

ARE BIODEGRADABLE PLASTICS THE FUTURE FOR AGRICULTURAL MULCH FILM APPLICATIONS?

FOCUS GROUP REPORT
& RECOMMENDATIONS FOR POLICY



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

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Executive summary

This report summarises the findings of a focus group conducted by the University of Bologna on May 25, 2023, as part of the BIO-PLASTICS EUROPE project.

With the aim to investigate the potential of biodegradable plastics to increase the sustainability of the agriculture sector, the focus group was joined by stakeholders, experts and researchers from public and private organisations representing the whole value chains.

Using system thinking and multi-dimensional analysis, the findings reveal that biodegradable plastics have a high potential to contribute to the sustainability of the agriculture sector. However, many questions remain open and multiple measures must be implemented. Among the priorities, the most compelling are:

1. To increase farmers' awareness about the impact of certain practices to the soil and the human health
2. To define applications and contexts where conventional mulch films are still a valid option, provided that removal, collection and recycling is ensured
3. To invest in R&D to improve the technical characteristics of biodegradable mulch films
4. To introduce guidelines for better removal of conventional mulch films from soils
5. To establish mandatory or voluntary Extended Producer Responsibility schemes in each EU country

It follows that biodegradable plastics are not conceived as a stand-alone solution but as one of the alternatives in a more comprehensive sustainability roadmap. These elements reveal the necessity for a systemic joint policy intervention in the sector oriented to build up new business ecosystems, going beyond the boundaries of a single business to embrace collective actions in innovative ecosystems.

About BIO-PLASTICS EUROPE

BIO-PLASTICS EUROPE is a research and innovation project funded by the European Commission Horizon 2020 Framework Programme under Grant Agreement N° 860407.

The vision is to develop and implement sustainability-based solutions for bio-based biodegradable plastic production by turning knowledge into practice through technical, policy and business-model innovations. One way to accomplish this vision is to explore and gather insights regarding the frameworks, mechanisms and business models required for bio-based and biodegradable plastics' social and business expectations. To ensure that the BIO-PLASTICS EUROPE journey is successful, it is vital to integrate the viewpoints of different experts, actors, and stakeholders across value chains. This initiative contributed to achieve the goal and support the definition of policy recommendations.

About Department of Management - Alma Mater Studiorum University of Bologna

Founded in 1088, the Alma Mater Studiorum - University of Bologna (UNIBO) constitutes the most populated university community in Italy, with 86.000 enrolled students, 2800 teaching professors (full, associate and assistant) and 3000 technical-administrative staff. UNIBO is a comprehensive higher education institution with 32 departments and 219 Degree Programmes: 92 first-cycle programmes (BA), 114 second-cycle programmes (MA) and 13 single-cycle programmes. UNIBO also offers 45 PhD programmes, 52 specialisation schools, 74 professional courses, 16 of which are international.

The Department of Management works in different research areas ranging from Accounting, Banking, and Finance to Entrepreneurship and innovation, Marketing, Organization, and Human Resources, Arts and cultural organisations, social management and sustainability, and Strategy.

The authors of this report have expertise in Circular economy, sustainable business models, performance management systems, governance and accountability for sustainability.

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- [Agrofill](#)
- [BASF](#)
- [Woolf Farming](#)
- [ECOEMBES](#)
- [European Bioplastics](#)
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Disclaimer

The content of this report reflects the views of the authors and participants to the focus group, and the Commission cannot be held responsible for any use which may be made of the information contained therein. to the focus group, and the Commission cannot be held responsible for any use which may be made of the information.

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1. Introduction

The EU agriculture sector is characterised by an intensive use of plastic materials. Plastics Europe (2020) reveals that 1.6Mt of plastics were demanded by the sector in 2019. Key agri-plastic applications include **films, nets, twines, packaging, piping, irrigation, and drainage systems**. Excluding packaging, the total volume of agri-plastic applications accounted for around 722 kt in the same year (European Commission, 2021). Of this amount, 76% has been covered by films, thus representing the largest share of the agri-plastics market.

About 80% of the EU market 2018 was represented by ten countries: Italy, Spain, France, Germany, UK, Poland, the Netherlands, Ireland, Sweden, and Belgium (see). Today, the market is concentrated in specific areas of France, Spain, Germany, Italy and UK.

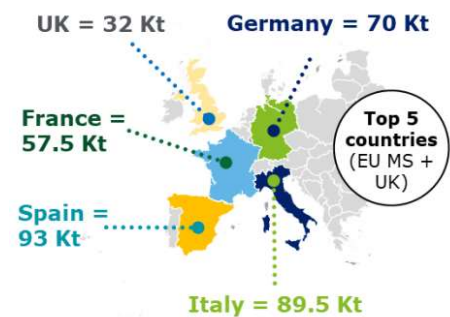


Figure 1. Agri-plastic applications market by top countries - Source: APE Europe

Considering the type of the material (see), in 2018, the demand was dominated by conventional plastics (709kt), mainly LDPE, HDPE and PP, followed by oxodegradable plastics (5kt) -which have been restricted in the EU market from July 2021- and biodegradable materials (5kt), like PHA, PLA, PBS, PBAT, which market share is instead rapidly gaining because of the growing interest towards biodegradable mulch film applications.

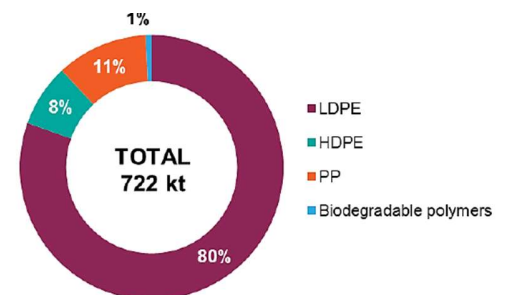


Figure 2. Agri-plastic applications market by materials, 2018 - Source: APE Europe

Indeed, while the demand for conventional mulch films is expected to decline, recent market studies estimate an average of 4000-5000 tons of biodegradable mulch films sold in Europe. In 2021, the market of biodegradable mulch films was valued at USD 43.03 million, and it is expected to grow at a compound annual growth rate (CAGR) of 7.8% from 2022 to 2030 (see).

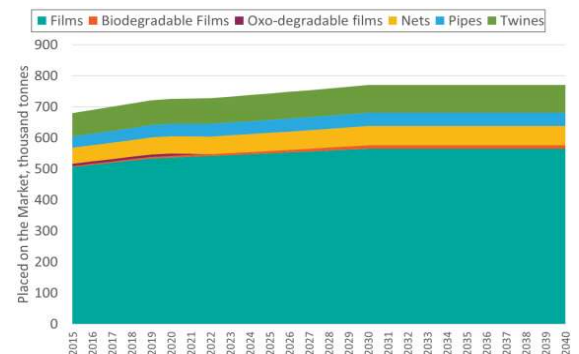


Figure 3. Agri-plastic applications market projection, 2015-2040 - Source: APE Europe

From the supply side, the biodegradable agricultural mulch film segment presents a high concentration level with global key players, such as BASF SE, Dow Chemical Company, Novamont, Armando Alvarez Group, and BioBag International AS.

Looking at the end-of-life (see [Figure 4](#)), it is impressive to see that 419kt of non-packaging agri-plastic waste (34% of the total non-packaging agri-plastic waste generated in the year) is not monitored since the destination is unknown and standard practices are open burning or burying on-site. The remaining amount, accounting for 765kt, is mainly recycled (40%) and incinerated (44%), but 16% of waste is still landfilled.

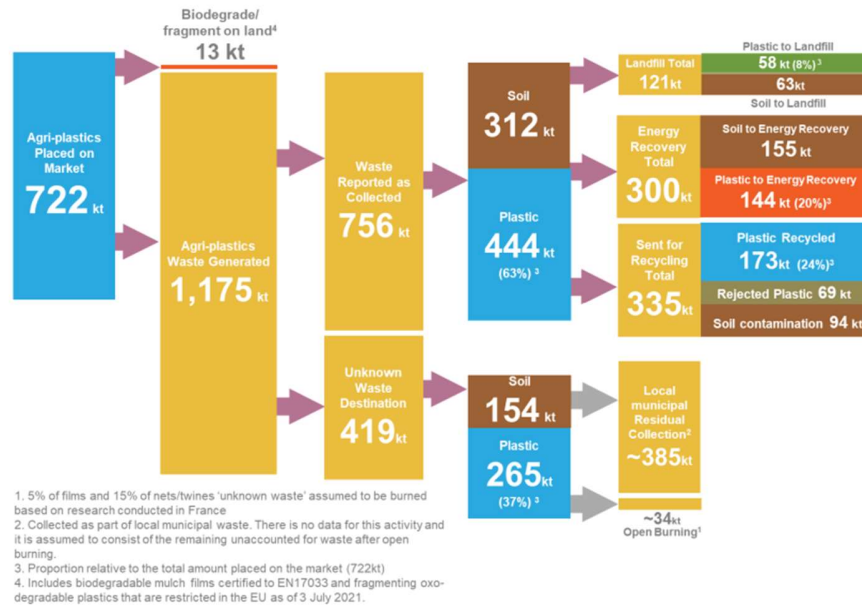


Figure 4. End-of-waste scenario of agri-plastics, 2018 - Source: APE Europe

The recycled agri-plastic waste volume mainly refers to greenhouse, silage and stretch films. Because of the high soil content, varying from 3 to 5 times the weight of the film itself, mulch film recycling is highly challenging today, and the recycling rate is relatively low.

2. Methodology

Sustainability requires the integration of different viewpoints at different levels to analyse complex issues, provide reliable and legitimate solutions, and create substantial changes in production and consumption patterns (Starik and Rands, 1995). This can be applied through multistakeholder dialogue.

In this case, a focus group has enforced the multi-stakeholder dialogue. A focus group is a qualitative research methodology aimed at gaining an in-depth understanding of opinions, knowledge, perceptions, and attitudes (Nyumba *et al.*, 2018) of a group of people in collective discussions about a "focused" issue (Glitz, 1997; Sim and Waterfield, 2019). Generally, 10-15 participants create a group large enough to gain various perspectives and small enough to avoid becoming disorderly or fragmented (Krueger, 2014).

Focus groups do not use probability or random samples since their creation draws on convenience sampling. Specifically, participants have been identified through the implementation of the Prospex-CQI methodology. **CQI methodology** is part of the **stakeholder-integrated research (STIR) approach** to stakeholder engagement (Gramberger *et al.*, 2015). It considers criteria affecting the research topic, quota, and individuals fitting the quotas set and the expertise required. In our case, a value chain approach is used with the criteria to engage at least one representative per step, from raw materials providers to recyclers. The focus group has been organised online to discuss present issues and trends in the mulch film sector and investigate the role of bio-based plastics in accelerating sustainability transition processes. The focus group was finally attended by 14 people (five female and nine male) representing the following domains: Industry (n.6); NGOs (n.3); Public Entities (n.1); Research Institutions/Academia (n.3), Others (n.1).

The dialogue has been organised in opening, introductory, transitioning, key, and closing sessions (Creswell and Clark, 2011) with open-ended questions designed through a "funnel" technique, moving from general to specific issues and considering the most important and representative themes.

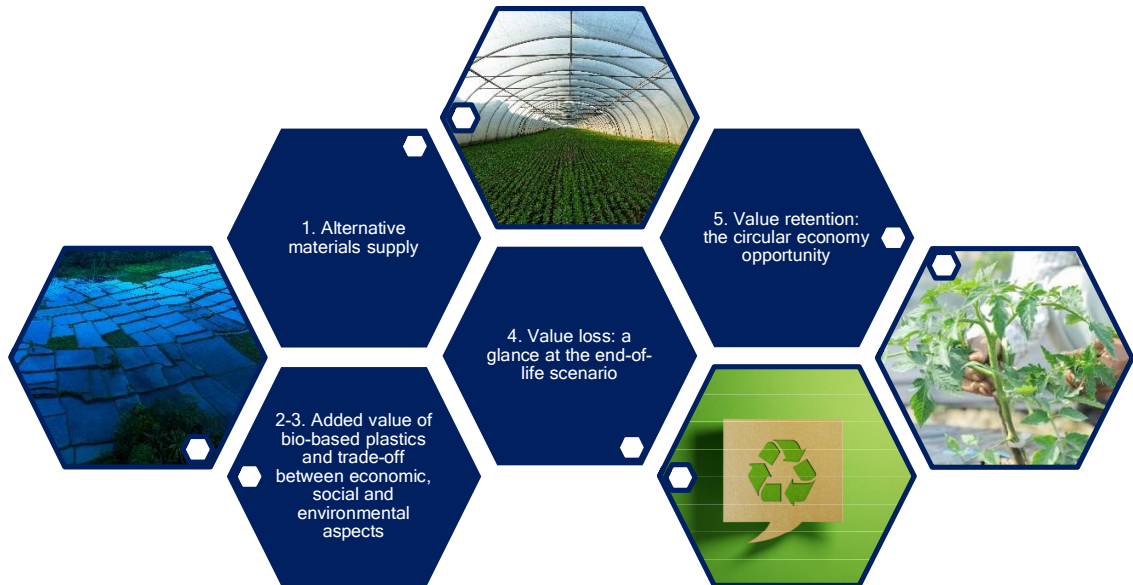


Figure 5. Themes addressed in the focus group

The overarching themes, addressing both general and specific issues, are represented in . The discussion has been enabled by a facilitator and the use of Mentimeter¹ platform.

¹ Mentimeter is an online presentation-building tool with real-time feedback, available at: www.mentimeter.com. The answers collected via Mentimeter.com are voluntary based and only participants with specific expertise on the field were invited to answer.

3. Findings

Theme 1 - ALTERNATIVE MATERIALS SUPPLY

The global yearly consumption of plastic materials in agriculture accounts for 6.5Mt, where more than 10% of the total consumption refers to mulch films (Scarascia-Mugnozza *et al.*, 2006). **Mulch films** are used in agriculture to modify soil temperature, limit weed growth, prevent moisture loss, and improve crop yield.

If standard plastic films for soil mulching used to be PE, PVC, polybutylene, or copolymers of ethylene with vinyl acetate, the growing pressure on conventional plastics has boosted the interest towards alternative materials like bio-based and/or biodegradable plastics (Iles and Martin, 2013). Biodegradable mulch films can be prepared from bio-based polymers or fossil-sourced materials (Bandopadhyay *et al.*, 2018) or blends of them (Razza *et al.*, 2020). Common bio-based polymers used in biodegradable mulch films include PLA, starch, cellulose, and PHA, while fossil-sourced polyesters include PBS, PBSA, and PBAT (Bandopadhyay *et al.*, 2018).

- *Considering biodegradable plastics, do you think there is the added value that they can provide in agricultural mulch films?*



Figure 6. Alternative materials supply: answers collected via Mentimeter.com

The discussion shows convergent views on the added value of biodegradable plastics for mulch films (see Figure 6). Indeed, the prevalence of stakeholders provides positive feedback, except for one academic and one industrial player. Bio-based biodegradable plastics are perceived as an excellent alternative to conventional plastics for the benefits registered at the end of life and the potential to reduce littering and address persistent microplastic accumulation in open environments. However, in all the alternatives, some problems persist and

include: (a) the confusion around renewability and biodegradability meanings as well as the misconception around universal biodegradability; (b) the scarce competitiveness of biodegradable mulch films in the EU market, motivated by the higher price and lower production capacity of these films compared with the conventional ones; (c) the lack of robust scientific evidence about the impacts of biodegradable plastics on soil environments and soil microbial community.

Theme 2 - THE ADDED VALUE OF BIO-BASED AND BIODEGRADABLE PLASTICS: AN ENVIRONMENTAL PERSPECTIVE

In this session, environmental value is mainly discussed in agronomic terms, investigating the effect on crop growth, yield, and water use efficiency generally increase when mulch films are used. The study conducted by Deng et al. (2019) on the use of three films (transparent PE-based conventional film, transparent PBAT-based film, and black PBAT-based film with a thickness of 0.010 mm) on maize and cotton cultivation in a Chinese arid region from 2015 to 2017 reveals that plant height, stalk diameter, and leaf area of maize in the different treatments are higher than those in the bare soil. However, the positive effect of biodegradable mulch films on crop plant height, stalk diameter, and leaf area seems comparable to that of the typical plastic film. Specifically, the most significant increase in crop yield is detected for common plastic films, motivated by their higher stable properties. The black biodegradable mulch film has the second highest effect due to the more extended growth period. In contrast, the impact of the clear biodegradable mulch film is slightly smaller than that of the black biodegradable film. In Europe, studies are mainly conducted in Southern countries (Spain, Italy, Portugal), showing similar findings to those from China. Yet, there is a research gap in evaluating the agronomic performance of biodegradable films in northern countries (European Commission, 2021), where adverse climate conditions may accelerate the deterioration of the biodegradable film itself while in use.

- *Compared with conventional mulch films, do biodegradable mulch films improve the nature of the soil?*



Figure 7. The added value of bio-based plastics - environmental perspective: answers collected via Mentimeter.com

The thematic discussion shows different opinions and reveals the need for future investigation (see). Indeed, while there is a convergence on the benefits of mulch films to generally improve the characteristics of soils in terms of capacity to support life, store water, and provide nutrients, there is limited information and sporadic studies about the higher/lower performances of biodegradable films compared with conventional ones. It is demonstrated by the uncertain answers provided by scholars, answering “maybe” and showing their doubts about the effects. It is mainly due to the complexity that characterises such a type of research since results can be affected by the type of film, the nature of the soil, the microbial activity, the weather conditions, the removal practices (when dealing with conventional mulch films), the season, the degradation process, etc. For example, an interesting aspect that emerged from the discussion is the effect of conventional plastic film removal practice, which commonly causes a massive removal of humus, too. So, it highlights the necessity to define robust field test protocols to perform comparative analysis and, so, foster replicability and scalability. The deterioration may be solved at the design stage by identifying appropriate material thickness and defining the functional lifespan in line with the growing pattern of the crop. It reveals the necessity of proactive collaboration among material scientists and designers.

Theme 3 - THE ADDED VALUE OF BIO-BASED PLASTICS: AN ECONOMIC PERSPECTIVE

The price of biodegradable mulch films (€500-1000) is almost 1,25-2,5 times higher than the price of conventional mulch films (around €400) (Marí *et al.*, 2019). This may hamper farmers from using them. However, looking at the entire value

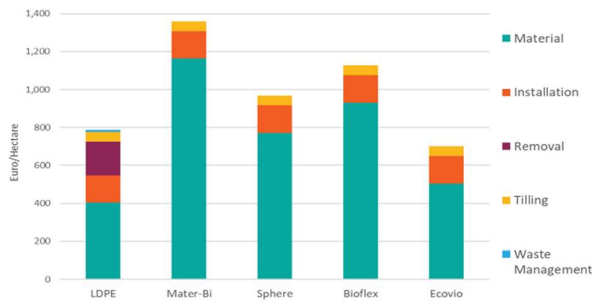


Figure 8. Total cost of LDPE and biodegradable mulch films - Source: European Commission (2021), adapted from Mari *et al.* (2019)

chain, the total cost of biodegradable mulch film may be lower than that of conventional mulch film (see). Indeed, no costs for removal, which takes approximately 42h/ha (Velandia *et al.*, 2020), and disposal, which is 180€/ha on average (Marí *et al.*, 2019), need to be considered where biodegradable mulch films are used.

The Spanish comparative total cost study conducted by Marí *et al.* (2019) on LDPE-based film and different types of biodegradable films shows relatively tiny but positive differences between conventional and biodegradable films. However, recent literature on environmental accounting reveals a big concern about quantifying externalities. It means that total costs may broadly vary since environmental and social costs are context-dependent.

- Are the farmers aware of these benefits? Would they be willing to pay more against the no costs for removal and disposal?



Figure 9. The added value of bio-based plastics - economic perspective: answers collected via Mentimeter.com

This business-oriented question shows diverse opinions (see). While compounders and mulch film manufacturers all agree with the farmers' consciousness of the lower economic impact of biodegradable mulch films when

total cost is considered, it is not the same for academics and other stakeholders who do not provide feedback or do not have strict and firm opinions. This suggests an urgent need for more research investments on this topic and that the lack of knowledge still represents a barrier to their adoption. Indeed, although sectorial associations and manufacturers are putting efforts into educating, training, and informing farmers, issues remain particularly evident in the distribution network learning process. Coherently, the learning process represents a considerable effort for distributors since these studies are strongly affected by the local agriculture landscape and relative peculiarities.

Theme 4 - THE ADDED VALUE OF BIO-BASED PLASTICS: A SOCIAL PERSPECTIVE

Repeated years of improper collection of mulch films they led to an accumulation of plastic residues -including microplastics- in the soil, which are likely to be transferred into the human body through the food cycle, thus resulting in potential soil and health risks. Research outputs reveal sparse field or laboratory-based experiments with contradictory results (Gao *et al.*, 2019). Regarding the possible impact of mulch films on soil's physical structure, evidence shows effects on water and nutrient transport interference. For what concerns soil organisms, microplastics can influence earthworm growth and mortality (Huerta Lwanga *et al.*, 2016). Regarding human health, infiltration of microplastics in the root, seed, leaf, culm, and plant cells of fruit crops and so food chain, is documented. However, only a few research studies provide evidence of the link with the body's inflammatory responses (Sharma *et al.*, 2023).

- *Compared to traditional mulch films, do bio-degradable ones effectively decrease ecotoxicity and associated human health risks?*

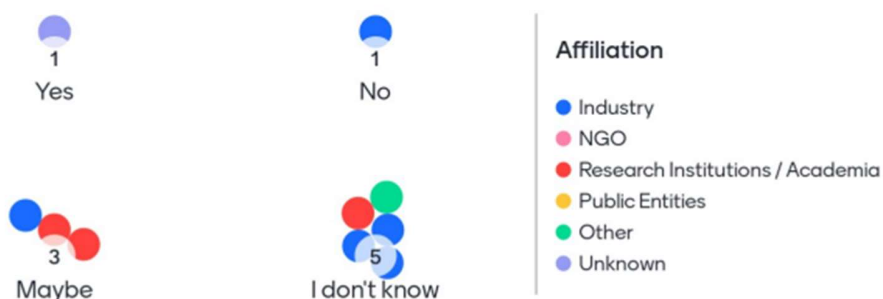


Figure 10. The added value of bio-based plastics - social perspective: answers collected via Mentimeter.com

The feedback orientation towards “*Maybe*” and “*I do not know*” shows a knowledge gap in this vital area (see). From the testing point of view, the UNI EN 17033 includes three mandatory ecotoxicity tests on three different types of microorganisms. Yet, no standard today assesses the impact on human organisms. An emerging research stream is examining the impact of microplastics on food and human chains to demonstrate the presence of microplastics in the human body, too. However, today, it is difficult to examine the correlation between mulch films and microplastics since it is challenging to identify the relative generation sources (e.g., polluted water, tires, irrigation equipment, etc.).

Theme 5 - VALUE LOSS: A GLANCE AT END-OF-LIFE SCENARIOS

As mentioned, EU agri-plastic waste accounts for approximately 700,000 tons annually (Briassoulis *et al.*, 2013). Plastic films represent about 80% of agri-plastic waste. As already pointed out, recycling performance is relatively small, making mechanical recycling technically and economically unfeasible. So, many films remain in the soil or are burned uncontrollably in the fields (Pazienza and De Lucia, 2020). Where implemented, Extended Producer Responsibility is a good approach to give responsibility to producers and users about their mulch film when reaching the end-of-life. However, only eight countries in the EU (Finland, France, Germany, Greece, Ireland, Italy, Spain, and Sweden) have adopted appropriate schemes for agricultural plastics (Leal Filho *et al.*, 2023). Even so, although mandatory schemes are the most effective, most of the schemes implemented in the EU are voluntary-based and mainly used for conventional plastics. Biodegradable plastics do not play a crucial role in this policy measure today.

- *Should we invest in biodegradable plastics in open environments, and can better waste management solve the issue of conventional mulch film?*



Figure 11. Mulch film end-of-life: answers collected via Mentimeter.com

Most stakeholders agree on the co-existence of both scenarios. Investing in biodegradable mulching films may bring lower direct and indirect costs (see [\[1\]](#)). However, since it is impossible - and not desired- to replace all conventional plastics with biodegradable ones, it is essential to have both solutions coworking to address current circularity gaps and foster loop-closing. To sum up, it is crucial to establish national Extended Producer Responsibility schemes for conventional mulch films, improving design and removal practices and, so, recycling processes. At the same time, it is essential to boost innovation by continuing to invest in biotechnologies and bio-based products.

Many aspects need to be considered. There is not a silver solution for this complex issue. We need to be constructive and give complex answers to complex situation and even more, provide all the alternatives and solutions to farmers.

Theme 6 - VALUE RETENTION: THE CIRCULAR BIOECONOMY OPPORTUNITY

Mulch films are characterised by a short lifespan, and reuse is rare. The key option to promote circular paradigms is represented by recycling for conventional films and soil biodegradability for biodegradable mulch films. Regarding biodegradability, biodegradable mulch films should be completely catabolised by soil microorganisms, which convert films to microbial biomass, CO₂, and water. The standard UNI EN 17033 introduces two criteria of biodegradability in soil

(release of more than 90 % of CO₂ equivalent in 24 months). However, one of the main concerns is related to the unpredictable behaviour of mulch films in the real world (Bandopadhyay *et al.*, 2018). Yet, the standard does not investigate transportation, leaching into waterways, or degradation processes in aquatic environments. It reveals the necessity to increase field experiments better to understand the overall process in different environments and settings.

- *In your opinion are there any elements of the standard that can be improved to ensure biodegradability under different conditions?*



Figure 12. Circular bioeconomy for mulch films: answers collected via Mentimeter.com

The feedback orientation towards “*I do not know*” shows the need to reexamine the standard deeply, how it has been designed and which progress research and technology made after its release (see). The EU Commission has already manifested the need to revise the standard in the Policy Framework highlight the urge to extend the investigation and orientate the research effort towards aquatic ecosystems too.

4. Conclusion and recommendations for policy

As part of the EU Green Deal, the EU Commission introduced the ambitious target of becoming climate-neutral by 2050. The *New Circular Economy Package* is the primary building block of the *Green Deal*, fostering a 50% reduction of plastic litter, a 30% reduction of microplastic release by 2030, and other reducing, reusing, and recycling targets. With 35 actions, the Commission plans to set up a sustainable product policy framework, measures to increase the circularity of product value chains, and actions to harmonize waste reduction, collection, and recycling initiatives. Among others, the *Policy framework for biobased, compostable, and biodegradable plastics* published in 2022 emphasises the need to adopt a more systemic approach to underpin decisions.

All these initiatives have far-reaching consequences for businesses. The agriculture sector is strategic in the EU economy and fundamental to guarantee safe access to food today and tomorrow. Big and small companies are in turmoil to guarantee alignment with EU policy vision on one side and ensure their strategic positioning on the other.

- *From your point of view, what needs to be prioritised to make the agriculture sector more sustainable by 2050?*

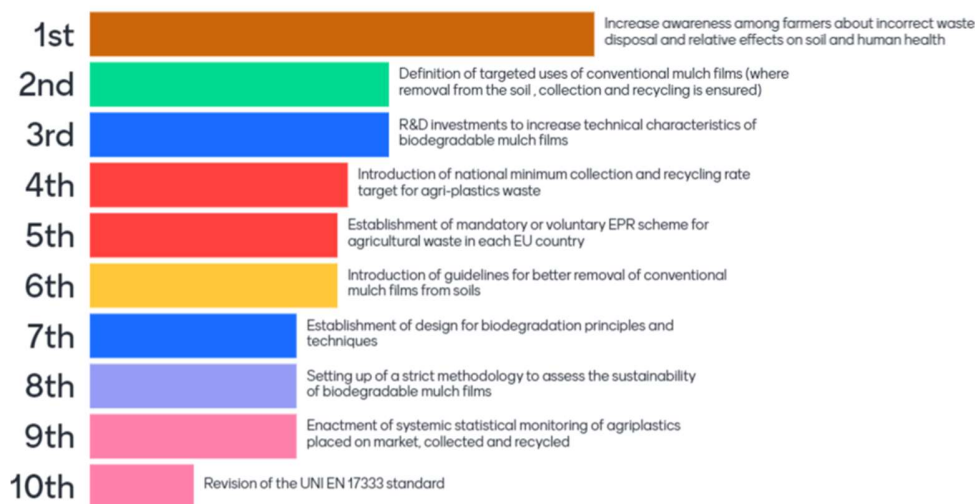


Figure 13. Priorities of the agriculture sector: ranking collected via Mentimeter.com

Following the multi-stakeholders and experts' priorities, biodegradable plastics have a high potential to contribute to the sustainability of the agriculture plastic sector (see). However, many questions remain open, and multiple

measures must be discussed and implemented. Specifically, among the priorities, the most compelling are:

1. To increase farmers' awareness about the impact of certain practices on the soil and human health.
2. To define applications where conventional mulch films are still valid, provided that removal, collection, and recycling are ensured.
3. To invest in R&D to improve the technical characteristics of biodegradable mulch films.
4. To introduce guidelines for better removal of conventional mulch films from soils.
5. To establish mandatory or voluntary extended producer responsibility schemes in each EU country.

These elements reveal the necessity for a systemic joint policy intervention in the sector. The findings demonstrate that the sector's sustainability can extend beyond the supply of alternative materials.

While R&D activities are crucial to make biodegradable mulch films competitive, sustainability requires a new logic, where education is vital, and pathways need to be arranged together

One of the conclusions is that we need both, conventional and biodegradable mulch films. For conventional, it is absolutely important to promote and implement EPR principle and scheme. For biodegradable, more research works is needed. That means not stopping innovation but continuing to investigate and answer all the questions that are still open.

with materials' suppliers, films manufacturers, farmers, researchers, associations, policy bodies etc., sharing the same vision and walking the exact roadmap. The priority demonstrates this at the top of the ranking, which is associated with a matter of culture and awareness. However, it is not enough. While the focus group has aimed to investigate the role of biodegradable plastics in mulching films, it is necessary to rethink the existing conventional mulch film industry, too. This is possible by defining where these applications are still valuable. Once done, it is beneficial to help farmers with proper waste governance systems and support the implementation of Extended Producer Responsibility schemes in each country. Still, it is urgent to have well-established waste infrastructures concurrently. Besides, biodegradability still poses issues in both scientific and non-scientific environments. It reveals the urgency to direct R&D investments towards field testing to investigate biodegradability performances

better and accurately explore the impacts of biodegradable plastics on soil quality, the food chain, and human health.

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