Tackling Agriculture Plastics for a Circular Future

Semi-quantitative analysis of polyethylene in paddy soil by ATR-IR

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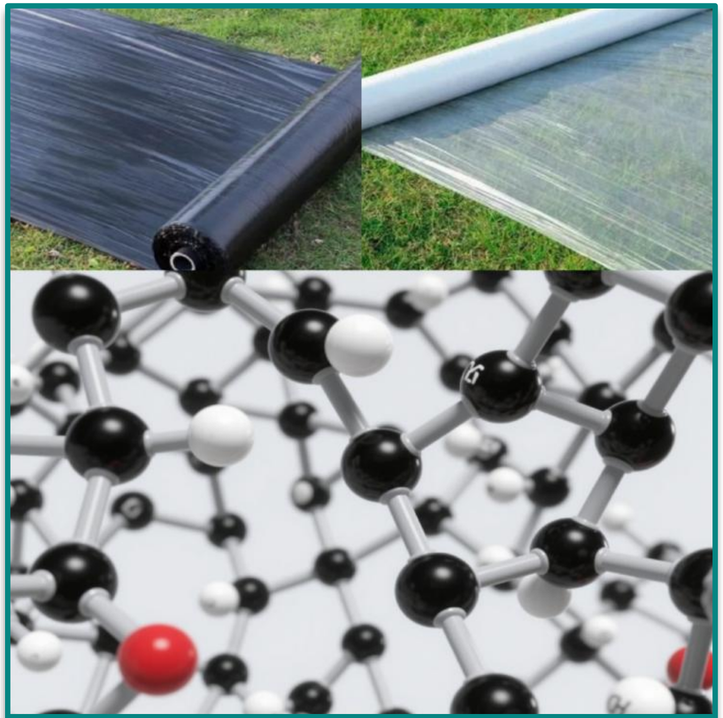
01 Rice mulching film

The utilization of PE plastic mulch film in paddy fields

Improving rice yield

The average rice yield could increase by nearly 2% (Gao et al., 2023)



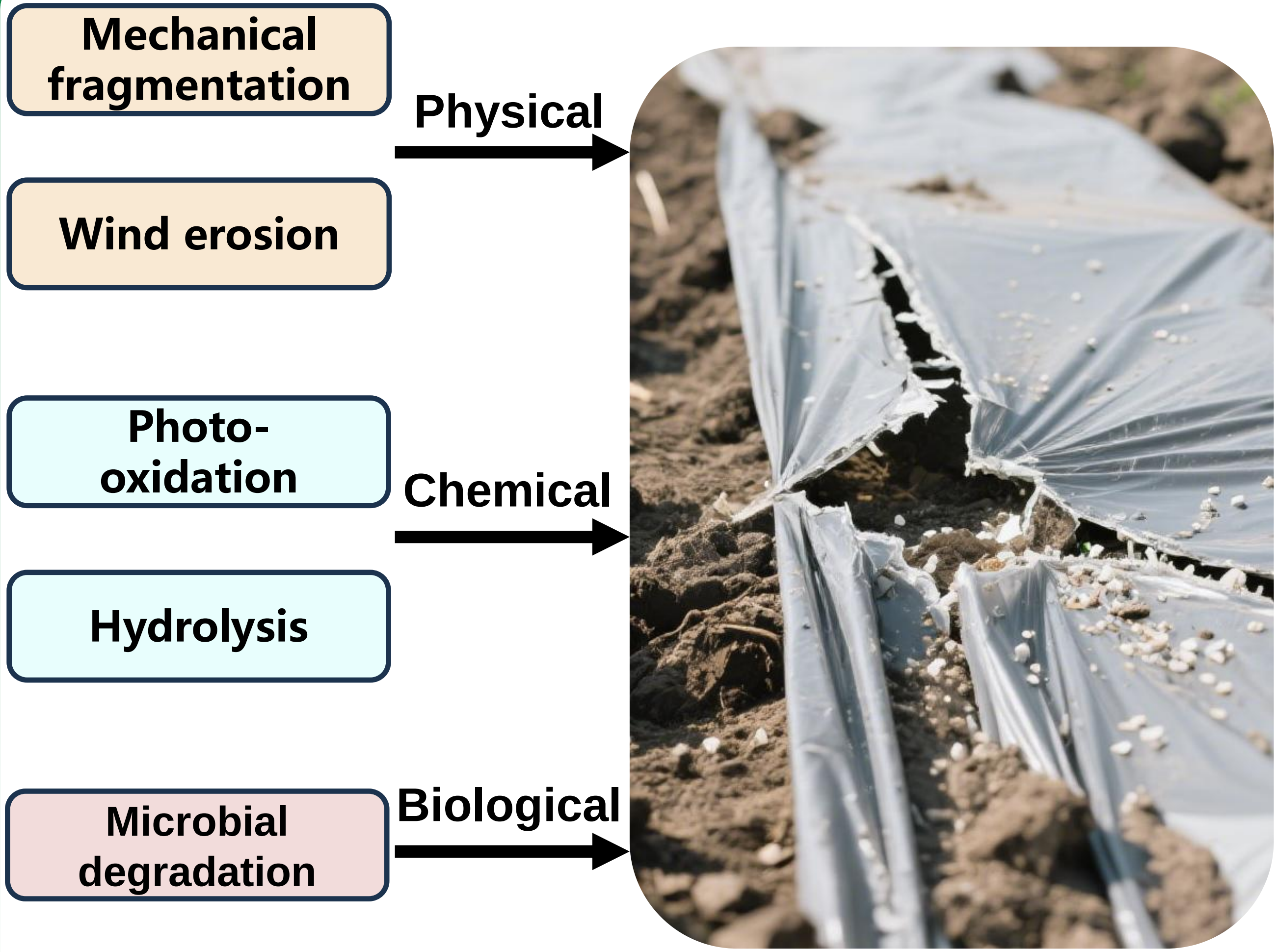
High strength and low cost

Nearly 30% of demand for plastic polymers (Qiang et al., 2023)

Worldwide increasing utilization

Global plastic mulch demand grows ~5% (Sintim et al., 2017)

Microplastics remained in paddy fields



➢ The formation mechanism of microplastics

Negative impacts

- Soil structure degradation
- Microbial diversity loss
- Rice yield reduction
- Heavy metal & toxin mobilization

Microplastic pollution situation

- High abundance of microplastics in soil

Over 4000 items·kg^{-1} average abundance (Ren et al., 2023)

- Spatially uneven distribution

Uneven vertical and horizontal distribution (Bo et al., 2023)

02 Microplastics detection

Common methods for microplastic detection

Detection Technology

Physical methods

- Optical microscope
- Scanning electron microscope (SEM)

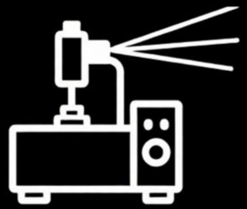
> ➢ **Low accuracy**
> ➢ **Sample-damaging**

Spectrum technology

- Fourier Transform Infrared Spectroscopy (FTIR)
- Raman spectroscopy

> ➢ **Non-destructive**
> ➢ **Rapid detection**

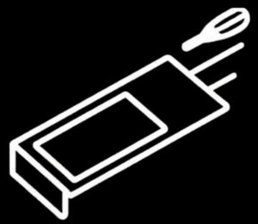
Thermal analysis



- Pyrolysis - Gas chromatography-Mass spectrometry (Py-GC/MS)

> ➢ **Destructive**
> ➢ **complex process**

Emerging Technologies

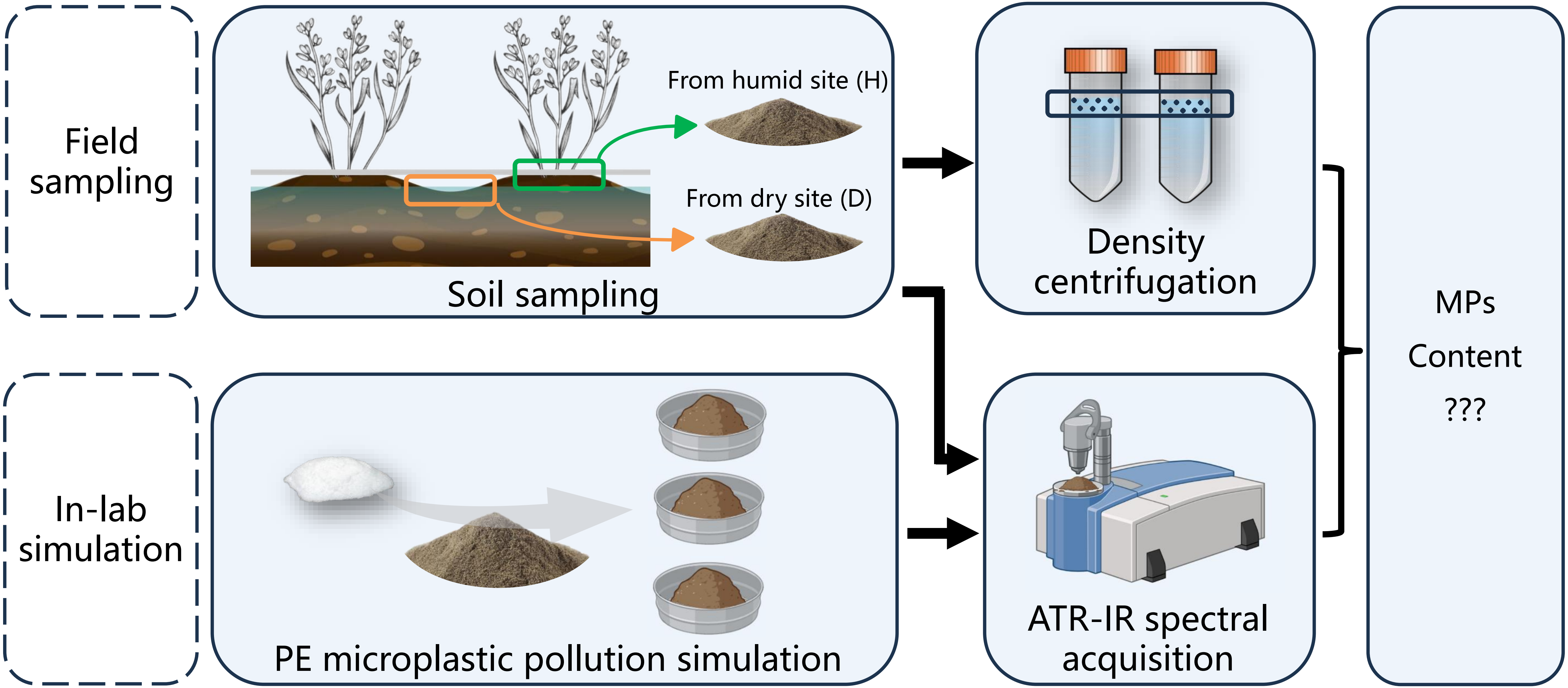


- Laser-induced Breakdown spectroscopy (LIBS)
- Microfluidic technology

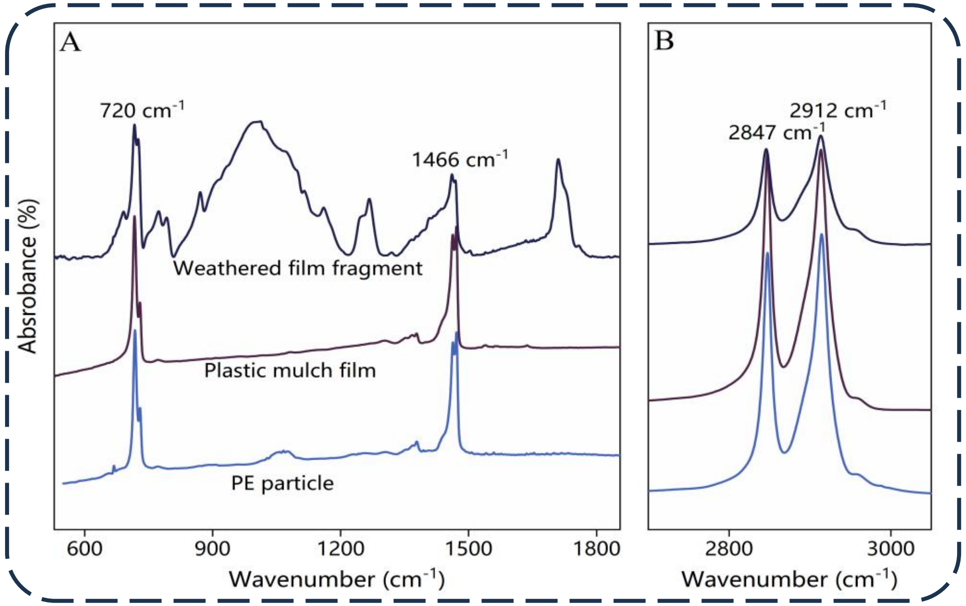
> ➢ **Low resolution**
> ➢ **Fluorescent labeling**

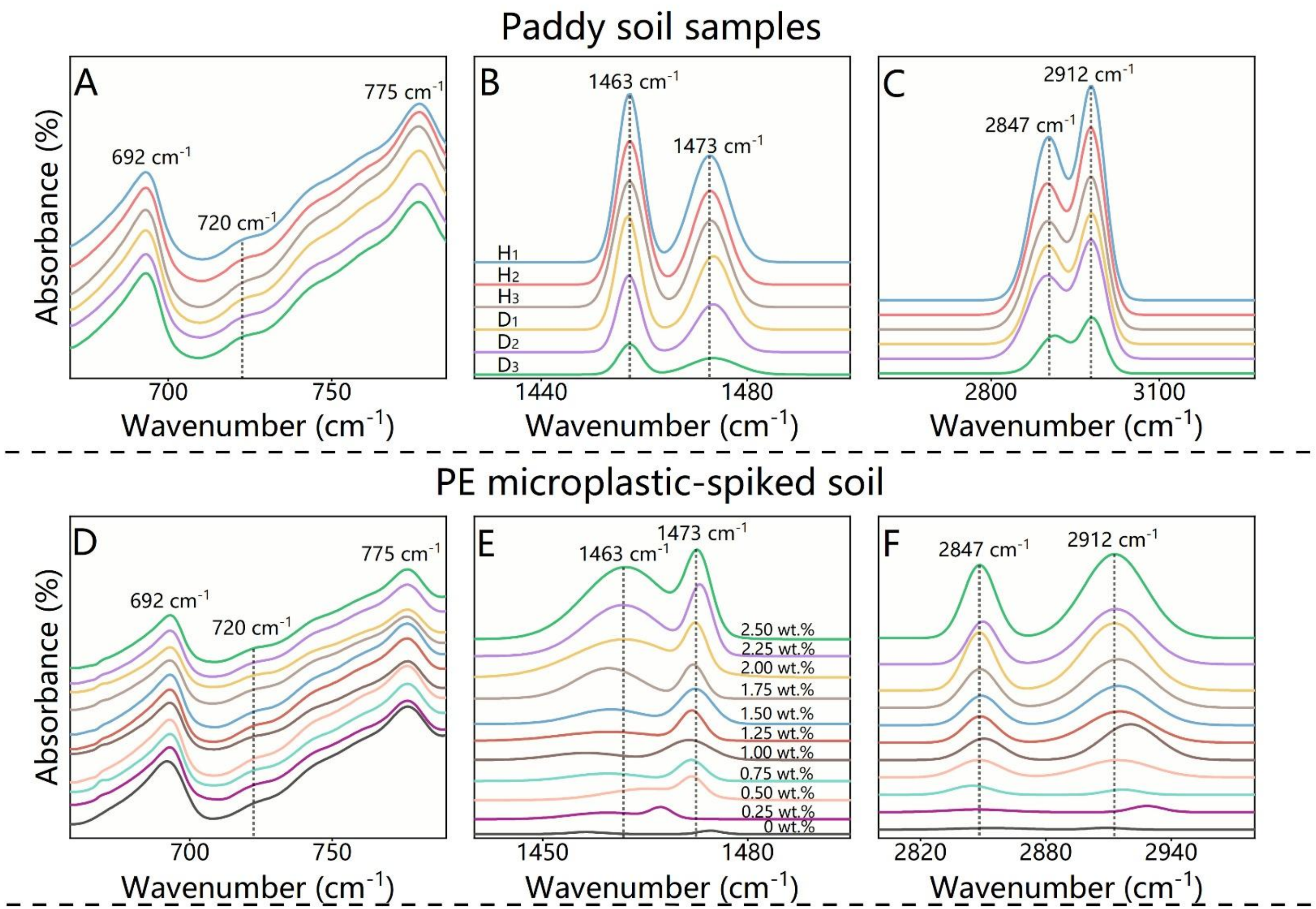
03 In-lab simulation

Experimental process



ATR-IR spectra





PE characteristic ATR-IR absorption bands

720 cm^{-1}	$-CH_2-$ rocking vibration
1466 cm^{-1}	$-CH_2-$ bending deformation
2847 cm^{-1}	$-CH_2-$ symmetric stretching
2912 cm^{-1}	$-CH_2-$ asymmetric stretching

PE microplastic could be qualitatively evaluated in soil by IR spectroscopy.

PE microplastic content analysis

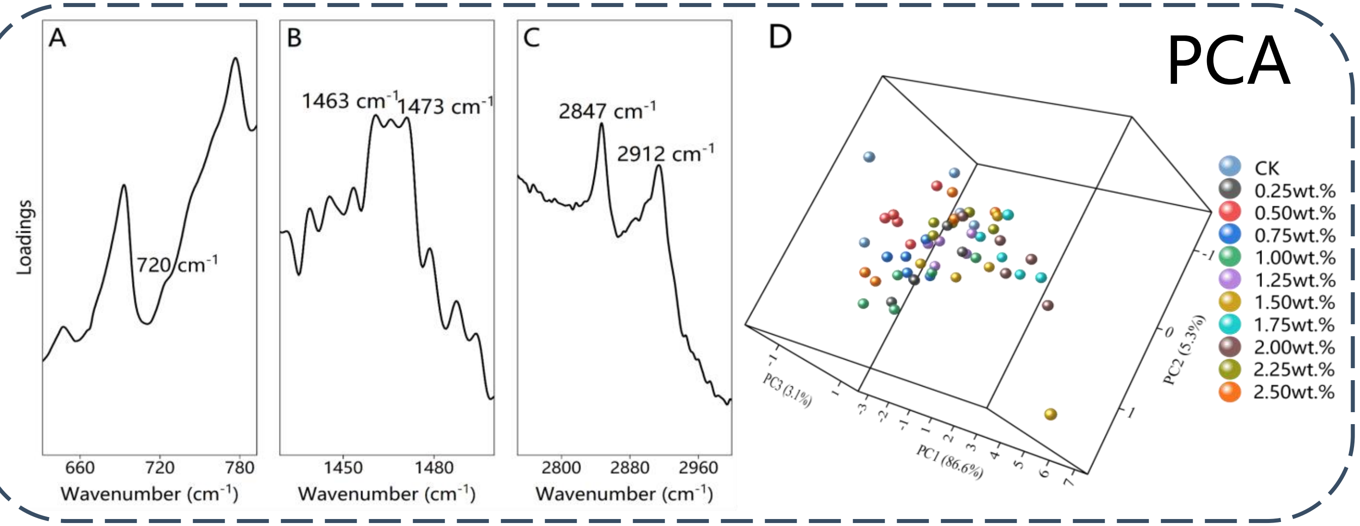
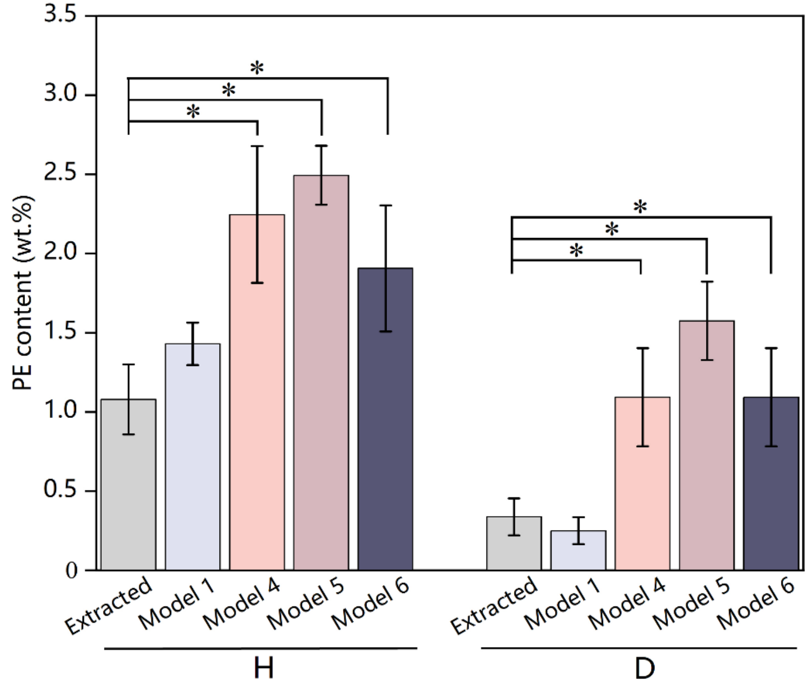


Table. Relationship between PE microplastic concentrations and intensities of different peaks.

Model	Wavenumber (cm^{-1})	R^2	RMSE (wt.%)
1	1466	0.98	0.94
2	1463	0.68	1.87
3	1473	0.52	1.18
4	2847+2912	0.80	1.08
5	2847	0.75	1.14
6	2912	0.79	1.09

Predicted content vs extracted content



- PE microplastic content:
  humid sites > dry sites
- Semi-quantification was possible
- Slight overestimation

04 Perspectives

Perspectives

Practical Applications

- Developing PE contamination screening tools for paddy field
- Link detection results to mulch recovery standards

Ecological Risk Assessment

- Investigating the aging behavior of PE in paddy soils
- Evaluate the combined pollution effect of PE with pesticides/heavy metals

Interdisciplinary Integration

- Track the migration of microplastics in combination with isotope labeling
- Soil remediation agents for microplastic-contaminated soil

Fungi promote the degradation of agricultural films

- Screening of high-efficiency degrading fungi
- Mechanisms of fungal degradation of agricultural films
- Factors influencing degradation efficiency

Perspectives

Fungal candidates： Aspergillus spp., Penicillium spp., Phanerochaete spp., and Trametes spp.

- （Nearly 95% degradation efficiency within three months） (Gao et al., 2022)

Biodegradation mechanism

Microorganisms

↓

Secretion of extracellular enzymes

↓

Adherence of enzymes to the polymer surface

↓

Cleavage of polymer chains

↓

Biodegradation
End products CO_2, H_2O, CH_4 are produced

The application of biodegradable mulching film

Fields in Fujian Province (2022)

Fields in Hainan Province (2023)

The high cost of biodegradable agricultural films hinders widespread adoption

Future research directions

- Screening of crop-safe natural microbial strains for non-biodegradable plastics (e.g., polyethylene)
- Enhancement of plastic film degradation efficiency through genetic engineering approaches

Tackling Agriculture Plastics for a Circular Future

Thanks

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Tackling Agriculture Plastics for a Circular Future – Webinar

An Overview of problems and potential solutions

17 June 2025

Ravinder Kumar, Hans Dobson, Adrienne Martin

UNIVERSITY OF GREENWICH

Natural Resources Institute

Trend in production and use of plastic for different uses in agriculture (1)

- In agricultural food systems – use of plastics is widely prevalent:
  - **Protective cultivation films** (greenhouses, high/low tunnels, plastic film placed on top of soil aka mulching, nursery films, direct covering and covering vineyards and orchards,
  - **Nets** (anti-hail, anti-bird, wind-breaking, shading)
  - **Piping, irrigation/ drainage** (water reservoir, channel lining, irrigation tapes and pipes, drainage pipes, micro-irrigation, drippers)
  - **Packaging** (fertiliser sacks, agrochemical cans, containers, tanks for liquid storage, crates)
  - **Polymer coated seeds and fertiliser**
  - **Other (silage films**, fumigation films, bale twines, bale wraps, nursery pots, strings and ropes, boxes, fittings, spray cones, tapes)
  - **Fishing gears and other plastics use in aquaculture, fisheries**, **plant protectors** (tree guards etc.) in agriculture and forestry
  - **Unintentionally added** (compost, sludge/ slurry).
- It is beneficial as plastic products enable better management of agriculture production, increasing yield, crop protection and reducing the use of inputs and irrigation

Trend in production and use of plastic for different uses in agriculture (2)

- Approximately **12.5 million tonnes annually of plastic products are used in agricultural applications annually** (FAO, 2018 estimates)
- The vegetable, fruit, crop, and livestock sectors are the largest users (10 m) followed by fisheries and aquaculture, then forestry. Asian countries consume almost half of global usage of plastics in agriculture
- **Europe: ~1 million tonnes annually**
- Each European country and UK: In the range of 25,000 to 50,000 tonnes annually
- Quantum of plastics used in agriculture is expected to increase by 50% by 2030

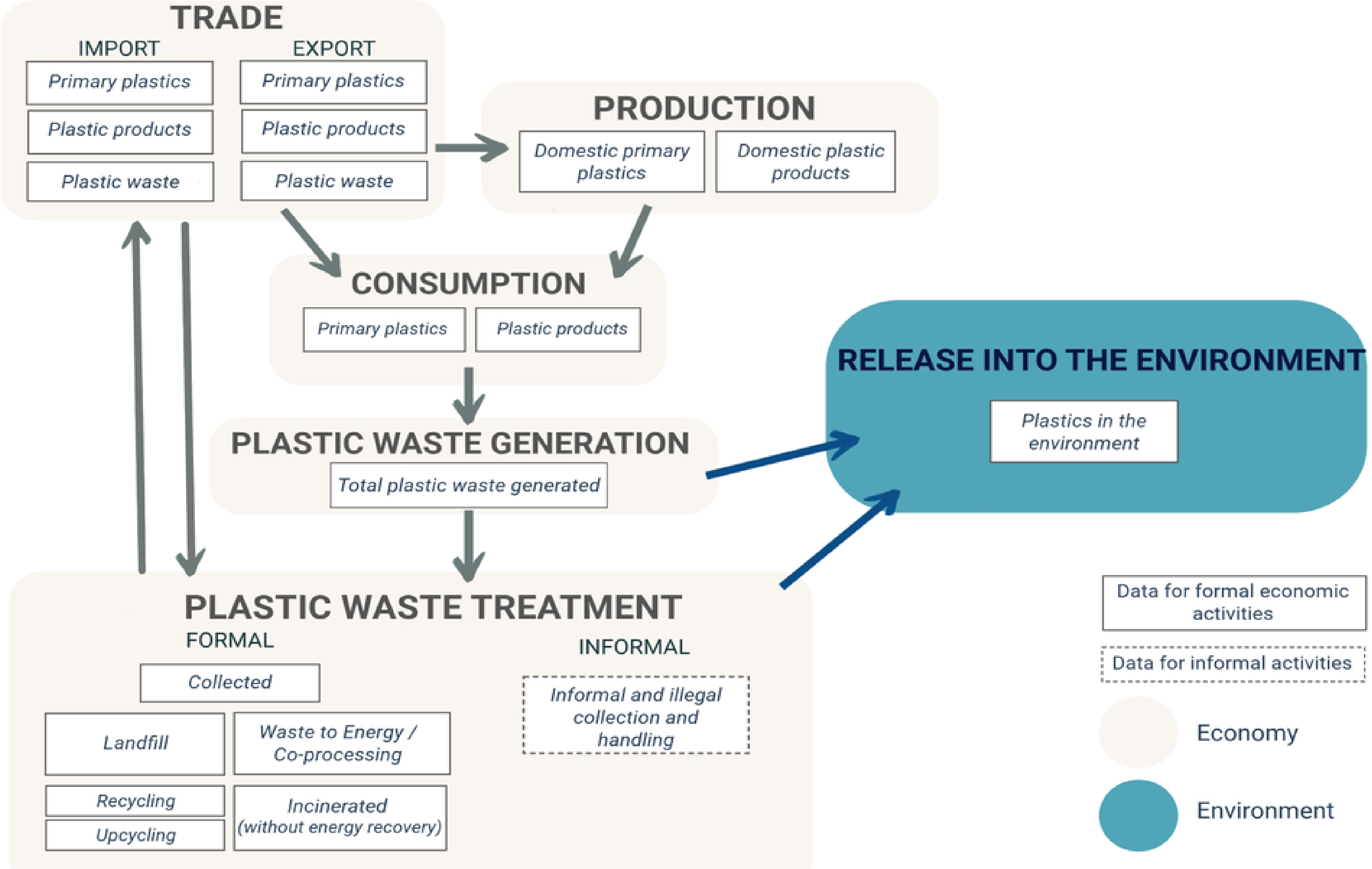
Micro plastic accumulation

- **Most agriculture plastics is single use and can persist in the environment (soil, air, water) after being used, damaged, degraded or discarded**
- EU PAPILLONS Horizon2020 data (70 soils across Europe, covering seven countries): 0.1% in mass. Some soils heavily contaminated through atmospheric fallout (e.g. proximity to industrial sites).
- A recent study in the UK estimated that the microplastic content of biosolids (3.5 million tonnes) could result in the equivalent of more than 20,000 bank cards worth of plastic being potentially applied to agricultural lands every month
- **It is no wonder that the soils are estimated to have more microplastics than oceans**

Economic, Human health and environmental impact of plastics

- **MPs reduce photosynthesis by 7.05–12.12%,** mostly by lowering chlorophyll content
- Accumulation of micro plastics in soil **reduces seed germination and plant growth** (through reduced chlorophyl content)
- Crops and organisms uptake plastics and chemicals from soil and store them in edible parts
- **Plastic resins (Phthalates, bisphenols etc) contain toxic additives having endocrine disruptive properties**
- Without solutions adopted at large scale, life-cycle GHG emissions from plastics would reach 15% of the global carbon budget by 2050

Availability of site-specific data on plastic pollution? Data on environmental, economic and health impact of agricultural plastic? (1)



Data-driven solutions: the Plastics Data Checklist

- The extent and severity of the problem in different hotspots /type of agriculture production (commercial horticulture, commercial plantations, small holder agriculture, different cropping systems etc.) is not known
- There are significant data gaps on the pathways and impacts of plastics and their alternatives (including biodegradable plastic) on human and ecosystem health.

Availability of site-specific data on plastic pollution? Data on environmental, economic and health impact of agricultural plastic? (2)

- **Countries are not publishing data** related to plastics production, consumption, trade and waste generation. These data gaps hinder the ability to establish meaningful national action plans, track progress, identify effective interventions, and allocate resources efficiently.
- Cumulative and interactive effects (plastics, pesticides, heavy metals, other chemical additives) over multiple growing season require further research
- **Global estimates about the quantity of agricultural plastics recycled are not available**, with only a few countries (mainly OECD) providing data
- **Chemicals – need concrete toxicity data** to evaluate the impacts including endocrine-disrupting possibilities.

Are there ‘collection systems’ in operation?

- **Only a small portion of waste generated is collected or recycled**, the rest of the plastic waste is found scattered in terrestrial and aquatic environments endangering flora and fauna, including human health through the food chain
- There are **several good practices in European countries** related to agriculture plastics collection and recycling systems (France, Finland, Ireland, and to some extent in UK etc.). In France (an exemplar), In 2023, 97,000 tonnes of plastic waste (film, packaging, twine and netting) were collected, representing an average collection rate of 79%, over 90% of which was recycled
- **EPR schemes /regulation effectively designed and enforced** in some countries (Canada, New Zealand, Norway, France, UK and other countries)

Lack of or inadequate ‘recyclability’ thinking in most product designs?

- **Less than 10 per cent of plastic waste as a whole was recycled** in 2019 globally (OECD estimate)
- Improving recycling rates of retrievable plastic is happening mainly in European countries, and to some extent in India and Vietnam but much more is needed to achieve >90% recycling
- **High thickness and high strength mulching films >20μm** (not easily broken, and have high recycling efficiency (China and EU standard EN 13655);
- **Design of an effective system for managing plastic waste flow can increase recycling opportunities** and sustainability. For instance, introduction of intermediate collection centres significantly improves efficiency
  - One study estimates that the system reduces waste transport distance by 62% and lowers Co2 emissions by 20% compared to direct farm-to-recycling transport
- This would obviously require **more finance /investments in R&D**

Economically viable /cost effective and scalable alternatives to agricultural plastic?

- **The uptake of potential agricultural plastic alternatives is not without environmental or human health issues**
  - Whether it be the use of biodegradable plastics or increased use of organic fertiliser derived from sludge over petrochemical-derived synthetics
- E.g., Oxo-degradable plastics are said to be degradable polymers. However, it has been clearly established these low-density polyethylene (LDPE) with additives undergo low or no degradation by microorganisms and do not meet biodegradation requirements as outlined in current biodegradable mulch standards
- **In many cases, requirement of bio-degradability (temp, humidity, etc.) would require industrial composting infrastructure**, rather than conventional farm /field conditions
- Scaling up would require business models /business case for investments as well as more **financial support to innovators /businesses**

Inadequate regulation and standards for plastics (including problematic polymers) used in agriculture and food systems?

- **No overarching international policy or legislative instrument** that addresses all aspects of the use of plastics in agrifood value chains and throughout their lifecycle
- **Ban on single use plastics** (in several countries including in FARM countries, however, except a few, enforcement is a major challenge);
- Some products with a high potential for pollution, such as mulching films (EU standard EN 13655 >20μm) and polymer coated fertilizer, are beginning to receive attention from policymakers and regulators (China, EU).
- In the UK, current Sludge (Use in Agriculture) Regulations (SUiAR) do not control new hazards, including microplastics
- FAO has developed a soft-law instrument (2021), a voluntary code of conduct (VCoC) for the sustainable management of agricultural plastics - guidelines for governments and the private sector on the sustainable use of agricultural plastics.

Do standards exist for biodegradable and recyclable products?

- **EU's soil monitoring directive** - a series of amendments are being brought about, which include:
  - Monitoring of microplastics presence in soil
  - Plastic chemical additives
  - Low plastic content certification for biofertilisers
- **Biodegradable mulch standards are lacking** (laboratory testing does not infer biodegradability in real-world conditions, micro- and nano-plastic residue determination not required, additional toxic adsorption concerns)
- Supportive regulation and voluntary /mandatory EPR schemes would be needed in developing economies

Tackling Agriculture Plastics for a Circular Future

Webinar – 17 June 2025

Designing Successful EPR Schemes for Agri-Plastics: Insights from 20 Years of Practice

Pierre de Lépinau, Agricultural Plastics and EPR Expert

Office of Climate Change, Biodiversity and Environment

Food and Agriculture Organization of the United Nations

FRANCE : KEY FIGURES ON AGRI-PLASTIC MANAGEMENT

125.000 t of Agri- Plastic (Products + packaging) placed on the market annually

Main User Groups :

- 300.000 farmers
- Livestock growers : silage wrap, nets, twines
- Horticultural farmers : mulching films, tunnels, greenhouses covers, nets

Program Milestones:

2001: Launch of Voluntary initiative (pesticide packaging)

2005-2025: Scope expanded to all plastic packaging and products used in primary agriculture

2010-2025 : Development of additional recycling infrastructure and capacity

2020-2025 : Promotion of Eco-design and increased incorporation of Recycled Content

2024 key Indicators :

- 8 000 drop off stations
- 25 Waste Streams managed separately
- 79% collection rate (on average)- 90% of collected plastics recycled

KEY SUCCESS FACTORS (LOW SENSIBILITY TO LOCAL CONDITIONS)

Pilot Experiences
Farmers Good Practices
Collection Operational Procedures
Cost Estimates

Brand Owners Leadership
Alignment with Stewardship Commitments
Technical knowhow (packaging for hazardous goods, close loop recycling systems)

Farmers Involvement :
- Active Participation in Governance
- Multistakeholder dialogue across each agri value chains (milk, fruits, vegetables, meat, etc)

Cost Coverage
- Transport
- (Recycling)

Collection Network design
- Local drop-off stations for small and medium-sized farms
- On-farm collection or direct Recycling Plant Delivery systems for large farms

KEY SUCCESS FACTORS (DEPENDENT ON LOCAL CONTEXT)

Mandatory EPR Requirements from the National Authorities:
- Ministry of the Environment
- Ministry of Agriculture

Recovery Pathways aligned with local Waste Regulation
- Classification
- Transport
- Storage
- Final treatment : Recovery (Landfilling, Incineration) vs recycling

Partners for collection
- Distributors
- Municipalities
- Waste Company
- Recyclers

Cross Compliance Requirements
- Certification Programs
- European Policy

Pierre de Lépinau- Agricultural Plastics and EPR Expert;
Role of Private Sector in Sustainable Management of Agricultural Plastics

STILL UNDER DEVELOPMENT

European Harmonized Data base
- Currently developed by the EPRO Agricultural Plastic Working Group (1) and the APE Association (2)

Packaging Waste Regulation
- Entered into force : February 2025
- Included Agri-Plastic Packaging.
- 2025-2030 : implementation of delegated Acts and Compliance Measures.

EU EPR Regulation framework for non packaging Agricultural Plastics
- 2025-2026 : Impact Assessment Study led by DG ENVI.
- 2026-2027 : Drafting & Public Consultation Phase.
- 2028-2029 : Potential Entry into force (to be confirmed)

(1) https://epro-plasticscircularity.org/agricultural-plastics/;
(2) https://apeeurope.eu/

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References :

- www.adivalor.fr
- *"Conventional and Biodegradable Plastics in Agriculture"*, 2021, Eunomia

THANK YOU FOR YOUR ATTENTION

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Food and Agriculture Organization of the United Nations