BioMAgE

كليـــــة العلوم السملالية - مراكش
FACULTÉ DES SCIENCES SEMLALIA - MARRAKECH

Microbial Biotechnologies Agrosciences and Environment Laboratory (CNRST Labeled Research Unit No. 4)

Hafidi@uca.ac.ma

Missions

- **Mission I** – Teaching
- **Mission II** – Taring.
- **Mission III** – Research & Development

BioMAgE laboratory focused on the environment typically engages in a range of activities aimed at understanding, monitoring, and mitigating environmental and agricultural issues. BioMAgE meets the requirements on biomass valorization and microbial biotechnologies which offers a dual approach to sustainability of valorizing of different kind of waste to produce biofertilizers, Biocontrols, and biostimulants.

BioMAgE Technical Sheet

Teams ?

Team 1: Microbial Biotechnologies

Team 2: Agrosciences & Environment

Accreditation Period: Since November

Research Topics:
1- Microbial Biotechnologies and Agrosystems
2- Microbial Biotechnologies and Environment

Head of the Lab: Professor Mohamed HAFIDI

BioMAgE in figures (2019-2023)

- 18 : Professors
- 300 : Publications
- 06 : Book Chapter
- 03 : Patents
- 40 : Defended theses

BioMAgE's Activities

TEAMS	Staff	Management	Supervision	Projects
1 & 2	PA	Bachelor's degree	FP-Fundamental License	PRIMA
			FP-Professional license	SUSFOOD
	PH	Professional Bachelor's degree/excellence	FP-Masters	PHC Maghreb
			PhD theses	Ministry of the Environment
				CNRST
	PES	Master's degree	Habilitation theses	IRD
				German Ministry
			Cotutelle theses	Others
			TB/VIH	
1 & 2	BioMAgE			
	Pedagogical Activities		Research & Development	
	Research activities			

Objectives – *Education & Scientific Research*

2 Projects

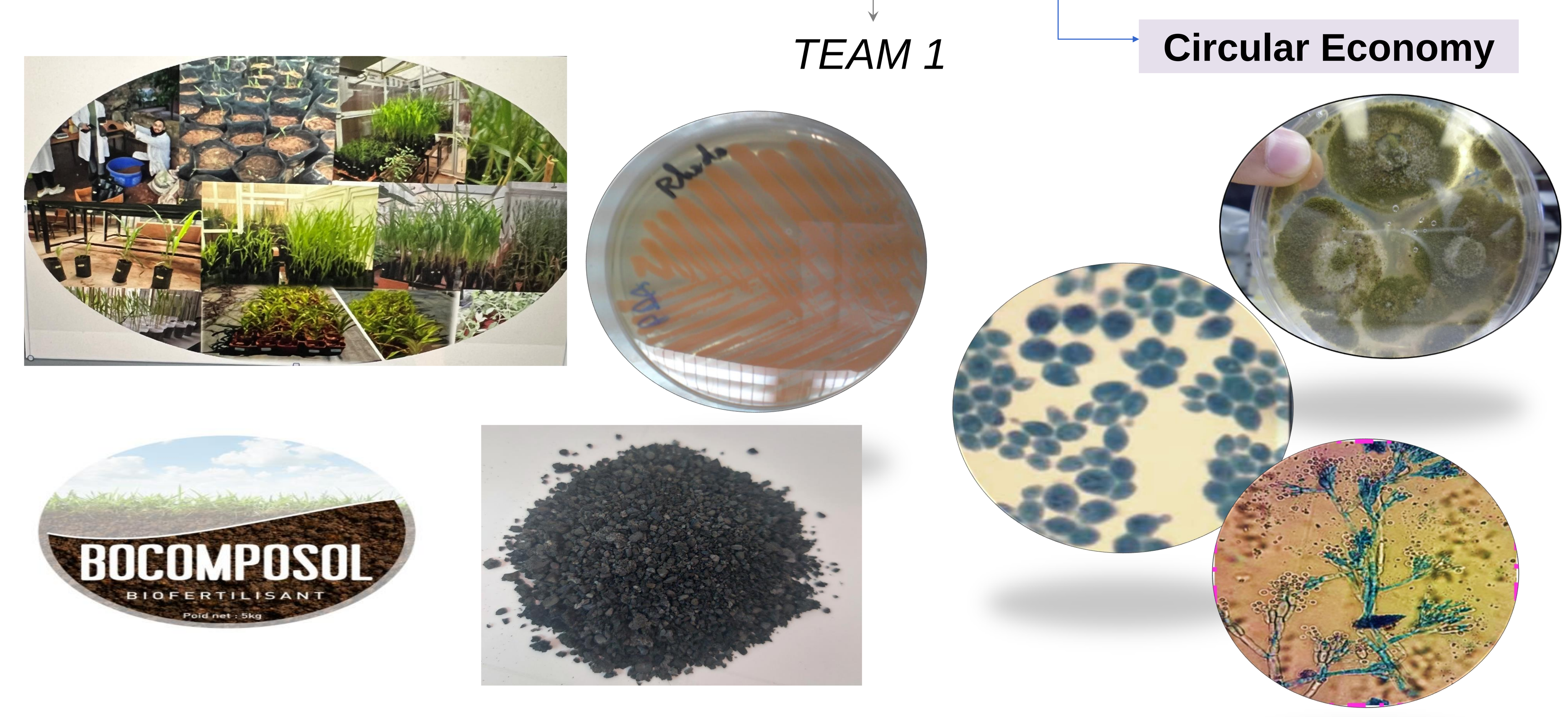
3 Research topics

Results indicators

National and international rankings

4
- **Themes 1** – *TEAM 1*
  - Water microbiology
  - Soil microbiology
  - Medical Microbiology
- **Themes 2** – *TEAM 1 & 2*
  - Agrosystem
  - Mycorrhiza
  - Agriculture
  - Agronomic trials
- **Themes 3** – *TEAM 1*
  - Bioprocess
  - Biotechnologies
  - Waste treatment
  - Circular Economy

BioMAgE's main Products



Bioprocess & Biofertilizers

Microbial Biotechnologies Agrosciences and Environment Lab (CNRST Labeled Research Unit No. 4)

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Aerobic & Anaerobic decomposition of organic material by microorganisms, it's environmental impacts and benifits can help limit the dangers of throwing trash in landfills and incinerators.

Organic waste statistics

In 2023, global solid waste production was estimated at around 2.24 billion tonnes. This is expected to increase by 73% by 2050, reaching 3.88 billion tonnes:

30-40% of agricultural produce is never consumed.

931 million tonnes of food waste are generated each year, representing around 17% of the world's total food production.

28 billion tonnes/year of global manure production.

Impacts of bioprocess

- Pollution of surrounded soil, air and water.
- Climate Change
- Health hazards to humans and animals.

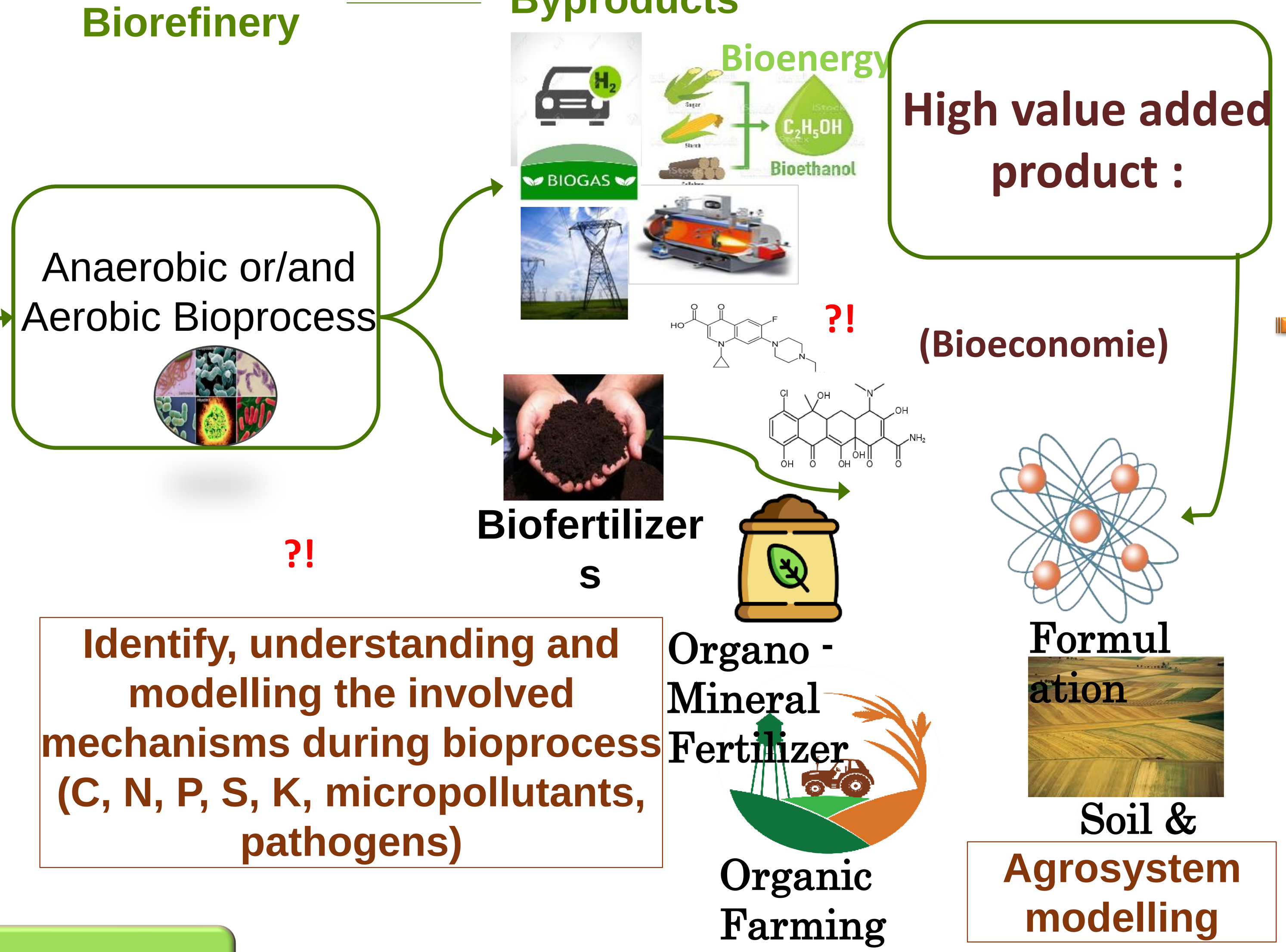
Advantages of Bioprocess

- Avoids the consequences of gas emissions .
- Carbon sequestration.
- Enhances soil quality.
- Builds community resiliency.

Organic biomass — Environmental Biorefinery — Byproducts

By-products characterization

Characterization, Pretreatment (DataBase, Mapping)



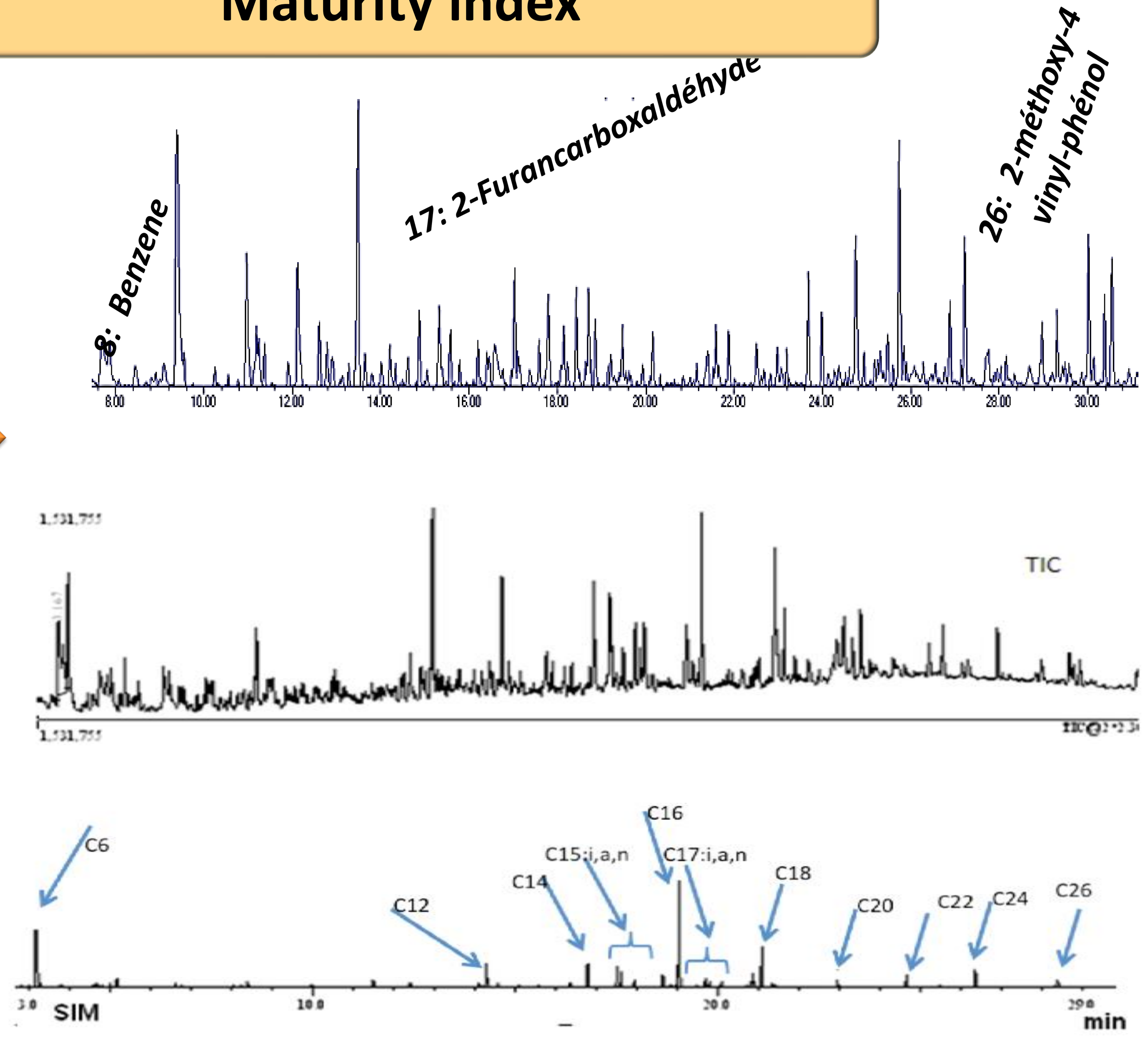
High value added product :

(Bioeconomie)

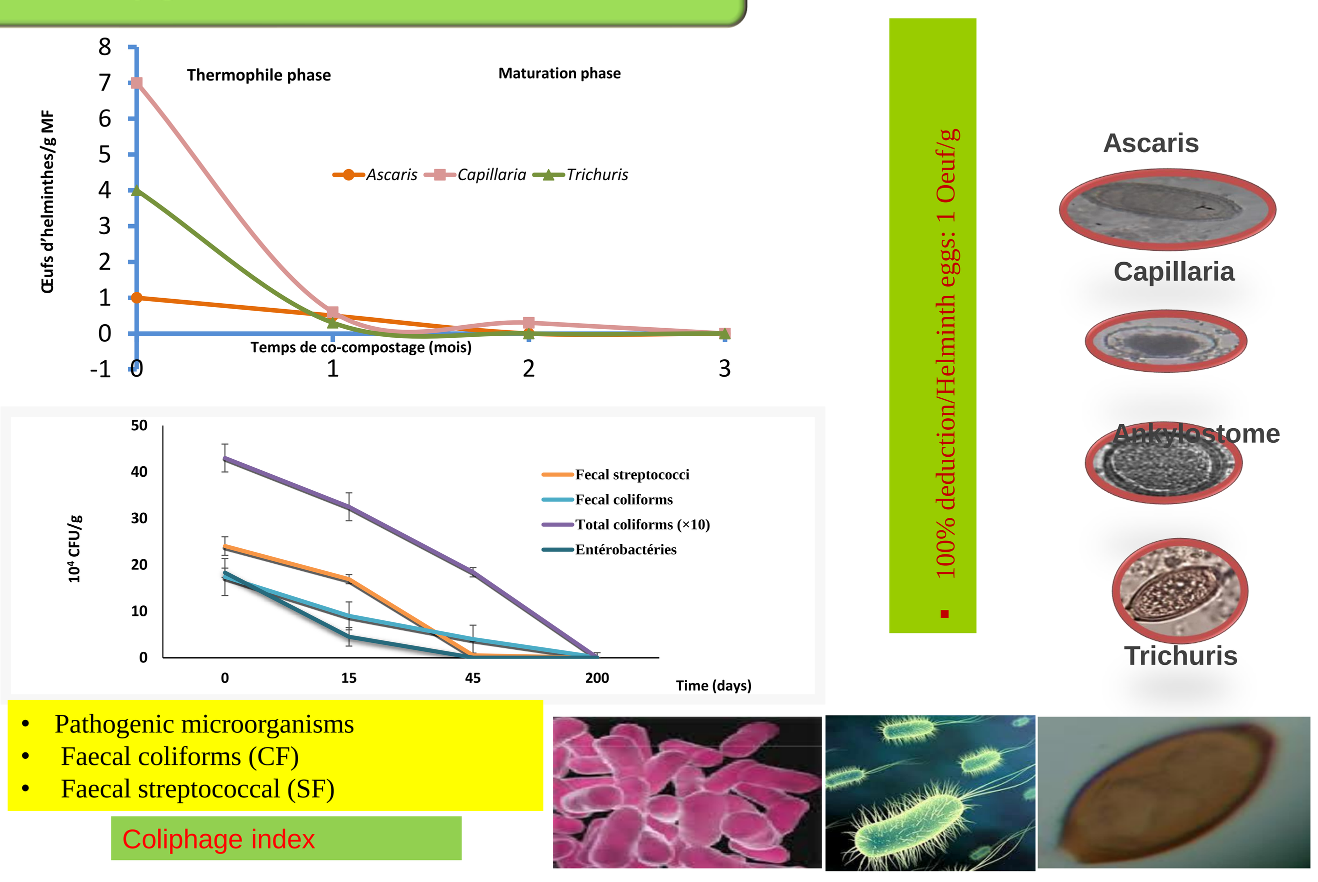
?!

Identify, understanding and modelling the involved mechanisms during bioprocess (C, N, P, S, K, micropollutants, pathogens)

Maturity index



Hygienization



Semi-industrial scale experiences

EL FELS et al., 2014- 2023

Transformation of Biomass to Biochar and renewable Energy

Laboratory of Microbial Biotechnologies Agrosciences and Environment (BioMAgE)

Imad RABICHI, Kawtar EZZAHI, Loubna EL FELS

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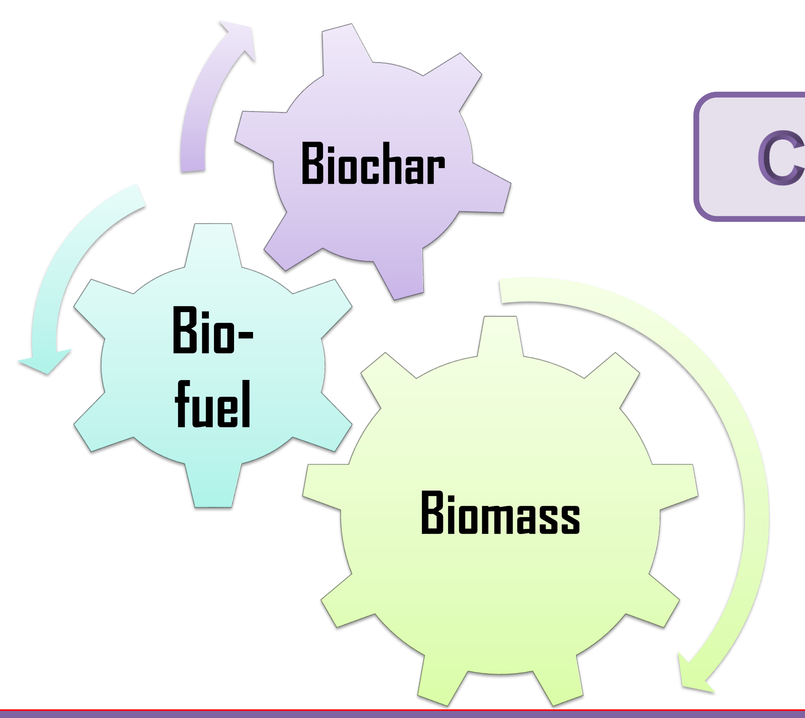


Context

Biomass valorization offers a dual approach to sustainability by converting biomass into renewable energy and biochar. Processes like anaerobic digestion and pyrolysis efficiently transform biomass into biofuels while yielding biochar, a carbon-rich material beneficial for soil health and water management. Integrating biochar into agricultural practices improves soil fertility, water retention, and crop yields while sequestering carbon.

Objectif

- Optimisation from the lab to the pilote scale production of biochar.
- Optimization of the preparation of high-quality biochar for wastewater treatment and soil.
- Waste Reduction: Pelletization can utilize waste products from other processes, turning them into useful products.

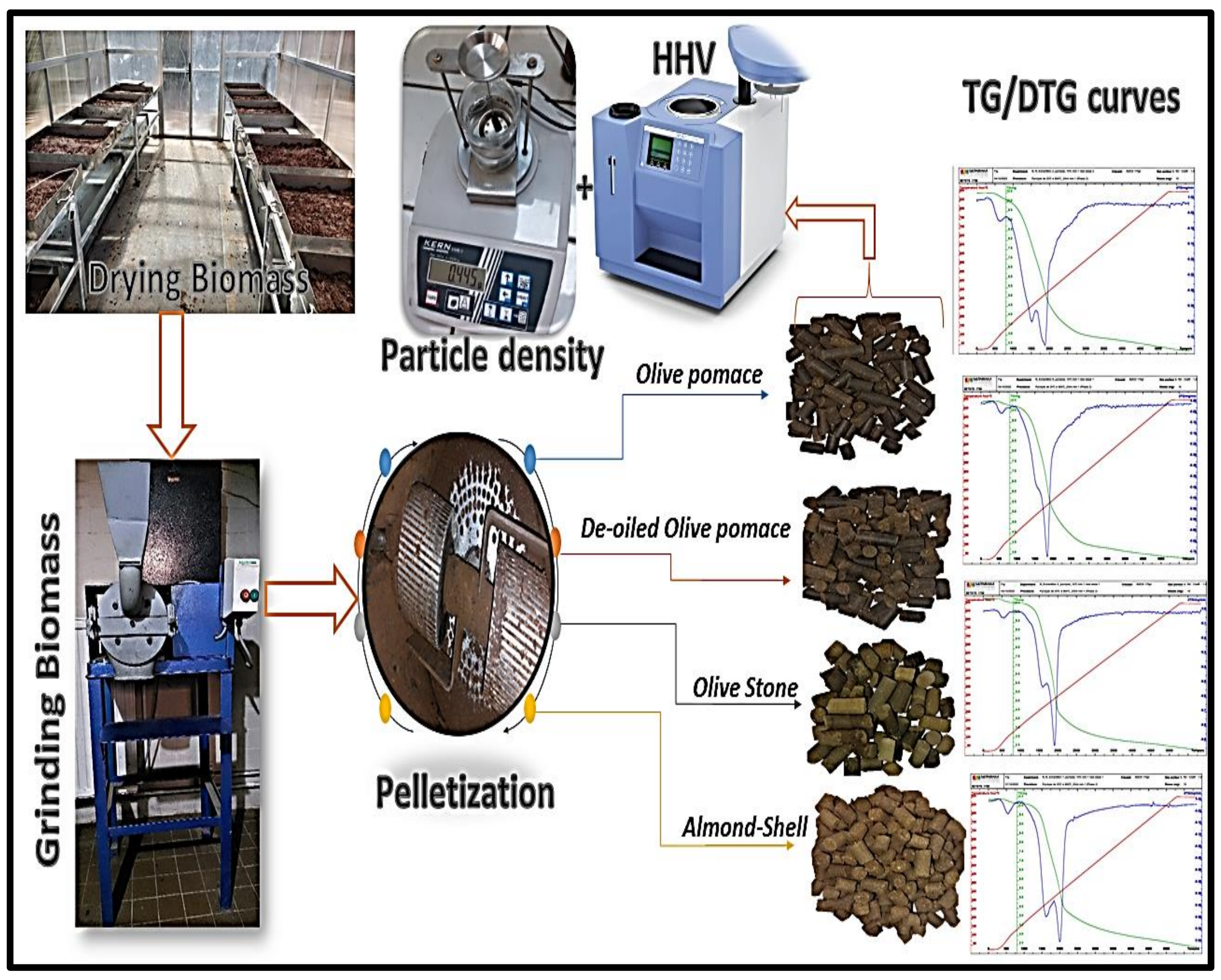
Part I
- Pelletization of Biomass
- Production of Energy.

Part II
- Optimisation of preparation of biochar condition.

Part III
- Utilisation of biochar on Soil.

Table 1. Physical-energy characterization of two-phase olive pomace. (wb) wet basis; (db) dry basis.

Elemental analysis [%]	C	52.85
	H	6.69
	N	6.98
	S	3.20
	O	30.28
Proximate analysis [%]	Moisture (wb)	54.00
	Volatile matter (db)	84.23
	Ash (db)	3.19
	Fixed carbon (db)	8.58
	HHV (MJ/kg) (db)	22.68
	LHV (MJ/kg) (db)	22.33



Variation of the Yield (Y_1, %), of biochar (isoresponse curves)

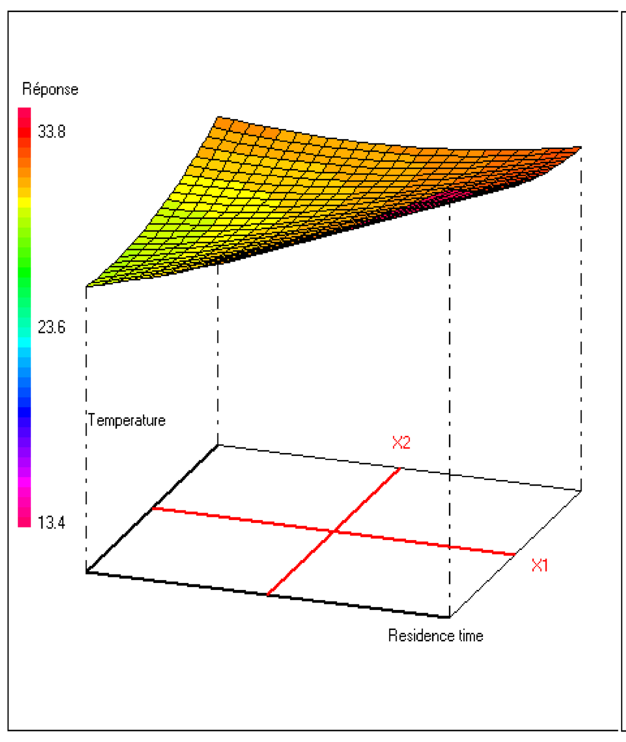
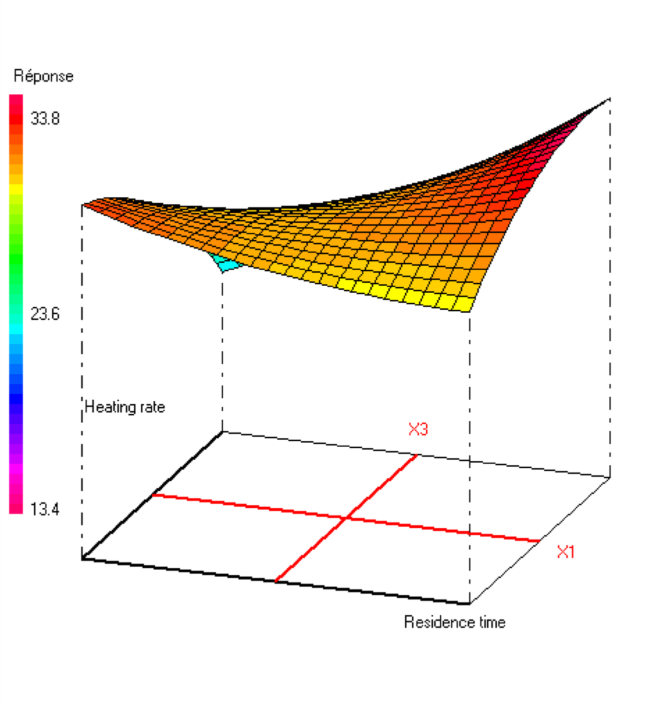
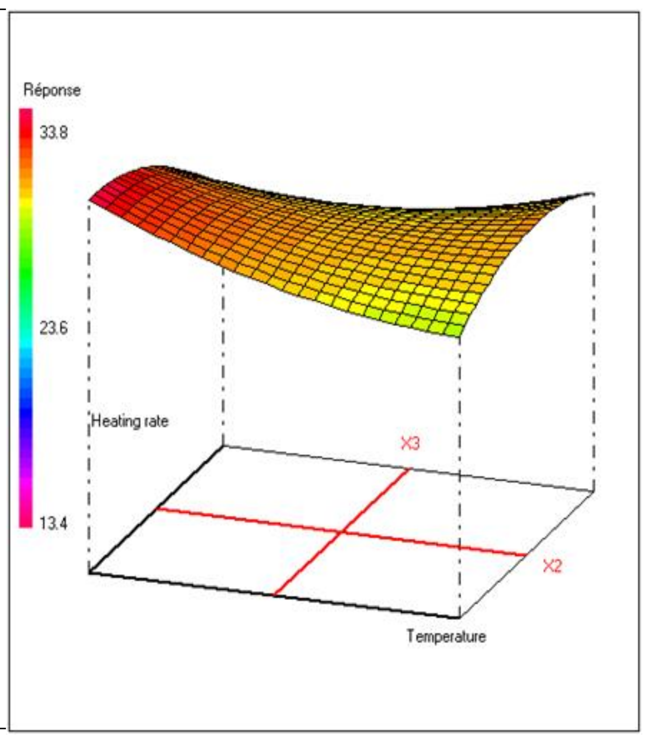


Fig.1.a) Y1 Function of Residence Time and Temperature and Heating rate = 12.5 °C/min.



b) Y1 Function of Residence time and Heating Rate and Temperature = 500.0 °C.



c) Y1 Function of Temperature and Heating Rate and Residence time = 120.0 min.

Variation of the MB adsorption (Y2, mg/g), of biochar (isoresponse curves)

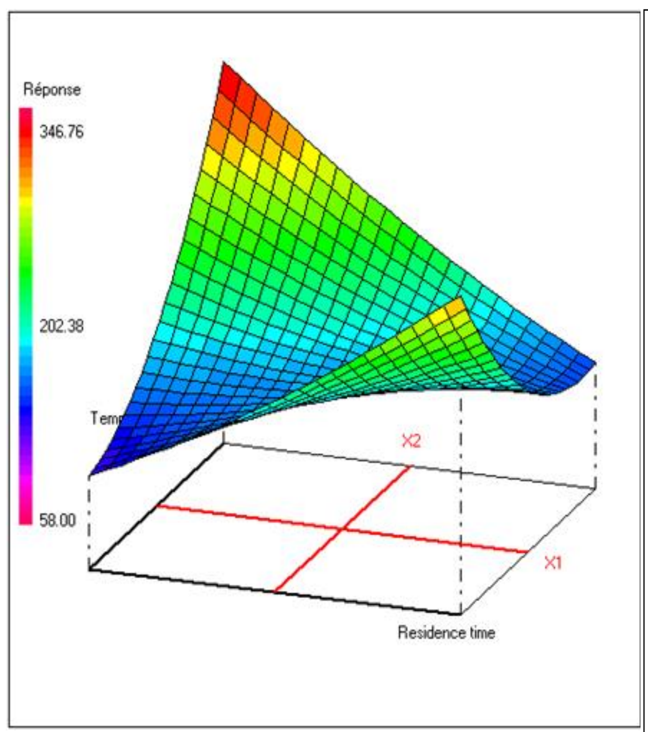
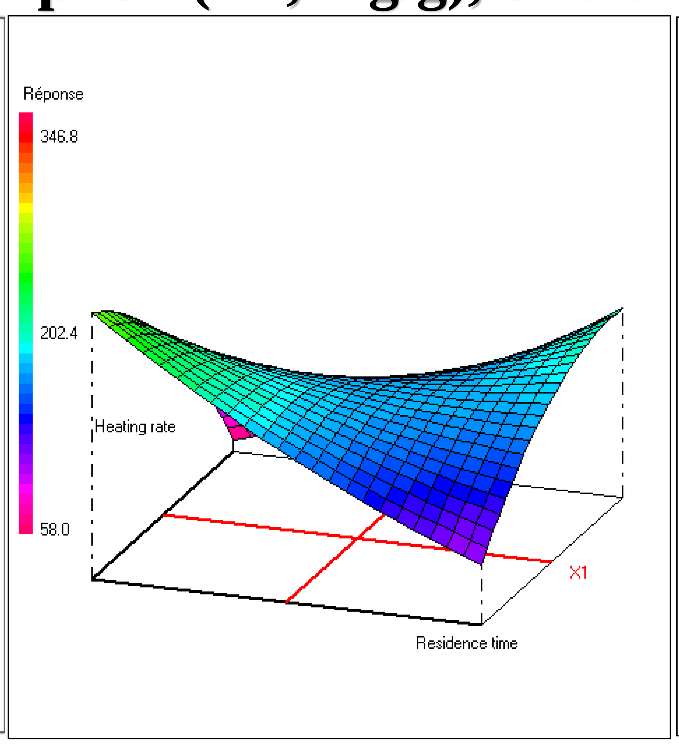
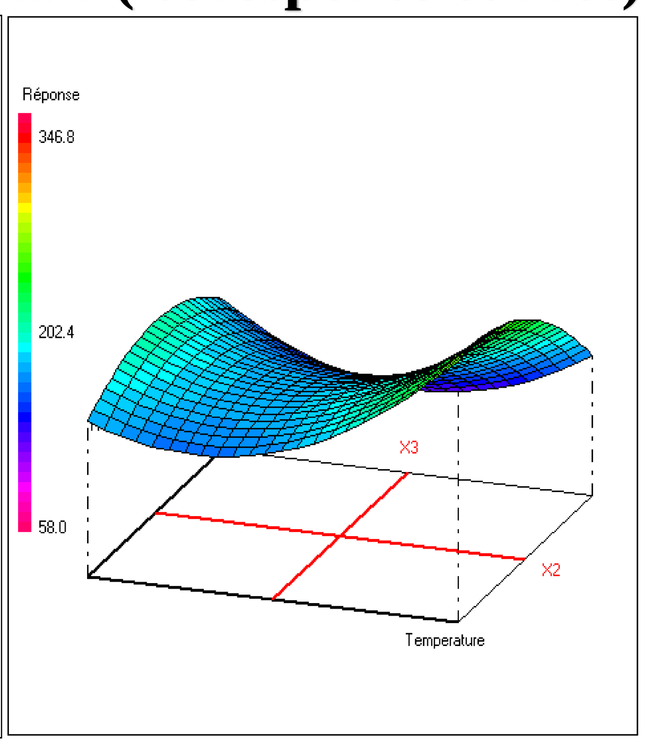


Fig.2.a) Y2 Function of Residence time, Temperature, and Heating rate = 15.0 C°/min.



b) Y2 Function of Residence time, Heating rate, and Temperature = 500.0 °C.



c) Y2 Function of Temperature, Heating rate, and Residence time = 120.0 min.

From the Lab to the semi-pilot scale

Fig. 3. Raw two-phase olive pomace.

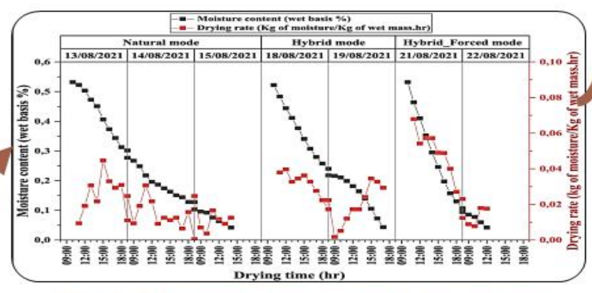


Fig.4. Moisture content and drying rate variations with drying time for natural, hybrid, and hybrid forced greenhouse drying of two-phase olive pomace.

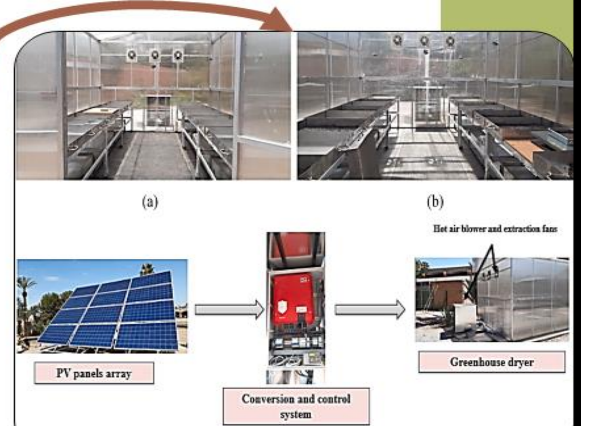


Fig.5. Inside view of the greenhouse dryer.

The moisture level of the olive pomace decreased from 54.0% to 0.04% in 28 h, while it was reduced to the same moisture content in 19 h and 14 h during the hybrid and hybrid forced drying modes, respectively.

Fig. 6. Pilote scale.

First Class of Biochar

- Contents of Co, Cr, Cu, Zn, As, Cd, Hg, Mo, Ni, Pb, and Se are significantly lower than those prescribed by the standards of the International Biochar Initiative (IBI), and European Biochar Certificate (EBC).

Parameters	European Biochar Certificate (EBC)	International Biochar Initiative (IBI)	Our Biochar
C total	C total	C organic	OP
	≥ 50%: Biochar	Class 1: C_org ≥ 60%	73.94
		Class 2: 30% ≤ C_org < 60%	-
		Class 3: 10% ≤ C_org < 30%	-
		Class 4: <10% no Biochar	-
Inorganic Carbon	Declaration	Declaration	< 0.01
H/C_org	Biochar if ≤ 0.7	Biochar if ≤ 0.7	0.27
O/C	Declaration	Declaration	0.32
Ash			13.43
pH	Declaration if ≥ 10	Declaration	10.90

- **Test category A:** Basic utility properties - required for all biochars.
- **Test category B:** Toxicity assessment - required for all biochars.
- **Test category C:** Advanced analysis and soil improvement properties – Optional.

Use of organo-mineral amendments and *Lupinus angustifolius* to enhance mine tailings rehabilitation

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INTRODUCTION

The burgeoning global demand for metals has resulted in extensive mining activities, contributing significantly to global economic development. However, the aftermath of mining operations often leads to post-mining landscapes that witness graded soil, devoid of essential nutrients and organic matter, with metal contamination standing as a testament to the irreversible damage inflicted upon these ecosystems (Shao et al., 2023; Iskandar et al., 2022; Kodir et al., 2017). The post-mining terrain poses ecological challenges, necessitating effective and innovative strategies not only to remediate the soil but also to promote sustainable and resilient ecosystems (Bandyopadhyay and Maiti, 2022; Festin et al., 2019). The Kettara mine, located in Morocco, illustrates the challenges associated with mining activities. Renowned in the past for its pyrrhotite reserves and economic contributions, the site experiencing issues related to degraded landscapes, salinity, drought, and heavy metal contamination, notably copper (Cu), zinc (Zn), lead (Pb), and arsenic (As), reflecting wider environmental impacts of intensive mining activities (Russo, 2023; Abdalla et al., 2022; Feizizadeh et al., 2022; Raklami et al., 2022, 2021; El Alaoui et al., 2021). Addressing the aftermath of mining here necessitates the urgent implementation of comprehensive remediation and sustainable land management practices to restore soil health and foster resilient ecosystems.

CASE STUDY

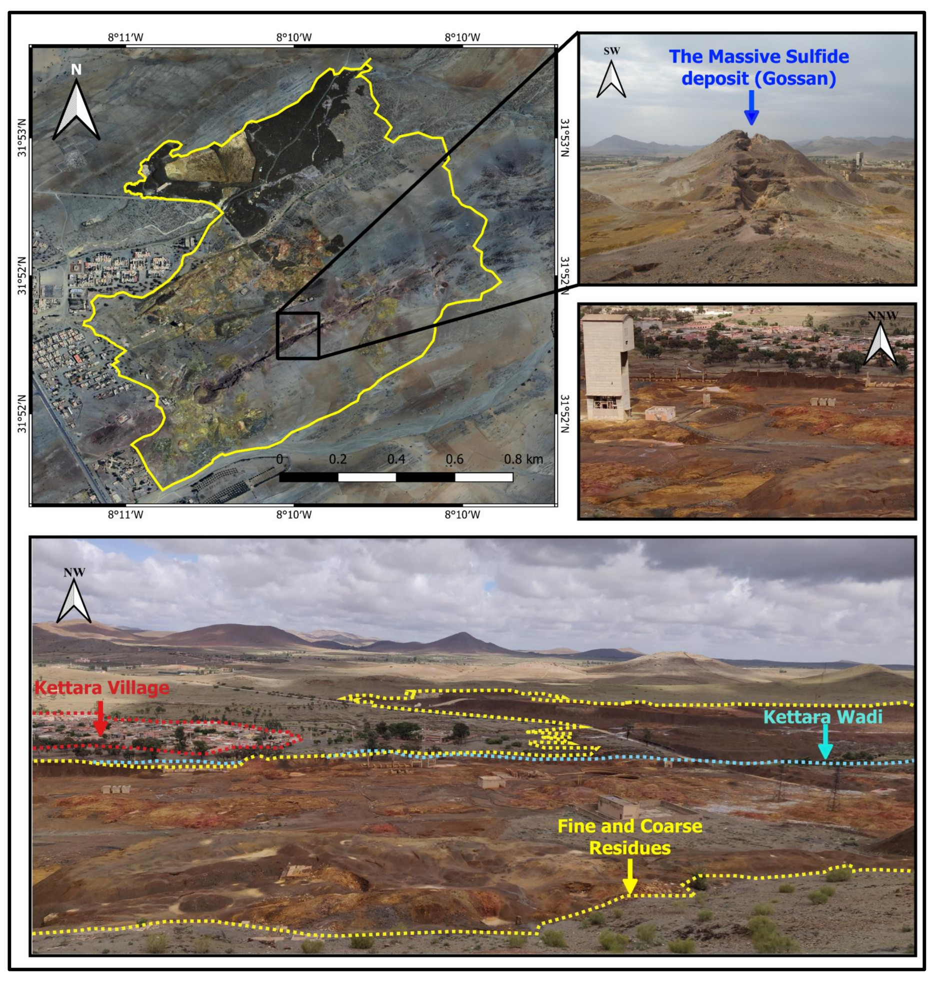


Fig. 1. Geospatial localization of the study area highlighting Kettara mine through site-specific imagery (Sahlaoui et al., 2024).

The study was conducted in the abandoned Kettara mine situated 30 km to the northwest of Marrakesh in the heart of the central Jebilet Mountains (Southern Morocco) (Fig. 1). The site is characterized by a semi-arid climate, with average temperatures ranging from 10 °C in January to 28 °C in August, respectively. The mine was operational to extract pyrrhotite from 1934 until 1982, resulting in the accumulation of over 3 million tons of sulfide tailings covering an area of 37 ha (Fig. 2) (Babi et al., 2016, El Amari et al., 2014). This mining site is distinguished by a multitude of stressors, including extreme soil acidity, elevated salinity related to the presence of high concentrations of soluble salts, low water holding capacity, high levels of heavy metals, poor substrate structure, high levels of sulfur, and low organic matter content (Raklami et al., 2021). The Kettara tailings display relatively high concentrations of iron, potentially attributed to the presence of pyrrhotite and pyrite, as well as secondary oxide and sulfate minerals (Fig. 2) (Hakkou et al., 2008).

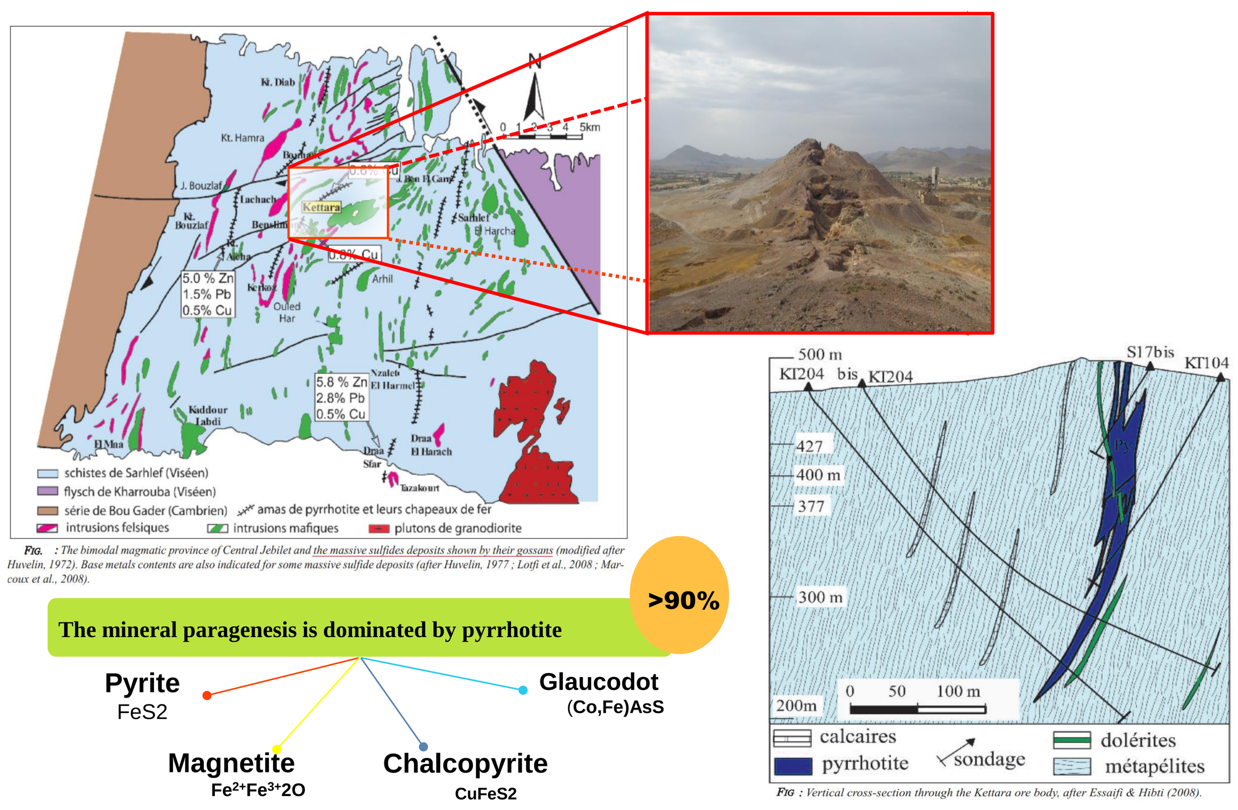


Fig. 2. The mineral paragenesis of the Kettara mine (Essaifi & Hibti, 2008)

STUDY SCOPE

Lupinus angustifolius
(Sahlaoui et al., 2024)

Compost

Clay

Marble waste

Our study represents a pioneering endeavor as it is the first to propose the synergistic utilization of clay, compost, and marble waste alongside assessing the ecological contributions of *Lupinus angustifolius*. Furthermore, our research breaks new ground by addressing the complexities of developing integrated combinations under a multitude of stressors present at our case study site, marking a novel contribution to the field. In the broader context of global sustainability, nature-based solutions for environmental challenges.

MATERIAL AND METHODS

RESULTS

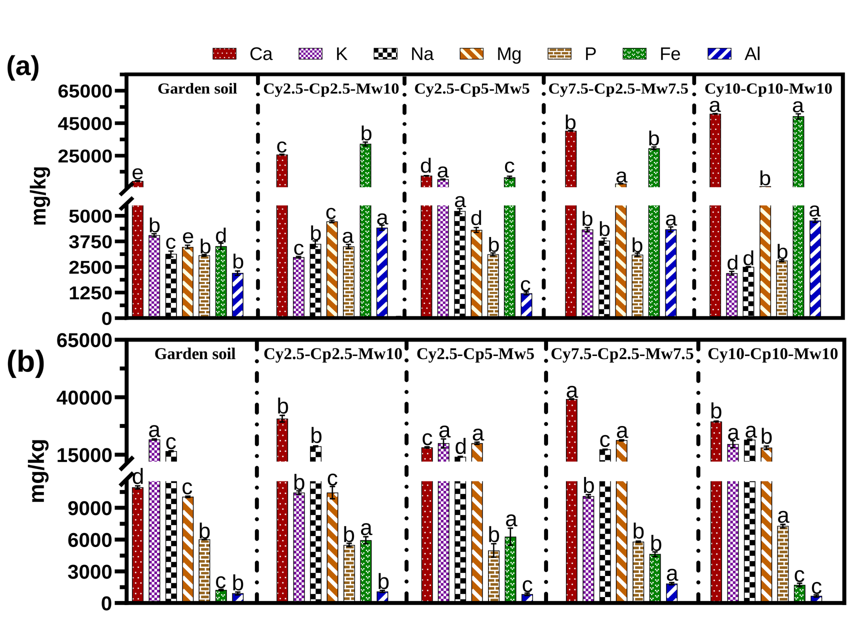


Figure 4. Impacts of organo-mineral amendments application in mining contaminated soil on nutrients concentration in roots (a) and shoots (b) of *L. angustifolius* L. Data are means ± standard deviation (n=3), different letters in the same column are showing significantly differences between the amendments at $p < 0.05$.

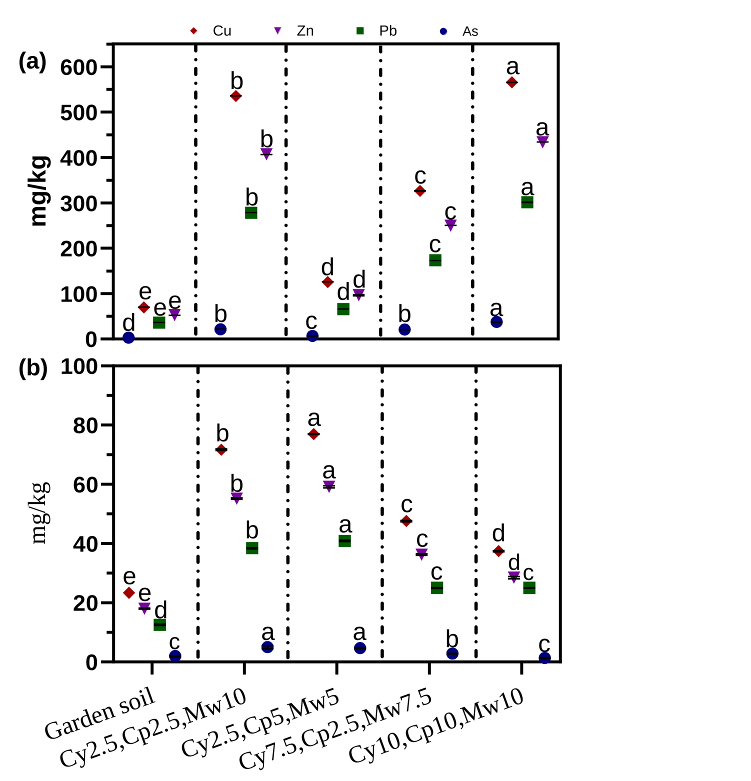


Figure 5. Impacts of soil organo-mineral amendments application in mining contaminated soil on heavy metals concentration in the root (a) and shoot (b) of *L. angustifolius* L. Data are means ± standard deviation, different letters in the same column are significantly different at $p < 0.05$.

Table 1. Impact of organo-mineral amendments application on the total and bioavailable fractions of heavy metals in mining contaminated soil. Data are means ± standard deviation (n=3), different letters in the same column are significantly different at p < 0.05.

Amendment treatments	pH ($CaCl_2$) at 23,5°C	EC (mS/cm) at 25,5°C	%GI *M. sativa*	%GI *Lepidium sativum*	%GI *Lupinus angustifolius*
$Cy_{2.5}$-$Cp_{2.5}$-Mw_{10}	7.43±0.02[b]	2.48±0.05[c]	50.38±4.75[b]	26.00±3.32[b]	30.55±4.56[c]
$Cy_{2.5}$-Cp_5-Mw_5	6.18±0.04[c]	3.18±0.02[b]	41.66±3.12[c]	29.73±2.94[b]	33.33±3.21[c]
$Cy_{7.5}$-$Cp_{2.5}$-$Mw_{7.5}$	7.54±0.02[a]	2.57±0.06[b]	74.48±9.32[a]	74.26±8.63[a]	41.66±3.63[b]
Cy_{10}-Cp_{10}-Mw_{10}	7.40±0.03[b]	2.94±0.03[b]	55.76±3.45[b]	25.83±2.89[b]	54.16±2.351[a]
Mine tailings	3.09±0.02[d]	5.7±0.05[a]	No seed germination	No seed germination	No seed germination

Table 2. Impact of organo-mineral amendments application on the total and bioavailable fractions of heavy metals in mining contaminated soil. Data are means ± standard deviation (n=3), different letters in the same column are significantly different at $p < 0.05$.

Amendment treatments	As (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Zn (mg/kg)	
	Total	Available	Total	Available	Total	Available	Total	Available
Garden soil	10.1±0.1[d]	0.4±0.0[b]	49.3±2.4[e]	4.1±0.7[b]	45.3±0.5[d]	1.0±0.0[b]	210.5±0.1[e]	1.2±0.2[b]
$Cy_{2.5}$-$Cp_{2.5}$-Mw_{10}	137.4±2.3[b]	~0.2±0.0[c]	1591.7±40.1[c]	2.7±0.9[b]	90.8±7.2[b]	~0.2±0.0[c]	211.2±4.8[d]	~0.0±0.0[c]
$Cy_{2.5}$-Cp_5-Mw_5	127.8±5.9[b]	~0.2±0.0[c]	1745.2±96.7[b]	1.1±0.2[c]	87.0±1.1[b]	~0.2±0.0[c]	238.6±1[c]	~0.0±0.0[c]
$Cy_{7.5}$-$Cp_{2.5}$-$Mw_{7.5}$	131.9±5.6[b]	~0.2±0.0[c]	1720.6±54.6[b]	2.1±0.1[b]	93.1±0.7[b]	~0.2±0.0[c]	266.6±6.9[b]	~0.0±0.0[c]
Cy_{10}-Cp_{10}-Mw_{10}	118.4±3.6[c]	~0.2±0.0[c]	1378.3±39.9[d]	3.3±0.2[b]	69.8±2.1[c]	~0.2±0.0[c]	340.0±10[a]	~0.0±0.0[c]
Mine tailings	175.8±2.4[a]	4.5±0.0[a]	1974.6±84.7[a]	510.8±7.5[a]	162.6±6.2[a]	23.6±0.3[a]	210.7±4.8[e]	67.2±28.2[a]

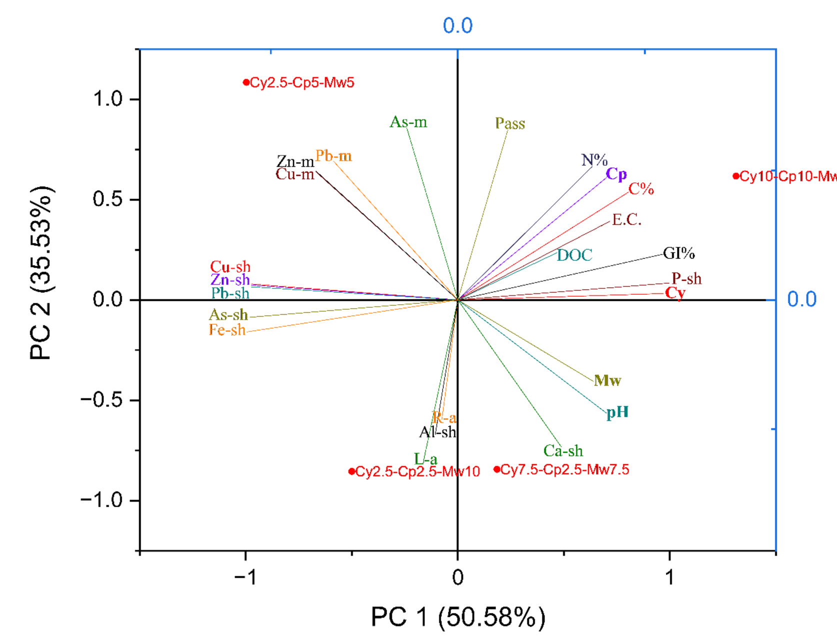


Figure 6. Principal component analysis (PCA) of lupine subjected to the four tested treatments; Cy2.5-Cp2.5-Mw10, Cy2.5-Cp5-Mw5, Cy7.5-Cp2.5-Mw7.5, Cy10-Cp10-Mw10. Cy: Clay; Cp: Compost; Mw: Marble waste; pH: Potential of hydrogen of soil; E.C.: Electrical Conductivity of soil; GI%: Lupines' Germination Index; L-a: Lupines' leaf area; R-a: Lupines' root area; C%: Carbon content in soil; N%: Nitrogen content in soil; Pass: Assimilable phosphorus in soil; DOC: Dissolved organic carbon in soil; Cu-m, Zn-m, Pb-m, and As-m: Mobile (bioavailable) fraction of heavy metal (Copper, Zinc, Lead, and Arsenic, respectively) in soil; Cu-sh, Zn-sh, Pb-sh, and As-sh: Heavy metals (Copper, Zinc, Lead, and Arsenic, respectively) concentration in the lupines' shoot; P-sh, Al-sh, Ca-sh, and Fe-sh: Nutrients (Iron, Aluminum, Calcium, and Phosphorus, respectively) concentration in lupines' shoot.

CONCLUSION

Our amendments demonstrated remarkable effectiveness in substantially mitigating the mobile fraction of metals within mine tailings, achieving a reduction of up to 99%. Moreover, soil fertility, as evidenced by essential plant nutrient concentrations, experienced enhancement following these amendments. Notably, the levels of N, P, K, Mg, and C improved by 264, 16, 150, 180, and 1367%, respectively. Moreover, the dissolved organic carbon was improved by 211%. When applied to *L. angustifolius*, these formulations exhibited positive impacts on diverse growth parameters, including root length, root area, root morphology, leaf area, and physiological properties such as stomatal conductance and chlorophyll contents. *L. angustifolius* plants exhibited a preferential accumulation of heavy metals in the root's biomass (Cu: 565.60, Zn: 433.52, and Pb: 301.44 mg kg^{-1}) with limited translocation to shoot parts (Cu: 37.44, Zn: 28.40, and Pb: 19.36 mg kg^{-1}). This sustainable approach proves the beneficial effects of these formulations for the improved rehabilitation of mining sites and tailings.

ACKNOWLEDGMENTS

This study was financially supported by the Alexander van Humboldt Foundation Research Group Linkage Program (Germany) and the PPR2/2016/42 CNRST project. We would like to thank Katja Gonschorek, Heidrun Kerkhoff, and Sabine Frölich from the Laboratory of the Institute of Geography at Ruhr-University Bochum for their great help during this experiment. We would like to thank, as well, the UM6P staff for their availability and support, particularly Meryem Haddine and Rachid Ghani. We extend our sincere gratitude to Professor Ahmed Ouhammou, Director of the Regional Herbarium MARK, for his invaluable assistance in accurately identifying the plant utilized in our study as *Lupinus angustifolius* L.

MARRAKECH

جامعة القاضي عياض

UNIVERSITÉ CADI AYYAD

AgroBiotech

URL-CNRST

Centre d'Agrobiotechnologie & Bioingénierie

Unité de Recherche labellisée CNRST

AgroBiotech

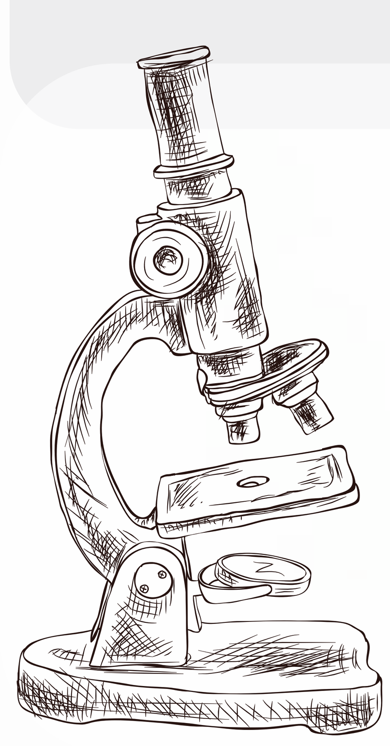
AGROBIOTECHNOLOGY AND BIOENGINEERING CENTER
RESEARCH UNIT LABELED CNRST-05

Objective

The center aims to harness natural biological resources such as microorganisms and Moroccan plants to enhance agricultural production sustainably. It conducts research in biotechnology and bioengineering to develop biofertilizers, biostimulants, and bioprotectors, while also exploring new biomolecules and bioproducts for therapeutic, cosmetic, agronomic, food, and energy-related applications, along with biosourced biomaterials.

Teams

- "Physiology of abiotic stress" team
- "Beneficial Microorganisms" Team
- "Management of the soil-plant-atmosphere continuum" team
- "Food science and technology" team
- "Biosourced biomaterials" team
- "Agrobiotechnology" team
- "Genetics and molecular biology" team
- "Valorization of aromatic and medicinal plants" team
- "Value-added biomolecules" team
- "Organic drying processes and techniques" team



10 TEAMS AND 40 PERMANENT RESEARCH PROFESSORS

Elaborated by Pr. El Modafar Cherkaoui[1] and Pr. Meddich Abdelilah[2]
[1] Director AgroBiotech
[2] Adjoint Director AgroBiotech

Unifying project

Biotechnology and Bioengineering tools for the exploitation of natural bio-resources for the improvement and valorization of agricultural production and the development of biomolecules and bioproducts with high added value.

Federating Axis 1: Improving the resilience of plants of agro-economic interest to climate change and biotic and abiotic constraints in a context of eco-production and sustainable development. — Theme 1 to 8

Federating Axis 2: Exploitation of beneficial microorganisms, algae and marine organisms for the development of biofertilizers, biostimulants and biocontrol agents. — Theme 9 to 15

Federating Axis 3: Valorization of agro-resources and agro-industrial co-products for the development of new bioproducts, biomolecules and biosourced materials of therapeutic, agronomic, cosmetic, food and energy interest. — Theme 16 to 20

Axis 1: Improving the resilience of plants of agro-economic interest to climate change and biotic and abiotic constraints in a context of eco-production and sustainable development.

Theme 1: Diversity and resilience of the olive tree, cultivation systems, and olive oil markets challenged by global change.

Theme 2: Biological approaches to combat phytopathogens responsible for tracheomycoses. Case studies include olive verticillium wilt and vascular fusariosis of date palms and tomatoes,

Theme 3: Mechanisms of adaptation and selection of genotypes tolerant to abiotic constraints.

Theme 4: Determinants of date palm tolerance to environmental constraints: Role of arbuscular mycorrhizal fungi.

Theme 5: Agronomic benefits of legume crops in association with cereals in mixed or rotational cropping systems as low-input and sustainable cultivation.

Theme 6: Study of the performance of Faba bean-rhizobia symbiotic combinations for Biological Nitrogen Fixation (FBN) under combined water deficit and phosphorus limitation stress.

Theme 7: Assessment of water stress impact on chickpea and bean accessions, and characterization of tolerance.

Theme 8: Seasonal yield forecasting for cereals and the impact of global changes.

AgroBiotech in numbers (2021-2024)

27+	BOOKS AND BOOK CHAPTERS (average per year)
100+	PUBLICATIONS (average per year)
200+	COMMUNICATIONS (average per year)
50+	THESES DEFENDED (2021-2024)
40+	RESEARCH PROJECTS FUNDED (2021-2024)
06+	PATENTS REGISTERED AND ACCEPTED (2021-2024)
02+	AWARDED WITH HASSAN II GRAND PRIZE FOR INVENTION AND RESEARCH IN AGRICULTURE

Axis 2: Exploitation of beneficial microorganisms, algae and marine organisms for the development of biofertilizers, biostimulants and biocontrol agents.

Theme 9: Research on polysaccharides/oligosaccharides from marine algae stimulating natural plant defenses.

Theme 10: Biotechnological processes for the valorization of phosphate sludge: Formulation of a biofertilizer biostimulant for plant growth and biocontrol against tracheomycosis-causing phytopathogens for direct application in productive and environmentally friendly agriculture.

Theme 11: Establishment of a mycorrhizal strain bank of local mycorrhizal fungi confirmed for efficiency under specific stresses, and intensification of plant production.

Theme 12: Valorization of phosphate-solubilizing rhizobacteria (PSB) and Plant Growth-Promoting Rhizobacteria (PGPR) as biofertilizers.

Theme 13: Isolation and characterization of nitrogen-fixing endophytic bacteria for cereal crops.

Theme 14: Development of biofertilizers from marine algae. Objective: Formulation of biofertilizers from marine algae.

Theme 15: Agronomic and agri-food valorization of chitosans extracted from crustaceans.

Axis 3: Valorization of agro-resources and agro-industrial co-products for the development of new bioproducts, biomolecules and biosourced materials of therapeutic, agronomic, cosmetic, food and energy interest.

Theme 16: Valorization of co-products from argan oil extraction processes. Application in the development of biomolecules and biosourced materials.

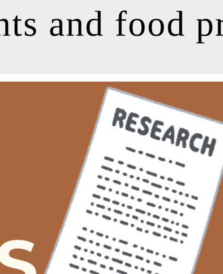
Theme 17: Bioactivity, functionality, and development of new biomolecules and bioproducts with high added value from natural resources and agri-food industry co-products.

Theme 18: Development of new nanocomposites combined with nanoparticles produced through biological methods.

Theme 19: Diversity, conservation, domestication, pharmacology, toxicology, and therapeutic and agronomic valorization of aromatic and medicinal plants in Morocco.

Theme 20: "Bio" drying processes and techniques for aromatic and medicinal plants and food products.

300+ PUBLICATIONS 2021-2024



ReCROP Project – Bioinocula and CROPping systems: an integrated biotechnological approach for improving crop yield, biodiversity and REsilience of Mediterranean agro-ecosystems

MARRAKECH جامعة القاضي عياض UNIVERSITÉ CADI AYYAD

كليــة العلــوم والتقنيات - مراكش FACULTE DES SCIENCES ET TECHNIQUES - MARRAKECH

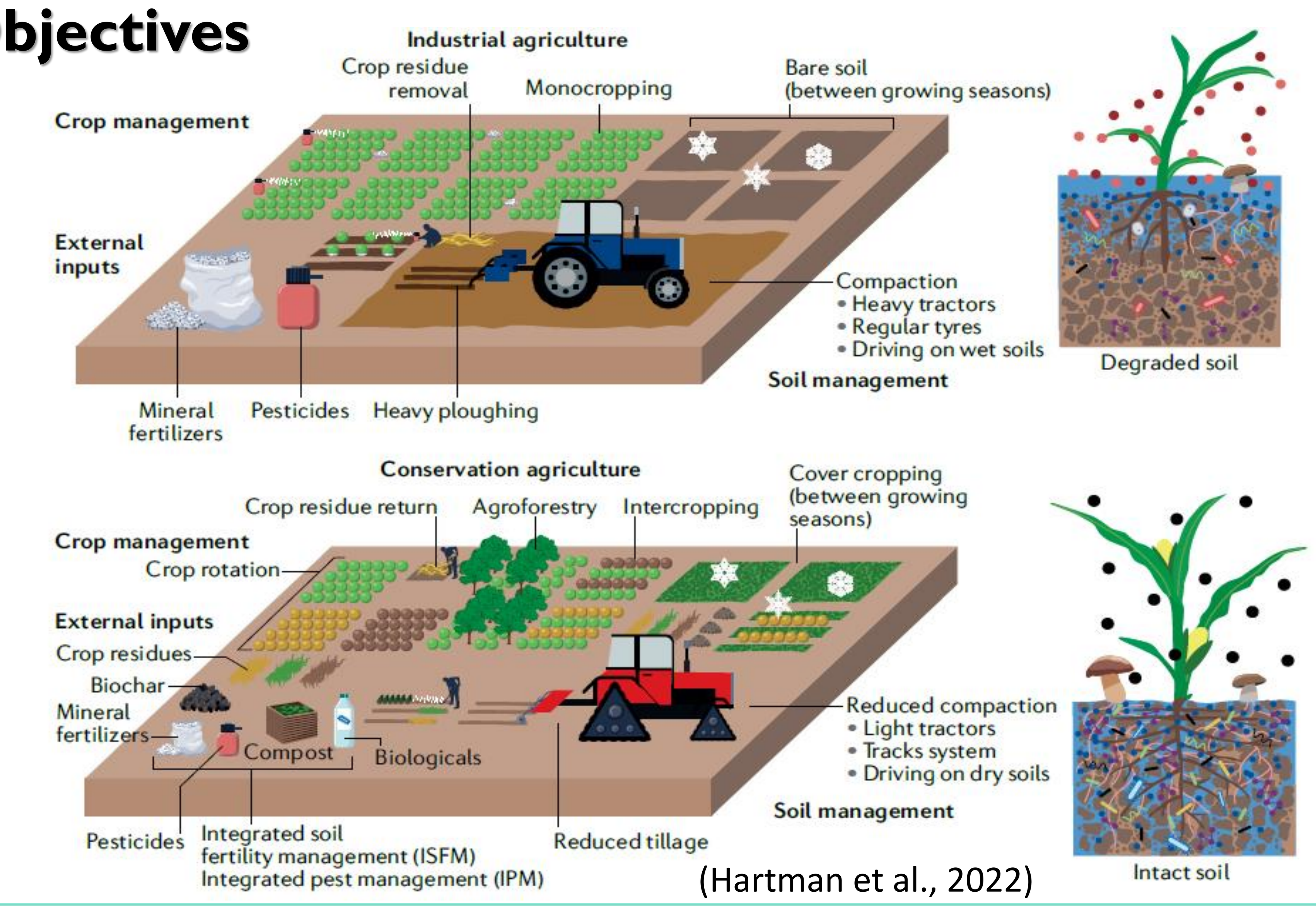
ReCROP

PRIMA IN THE MEDITERRANEAN AREA

Introduction

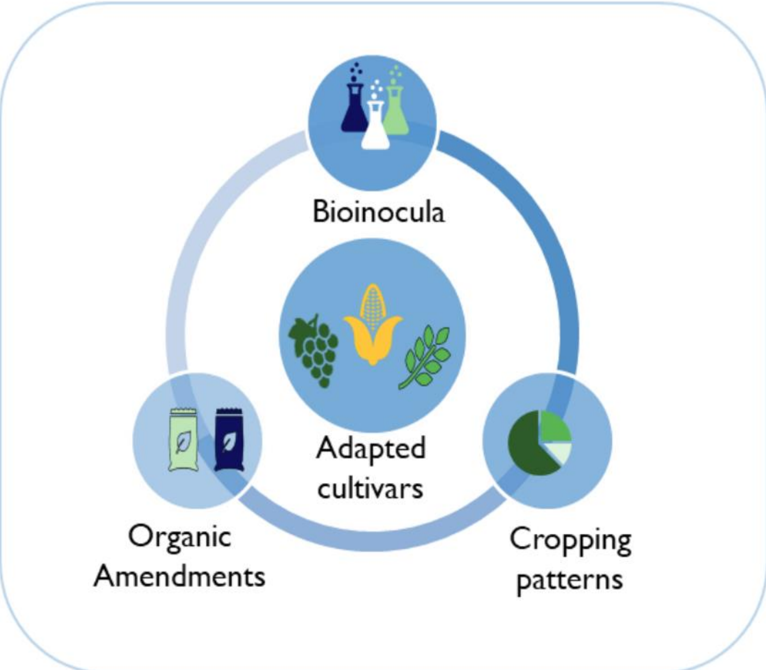
The agriculture sustainability production in the Mediterranean region is under serious threat due to climate change, soil degradation and depletion of water resources that limits crop productivity. This is worsened by poor management practices, such as the overuse of chemical fertilizers, pesticides, overgrazing and monoculture farming. This has led to adverse effects such as groundwater pollution and destruction of microorganisms, in addition to the vulnerability of plants to disease attacks. Therefore, new and more effective alternatives that preserve and improve the quality and fertility of agricultural lands is needed. Designing an agricultural systems favoring sustainable and resilient agriculture, using biotechnological tools will allow farming systems to withstand extreme climatic events while increasing crops' growth and soil health by improving the below and aboveground biodiversity, fertility, and water conservation.

Objectives



(Hartman et al., 2022)

Strategy



In the Mediterranean region, different agro-ecosystems with local key crops (**vineyard**, **maize** and **aromatic/medicinal plants**) are studied under field conditions to help improve crop resilience, yield, water conservation and soil health.

Identify obstacles and opportunities encountered by farmers on target crops through questionnaires, interviews and workshops with farmers and farmers' associations.

Identify solutions to increase crop production in a sustainable way while ensuring farmer's incomes

Expected impacts

IMPACTS: Redesigned farming systems with improved resilience capacity

Provision of ecossystems services	Sustainable and resilient farming	Preservation of natural resources	Social and Economic development
- Increase of soils' health, fertility and functions	- Climate change adaptation - Resilient agroecossystems	- Water conservation - Increase of biodiversity	- Increase farmers' income and satisfaction - Stakeholders' Networks

Improvement of crop yields and soil health in Mediterranean agro-ecosystems

Vineyards:
- Mulching

SPAIN

Maize crops:
- Organic vs Conventional
- Crop rotation

TUNISIA

MOROCCO

Aromatic/medicinal crops:
- Intercropping with legumes
- Intercropping with olive trees
- Intercropping with legumes and olives trees

Aromatic/medicinal crop:
- **Bioinoculants**
- **Organic amendement**
- **Intercropping**

EGYPT

Maize crops:
- Intercropping
- Composted biochar
- Effective microorganisms
- Antioxidant foliar application

FRANCE

Vineyards:
- Natural cover crop all year long
- Natural cover crop in winter
- Seeded cover crop in winter

PORTUGAL

Vineyards:
- Bioinoculant

ITALY

Vineyards and aromatic/medicinal crops:
- Bioinoculation
- Compost

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