# EIP-AGRI Focus Group

# Reducing the plastic footprint of agriculture

February 2021

**Minipaper A**: The actual uses of plastics in agriculture across EU: An overview and the environmental problems

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## 1. Introduction

In the last decade, the world awakened to the problem of plastics contamination primarily in the oceans, thanks to unequivocal evidence of marine mammals, birds and fish entrapped on macroplastics or found dead with their guts clogged by plastic debris. It took some time to link the contamination of oceans with their sources on land.

Global production of plastics increased twenty fold since the 1960s, reaching 322 million tonnes in 2015. It is forecast to double over the next 20 years. Reuse and recycling of end-of-life plastics is very low, particularly in comparison with other materials such as paper, glass or metals (EC, 2018a). Thus, the increase of plastic wastes in the different environmental compartments is forecast to continue. In Europe, packaging was the segment with the greatest demand of plastics (39.9%) from a total production of about 51.2 million tonnes (PlasticsEurope, 2019) a tendency that was likely kept and reinforced in 2020. Although the demand for plastics in agriculture has been more than 10 times less than this (3.4%) its use in the sector is expected to increase.

The use of plastics in agriculture serves different purposes (e.g. greenhouse covers, tunnels and solarisation and mulch films, silage wraps and polymer coated fertilizers, seeds or pesticides). The recognized benefits vary, including increased crop yield, elimination of weeds, improved efficiency of water and nutrient use, and reduced soil erosion (Gao et al., 2019; Rodríguez-Seijo and Pereira, 2019). However, situations where an intimate contact between the polymers and soil is developed (such as when using mulching films, controlled-release fertilisers (CRFs), plant protection products using capsule suspension (CSPs) and coated seeds) have come under increasing scrutiny. Use of these plastics may in some cases lead to the release of micro- and nanoplastics in the underlying soil (Accinelli et al., 2019; ECHA, 2019; Huang et al., 2020). Further, it has been realized, in the last few years, that policies encouraging the use of sewage sludge and municipal compost to fertilize soils (with some exceptions depending on the crops), as well to reduce their accumulation in landfills has also contributed to the addition of meaningful amounts of microplastics, carried over from contaminated feedstocks, (Corradini et al., 2019; Nizzetto et al., 2016b). Compost, often used in organic farming may similarly lead to microplastics accumulation in soils (Nizzetto et al., 2016b; Weithmann et al., 2018). The continuous input of plastics to soils combined with their persistence (half-life in soil >120 days (according to REACH annex XIII) (EC, 2006) leads to their accumulation in soils, and this is particularly true for agricultural soils. It was suggested the plastic mass in the world agriculture soils is higher than that found in oceanic surface waters given the estimated input of microplastics in European farmlands of 430 000 tons per year (Nizzetto et al., 2016b).

Therefore, a more precise understanding of the scope of plastic pollution in soils and the potential damaging effects it might have to agricultural production is thus required to balance potential deleterious effects with the obvious benefits of using plastics and/or urban by-products.

## 2. Main uses and benefits of using plastic in agriculture

Plastics play an important role in ensuring the productivity and sustainability of agricultural production. These polymers are used in many forms in European agriculture. A major advantage of plastic materials is that they are light and cheap and can thus be used in the large quantities required for agriculture. Some agricultural applications of plastics have specific advantages:

### 2.1. Mulch films

Mulch films are mostly used for horticultural crops where they can increase crop yields, reduce weed growth and/or the need for fertilizer, and improve water retention (Gao et al., 2019; Kader et al., 2019; Rodríguez-Seijo and Pereira, 2019) (Figure 1). The main reasons for using mulch films by farmers depend on the climatic region. The amount of water saved by this soil cover is still unknown, as it depends on climate or microclimate factors, soil and plant species (Steinmetz et al., 2016).



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About 83,000 tonnes of mulch films were sold in Europe in 2019[1]. Single-use mulch films made from low density polyethylene (LDPE) are by far the most used currently. The disadvantage of these films is as they get very dirty with soil this restricts recycling options (Briassoulis et al., 2012; Valavanidis et al., 2008). Collected single-use mulch films are thus predominantly landfilled or incinerated, imposing high costs on local authorities as well as great environmental challenges (Valavanidis et al., 2008). The films are often incompletely collected after harvest and fragments are ploughed into the soils where they may further fragment and ultimately release microplastics into the soil, as well as other contaminants such as phthalates and agrochemicals (Huang et al., 2020). Mulch plastic debris may also promote soil degradation and water repellence (Steinmetz et al., 2016).

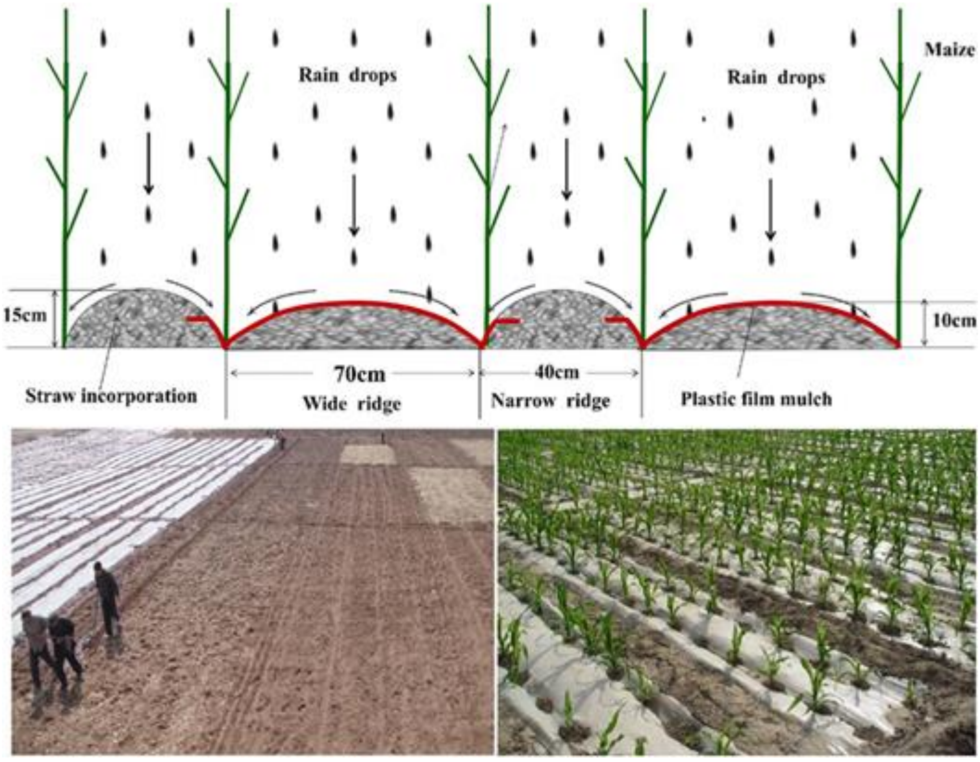


**Figure 1:** Film-mulched ridge-furrow tillage combined with straw incorporation to increase the water use efficiency and the soil quality, experimental case for maize growing in the Semiarid Loess Plateau, China (Yang et al. 2020)

Biodegradable mulch films are therefore increasingly used as an alternative. The generally higher purchasing cost of biodegradable films may be offset by minimal after harvest management requirements. However, despite having a clear definition of biodegradable and compostable materials (EN 13432:2000 for compostability and EN 17033:2018 for biodegradable mulch films[2]), there is still confusion with the terminology. Biodegradable mulch films are intended to fully biodegrade due to the effect of microorganisms, following hydrolysis into $CO_2$, water and microbial biomass (Lucas et al., 2008). These materials generally perform well during standard ecotoxicological tests (Hayes and Flury, 2018) although very little data exists to allow inferences on soil microbiome, plants and other organisms (Serrano-Ruiz et al., 2021). Nevertheless, biodegradable mulch films have been shown to have a similar efficiency to increase crops growth, yield and water use efficiency as the conventional polyethylene (PE) plastic films (Deng et al., 2019).

Oxo-biodegradable (more precisely named as oxo-fragmentable[3]) mulch films are conventional single-use PE plastic films containing additives intended to initiate degradation by oxidation. At present it was demonstrated that these materials would meet the standard for biodegradability or compostability (Deconinck and De Wilde,

[1] https://apeeurope.eu/statistics/.
[2] https://www.en-standard.eu/
[3] https://www.european-bioplastics.org/avada_faq/what-is-the-difference-between-oxo-fragmentable-and-biodegradable-plastics

2013; Thomas et al., 2012)[4]. However, it is increasingly being claimed that these plastics only partially biodegrade thus generating microplastic residues in the soil (Deconinck and De Wilde, 2013). Under the EU Strategy for Plastics, a process to restrict the use of oxo-plastics via **REACH**[5] in the EU is ongoing (EC, 2018a). Bioplastic mulch films have been produced from renewable biomass sources and have been promoted by the EU as a means to achieve a bio-based economy (EC, 2018b).

## 2.2. Polymer-coated soil additives and seeds

Conventional fertilizers and pesticides often dissolve/release too fast thus missing their targets and contributing to leaching to groundwater and/or nearby environmental compartments. Polymer coatings can contribute to a more controlled release and constant dose release of pesticides and fertilizers over a longer period of time, thus increasing both their efficiency and sustainability (Gil-Ortiz et al., 2020). Seed coatings with superabsorbent materials aid controlling the moisture to spark germination (Scudo, 2017; Su et al., 2017) and to provide associate growth promoting organisms. Moreover, the coatings can be completed with pesticides to maximize the viability of the seed and the survival of the seedlings (Accinelli et al., 2019). However, concerns persist in what regards the impact of coat fragments on soil quality and health. Although this later study from (Accinelli et al., 2019) showed that detached coating film fragments do not generally persist very long in soil, the degradation rate was variable, depending on the composition of the coating, thus more research is needed regarding the impacts of these polymeric coats in soil.

## 2.3. Greenhouses and polytunnels

Greenhouses appeared with the initial objective of growing heat-demanding crop species during the winter season in temperate countries, i.e. countries with a cold winter season (FAO, 2013). The main greenhouse cladding materials are glass, plastic sheets, and films, double or single glazing. Plastic is the preferential material, especially in the South of Europe (Figure 2), because it guarantees the ideal UV light transmission and have excellent heat retention capability and ideal transmission in the photosynthetically active radiation (PAR) bandwidth (Al-Mahdouri et al., 2014). In 2019, greenhouses were the structures that most account for the European sales of plastics (120.000 tonnes)[6] and the recycling of greenhouse plastics is one of the main challenges to sustainability of this production system. The properties of plastics such as heat resistance, heat loss, droplet formation, and dust forming on the film can be even improved through the integration of several functional additives (Maraveas, 2019; Sangpradit, 2014). These additives contributed to increase plastics lifetime, that nowadays varies between 6–45 months, depending on the photostabilizers used, the geographic location, the pesticide applications, among other aspects (Espí et al., 2006). Polyethylene, ethylene vinyl acetate (EVA) and ethylene butyl acrylate (EBA) and polyvinyl carbonate (PVC) are the main polymers being used in greenhouses and polytunnels. The former plastic material is the cheapest, the most accessible and is easy to repair thus being the main cover material.

[4] (https://echa.europa.eu/-/echa-to-consider-restrictions-on-the-use-of-oxo-plastics-and-microplasti-1

[5] The REACH Regulation places responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. Manufacturers and importers are required to gather information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database in the **European Chemicals Agency (ECHA)** in Helsinki.

[6] https://apeeurope.eu/statistics/


**Figure 2.** Greenhouses near Almeria in south east Spain. This area is known as the "sea of plastic" for the intense use of plastic in agriculture.

## 2.4. Silage

Silage is the animal fodder that is preserved by fermentation within plastic films (Figure 3). As opposed to mulch films, the plastic films used for silage are not soiled as much and can thus be more easily collected and sent for recycling. Very successful collection and recycling schemes have been set up in several EU-Member States. National collection schemes have been adopted by several European countries (Ireland, Iceland, Sweden, France, Spain, Norway, UK and Germany) where the collection rate is between 75 and 95 %[7].

## 2.5. Packaging

Containers used in agriculture consist of polymers, usually high-density polyethylene (HDPE) that, in principle could be re-used and/or recycled, but containers used to store chemical substances such as fertilizers and pesticides (Figure 3) require special attention to avoid environmental contamination and/or accumulation of these chemicals in the human food chain. The Food and Agriculture Organization and the World Health Organization published Guidelines on Management Options for Empty Pesticide Containers (FAO and WHO, 2008) reinforcing that all the stakeholders from the supply chain of pesticides must be involved in the management of these containers. Many EU-Member States have therefore set up collection schemes sometimes complemented with eco-taxes with varying success specifically for the collection and storage of containers (EU, 2017; Jones, 2014).


**Figure 3.** Bale being wrapped in plastic for silage preparation (A), empty plastic containers stored on farm (B).

[7] https://apeurope.eu/statistics/

## 3. Main impacts of plastic residues in soil

The analysis of the impacts of plastics in soils can follow two different approaches, either considering this contaminant as a physical or as a chemical stressor. Plastics may exert their effects depending on their size, on the leaching of additives such as plasticizers or of other chemicals that adsorb to their surface (Wang et al., 2020; Yang et al., 2019). With regard to size, plastic residues can be classified as: macroplastics (> 25 mm), mesoplastics (5-25 mm), large microplastics (1-5 mm), small microplastics (1mm-1μm) and nanoplastics (< 1μm) (Blettler et al., 2017; Gigault et al., 2018). Usually small microplastics tend to dominate in soils (Chen et al., 2020), as they become part of the complex mixture of soil components, migrating to deeper soil layers due to soil water movement or transport by animals and anthropogenic activities, such as soil ploughing (Guo et al., 2020; Maaß et al., 2017). The presence of nanoplastics in soils was not yet characterized due to the lack of appropriate methodologies

### 3.1. Soil physical and chemical properties

Once in the soil, plastic residues may affect soil physical properties such as the bulk density, soil porosity, hydraulic conductivity, soil water repellence, water holding capacity (WHC), the vertical flow of water and water stable aggregates. These effects seemed to be more size rather than concentration dependent (De Souza MacHado et al., 2018; Höfer et al., 2015; Jiang et al., 2017; Vezzani and Mielniczuk, 2009). Plastic residues may also affect the distribution of organic carbon in soil aggregates, likely compromising the conservation of soil organic carbon. Zhang et al. (2019) observed that only 30% of PE macrofibers added to soils were incorporated in soil aggregates, however they were able to reduce the organic content of the larger aggregates > 2 mm. Boots et al. (2019) also observed that HDPE and PLA were able to reduce the proportion of large aggregate (> 2mm) and increase the smaller ones (250-63 mm) in the soil. In fact, studies suggest that microplastics are able to reduce the cohesion between soil components, affecting water stable soil aggregates which are an indicator of soil health, more precisely of its resistance/vulnerability to erosion (Boots et al., 2019). Plastic residues (meso- and microplastics) are also able to create water channels, enhancing soil evaporation and thus changing soil water content (Wan et al., 2019).

Microplastics may also change the availability of potential toxic elements, as metals, by offering surfaces for physical adsorption or by indirectly changing their speciation and affinity for stable organic forms (Yu et al., 2020). Wang et al.(2019) demonstrated that microplastics were able to reduce the amount of hydrophobic organic contaminants (PCB and PAH) in soil pore water as well as their bioavailability through competitive adsorption on their hydrophobic surfaces.

### 3.2. Soil microbial community

The effects of microplastics on the soil microbial community will depend on many factors as the type of soil, the climatic conditions, the soil management practices, water availability, the chemical composition of plastics, their concentration, ageing, and many other factors. Plastic residues of different sizes (from nano- to mesoplastics) and chemical compositions (including biodegradable plastics) have shown to inhibit and/or reduce several microbial parameters as soil enzyme activity, microbial biomass and the structural and functional diversity of soil microbial communities (Awet et al., 2018; Bandopadhyay et al., 2018, 2020; Fei et al., 2020; Qian et al., 2018; Wang et al., 2016). Such impairment may be caused by both changes on soil physical and chemical parameters, as mentioned above, as well as by the exposure of soil microorganisms to plastic components as lipophilic phthalates that have the ability to disrupt cell membranes (Wang et al., 2016). In contrast, plastic particles may offer physical surfaces to be colonized by a distinct and specific microbioma (e.g., plastic degrading and pathogenic bacteria and fungi such as *Aspergillus flavus*), thus changing the overall balance in the structure of the soil microbial community and possibly favouring the development of some concerning species regarding the food safety and human health risks (Accinelli et al., 2019; Huang et al., 2020).


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## 3.3. Soil invertebrates

The first reaction of invertebrates could be to avoid contaminated soils with microplastics as it was shown for earthworms, enchytraeids, springtails and nematodes (Ju et al., 2019; Kim et al., 2020a, 2020b; Pflugmacher et al., 2020; Rodríguez-seijo et al., 2017; Rodríguez-seijo, 2018; Wang et al., 2019). However, this behavioural response was not consistent in all the studies (Prendergast-miller et al., 2019), especially when microplastics of different types were added to soils previously amended with organic compost (Kim et al., 2020b). In fact other studies do not confirm the avoidance behaviour and in opposition demonstrated the role of earthworms in the transport of microplastics to soil depths lower than 10 cm (Rillig et al., 2017). In parallel with physical factors, such as those related with water movements, microplastics can be pushed down during the movement of the earthworms - they can be transported inside their guts and released in casts to a greater depth or be transported glued to the mucus that covers the body surface.

The ingestion of small microplastics by soil invertebrates is obviously determined by physiological limitations to small microplastics and nanoplastics, although some species displayed selective feeding on microplastics (Rillig et al., 2017; Rodriguez-seijo et al., 2017). The form of the microplastics may also influence their ingestion, their gut retention and subsequently the effects reported. Through the analysis of microfibers found in casts of earthworms it was suggested that they may accumulate on their gut where they are retained (Prendergast-miller et al., 2019). As a consequence of the exposures, different effects on soil invertebrates (including nematodes, earthworms, springtails and snails) were reported by different authors (Boots et al., 2019; Ju et al., 2019; Lahive et al., 2019; Prendergast-miller et al., 2019; Rodríguez-seijo, 2018; Rodriguez-seijo et al., 2017; Selonen et al., 2020; Song et al., 2019). Further, some studies suggested that the effects may be more pronounced in geophagus species (those that live inside the soil and are more dependent of it), because they have a highest consumption and turnover of large quantities of soil, as they fed on soil organic matter rather than on organic matter enriched litter (Boots et al., 2019).

## 3.4. Terrestrial plants

The studies on the impacts of plastic residues in plants are still scarce (Du et al., 2020). However, it was already demonstrated that the effects of plastic residues are mainly governed by physical processes, both through direct interaction of residues with plant roots, or indirectly by changing soil properties. Changes in soil structure with impacts on water availability, bulk density and in soil aeration may affect plants performance and root development. However, these effects are not necessarily negative (De Souza Machado et al., 2019; Rillig et al., 2019). The impacts of plastic residues in water cycling in soil may also affect the availability of nutrients through different processes, including changes in soil microbial activity. The effects on the roots' colonization by symbionts seem to be dependent on the chemical nature of plastic and both positive and negative effects were already recorded (De Souza Machado et al., 2019; Lehmann et al., 2020). Zang et al., (2020) recorded 13 to 53% reductions in wheat root and shoot biomass exposed to percentages of 1 to 5% of microplastics in soil (being more responsive to PVC), but no changes in the root-to-shoot ratio were recorded. The authors attributed these effects to changes in soil microbial activity and altered carbon flow between plant-soil system.

Plastic residues (nano- and smaller microplastics) can also interact directly with plants blocking pores of seed coats and later persist on root hairs of seedlings. However, only transient effects on germination and on the growth of cress roots resulted from these interactions (Bosker et al., 2019). Other studies reporting disturbing physical interactions between plastic residues and plant roots were not conducted under real conditions, thus becoming difficult to infer similar effects in the environment (Jiang et al., 2019).

It has been assumed that plastic residues are not able to enter plant cells, however very recently it was demonstrated that nano- and small microplastics may enter wheat and lettuce plant roots through cracks, between primary and secondary roots, being then transported to the shoots (Li, 2020). Other authors also confirmed the uptake of nanoplastics by plants (e.g. cucumber), with subsequent negative effects on seedlings development and plant growth or in other parameters such as the chlorophyll and sugar concentration in leaves (Li, 2020; Sun et al., 2020). However, nanoplastics are expected to strongly adsorb to the surfaces of soil components, being less available for being taken up by plants (Rillig et al., 2019).



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The effects of plastic residues in plants may also vary depending on their chemical composition. The study of Pignattelli et al. (2020) showed that microplastic residues affected differently the physiological responses of garden cress, PVC being the most toxic. Biodegradable mulches also showed the ability to release compounds with inhibitory effects in the development shoots and roots of tomato and lettuce (Serrano-Ruiz et al., 2021).

The uptake of nano- and microplastics by plants and soil invertebrates points for a new concern related with the possible transference of plastic residues through trophic chains.

# 4. Plastics as carriers of contamination

## 4.1. Release of additives

Plastic products contain a wide variety of chemicals in addition to the polymers that are their main constituents. These include plasticisers, antioxidants and stabilisers (used to improve their physical characteristics and longevity), fillers (used to reduce the cost of raw material) and pigments (used to make the products more attractive or better suited to their intended purpose) (Hahladakis et al., 2018). As the plastics are degraded by either physical or biological action, these compounds can be released into the environment where they can potentially be more damaging than the remains of the polymers themselves. For example, the concentrations of a range of phthalate plasticisers were determined in soils, and in the plant growing in them, following the use of film mulches (Wang et al., 2015). Researchers are also gathering evidence of the harm to agroecosystems that such contamination can cause. Kim et al., (2020b) showed that additives caused toxic effects on nematodes. Bandopadhyay et al., (2018) drew attention to the fact that standard tests for plant toxicity have not been adapted to identify the effects of compounds released from degrading plastics as they are generally short term.

## 4.2. Co-transport of agrochemicals and other organic contaminants

Plastics and microplastic particles, once in soils, become exposed to a wide range of organic anthropogenic compounds such as persistent organic pollutants (POPs, such as pesticides or polycyclic aromatic hydrocarbons), antibiotics or antibodies (Figure 4). These can become adsorbed onto their surfaces, a process that can facilitate their dispersal and delay their degradation. Most studies have been done in the marine environment but some recent studies done in soils do give cause for concern (Wang et al., 2019). For example, Wang et al. (2020) studied the adsorption of five pesticides onto agricultural polyethylene films whilst; Fang et al. (2019) looked at the adsorption of fungicides onto polystyrene fragments, finding that smaller particle size contributed to increased adsorption capacity. Sunta et al. (2020) demonstrated that microplastics in soil can indeed act as carriers of pollutants in soil with their presence resulting in the retention of higher concentrations of a range of pesticides.



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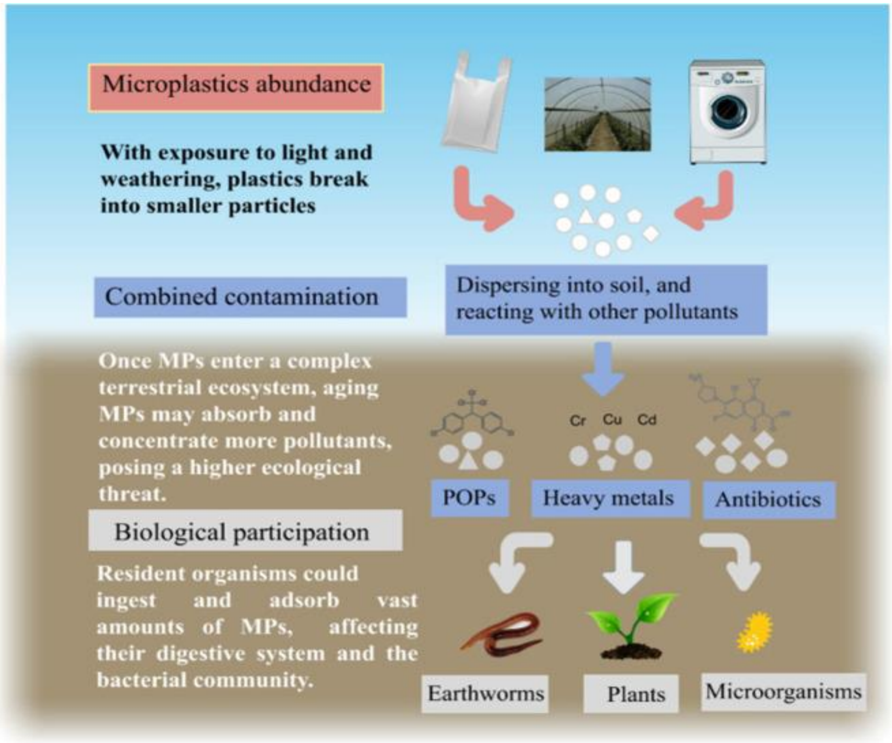


**Figure 4.** Infographic summarizing the interactions between microplastics, other contaminants and organisms by Whang et al 2019.

## 5. Legislation on plastic waste in agriculture: What do we need more

Despite disposal occupying a place at the bottom of the waste management hierarchy proposed by Directive 2008/98/EC (EC, 2008), about 70% of plastic wastes in Europe are landfilled or incinerated[8]. Agriculture only accounts for 5% of European plastic waste, however the use of plastics in agriculture is putting a great pressure on farmers, as more evidence of the environmental impacts of plastic residues on soils and water resources is being compiled. This small contribution of agriculture resulted in legislation and strategies more specifically designed for packaging. An example is the Directive EU DIRECTIVE EU 2019/904 on the reduction of the impact of single-use plastic products and of products made from oxo-degradable plastic that does not address for example single-use mulch films. The lack of alternative solutions, the costs of cleaning the films after use, and the lack of appropriate collecting systems are some of the limitations that are preventing the application of more strict restrictions in the agriculture sector, at least for now. Regarding the oxo-plastics, in 2018, the European Chemicals Agency (ECHA) started the preparation of a restriction proposal, under the scope of REACH regulation, for these plastic materials (ECHA, 2019).

The Roadmap to a Resource Efficient Europe, published in 2011, claimed for the need of converting wastes in resources to fuel for a total recycling economy (EC, 2011). Recycling of wastes was also envisaged as an opportunity to create new jobs, decrease dependence on imports of raw materials and reduction of impacts in the environment. China's restrictions to imports of certain types of plastic wastes opened the door for European innovation on plastic wastes recycling, although it also brought additional difficulties for farmers, as collectors lost interest in these wastes.

[8] https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf


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The European Strategy for Plastics in a Circular Economy launched in 2015 suggested the Extended Producer Responsibility (EPR) policy approach[9] as a good tool to manage plastic wastes (mulch films and greenhouse plastics) in agriculture (EC, 2018a). Through EPR plastic producers become responsible for the treatment or disposal of used plastics, this being seen as an incentive for a targeted product design aimed in enhancing the re-use, the degradability or the recycling of plastics for regeneration of raw materials to be reintroduced in the production systems.

EPR is being discussed and recommended at the European level; however, it depends on efficient dedicated sorting and collecting systems, incentives to support these operations without compromising the economic viability of farms, and funding to support innovation in chemical recycling processes. A payback mechanism could also be a good alternative to incentivize collection, sorting and returning of plastic wastes to producers (Pazienza and De Lucia, 2020).

Labelling of agriculture plastic wastes is another difficulty that needs to be overcome for sustainable management. There is no legal basis for establishing labelling schemes for these wastes under the current version of the revised Waste Framework Directive 2008/98/EC, followed by simple and practical guidelines for the use and installation of new plastic materials and its removal, sorting and storing after use (Briassoulis et al., 2010).

Applying organic residues, such as Waste Water Treatment Plants (WWTP) sludge or compost, unintentionally exposes agricultural soils to secondary micro- and nanoplastics, which contributed to restrict the application of WWTP sludge on agricultural soils by some EU Member States (EC, 2014), and may also restrict the application of composts (EA, 2019). An evaluation of the Sludge Directive 86/278/EEC (EEC, 1986), demonstrated that rather the importance of it to manage this type of waste it is clearly outdated as does not take into account the impact of nano- and microplastics in sludge to be used for fertilization purposes (EC, 2014). Reusing urban carbon sources, however, serves the EU goal of becoming a bio-based economy by recycling carbon and nutrient sources back into the food chain (EC, 2020).

## 6. Conclusions and future research and innovation needs

Despite some evidence of the negative effects of plastics on soil quality and health, data were mainly gathered from laboratory studies and several were performed under soilless exposure, giving rise to relevant data to understand mechanistic aspects but with little ecological relevance. No studies addressed the impact on important soil functions, such as for example the organic matter decomposition, contaminant residuals degradation. Efforts also need to be made to characterize the abundance and composition of plastic residues in agricultural soils to allow testing at realistic concentrations. Furthermore, the great majority of studies have focused on direct effects on individual crop species, rather than on more complex species interactions in the overall agroecosystems and subsequently on highly relevant indirect effects that may compromise natural communities. Particular attention should be payed to nanoplastics as they have more potential for bioaccumulation in plants and for food web transferences. If confirmed, this could be a major reason to ban conventional plastics from agriculture, and a great driver for adopting agriculture practices able to reduce plastics use.
The development of biodegradable plastics is being claimed to reduce the plastic footprint; however, it is important to understand if previous changes to soils' microbial community did not compromise the degradability of certified materials. Clear labelling schemes need to be developed for agriculture plastic wastes, and biodegradability needs to be tested under diverse and environmental relevant conditions. The management of agriculture plastic wastes requires a specific legislation framework; however, a higher innovation capacity is needed before in eco-design, in recycling processes and in the development of collecting and sorting systems to reduce the plastic footprint in agriculture.

[9] https://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm


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# 7. References


Accinelli, C., Abbas, H.K., Shier, W.T., Vicari, A., Little, N.S., Aloise, M.R., Giacomini, S., 2019. Degradation of microplastic seed film-coating fragments in soil. Chemosphere 226, 645–650. doi:10.1016/j.chemosphere.2019.03.161

Al-Mahdouri, A., Gonome, H., Okajima, J., Maruyama, S., 2014. Theoretical and experimental study of solar thermal performance of different greenhouse cladding materials. Sol. Energy 107, 314–327. doi:10.1016/j.solener.2014.05.006

Awet, T.T., Kohl, Y., Meier, F., Straskraba, S., Grün, A.L., Ruf, T., Jost, C., Drexel, R., Tunc, E., Emmerling, C., 2018. Effects of polystyrene nanoparticles on the microbiota and functional diversity of enzymes in soil. Environ. Sci. Eur. doi:10.1186/s12302-018-0140-6

Bandopadhyay, S., Martin-Closas, L., Pelacho, A.M., DeBruyn, J.M., 2018. Biodegradable plastic mulch films: Impacts on soil microbial communities and ecosystem functions. Front. Microbiol. 9, 1–7. doi:10.3389/fmicb.2018.00819

Bandopadhyay, S., Sintim, H.Y., DeBruyn, J.M., 2020. Effects of biodegradable plastic film mulching on soil microbial communities in two agroecosystems. PeerJ 2020, 1–27. doi:10.7717/peerj.9015

Blettler, M.C.M., Ulla, M.A., Rabuffetti, A.P., Garello, N., 2017. Plastic pollution in freshwater ecosystems: macro-, meso-, and microplastic debris in a floodplain lake. Environ. Monit. Assess. 189. doi:10.1007/s10661-017-6305-8

Boots, B., Russell, C.W., Green, D.S., 2019. Effects of Microplastics in Soil Ecosystems: Above and below Ground. Environ. Sci. Technol. 53, 11496–11506. doi:10.1021/acs.est.9b03304

Bosker, T., Bouwman, L.J., Brun, N.R., Behrens, P., Vijver, M.G., 2019. Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant Lepidium sativum. Chemosphere 226, 774–781. doi:10.1016/j.chemosphere.2019.03.163

Briassoulis, D., Hiskakis, M., Babou, E., Antiohos, S.K., Papadi, C., 2012. Experimental investigation of the quality characteristics of agricultural plastic wastes regarding their recycling and energy recovery potential. Waste Manag. 32, 1075–1090. doi:10.1016/j.wasman.2012.01.018

Briassoulis, D., Hiskakis, M., Scarascia, G., Picuno, P., Delgado, C., Dejean, C., 2010. Labeling scheme for agricultural plastic wastes in Europe. Qual. Assur. Saf. Crop. Foods 2, 93–104. doi:10.1111/j.1757-837X.2010.00061.x

Chen, Y., Leng, Y., Liu, X., Wang, J., 2020. Microplastic pollution in vegetable farmlands of suburb Wuhan, central China. Environ. Pollut. 257, 113449. doi:10.1016/j.envpol.2019.113449

Corradini, F., Meza, P., Eguiluz, R., Casado, F., Huerta-Lwanga, E., Geissen, V., 2019. Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. Sci. Total Environ. 671, 411–420. doi:10.1016/j.scitotenv.2019.03.368

De Souza Machado, A.A., Lau, C.W., Kloas, W., Bergmann, J., Bachelier, J.B., Faltin, E., Becker, R., Görlich, A.S., Rillig, M.C., 2019. Microplastics Can Change Soil Properties and Affect Plant Performance. Environ. Sci. Technol. 53, 6044–6052. doi:10.1021/acs.est.9b01339

De Souza MacHado, A.A., Lau, C.W., Till, J., Kloas, W., Lehmann, A., Becker, R., Rillig, M.C., 2018. Impacts of Microplastics on the Soil Biophysical Environment. Environ. Sci. Technol. 52, 9656–9665. doi:10.1021/acs.est.8b02212

Deconinck, S., De Wilde, B., 2013. Benefits and challenges of Bio- and Oxo-Degradable plastics. Final Rep. Stydy DSL-1 118.

Deng, L., Yu, Y., Zhang, H., Wang, Q., Yu, R., 2019. The Effects of Biodegradable Mulch Film on the Growth, Yield, and Water Use Efficiency of Cotton and Maize in an Arid Region. Sustain. 11, 1–15. doi:10.3390/su11247039

Du, J., Zhou, Q., Li, H., Xu, S., Wang, C., Fu, L., Tang, J., 2020. Environmental distribution, transport and ecotoxicity of microplastics: A review. J. Appl. Toxicol. 1–13. doi:10.1002/jat.4034

EA, 2019. Standard rules consultation no 20 : revision of standard rules sets for biowaste treatment. Bristol.

EC, 2020. European Commission, Communication from the Commission to teh European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A new Circular Economy Action Plan. For a cleaner and more competitive Europe. COM(2020) 98 final. Brussels.

EC, 2018a. Communication from the Community to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions. A European Strategy for Plastics in a Circular Economy. Brussels.

EC, 2018b. A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. Brussels. doi:10.2777/478385

EC, 2014. COMMISSION STAFF WORKING DOCUMENT Ex-post evaluation of Five Waste Stream Directives. SWD(2014) 209 final. Brussels.

EC, 2011. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. Brussels.

EC, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 Novemeber 2008 on waste and repealing certain Directives. Off. J. Eur. Union L312/3-L312/30.

EC, 2006. Regulation (EC) No 1907/2006 of the European Parliament and of the Coucil. ANNEX XIII: CRITERIA FOR THE IDENTIFICATION OF PERSISTENT, BIOACCUMULATIVE AND TOXIC SUBSTANCES, AND VERY PERSISTENT AND VERY BIOACCUMULATIVE SUBSTANCES. Off. J. Eur. Union L 396, 1–530.

ECHA, 2019. ANNEX to the ANNEX XV RESTRICTION REPORT – intentionally added microplastics. ECHA Propos. A Restrict. 1.2. Helsinki, Filand.

Espí, E., Salmerón, A., Fontecha, A., García, Y., Real, A.I., 2006. Plastic films for agricultural applications. J. Plast. Film Sheeting 22, 85–102. doi:10.1177/8756087906064220

EU, 2019. Directive (Eu) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. Off. J. Eur. Union L 155/1-L155/19.

EU, 2017. Sustainable Use of Pesticides. Overview Report. DG Health an Food Safety., European Commision. Luxembourg. doi:10.2875/604951

Fang, S., Yu, W., Li, C., Liu, Y., Qiu, J., Kong, F., 2019. Science of the Total Environment Adsorption behavior of three triazole fungicides on polystyrene microplastics. Sci. Total Environ. 691, 1119–1126. doi:10.1016/j.scitotenv.2019.07.176

FAO, 2013. Good Agricultural Practices for greenhouse vegetable crops, Plant Production and Protection Paper 217. Rome. doi:10.1201/b13737-8

FAO, WHO, 2008. International Code of Conduct on the Distribution and Use of Pesticides: Guidelines on Management Options for Empty

Pesticide Containers. Rome, Italy.
Fei, Y., Huang, S., Zhang, H., Tong, Y., Wen, D., Xia, X., Wang, H., Luo, Y., Barceló, D., 2020. Science of the Total Environment Response of soil enzyme activities and bacterial communities to the accumulation of microplastics in an acid cropped soil. Sci. Total Environ. 707, 135634. doi:10.1016/j.scitotenv.2019.135634
Gao, H., Yan, C., Liu, Q., Ding, W., Chen, B., Li, Z., 2019. Effects of plastic mulching and plastic residue on agricultural production: A meta-analysis. Sci. Total Environ. 651, 484–492. doi:10.1016/j.scitotenv.2018.09.105
Gigault, J., Halle, A. ter, Baudrimont, M., Pascal, P.Y., Gauffre, F., Phi, T.L., El Hadri, H., Grassl, B., Reynaud, S., 2018. Current opinion: What is a nanoplastic? Environ. Pollut. 235, 1030–1034. doi:10.1016/j.envpol.2018.01.024
Gil-Ortiz, R., Naranjo, M.Á., Ruiz-Navarro, A., Caballero-Molada, M., Atares, S., García, C., Vicente, O., 2020. New eco-friendly polymeric-coated urea fertilizers enhanced crop yield in wheat. Agronomy 10. doi:10.3390/agronomy10030438
Guo, J.J., Huang, X.P., Xiang, L., Wang, Y.Z., Li, Y.W., Li, H., Cai, Q.Y., Mo, C.H., Wong, M.H., 2020. Source, migration and toxicology of microplastics in soil. Environ. Int. 137, 105263. doi:10.1016/j.envint.2019.105263
Hahladakis, J.N., Velis, C.A., Weber, R., Iacovidou, E., Purnell, P., 2018. An overview of chemical additives present in plastics : Migration , release , fate and environmental impact during their use , disposal and recycling. J. Hazard. Mater. 344, 179–199. doi:10.1016/j.jhazmat.2017.10.014
Hayes, D.G., Flury, M., 2018. Summary and Assessment of EN 17033:2018 , a New Standard for Biodegradable Plastic Mulch Films. Rep. No. EXT-2018-01 1–7.
Helmberger, M.S., Tiemann, L.K., Grieshop, M.J., 2020. Towards an ecology of soil microplastics 550–560. doi:10.1111/1365-2435.13495
Höfer, H., Astrin, J., Holstein, J., Spelda, J., Meyer, F., Zarte, N., 2015. Propylene glycol – a useful capture preservative for spiders for DNA barcoding. Arachnol. Mitteilungen 50, 30–36. doi:10.5431/aramit5005
Huang, Y., Liu, Q., Jia, W., Yan, C., Wang, J., 2020. Agricultural plastic mulching as a source of microplastics in the terrestrial environment. Environ. Pollut. 260, 114096. doi:10.1016/j.envpol.2020.114096
Jiang, X., Chen, H., Liao, Y., Ye, Z., Li, M., Klobučar, G., 2019. Ecotoxicity and genotoxicity of polystyrene microplastics on higher plant Vicia faba. Environ. Pollut. 250, 831–838. doi:10.1016/j.envpol.2019.04.055
Jiang, X.J., Liu, W., Wang, E., Zhou, T., Xin, P., 2017. Residual plastic mulch fragments effects on soil physical properties and water flow behavior in the Minqin Oasis, northwestern China. Soil Tillage Res. 166, 100–107. doi:10.1016/j.still.2016.10.011
Jones, K.A., 2014. The Recycling of Empty Pesticide Containers: An Industry Example of Responsible Waste Management. Outlooks Pest Manag. 25, 183–186. doi:DOI: https://doi.org/10.1564/v25_apr_08
Ju, H., Zhu, D., Qiao, M., 2019. Effects of polyethylene microplastics on the gut microbial community , reproduction and avoidance behaviors of the soil springtail , Folsomia. Environ. Pollut. 247, 890–897. doi:10.1016/j.envpol.2019.01.097
Kader, M.A., Singha, A., Begum, M.A., Jewel, A., Khan, F.H., Khan, N.I., 2019. Mulching as water-saving technique in dryland agriculture: review article. Bull. Natl. Res. Cent. 43. doi:10.1186/s42269-019-0186-7
Kim, S.W., Kim, D., Jeong, S., An, Y., 2020a. Size-dependent effects of polystyrene plastic particles on the nematode Caenorhabditis elegans as related to soil physicochemical. Environ. Pollut. 258, 113740. doi:10.1016/j.envpol.2019.113740
Kim, S.W., Waldman, W.R., Kim, T., Rillig, M.C., 2020b. E ff ects of Di ff erent Microplastics on Nematodes in the Soil Environment: Tracking the Extractable Additives Using an Ecotoxicological Approach. doi:10.1021/acs.est.0c04641
Lahive, E., Walton, A., Horton, A.A., Spurgeon, D.J., Svendsen, C., 2019. Microplastic particles reduce reproduction in the terrestrial worm Enchytraeus crypticus in a soil exposure *. Environ. Pollut. 255, 113174. doi:10.1016/j.envpol.2019.113174
Lehmann, A., Leifheit, E.F., Feng, L., Bergmann, J., Wulf, A., Rillig, M.C., 2020. Microplastic fiber and drought effects on plants and soil are only slightly modified by arbuscular mycorrhizal fungi. Soil Ecol. Lett. doi:10.1007/s42832-020-0060-4
Li, Z., 2020. Physiological responses of lettuce ( Lactuca sativa L .) to microplastic pollution 30306–30314.
Lucas, N., Bienaime, C., Belloy, C., Queneudec, M., Silvestre, F., Nava-Saucedo, J.E., 2008. Polymer biodegradation: Mechanisms and estimation techniques - A review. Chemosphere 73, 429–442. doi:10.1016/j.chemosphere.2008.06.064
Maaß, S., Daphi, D., Lehmann, A., Rillig, M.C., 2017. Transport of microplastics by two collembolan species. Environ. Pollut. 225, 456–459. doi:10.1016/j.envpol.2017.03.009
Maraveas, C., 2019. Environmental sustainability of greenhouse covering materials. Sustain. 11. doi:10.3390/su11216129
Nizzetto, L., Bussi, G., Futter, M.N., Butterfield, D., Whitehead, P.G., 2016a. A theoretical assessment of microplastic transport in river catchments and their retention by soils and river sediments. Environ. Sci. Process. Impacts 18, 1050–1059. doi:10.1039/c6em00206d
Nizzetto, L., Futter, M., Langaas, S., 2016b. Are Agricultural Soils Dumps for Microplastics of Urban Origin? Environ. Sci. Technol. 50, 10777–10779. doi:10.1021/acs.est.6b04140
Pazienza, P., De Lucia, C., 2020. The EU policy for a plastic economy: Reflections on a sectoral implementation strategy. Bus. Strateg. Environ. 29, 779–788. doi:10.1002/bse.2445
Pflugmacher, S., Huttunen, J.H., Wol, M. Von, Penttinen, O., Kim, Y.J., Kim, S., Mitrovic, S.M., 2020. Enchytraeus crypticus Avoid Soil Spiked with Microplastic 1–10.
Pignattelli, S., Broccoli, A., Renzi, M., 2020. Science of the Total Environment Physiological responses of garden cress ( L . sativum ) to different types of microplastics. Sci. Total Environ. 727, 138609. doi:10.1016/j.scitotenv.2020.138609
PlasticsEurope, 2019. Plastics – the Facts 2019.
Prendergast-miller, M.T., Katsiamides, A., Abbass, M., Sturzenbaum, S.R., Thorpe, K.L., Hodson, M.E., 2019. Polyester-derived micro fi bre impacts on the soil-dwelling earthworm. Environ. Pollut. 251, 453–459. doi:10.1016/j.envpol.2019.05.037
Qian, H., Zhang, M., Liu, G., Lu, T., 2018. Effects of Soil Residual Plastic Film on Soil Microbial Community Structure and Fertility.
Rillig, M.C., Ingraffia, R., Machado, A.A.D.S., 2017. Microplastic Incorporation into Soil in Agroecosystems 8, 8–11. doi:10.3389/fpls.2017.01805
Rillig, M.C., Lehmann, A., de Souza Machado, A.A., Yang, G., 2019. Microplastic effects on plants. New Phytol. 223, 1066–1070. doi:10.1111/nph.15794
Rodríguez-seijo, A., 2018. Oxidative stress , energy metabolism and molecular responses of earthworms ( Eisenia fetida ) exposed to low-density polyethylene microplastics.
Rodríguez-seijo, A., Cachada, A., Gavina, A., Duarte, A.C., Vega, F.A., Andrade, M.L., Pereira, R., 2017. Science of the Total Environment Lead and PAHs contamination of an old shooting range : A case study with a holistic approach. Sci. Total Environ. 575, 367–377. doi:10.1016/j.scitotenv.2016.10.018

Rodriguez-seijo, A., Lourenço, J., Rocha-santos, T.A.P., Costa, J., Duarte, A.C., Vala, H., Pereira, R., 2017. Histopathological and molecular effects of microplastics in Eisenia andrei Bouch e. Environ. Pollut. 220, 495–503. doi:10.1016/j.envpol.2016.09.092
Rodríguez-Seijo, A., Pereira, R., 2019. Microplastics in Agricultural Soils. Are they a real Environmental Hazard?, in: Sanchez-Hernandez, J.C. (Ed.), Bioremediation of Agricultural Soils. CRC Press, Toledo, Sapin. doi:10.1201/9781315205137
Sangpradit, K., 2014. Study of the solar transmissivity of plastic cladding materials and influence of dust and dirt on greenhouse cultivations. Energy Procedia 56, 566–573. doi:10.1016/j.egypro.2014.07.194
Scudo, A., 2017. Intentionally added microplastics. Amec Foster Wheel.
Selonen, S., Dolar, A., Kokalj, A.J., Skalar, T., Dolcet, L.P., Hurley, R., van Gestel, C.A.M., 2020. Exploring the impacts of plastics in soil – The effects of polyester textile fibers on soil invertebrates. Sci. Total Environ. 700, 134451. doi:10.1016/j.scitotenv.2019.134451
Serrano-Ruiz, H., Martin-Closas, L., Pelacho, A.M., 2021. Biodegradable plastic mulches: Impact on the agricultural biotic environment. Sci. Total Environ. 750, 141228. doi:10.1016/j.scitotenv.2020.141228
Song, Y., Cao, C., Qiu, R., Hu, J., Liu, M., Lu, S., Shi, H., Raley-susman, K.M., He, D., 2019. Uptake and adverse effects of polyethylene terephthalate microplastics fi bers on terrestrial snails ( Achatina fulica ) after soil. Environ. Pollut. 250, 447–455. doi:10.1016/j.envpol.2019.04.066
Steinmetz, Z., Wollmann, C., Schaefer, M., Buchmann, C., David, J., Tröger, J., Muñoz, K., Frör, O., Schaumann, G.E., 2016. Plastic mulching in agriculture. Trading short-term agronomic benefits for long-term soil degradation? Sci. Total Environ. 550, 690–705. doi:10.1016/j.scitotenv.2016.01.153
Su, L. qiang, Li, J. guo, Xue, H., Wang, X. feng, 2017. Super absorbent polymer seed coatings promote seed germination and seedling growth of Caragana korshinskii in drought. J. Zhejiang Univ. Sci. B 18, 696–706. doi:10.1631/jzus.B1600350
Sun, X., Yuan, X., Jia, Y., Feng, L., Zhu, F., Dong, S., Liu, J., Kong, X., Tian, H., Duan, J., Ding, Z., Wang, S., Xing, B., 2020. Differentially charged nanoplastics demonstrate distinct accumulation in Arabidopsis thaliana. Nat. Nanotechnol. 15, 755–760. doi:10.1038/s41565-020-0707-4
Sunta, U., Prosend, F., Trebse, P., Griessler, B., Kralj, M.B., 2020. Adsorption of acetamiprid , chlorantraniliprole and fl ubendiamide on different type of microplastics present in alluvial soil. Chemosphere 261, 127762. doi:10.1016/j.chemosphere.2020.127762
Thomas, N.L., Clarke, J., McLauchlin, A.R., Patrick, S.G., 2012. Oxo-degradable plastics: Degradation, environmental impact and recycling. Proc. Inst. Civ. Eng. Waste Resour. Manag. 165, 133–140. doi:10.1680/warm.11.00014
Valavanidis, A., Iliopoulos, N., Gotsis, G., Fiotakis, K., 2008. Persistent free radicals, heavy metals and PAHs generated in particulate soot emissions and residue ash from controlled combustion of common types of plastic. J. Hazard. Mater. 156, 277–284. doi:10.1016/j.jhazmat.2007.12.019
Vezzani, F.M., Mielniczuk, J., 2009. Uma vis??o sobre qualidade do solo. Rev. Bras. Cienc. do Solo 33, 743–755. doi:10.1590/S0100-06832009000400001
Wan, Y., Wu, C., Xue, Q., Hui, X., 2019. Science of the Total Environment Effects of plastic contamination on water evaporation and desiccation cracking in soil. Sci. Total Environ. 654, 576–582. doi:10.1016/j.scitotenv.2018.11.123
Wang, C., Sun, Z., Zheng, D., Liu, X., 2011. Function of mucilaginous secretions in the antibacterial immunity system of Eisenia fetida. Pedobiologia (Jena). 54, S57–S62. doi:10.1016/j.pedobi.2011.07.012
Wang, F., Zhang, M., Sha, W., Wang, Y., Hao, H., Dou, Y., Li, Y., 2020. Sorption behavior and mechanisms of organic contaminants to nano and microplastics. Molecules 25. doi:10.3390/molecules25081827
Wang, J., Chen, G., Christie, P., Zhang, M., Luo, Y., Teng, Y., 2015. Science of the Total Environment Occurrence and risk assessment of phthalate esters ( PAEs ) in vegetables and soils of suburban plastic fi lm greenhouses. Sci. Total Environ. 523, 129–137. doi:10.1016/j.scitotenv.2015.02.101
Wang, J., Coffin, S., Sun, C., Schlenk, D., Gan, J., 2019. Negligible effects of microplastics on animal fitness and HOC bioaccumulation in earthworm Eisenia fetida in soil. Environ. Pollut. 249, 776–784. doi:10.1016/j.envpol.2019.03.102
Wang, J., Lv, S., Zhang, M., Chen, G., Zhu, T., Zhang, S., Teng, Y., Christie, P., Luo, Y., 2016. Chemosphere Effects of plastic fi lm residues on occurrence of phthalates and microbial activity in soils. Chemosphere 151, 171–177. doi:10.1016/j.chemosphere.2016.02.076
Wang, T., Yu, C., Chu, Q., Wang, F., Lan, T., Wang, J., 2020. Adsorption behavior and mechanism of fi ve pesticides on microplastics from agricultural polyethylene films. Chemosphere 244. doi:10.1016/j.chemosphere.2019.125491
Wang, W., Gao, H., Jin, S., Li, R., Na, G., 2019. The ecotoxicological effects of microplastics on aquatic food web, from primary producer to human: A review. Ecotoxicol. Environ. Saf. 173, 110–117. doi:10.1016/j.ecoenv.2019.01.113
Weithmann, N., Möller, J.N., Löder, M.G.J., Piehl, S., Laforsch, C., Freitag, R., 2018. Organic fertilizer as a vehicle for the entry of microplastic into the environment. Sci. Adv. 4, 1–8. doi:10.1126/sciadv.aap8060
Yang, J., Cang, L., Sun, Q., Dong, G., Ata-Ul-Karim, S.T., Zhou, D., 2019. Effects of soil environmental factors and UV aging on Cu2+ adsorption on microplastics. Environ. Sci. Pollut. Res. 26, 23027–23036. doi:10.1007/s11356-019-05643-8
Yu, H., Fan, P., Hou, J., Dang, Q., Cui, D., Xi, B., Tan, W., 2020. Inhibitory effect of microplastics on soil extracellular enzymatic activities by changing soil properties and direct adsorption: An investigation at the aggregate-fraction level. Environ. Pollut. 267, 115544. doi:10.1016/j.envpol.2020.115544
Zang, H., Zhou, J., Marshall, M.R., Chadwick, D.R., Wen, Y., Jones, D.L., 2020. Microplastics in the agroecosystem: Are they an emerging threat to the plant-soil system? Soil Biol. Biochem. 148, 107926. doi:10.1016/j.soilbio.2020.107926
Zhang, G.S., Zhang, F.X., Li, X.T., 2019. Effects of polyester microfibers on soil physical properties: Perception from a field and a pot experiment. Sci. Total Environ. 670, 1–7. doi:10.1016/j.scitotenv.2019.03.149

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**EIPs aim** to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

**An EIP AGRI Focus Group*** is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

**The concrete objectives of a Focus Group** are:

- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

**Results** are normally published in a report within 12-18 months of the launch of a given Focus Group.

**Experts** are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
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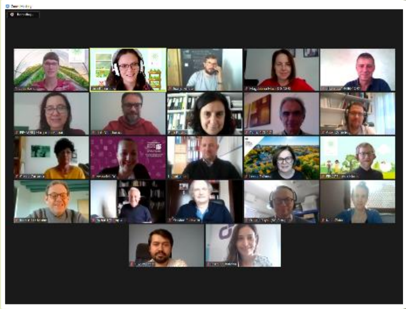


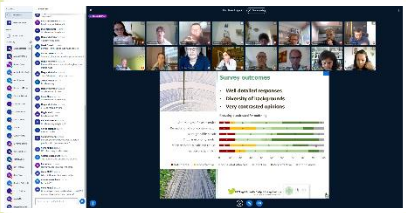



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