Agricultural plastics as source of microplastic pollution to soil ecosystems and crops

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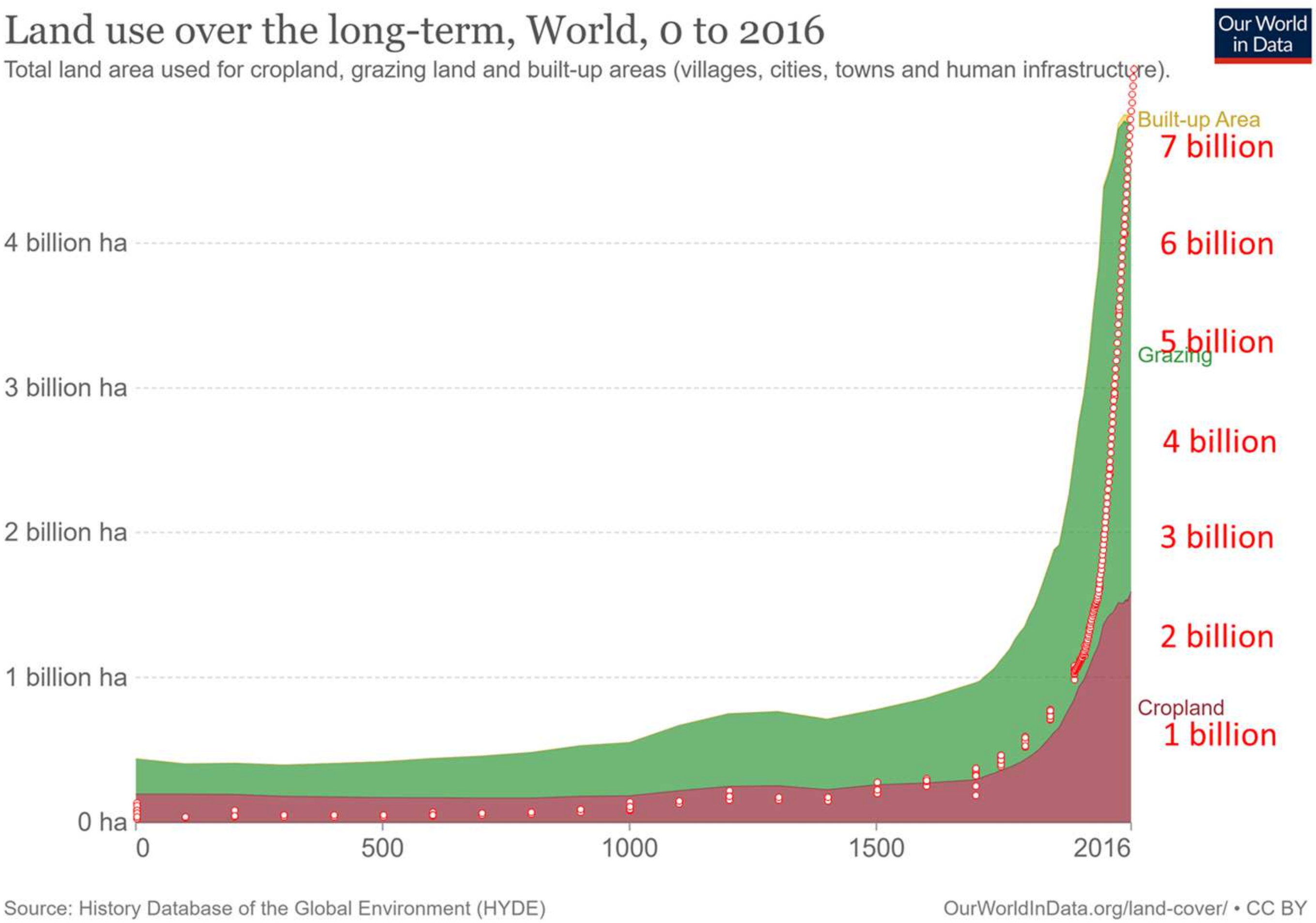
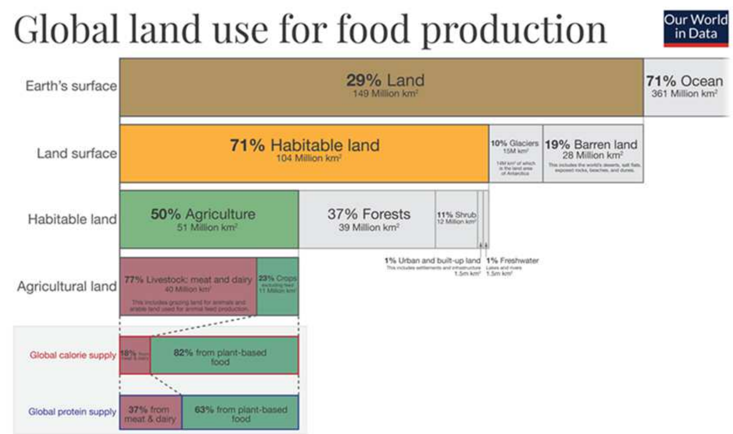
Norwegian Institute for Water Research



Land use over the long-term, World, 0 to 2016
Total land area used for cropland, grazing land and built-up areas (villages, cities, towns and human infrastructure).
Our World in Data
Built-up Area
Grazing
Cropland
7 billion
6 billion
5 billion
4 billion
3 billion
2 billion
1 billion
4 billion ha
3 billion ha
2 billion ha
1 billion ha
0 ha
0
500
1000
1500
2016
Source: History Database of the Global Environment (HYDE)
OurWorldInData.org/land-cover/ • CC BY



Global land use for food production
Our World in Data
Earth's surface
29% Land
149 Million km²
71% Ocean
361 Million km²
Land surface
71% Habitable land
104 Million km²
10% Glaciers
15M km²
19% Barren land
28 Million km²
Habitable land
50% Agriculture
51 Million km²
37% Forests
39 Million km²
11% Shrub
12 Million km²
1% Urban and built-up land
1.5m km²
1% Freshwater
1.5m km²
Agricultural land
77% Livestock: meat and dairy
40 Million km²
23% Crops
11 Million km²
Global calorie supply
18%
82% from plant-based food
Global protein supply
37% from meat & dairy
63% from plant-based food











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3.5% of total plastic produced is used in agriculture

3 Million tonnes AP in use
1 million tonnes/year

12.3 Million tonnes in use
5 million tonnes/year

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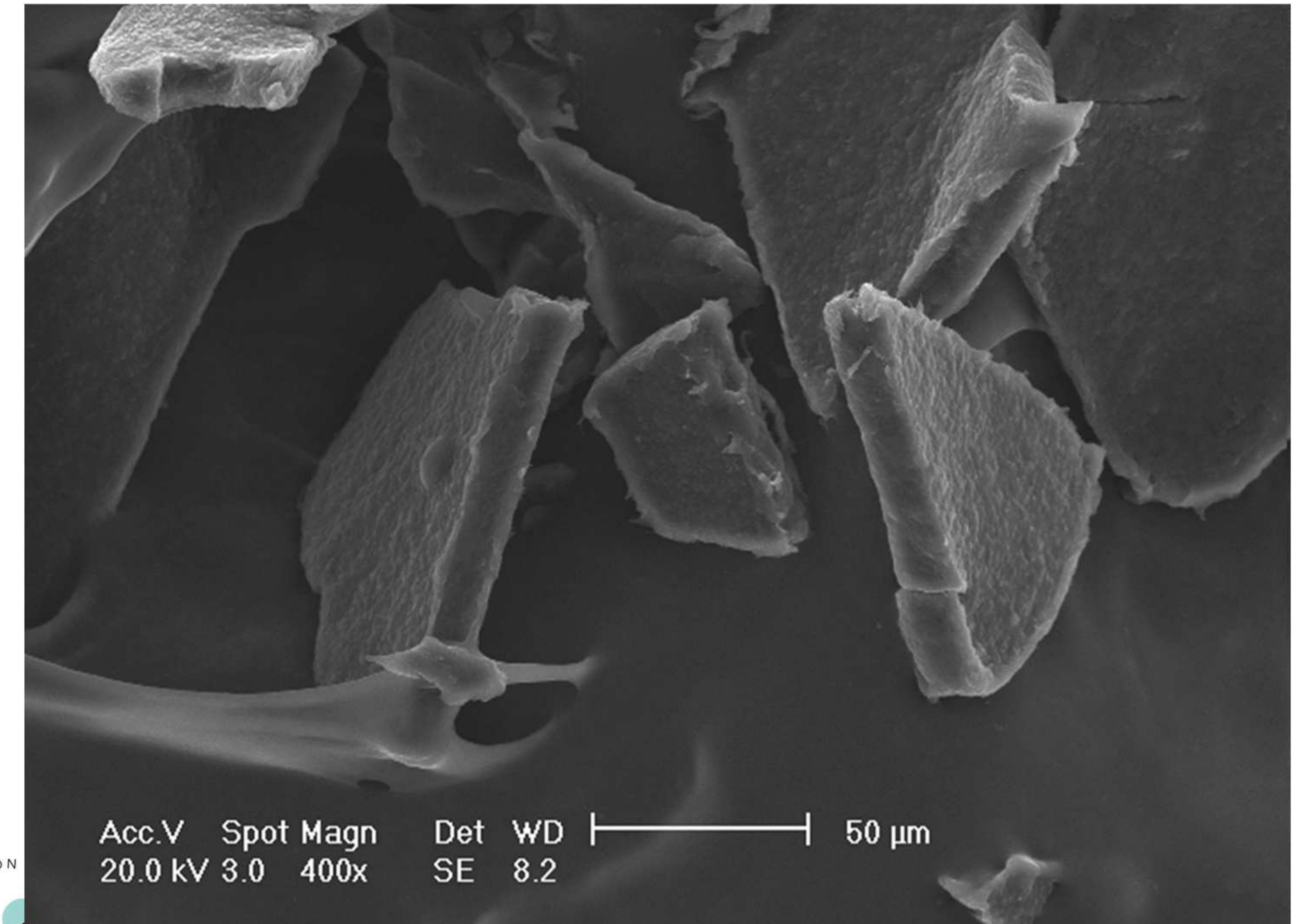
Sources: Briassoulis et al. 2013, Hann et al., EUNOMIA, 2021, FAO, 2021



Source: NIVA/Davide Spanu (Univ. Insubria)

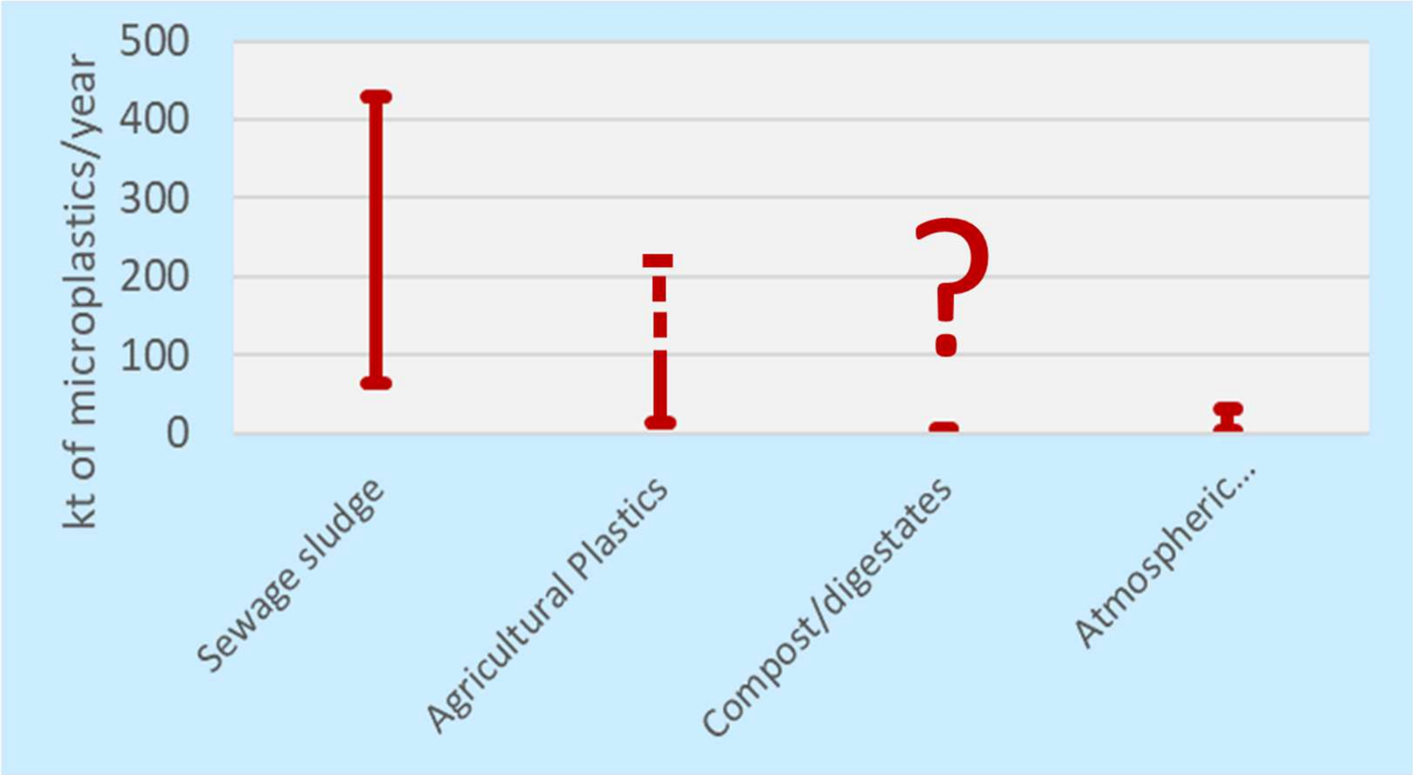
Source: JianPing, LiaoNing

Source: Agricultural University of Athens


Source: Plastic Soup


Source: FarmingUK

Sources of plastic to agricultural soil in Europe: first-tier estimates



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Elaborated based on the following sources: Nizzetto et al. 2016, van Schothorst et al. 2021, Eurostat, Brandes et al. 2021, Weithman et al. 2018, EUNOMIA 2021, Roblin et al 2020

Effects on soil properties by conventional MNPs

Physical

Decrease in soil aggregation and aggregate size and stability
(de Souza Machado et al., 2018; Lozano et al., 2021)

Increase in soil evaporation rate and surface desiccation (Wan et al., 2019)

Chemical

Increase in soil pH (Zhao et al., 2021)

Decrease in nutrient availability (Rong et al., 2021)

Biological

Effects on soil microbial community structure and functioning
(Wang et al., 2020; Hou et al., 2021)

Impacts on soil enzymatic activity (Huang et al., 2019; Zhao et al., 2021)

→Variable responses reported in studies: indicates level of complexity), including some studies reporting potential positive effects

→Missing information on indirect ecosystem effects ow changes in soil properties propagate across (de Souza Machado et al., 2019)

→Safety and resiience thresholds not yet identified

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Interactions and effects on soil organisms

Decrease in the number of individuals, diversity, mobility and reproduction
(for review: Wei et al. 2022)

Increase in mortality, but no changes in biomass of soil biota
(for review: Wei et al. 2022)

Negative, positive and no-effects depending on the exposed species and the type, shape, size and concentration of the MP
(Selonen et al. 2020; Reviews by Li et al. 2020; Wei et al. 2022; Seidenath et al. 2021; Ji et al. 2021)

Vertical and horizontal transportation of MPs by soil fauna
(Huerta Lwanga et al. 2017a, Maass et al. 2017; Zhu et al. 2018; Rillig et al. 2017; Reviews by Li et al. 2020, Xu et al. 2020 ; Yang et al. 2021)

Ingestion by soil invertebrates → Potential transportation to aboveground and food web
(Huerta Lwanga et al. 2017b; Rillig et al. 2017; Selonen et al. 2020; Reviews by Yang et al. 2021; Zhu et al. 2018)

Interactions and effects on soil organisms

Research on the effects of MNPs on terrestrial plants – limited, but increasing rapidly

Effect on plant growth differ with **polymer types** (Pignatelli et al., 2020) & **MNPs shape**
(de Souza Machado et al., 2019)

Biochemical responses in plants depend on **MNPs size**
(Li et al., 2020)

The majority of studies shows interactions and effects.

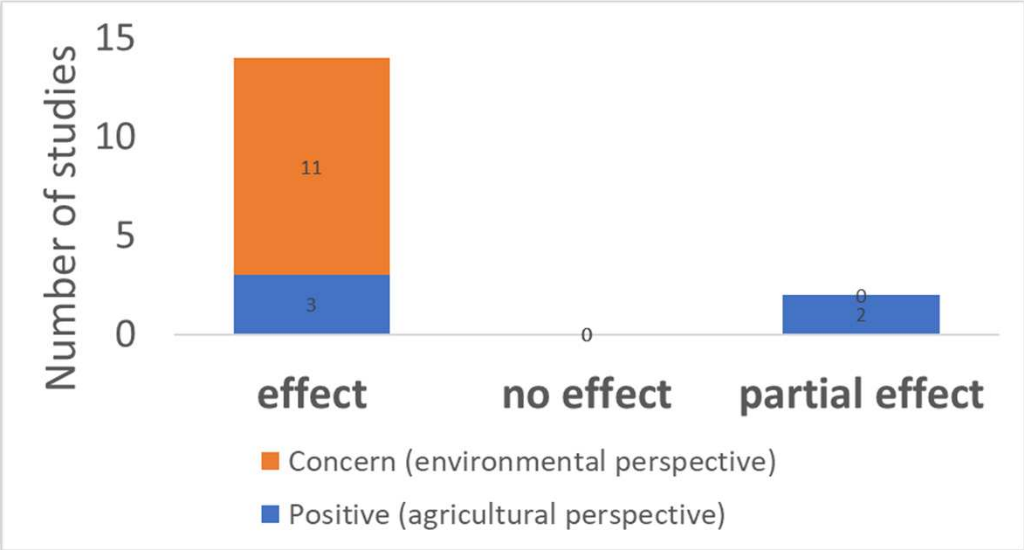
Uncertainty remains on uptake and effect of MNPs on plants, which needs to addressed

What about Biodegradable plastics?

The focus should be on the effects caused by residues over the mid-long term

Only 16 relevant studies identified

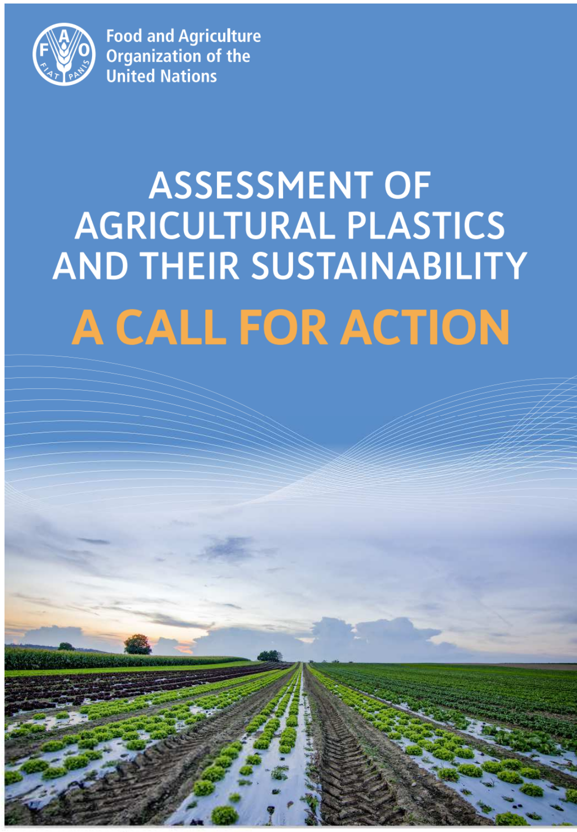
All study identified some form of effect (soil properties, microbial activity, plant performance)



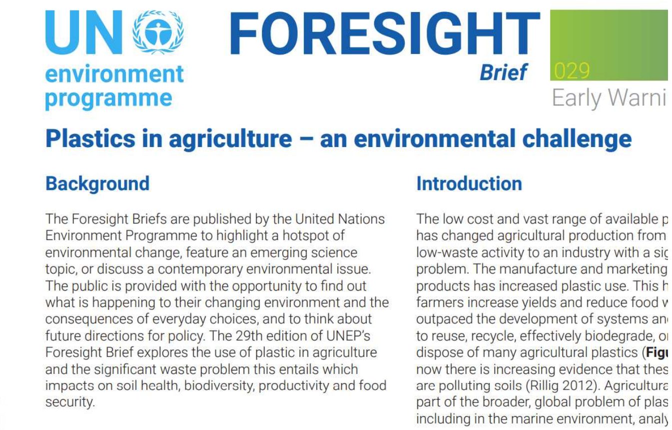
Web of Science search

Search string 1: Biodegradable Mulching film AND residue AND effect = 37 results of which 15 relevant

Search string 2: Biodegradable Mulching film AND microplastic* AND effect = 19 results of which 12 relevant



REFUSE
REDESIGN
REDUCE
REUSE
RECYCLE
RECOVER


UN environment programme
FORESIGHT Brief
029
Early Warni

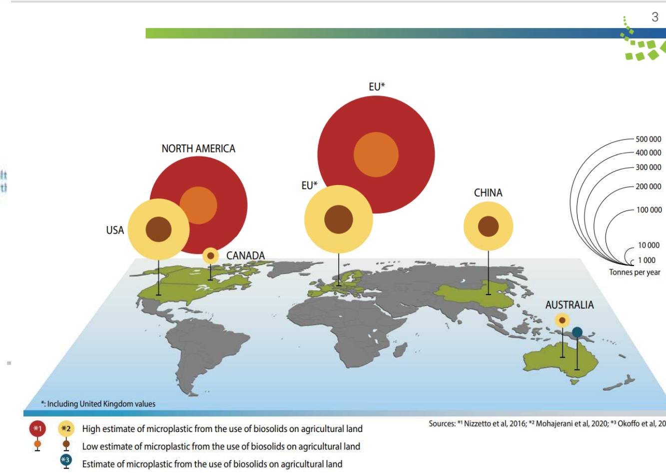
Plastics in agriculture – an environmental challenge

Background

The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 29th edition of UNEP's Foresight Brief explores the use of plastic in agriculture and the significant waste problem this entails which impacts on soil health, biodiversity, productivity and food security.

Introduction

The low cost and vast range of available p
has changed agricultural production from
low-waste activity to an industry with a sig
problem. The manufacture and marketing
products has increased plastic use. This h
farmers increase yields and reduce food w
outpaced the development of systems an
to reuse, recycle, effectively biodegrade, o
dispose of many agricultural plastics (Fig
now there is increasing evidence that thes
are polluting soils (Rillig 2012). Agricultura
part of the broader, global problem of plas
including in the marine environment, analy



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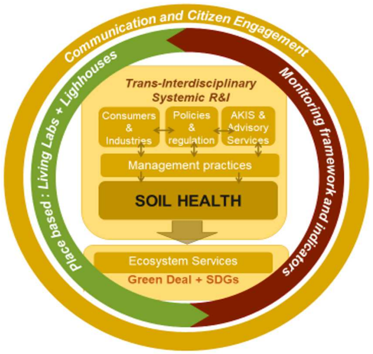
FAO. 2021. Assessment of agricultural plastics and their sustainability. A call for action. Rome. https://doi.org/10.4060/cb7856en
United Nations Environment Programme (2022). Plastics in Agriculture – An Environmental Challenge. Foresight Brief 029. Nairobi.



- Framing a “soil health certificate”(for land transaction)
- Prepare a set of sustainable soil management practices
- Restrict intentional uses of microplastics in soils (REACH)
- Adopt new biodegradability criteria for polymers used in soil

Knowledge gaps

- Poorly comparable studies
- Tested materials may not be representative of soil MNP
- Lack of adequate reference materials for testing
- Exposure scenarios often poorly representative
- Insufficient knowledge to address safety thresholds

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Plastic in Agricultural Production: Impacts, Lifecycles and LONg-term Sustainability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000210

https://www.papillons-h2020.eu/

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Physical chemical characterization and usage

- AP use and waste Inventories
- Fragmentability of AP
- Biodegradability in soil
- Chemical composition

Fate and behaviour in soil

- Runoff
- Vertical transport
- Plastic ageing in soil

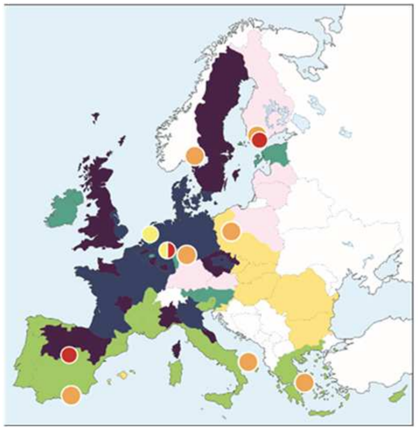
Ecological and agricultural effects

- Soil fauna
- Soil properties
- Soil nutrient cycle
- Soil microorganisms
- Plant health
- Crop production and Agricultural sustainability

PAPILLONS Goals

- Inspire innovation in the agenda of farmers, industry and policy to reduce/control the risk of MNP from agricultural plastics
- Enable characterization of ecological risk in soil
- Assess effects on agriculture

Inventories of agroplastic uses and pollution sources



European surveys of soil plastic pollution

Laboratory-scale experiments

Field-scale experiments

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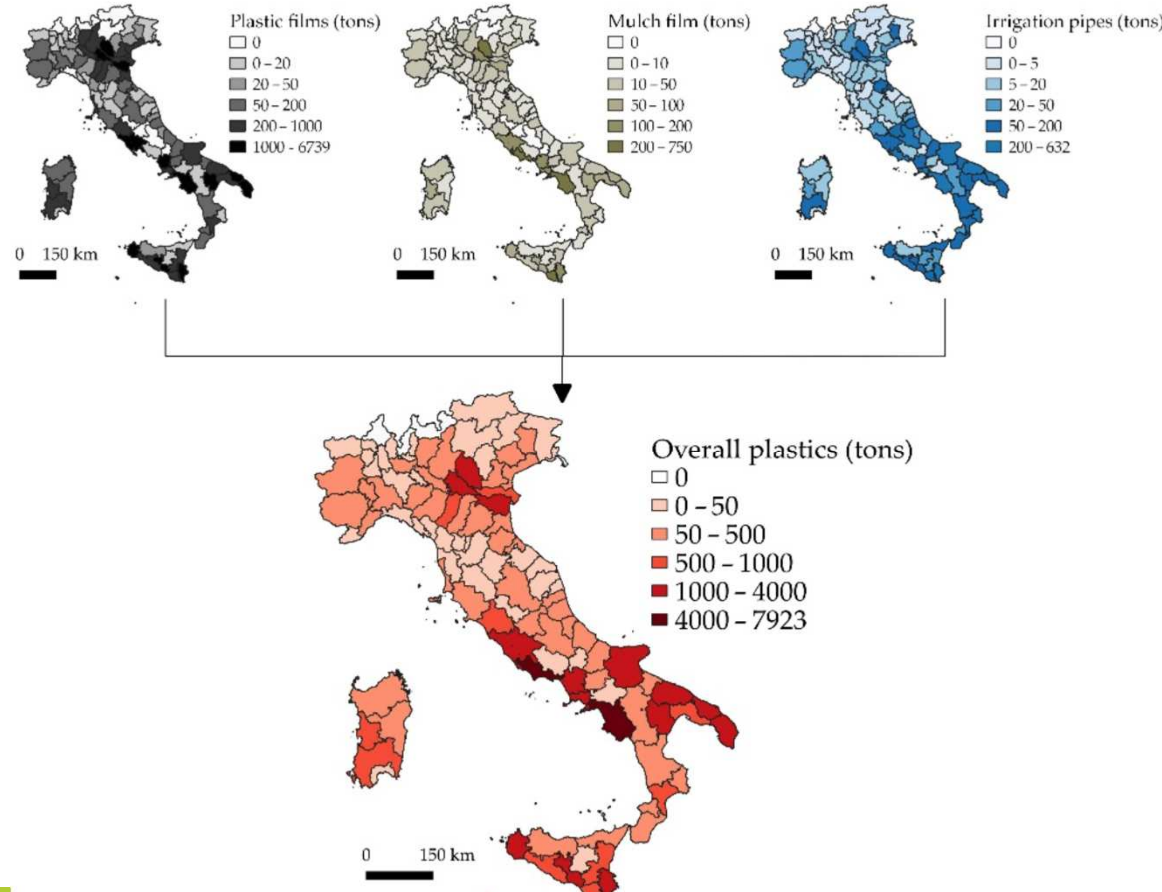
European agricultural plastic inventories

Usage
Waste generation
Potential for soil pollution
Fragmentability
Degradability

Foto: SYKE



Cillis et al. Implementing a GIS-Based Digital Atlas of Agricultural Plastics to Reduce Their Environmental Footprint; Part I: A Deductive Approach. Applied Sciences, 2022, 12 (3), 1330.

Laboratory studies with artificially generated particles from agrocultural plastics

Fate and behaviour
Long-term effects on single species
Mesocosms experiments


Foto: IMDEA


Foto: Landau University

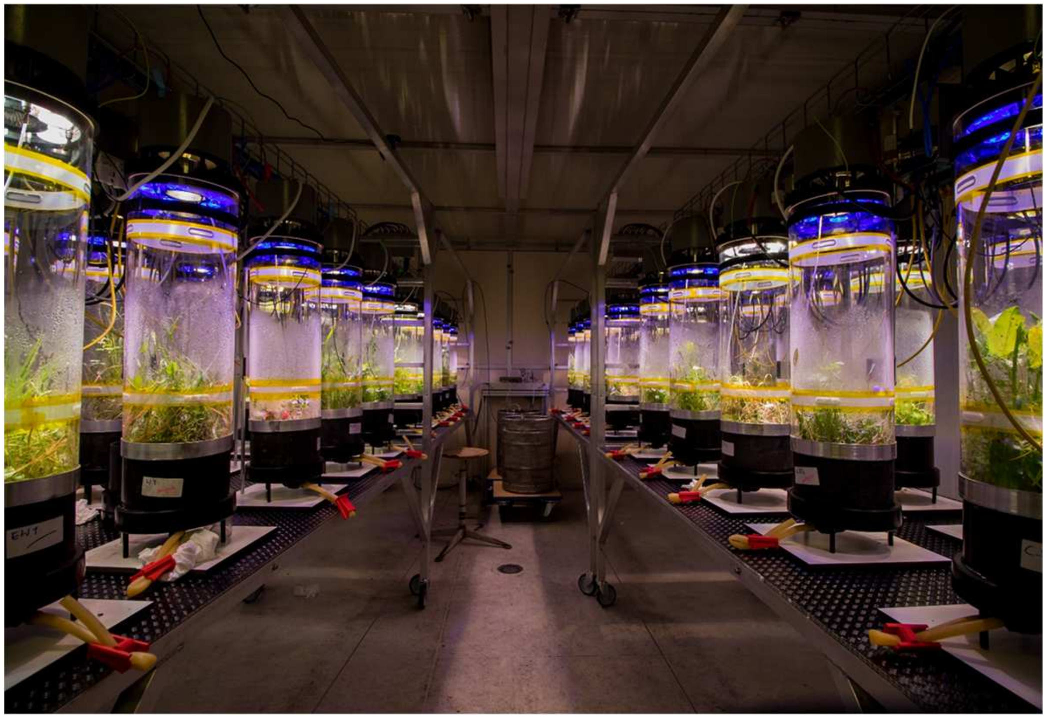


Foto: Vrije University Amsterdam

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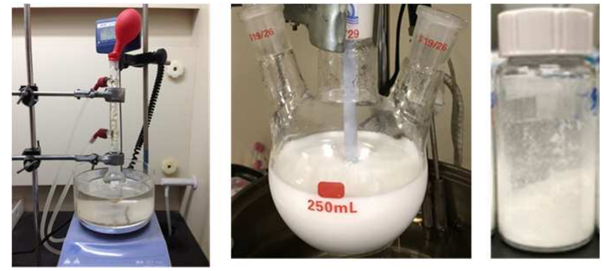
Mesocosm studies with radioactively-labelled nanoparticles

Foto: Jülich Forschungszentrum



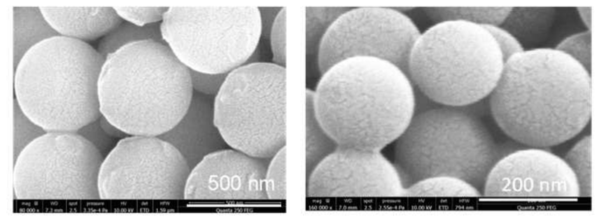


Foto: Nanjing University

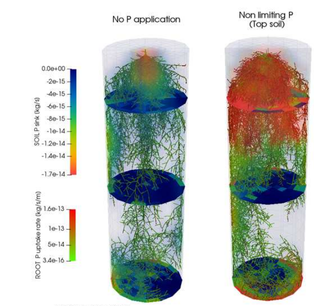


Foto: Jülich Forschungszentrum

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Multi-pronged field scale experiment – Paneuropean – 2 years

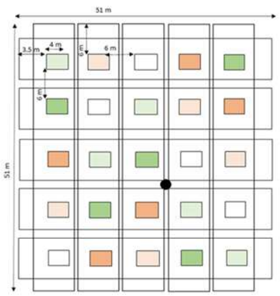

Foto: SYKE

MNP fate
Effects on microorganisms activity and community
Effects on soil invertebrate community
Effects on plant health
Effects on crop yield

Early policy recommendations

- Inventories of Agricultural plastic use, waste generation and intentional releases of MNP should be enforced through data sharing by industry, retailer and farmers.
- Schemes and technologies to allow traceability of relevant materials in use (e.g. films) should be considered.
- AP waste should be properly managed within the geographic context in which it is generated. Waste management should centralize EPR.
- Risk assessment and soil health criteria for MNP should be defined, including based on chronic exposure.
- Biodegradable plastics used in agriculture should be managed under a frame of risk assessment (including acute and chronic effects at high hierarchical level).
- Regulation should focus on defining sustainability criteria for the use of AP with high potential for soil pollution, as soon as sufficient knowledge is available.
- The standard for biodegradable mulching films should define requirements for degradability in different environments (including for chemical additives).
- Plasticulture should be disincentivized when negative impacts on the environment, the landscape and the society, exceed agricultural/economic benefits.

Thanks

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