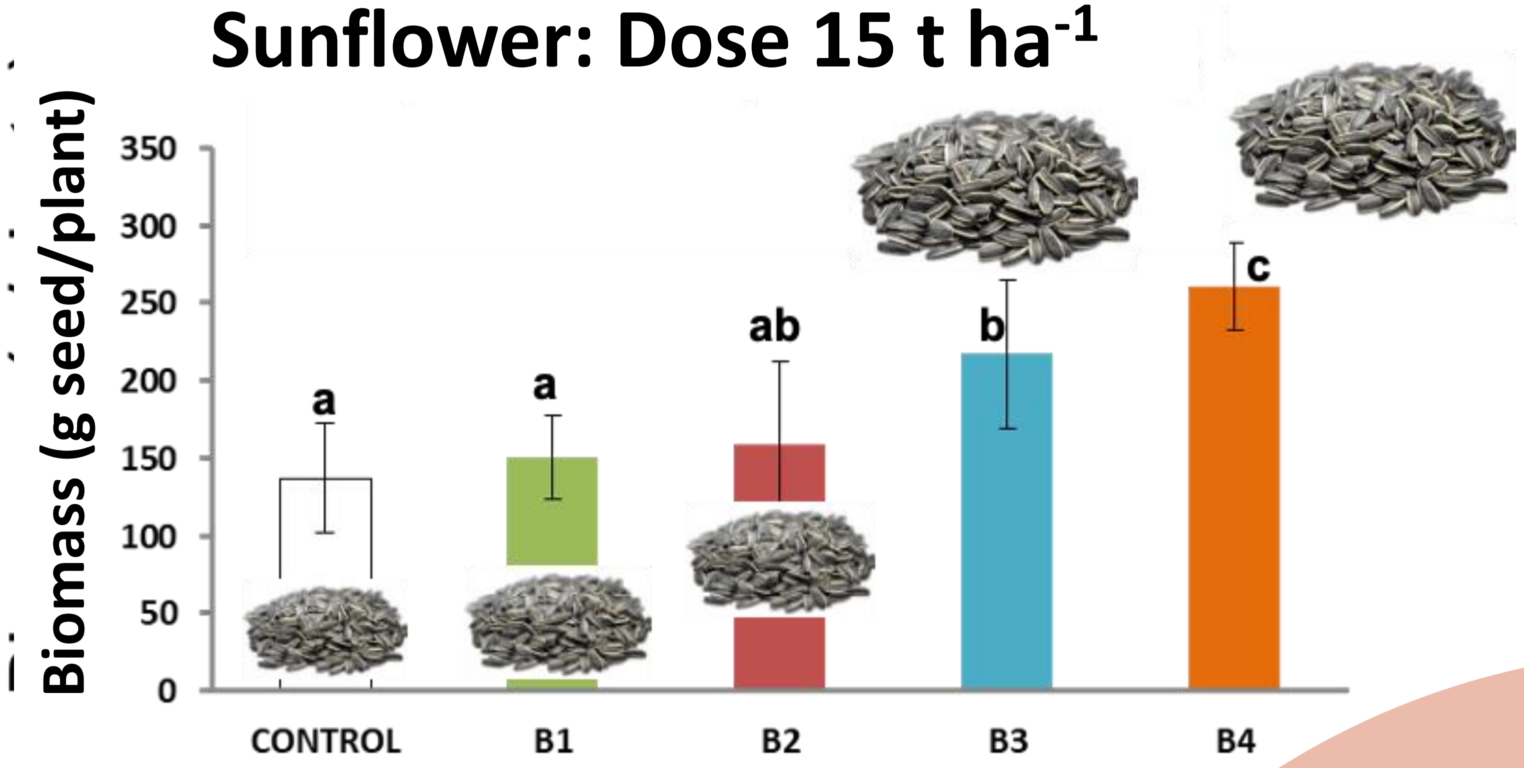
- **Soil:** ***Calcic Cambisol*** *(WRB)*; ***Typic Calcixerept*** (USDA) (TOC: 0.8%; TN: 0.09%, pH: 7.9)
- **Location:** Coría del Río (Seville); SW Spain; Mediterranean climate; 540 mm/year
- **Cultivation:** Barley and Sunflower
- **Treatment:** 4 contrasting biochars from organic residues

Barley: Dose 10 t ha^{-1}



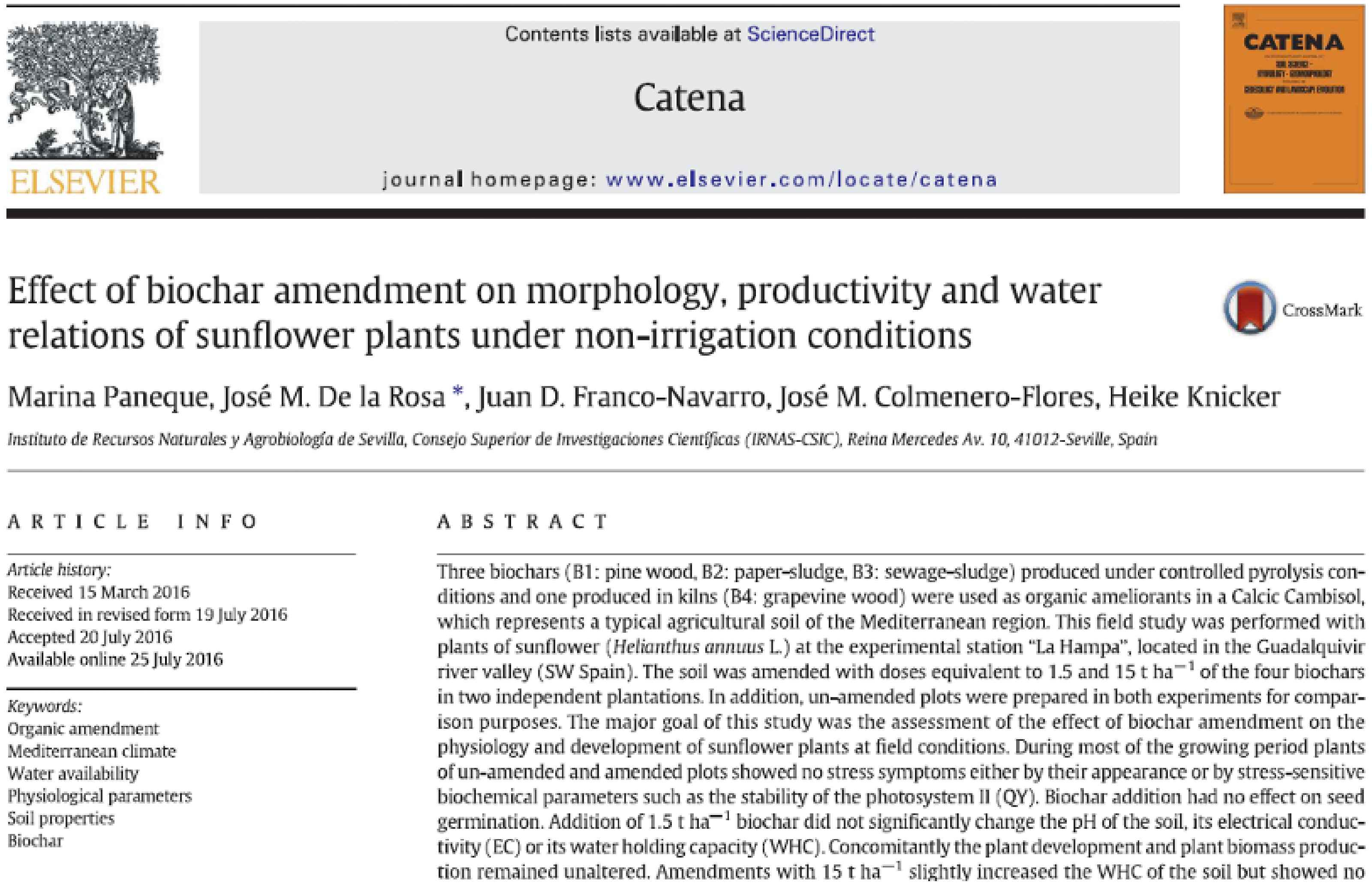
De la Rosa et al. (2014), STOTEN

Sunflower: Dose 15 t ha^{-1}



- **Biochars improved soil physical properties**
- **Productivity increased**

2. Calcic cambisol (alkaline, poor OC; dryland)



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journal homepage: www.elsevier.com/locate/catena

Effect of biochar amendment on morphology, productivity and water relations of sunflower plants under non-irrigation conditions

Marina Paneque, José M. De la Rosa *, Juan D. Franco-Navarro, José M. Colmenero-Flores, Heike Knicker

Instituto de Recursos Naturales y Agrobiología de Sevilla, Consejo Superior de Investigaciones Científicas (IRNAS-CSIC), Reina Mercedes Av. 10, 41012-Seville, Spain

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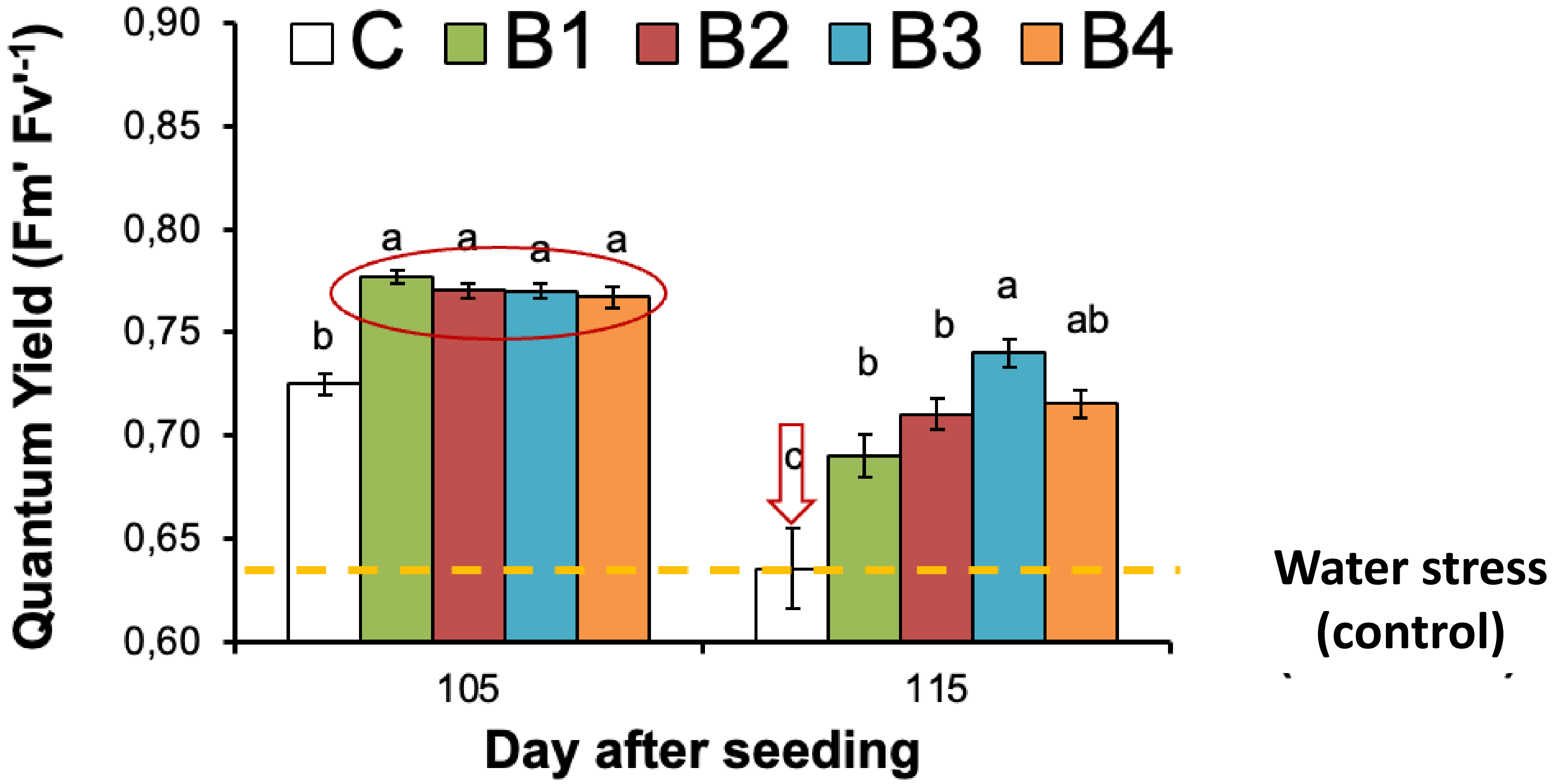
Biochar

ABSTRACT

Three biochars (B1: pine wood, B2: paper-sludge, B3: sewage-sludge) produced under controlled pyrolysis conditions and one produced in kilns (B4: grapevine wood) were used as organic ameliorants in a Calcic Cambisol, which represents a typical agricultural soil of the Mediterranean region. This field study was performed with plants of sunflower (*Helianthus annuus* L.) at the experimental station "La Hampa", located in the Guadalquivir river valley (SW Spain). The soil was amended with doses equivalent to 15 and 15 t ha^{-1} of the four biochars in two independent plantations. In addition, un-amended plots were prepared in both experiments for comparison purposes. The major goal of this study was the assessment of the effect of biochar amendment on the physiology and development of sunflower plants at field conditions. During most of the growing period plants of un-amended and amended plots showed no stress symptoms either by their appearance or by stress-sensitive biochemical parameters such as the stability of the photosystem II (QY). Biochar addition had no effect on seed germination. Addition of 1.5 t ha^{-1} biochar did not significantly change the pH of the soil, its electrical conductivity (EC) or its water holding capacity (WHC). Concomitantly the plant development and plant biomass production remained unaltered. Amendments with 15 t ha^{-1} slightly increased the WHC of the soil but showed no

Paneque et al. (2016), CATENA



The application of biochar:

- Increased water retention capacity
- Reduced soil compaction and bulk density
- Facilitated root development
- Reduced plant water stress (pre-harvest)
- Served as a niche for microorganisms

3

3. Super-intensive Olive crop (arbequina; deficit irrigation)

- **Experimental Field Station "La Hampa"**
- **Soil:** ***Calcic Cambisol*** *(WRB)*; ***Typic Calcixerept*** (USDA) (TOC: 0.8%; TN: 0.09%, pH: 7.9); Sandy loam
- **Location:** Coría del Río (Seville); SW Spain; Mediterranean climate; 540 mm/year
- **Cultivation:** *Olea europaea* L. (arbequina), 1660 certified trees per ha. **Irrigation:** 30% RDI
- **Treatments:** 4 Biochar, Green Compost, mix B+GC and Control

4 TREATMENTS:

- **Control**: No amendment; (**C-control**)
- **Olive pomace biochar**: 40 t ha^{-1} (**B**)
- **Green compost**: 40 t ha^{-1} (**GC**)
- **Mix of B+GC**:20+20 t ha^{-1} (**B+GC**)

Real dose: 6.7 t ha^{-1}

24 trees per treatment

3. Super-intensive Olive crop (arbequina; deficit irrigation)

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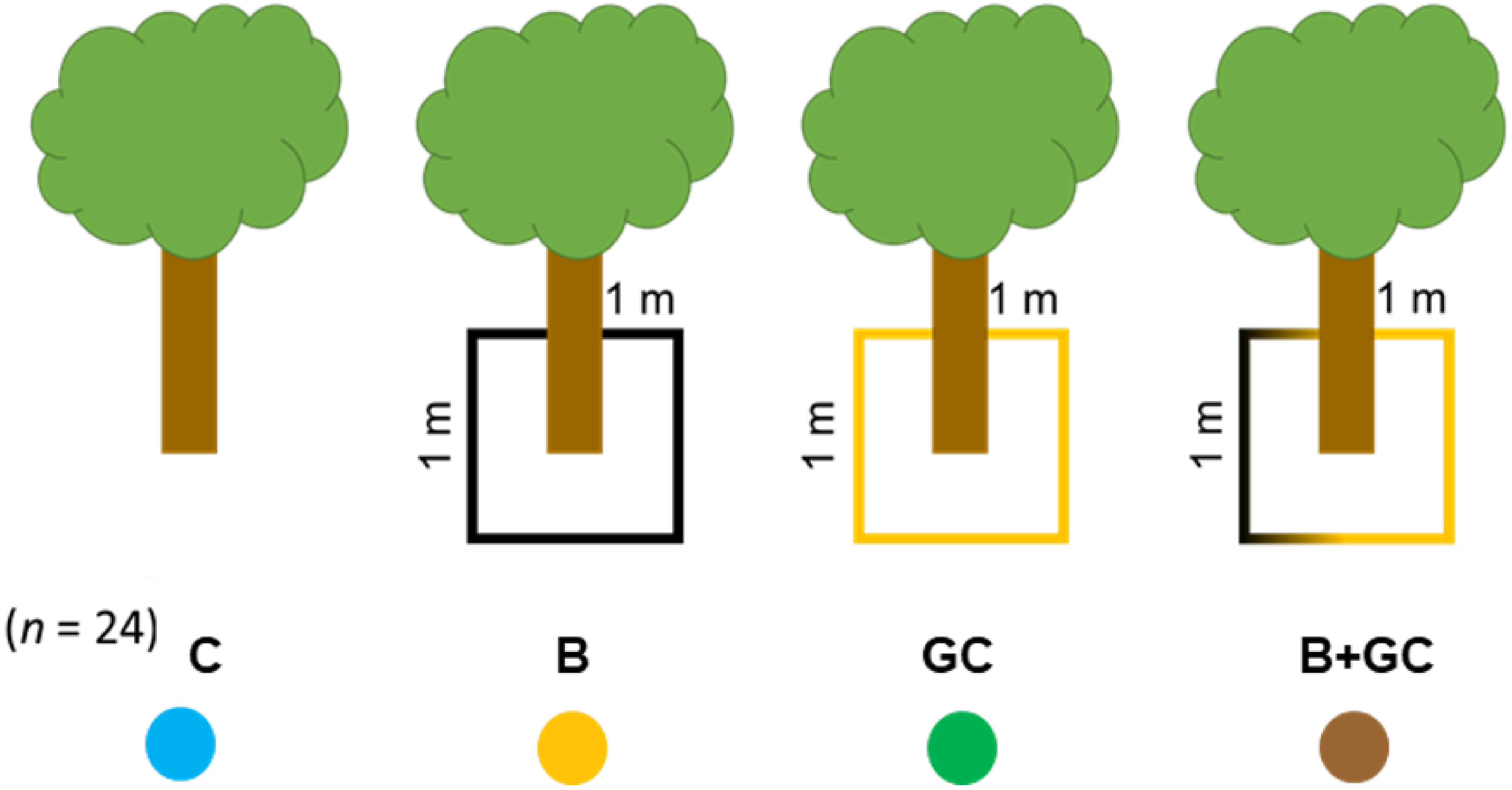

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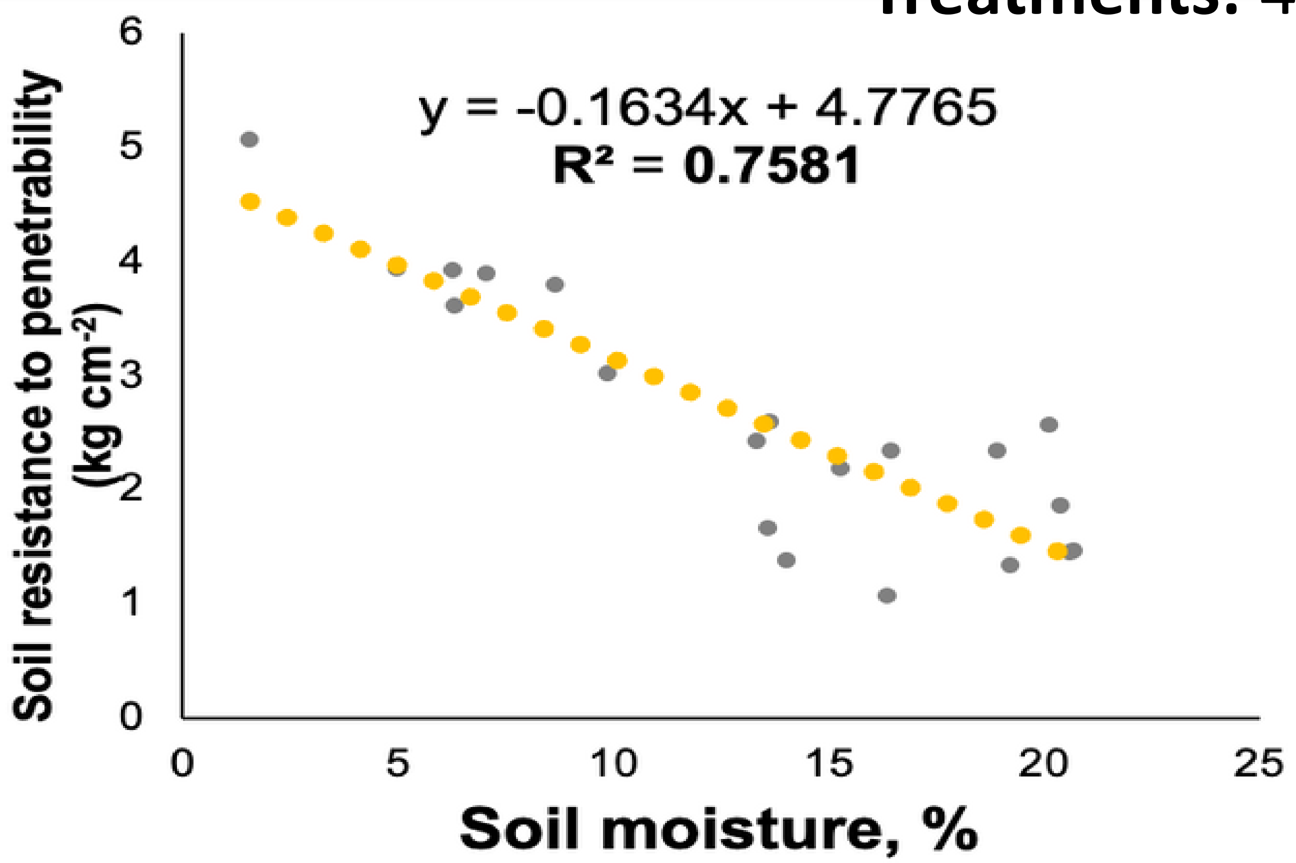

The application of biochar/compost:

- **Facilitated soil management (reduced penetration resistance).**
- **Increased soil moisture.**
- **Reduced pre-harvest water stress**

3

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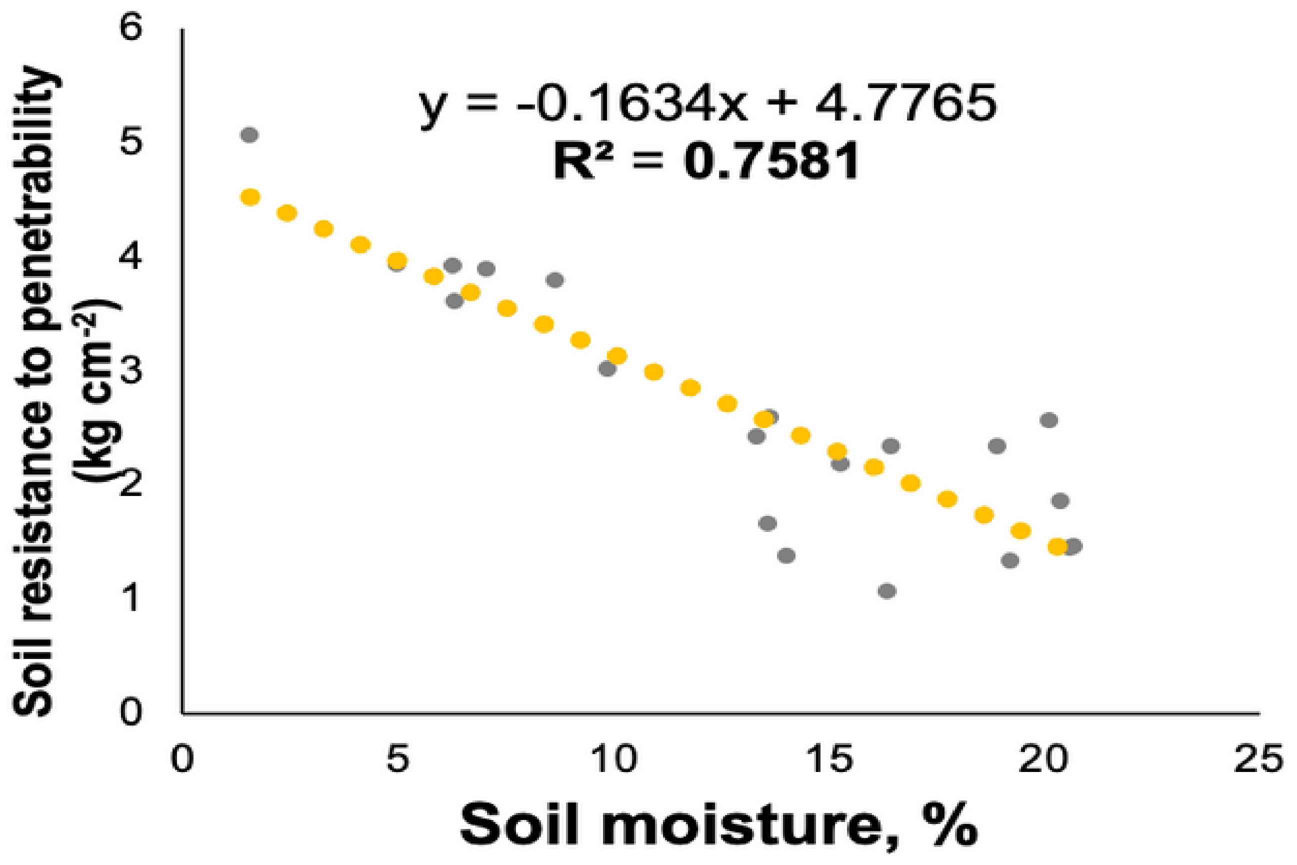

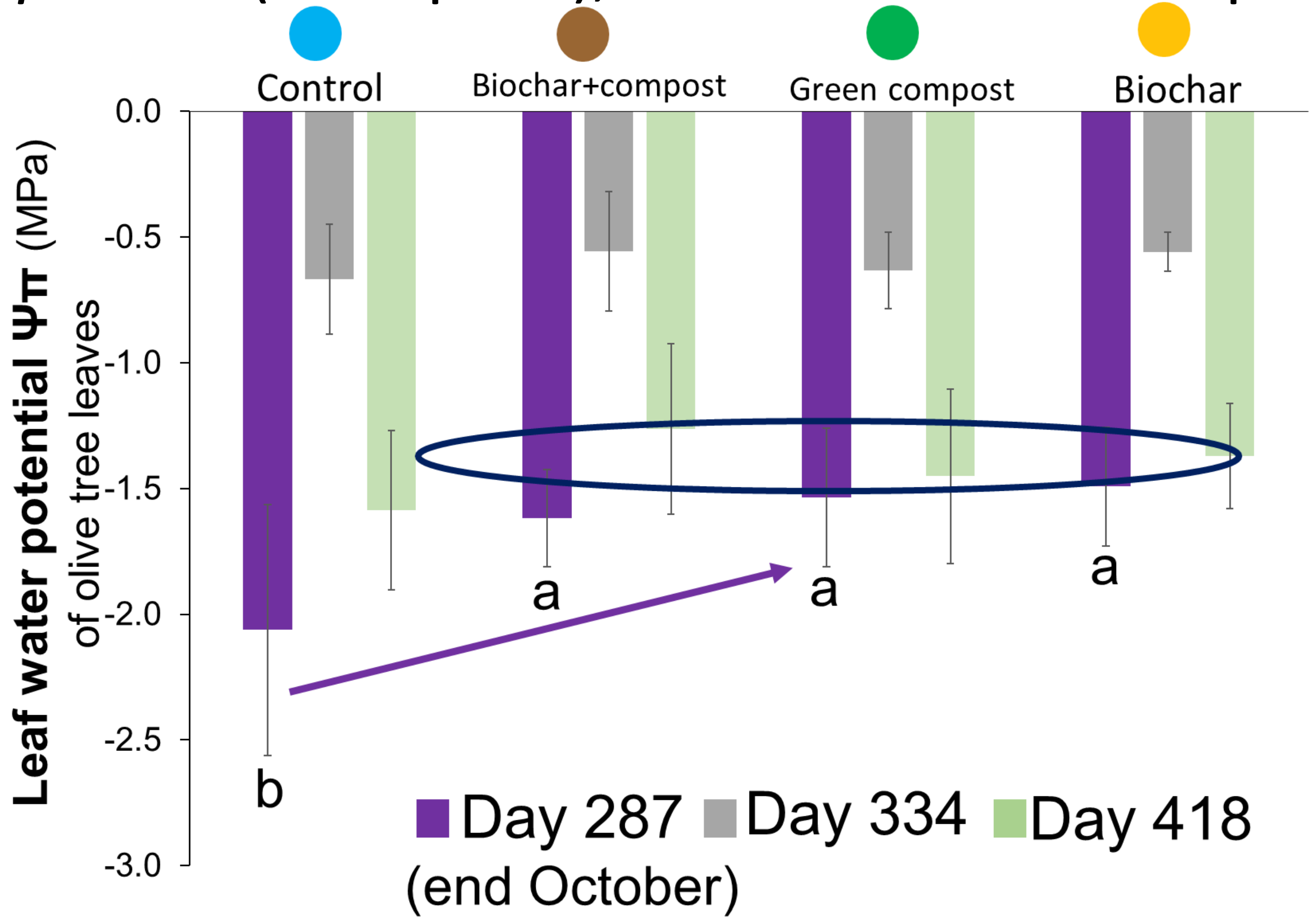

Improved: Leaf water potential **(Ψπ)** and water Use Efficiency (WUEi) in amended soils at pre-harvesting period

3

3. Super-intensive Olive crop (arbequina; deficit irrigation)

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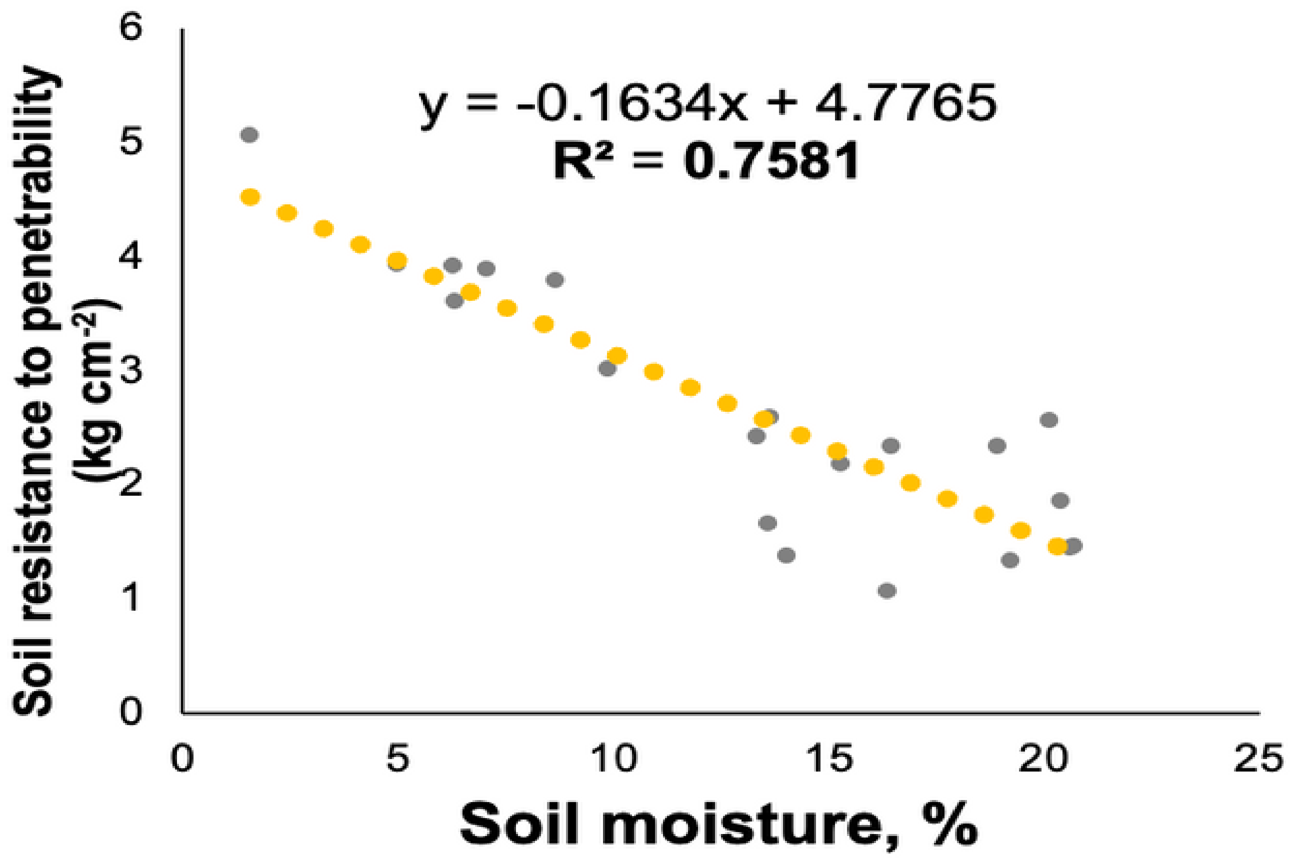

15 % increase in productivity

3

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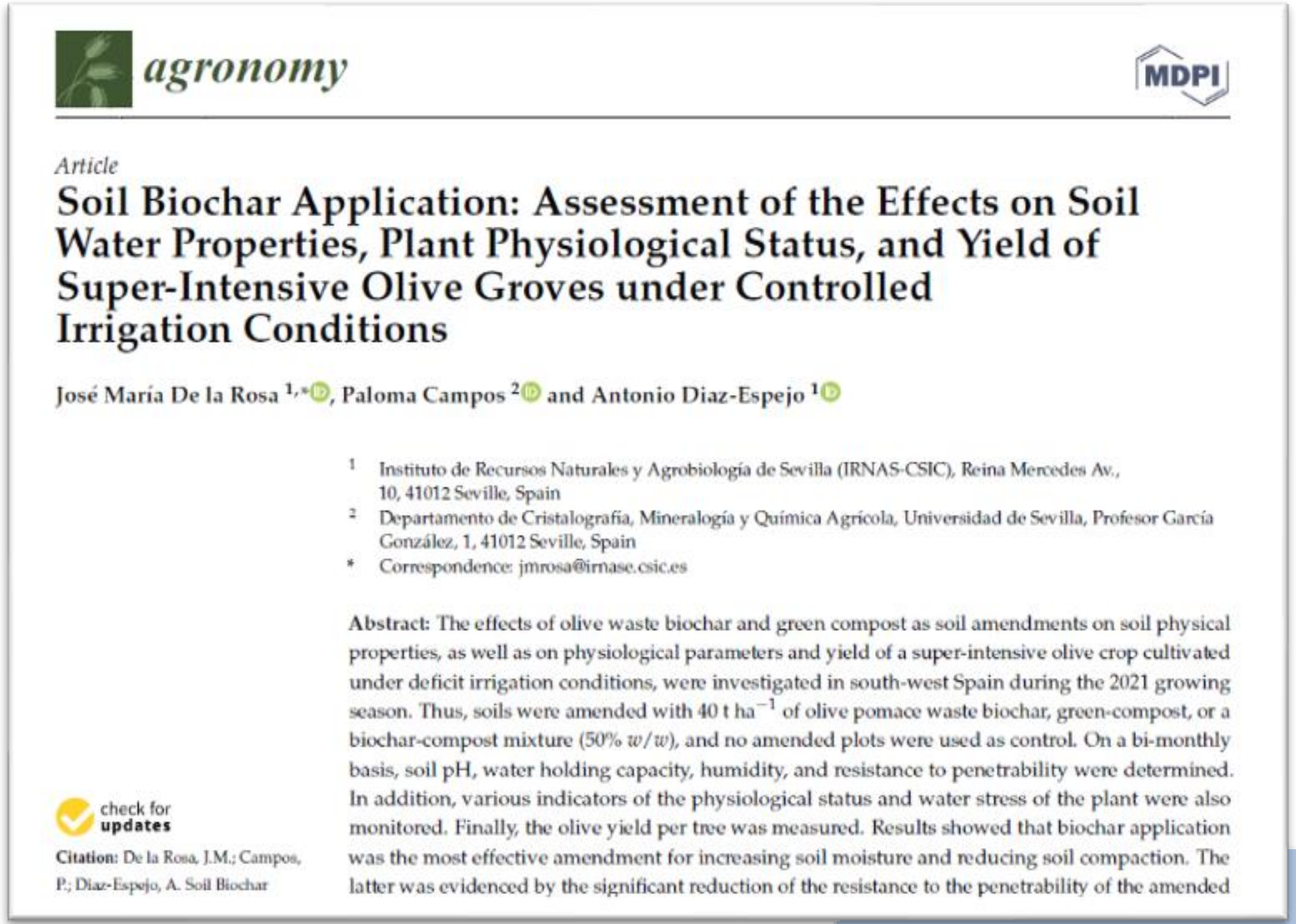
agronomy

MDPI

Article

Soil Biochar Application: Assessment of the Effects on Soil Water Properties, Plant Physiological Status, and Yield of Super-Intensive Olive Groves under Controlled Irrigation Conditions

José María De la Rosa [1,*], Paloma Campos [2] and Antonio Diaz-Espejo [1]

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Abstract: The effects of olive waste biochar and green compost as soil amendments on soil physical properties, as well as on physiological parameters and yield of a super-intensive olive crop cultivated under deficit irrigation conditions, were investigated in south-west Spain during the 2021 growing season. Thus, soils were amended with 40 t ha^{-1} of olive pomace waste biochar, green-compost, or a biochar-compost mixture (50% *w/w*), and no amended plots were used as control. On a bi-monthly basis, soil pH, water holding capacity, humidity, and resistance to penetrability were determined. In addition, various indicators of the physiological status and water stress of the plant were also monitored. Finally, the olive yield per tree was measured. Results showed that biochar application was the most effective amendment for increasing soil moisture and reducing soil compaction. The latter was evidenced by the significant reduction of the resistance to the penetrability of the amended

check for updates

Citation: De la Rosa, J.M.; Campos, P.; Diaz-Espejo, A. Soil Biochar

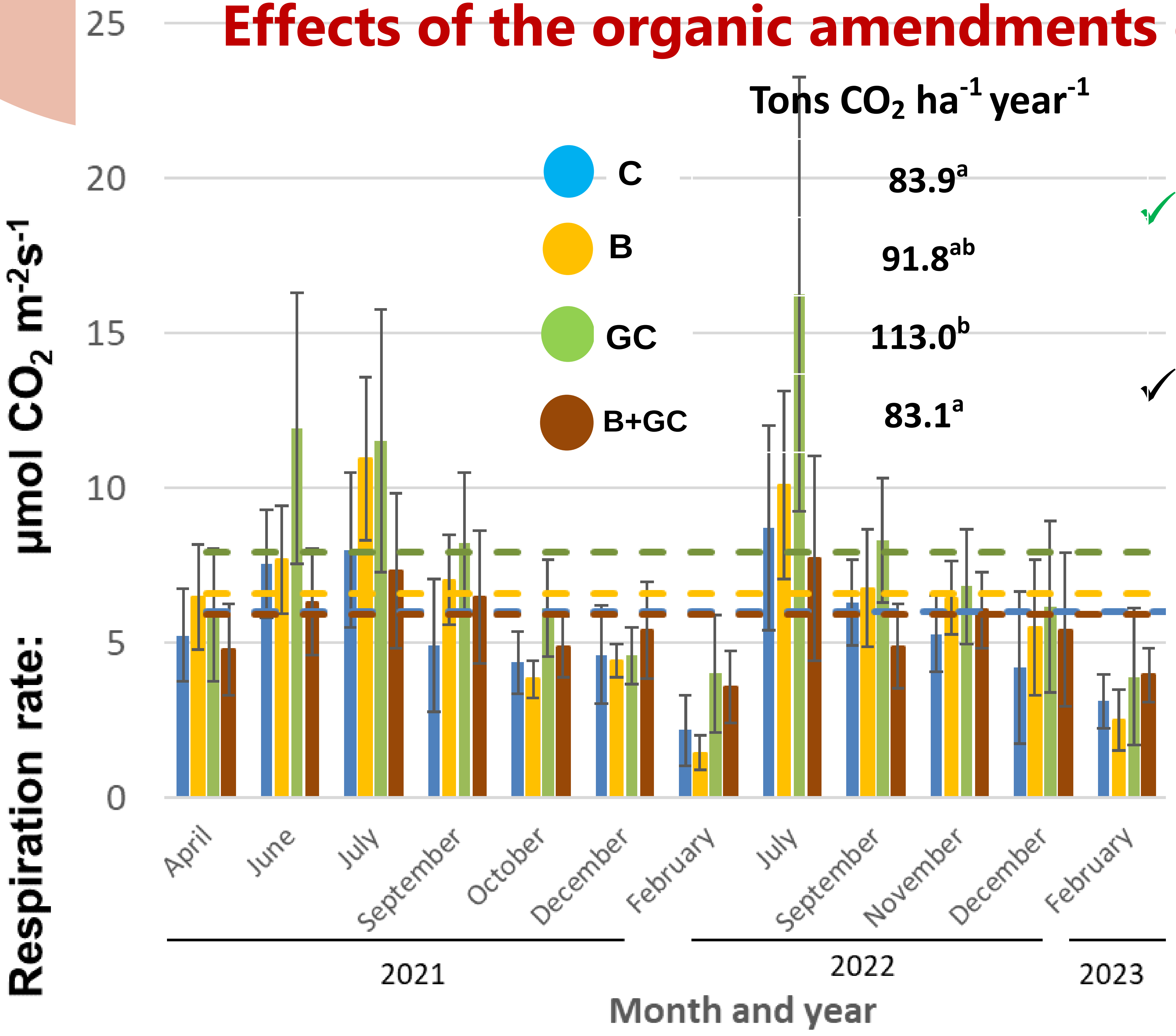
De la Rosa et al. (2022), Agronomy

15 % increase in productivity

3

3. Super-intensive Olive crop (arbequina; deficit irrigation)

Effects of the organic amendments on CO_2 emmisions

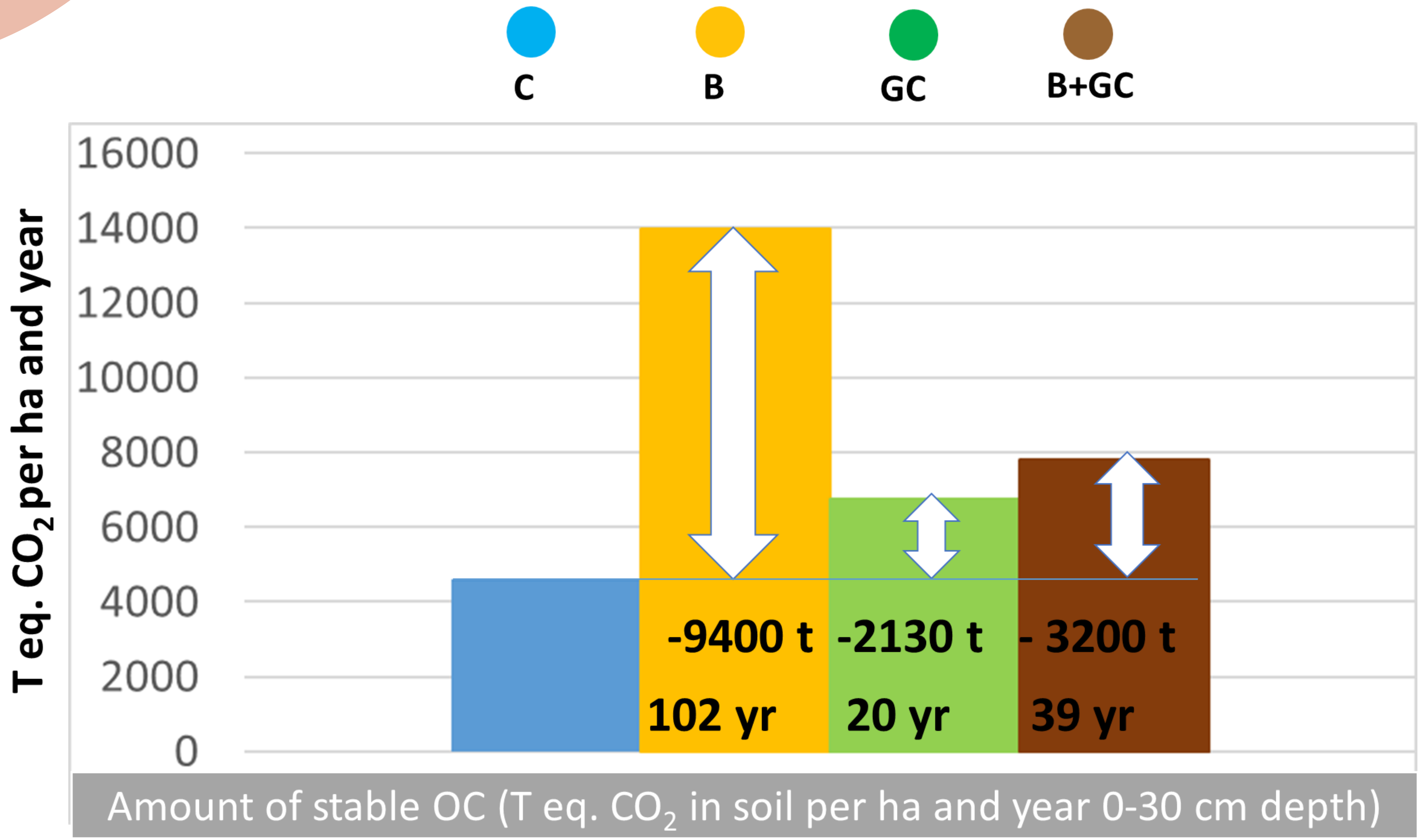


- ✓ **Green compost** increased soil respiration rates (summer)
- ✓ But… no increase was observed for the mixture **B+GC**

Open gas exchange system (LI-6400, Li-Cor)

3. Super-intensive Olive crop (arbequina; deficit irrigation)

Effects of the organic amendments on soil organic carbon stocks



Released CO_2 per year and ha	C	B	GC	B+GC
	83.9	91.8	113.0	83.1 t CO_2 ha^{-1} yr^{-1}

3

4. Impact of organic amendments on Carbon stability and Carbon use efficiency in acidic and alkaline soils (Respicond experiment)

8 organic amendments from agro/cattle waste

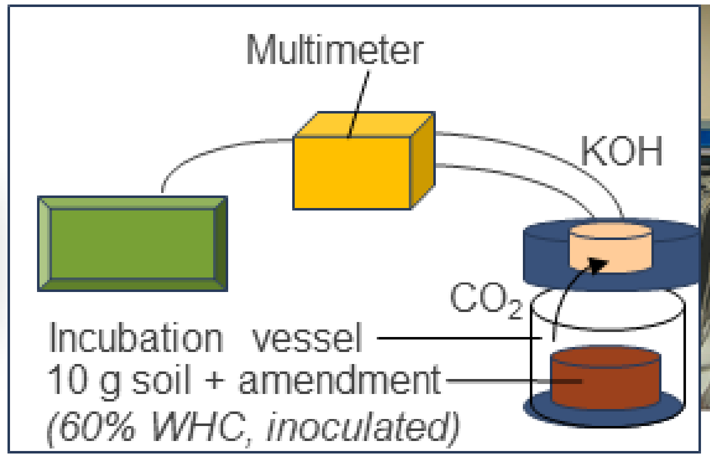
Pyrolysis
- Olive Pomace Biochar (OB)
- Poplar Wood biochar (WB)
- Wastewater sludge char (WSB)
- Rice husk biochar (RB)

Anaerobic digestion
- Cattle manure+Straw digestate CSD)
- Cow manure digestate (CD)

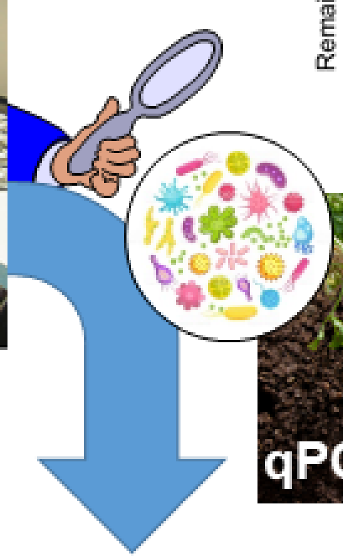
Composting
- Green compost (GC)

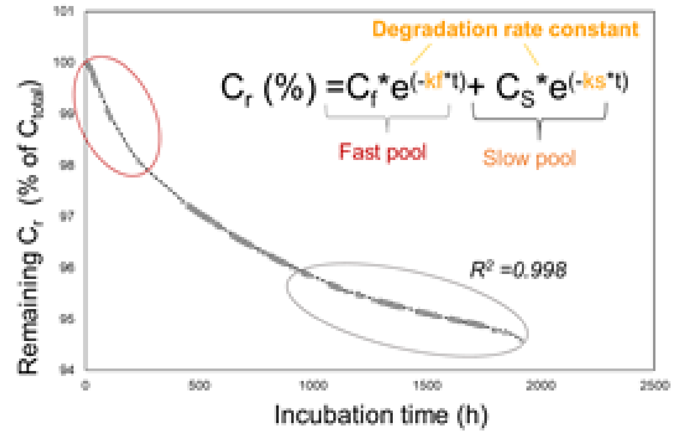
- Olive Pomace Biochar+Green compost (OB+GC)

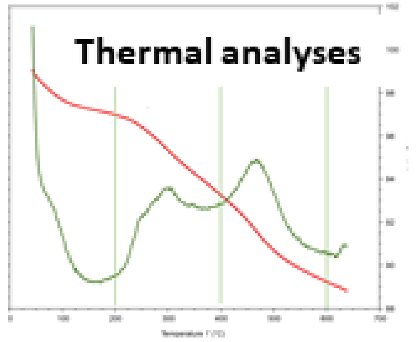
Respiration experiment
Determination of biochemical degradability



Respicond (Nordgren Innovations, Sweden)







2 contrasting soils

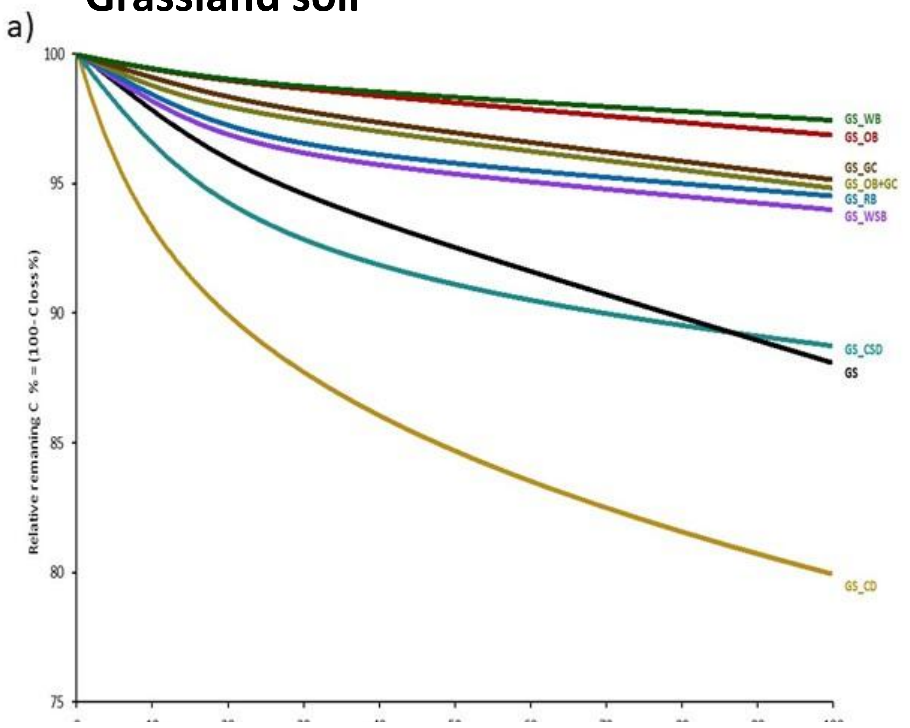
-Grassland acid soil (GS): Loamy-silty Cambisol; pH 5.2; TOC 9 g kg^{-1}

-Alkaline soil (AS): Sandy loam *Xerochrept*; pH 8.1; TOC 24 g kg^{-1}

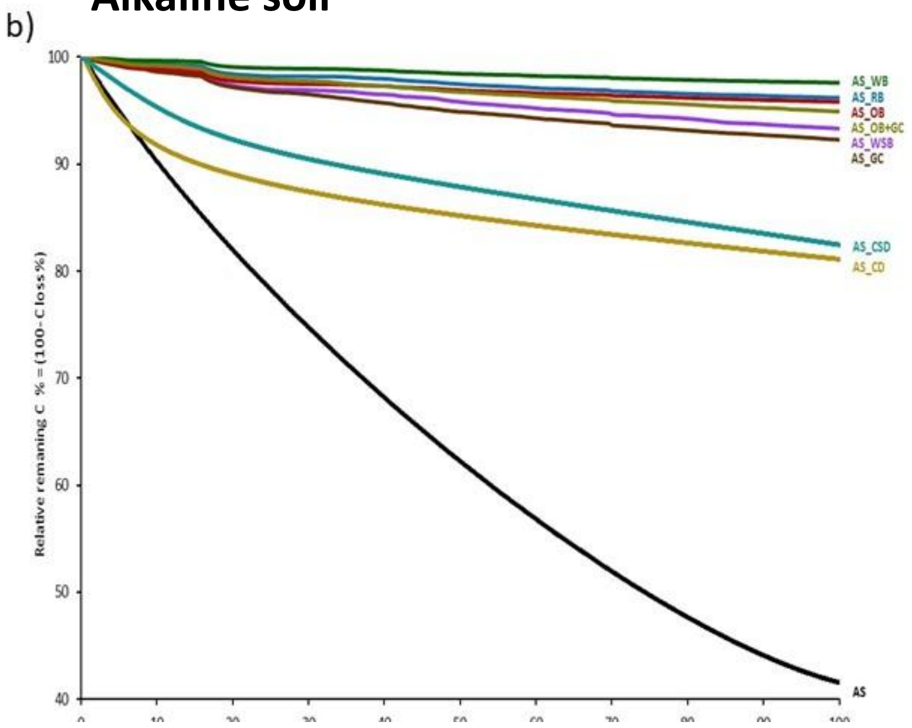
3

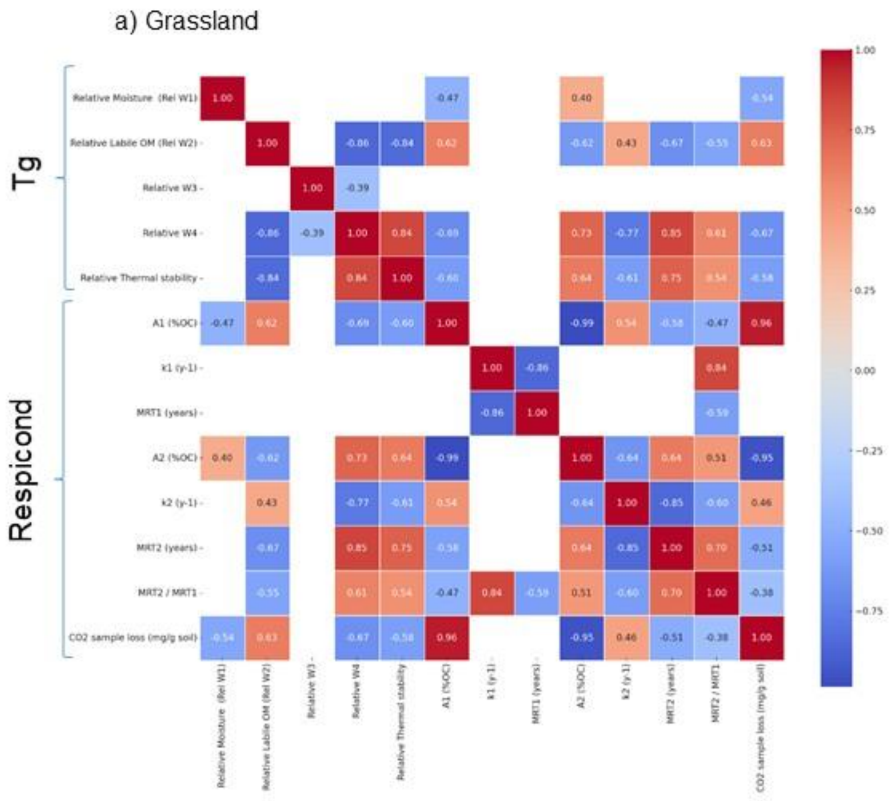
4. Impact of organic amendments on Carbon stability and Carbon use efficiency in acidic and alkaline soils (Respicond experiment)

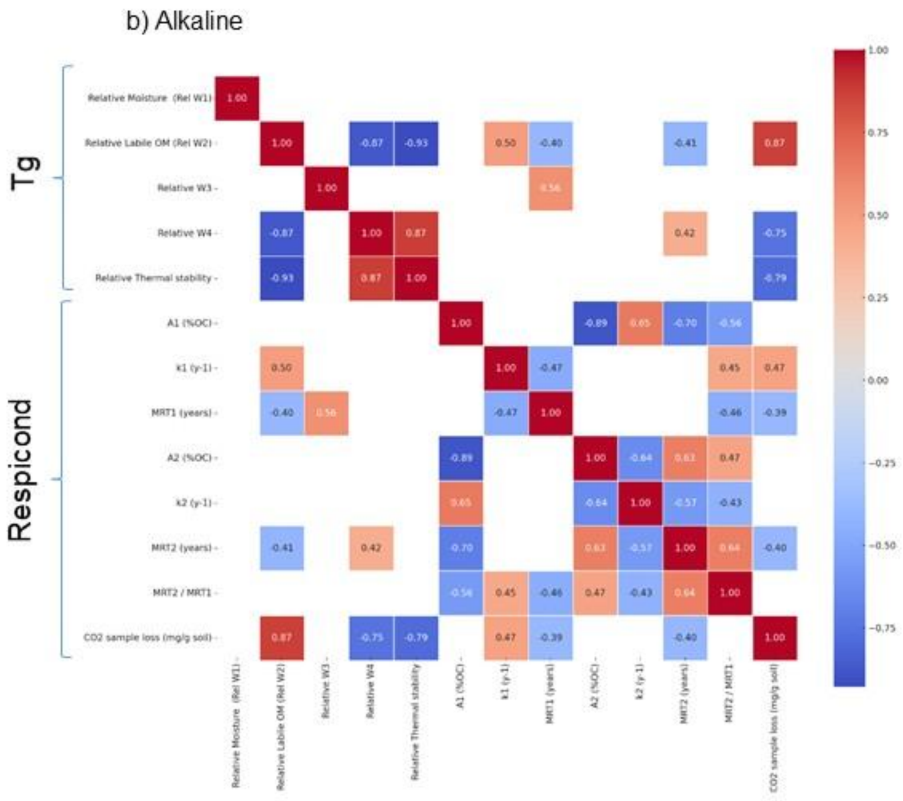
Grassland soil



Alkaline soil







✓ **Soil Respiration** (respired CO_2):
Digestates > Green compost > biochar ~ Control

✓ **Mean Residence Time of slow C pool (MRT_2) and Thermal stability:**
Wood biochars > Green compost > Digestates

✓ **CUE_{micro}:**
Digestates > Green compost > biochar ~ Control
Amendment selection crucial for optimizing soil CUE_{micro}

De la Rosa *et al.* (2025), Geoderma. *Under review*

Conclusions

The application of organic amendments to soils poor in OM improves their physical properties, facilitates management, and enhances WR capacity.

Soil productivity is closely linked to the improvement of its physical properties and the ability to meet crop needs during critical growth periods.

Biochar has a great potential to increase recalcitrant carbon in soil; it also helps to reduce emissions associated with other amendments.

There is no universal solution; it is essential to assess the available residues, possibilities for their valorization, and the specific soil needed.

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Abstract submission deadline: 15th may!

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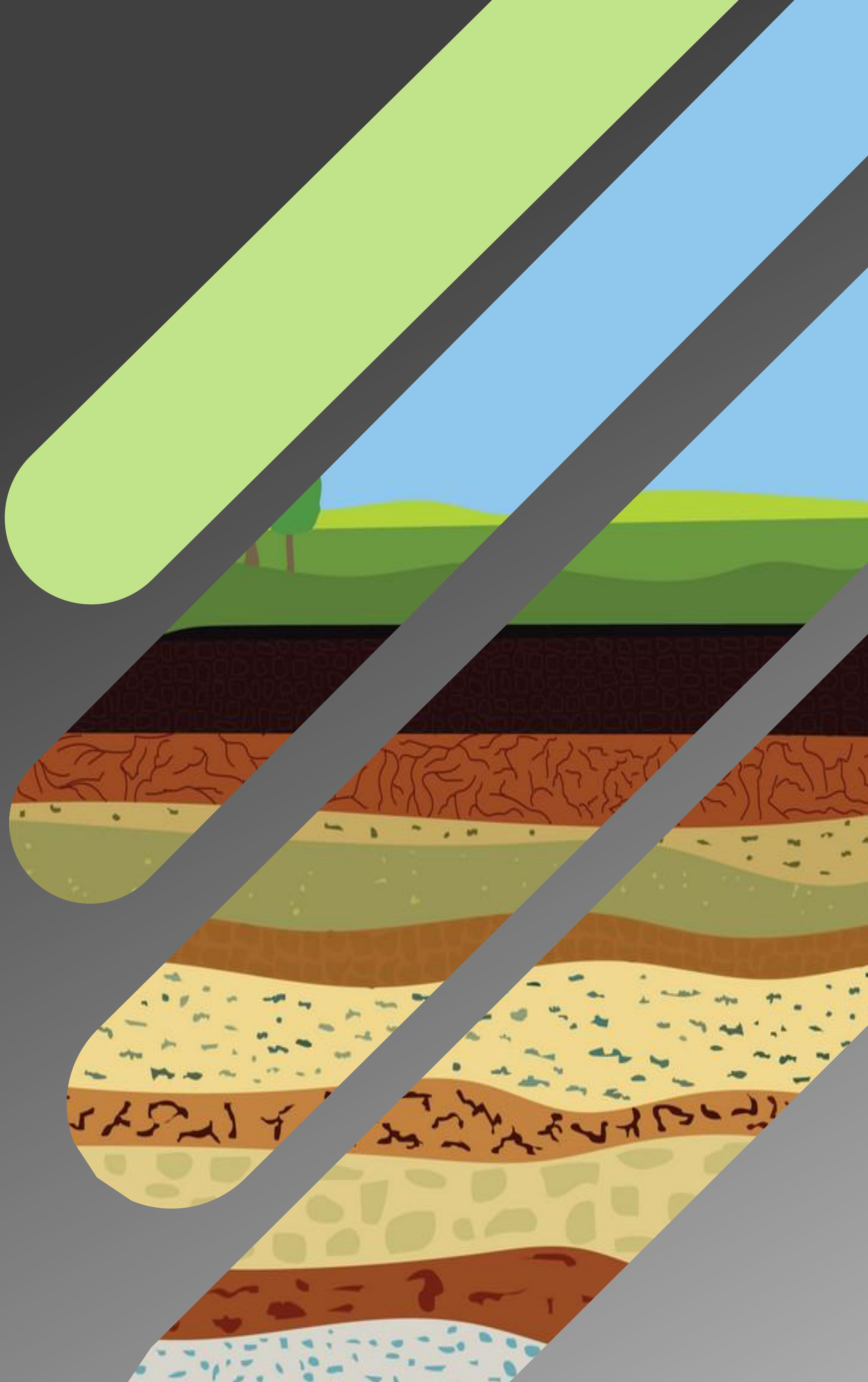

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Thank you for your attention

Supporting projects

AGRORES and RES2SOIL projects
(PID2021-126349OB-C21; PID2021-126349OB-C22)
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agrores
RES2SOIL
Biofertilizers from Agrowaste for Healthy Soils

Resioliva Operational Group (No. GOPO-CO-23-0004)
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