Food and Agriculture Organization of the United Nations

Analysis of stakeholder submissions towards the development of a Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture

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Contents

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Abbreviations

EPR	extended producer responsibility
FSN Forum	Global Forum on Food Security and Nutrition
FAO	Food and Agriculture Organization of the United Nations
HS	Harmonized System
ISO	International Organization for Standardization
LCA	life cycle assessment
PFAS	perfluoroalkyl and polyfluoroalkyl substances
PET	polyethylene terephthalate
PPE	personal protective equipment
PRO	producer responsibility organization
PVC	polyvinylchloride
SME	small and medium-sized enterprise
UN	United Nations
UNEP	United Nations Environment Programme
VCoC	Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture
WTO	World Trade Organization

Executive summary

To inform the development of a Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture (VCoC), the Food and Agriculture Organization of the United Nations (FAO) engaged interested stakeholders through the Global Forum on Food Security and Nutrition (FSN Forum), inviting them to a consultation on the management of plastics in agriculture. Stakeholders shared their insights on current practices in the use and management of agricultural plastics, and the opportunities and challenges related to their use, management, and regulatory frameworks, including regarding the design and implementation of a VCoC. One hundred and eight stakeholders contributed to the consultation, and this document provides a qualitative analysis and summary of their responses.

The considerable variation in perspectives and recommendations highlights the complexity of the topic and the diverse backgrounds of stakeholders, the wide geographical reach, and their various relationships with agricultural plastics. Despite a diversity of respondents and perspectives, several common themes emerged from the consultation, which are briefly described below.

Sustainability of the plastics life cycle

- Certain issues related to specific products, applications or materials could be addressed through prohibitions, limits, or phase-outs based on available evidence.
- The encouragement of biodegradable and bio-based materials should be contingent upon sufficient evidence and support that such materials are not more harmful than fossil-fuel based plastics throughout the product's complete life cycle.

Standards, guidelines and information

- Standards and guidelines for the life cycle of all plastics used in agriculture, including chemicals, should be developed.
- Many respondents suggest developing a database of all relevant information and data, including lists of products and applications that are suitable for interventions related to agricultural plastics.
- Policy guides for governments regarding industries or sectors, chemicals, and policy mechanisms, such as Extended Producer Responsibility (EPR), should be created.
- Respondents suggest addressing research gaps, ranging from social impact of alternative products to the recyclability of fossil-fuel based plastics, and the volumes of waste generated by plastics used in agriculture.

Structuring of the VCoC

- The VCoC should be flexible enough to account for contextual differences based on different geographical areas and agricultural sectors.
- Ensuring representation and inclusion among all stakeholders is paramount for success.
- The VCoC should acknowledge the contributions of plastic-free approaches, including Indigenous Peoples' and traditional practices.

Introduction

To inform the development of a Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture (VCoC), the Food and Agriculture Organization of the United Nations (FAO) has consulted with stakeholders via a call for submissions which was made available to the members of the FAO Global Forum on Food Security and Nutrition from 6 September to 7 November 2023. This call consisted of a 17-question consultation for the forum members allowing them to contribute their input towards key issues central to the development of the VCoC. In total, 108 responses were registered from stakeholders from industry, governments, civil society, and research/academia, 91 of which were qualitatively and quantitatively assessed and summarized into this report.

Study methodology

The data collected through the stakeholder consultation considered stakeholders' needs, experiences, knowledge gaps, and challenges related to agricultural plastic management and regulations. The consultation questions can be found in Appendix 1.[1]

From a quantitative perspective, descriptive data were gathered on the number of respondents who referenced each topic. This helps to identify which topics respondents have opinions on and which ones received less attention. Both qualitative and quantitative analyses of the coded text also allow researchers to determine whether perspectives are shared across different stakeholder groups or are unique to specific ones. This is crucial, for instance, to identify if certain perspectives and recommendations are held by one group but not supported by others. Appendix 2 outlines the study methodology and provides the codebook used, while Appendix 3 presents the quantitative analysis of the responses. Appendix 4 lists additional good practices, standards, and resources mentioned by respondents.

The consultation population indicates the outreach of the FSN forum is high amongst stakeholders with desktop work, like researchers, non-governmental organizations (NGOs), and industry representatives. There are few respondents with more practical experience of the daily work with agricultural plastics and plastic waste, like farmers (1 respondent noted as an individual farmer), and waste management companies (2 respondents), and almost no representation from other agricultural sectors such as aquaculture and fisheries. Furthermore, are many respondents from Europe, many of whom have highlighted the existing regulatory instruments in Europe. Among respondents from Africa, Asia, and Latin America, many respondents report as working for NGOs. On average, they have provided fewer legal references, but highlighted the importance of Indigenous Peoples' and traditional practices, alongside the important focus on food security and nutrition in many parts of the world. The diversity of the respondents brings forth the complexity of regulating agricultural plastics and plastic practices within a global Voluntary Code of Conduct.

[1] The document title "Voluntary Code of Conduct on the sustainable use of plastics in agriculture" was changed in January 2024 to "Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture". For this reason, the new name is not reflected in the form in Appendix 1.

Consultation limitations

- The respondents disproportionately represent the crop production sector (as opposed to livestock production, timber, fisheries, and aquaculture).
- Some answers from respondents make claims that they endorse as factually true and backed by evidence. Such claims have not been fact-checked for accuracy and may not be substantiated.
- Entirely duplicated responses were removed, whereas responses where part of an answer was duplicated across multiple respondents were retained. This may have happened because respondents conferred with one another in advance of submission. Quantitative data regarding number of respondents may include duplicate responses across participants.
- Some respondents did not provide answers to the consultation, but wrote a general statement about plastics in agriculture, or only supplied references to published papers. As this has been a round of stakeholder consultation, we have coded relevant text from the general statements, but considered published papers out of scope for this report.
- Some of the questions included leading content, such as question 4, which mentioned oxo-degradable plastics and PVC. This may have led some respondents to copy their answer directly from the question, instead of providing their opinion and experience.

1. Addressing plastic products and their alternatives

1.1 Problematic plastic products and practices

Respondents supported bans or restrictions on a variety of products, polymer types, and practices. Among these, mulch films, the practice of mulching, and the use of oxo-degradable and polymer coated products like fertilizers and seeds, were among the most often recommended for restrictions. Other respondents urged for careful decision making about which alternatives or substitutes should be promoted, noting that there are many tradeoffs or unintended consequences associated with these. In some cases, such as for biodegradable plastics or mulching films, some stakeholders recommended existing standards (i.e. ISO 23517 and ISO 17556). However, these do not exist yet for all products, polymers, practices, or have not been tested in real-life conditions. As such, respondents also encouraged the standardization, development, and use of assessment methods, notably LCAs, to support decision making about both the prohibition or restriction of certain products, polymers, or practices, as well as the transition to alternatives and substitutes.

Problematic plastic products, polymers and substances of concern

Forty-six respondents referenced specific products that they recommend be banned, reduced, or phased out in response to question 4.[2] The two most recommended products to be addressed via bans or limits through the VCoC include oxo-degradable plastics (29 respondents) and polymer coated products (22 respondents), followed by haybale silage products (nets and films) (9 respondents), and non-biodegradable plastics broadly (8 respondents).

Twenty-nine respondents recommended specific polymer types or products be banned, reduced, or phased out. These were: PVC (19 respondents), polystyrene (10 respondents) and plastic chemicals (5). For the responses regarding chemicals, respondents recommended both fossil fuel based and biodegradable plastics containing chemicals of concern (e.g. additives) for human and environmental health (e.g. endocrine disruptors, phthalate plasticizers, and flame retardants) be banned or severely restricted. Four polymer types[3] were recommended to be banned by only one respondent within the sample, reduced, or phased out.

[2] This section analyses the stakeholder's responses to Question 4: *Reducing problematic plastics: Which plastics polymers, substances, or products could the VCoC recommend banning, reducing, or phasing out?*
[3] ABS, PET, Polycarbonate, Polyurethane

Problematic practices related to agricultural plastics

Four practices were mentioned by 21 respondents as important measures to take in addition to or instead of measures to ban, reduce, or phase out plastics. Nineteen of these were related to the practice of mulching, in which the use of mulching films (which are characterized as difficult to recycle) on soil quickly fragment, resulting in plastics and chemicals entering soil. Respondents suggested addressing the practice of mulching through bans, reductions, phaseouts, or restrictions on mulching films of a certain thickness, and the application of measures to facilitate the use of alternatives (e.g. certified biodegradable films). In addition, two respondents recommended changes related to processing practices, one on the unintentional adding of microplastics to sludge, slurry, or compost, and the other on washing of bunch bags, which hinders their recyclability once wet. One respondent from the agri-plastics industry suggested plastics can be sustainably used with improved end-of-life management, rather than addressing plastics through bans, restrictions and phaseouts.

Stakeholders' suggestions for assessments of problematic products and polymers

Forty-eight respondents recommended the VCoC utilize, provide standard guidance for, or report on assessments of problematic plastic products and polymers. Thirty-three of these respondents suggested the use of comprehensive life cycle assessments (LCAs), with impacts assessed for relevant social, economic, and environmental criteria, including: cost, food safety, nutritional implications, GHG emissions, availability of alternative material and its appropriate end-of-life management, waste, water quality, equity, energy consumption, impacts on health, use of chemicals, and land use.

Fourteen respondents recommended conducting assessments specifically focused on pollution risks. These assessments would involve, for example, identifying which plastics or chemical additives are likely to end up in soil, water, or the broader environment, are considered persistent pollutants, and are difficult or impossible to recover. Eleven respondents suggested that such assessments should be carried out on a case-by-case or gradual basis, taking into account the national context. Similarly, five respondents recommended that decisions should be assessed based solely on feasibility criteria, such as whether it is feasible within the national context to eliminate, phase out, or replace the item, or if the item under consideration does not serve an essential use. Additionally, six respondents advocated for aligning the VCoC standards for assessment with the forthcoming legally binding instrument on plastic pollution, developed by the Intergovernmental Negotiating Committee.[4]

[4] The Intergovernmental Negotiating Committee was convened in 2022 to develop an international legally binding instrument on plastic pollution, including in the marine environment: https://www.unep.org/inc-plastic-pollution

1.2 Plastic alternatives and substitutes

In response to question 5, 63 respondents identified materials or approaches to replace fossil fuel-based plastics. Of these, 48 mentioned biodegradable plastics (often referred to as bioplastics), sharing both recommendations and reservations. Thirty respondents advocated for nature-based solutions in agriculture to reduce reliance on plastics, while 8 discussed alternative practices, including emerging technologies. Stakeholders indicated that alternative materials and practices are most likely to gain support if certain conditions are met, such as the existence of standards and guidelines for development, reduced risk to human and environmental health, existing infrastructure, and economic feasibility. The VCoC's approach to recommending these alternatives should be contingent on solid evidence that their benefits outweigh the risks and that they do not perpetuate the problems associated with the use of fossil fuel-based plastics in agriculture.

Bio-based and biodegradable plastics

Perspectives on the inclusion of bio-based and biodegradable plastics[5] within the VCoC are included in a significant part of the responses to this question, and are also reflected in answers to other questions throughout the consultation.[6] Across the participants, the perspectives on opportunities and challenges associated with substituting fossil fuel based plastic materials with bio-based ones, or promoting biodegradable alternatives, were mixed. Some participants saw promise and potential in the development of bio-based biodegradable plastics from organic material, including from algae and natural biopolymers such as cellulose and starch. Others pointed out the concern for food security, as land area could be allocated for bioplastic production as opposed to food production. For the biodegradability of plastics, some contributors responded that there are significant risks associated with maintaining or exasperating the problems associated with the use of plastics at large in agriculture, such as pollution and chemical exposure. To that end, perspectives on the role of VCoC to facilitate this transition and mitigate risk were concentrated across several themes, described below.

Certifications, standards, and transparency

Standards, when agreed upon and implemented, can ensure consistency and transparency in how a product is designed, used, and managed by stakeholders. Many respondents noted that sufficient and adequate standards or certifications for bioplastics will need to be developed and audited using third party and scientific experts.

[5] There exists a variety of terminology used interchangeably in many of the responses, with bioplastics being the most common word used across the responses. In this report, we seek to distinguish between responses that specifically speak about bio-based materials (without referring to their biodegradability), and responses that refer to biodegradable plastics whether they are based on natural or fossil-based polymers. However, it is often not clear that the respondents also speak of materials using the same distinction.

[6] This section analyses the stakeholder's responses to Question 5: *What guidance should the VCoC include on plastic alternatives and substitutes?* It also includes responses from Question 9 considering the impact of biodegradable plastics on soil microplastic content.

Standards for biodegradable materials should be comprehensive, and developed based on several criteria or considerations, including:

- all known information across the life cycle of a product (e.g. from LCA);
- whether the product or material is biodegradable under all relevant real-world conditions, including in soil, water, and in a large range of temperatures;
- the chemical composition of the product or material and known risk of both materials and additives to human and environmental health; and
- known risk of the product or material ending up as a pollutant in the environment.

Respondents also pointed to existing standards for biodegradable plastics that could serve as a reference for the VCoC, helping to assess which criteria or considerations are already covered and what might be missing. While respondents did not necessarily recommend that the VCoC promote the widespread use of these standards – citing that many were tested under laboratory conditions and may not be suitable for real-life applications – they acknowledged their value as important reference points for consideration.

Concerns about the use of bio-based or biodegradable plastic

Respondents noted several challenges associated with the life cycle of bio-based and biodegradable plastics that need to be addressed for these materials to be suitable for agricultural use. One major issue is the inadequate waste management infrastructure compared to what is needed for these types of plastics. Many countries, for example, lack adequate processing and composting infrastructure, as compostable biodegradable plastics and soil biodegradable plastics behave differently and require distinct waste management systems to properly degrade. Additionally, while biodegradable mulching film is intended to be left in the soil to biodegrade, concerns arise when bio-based materials that do not biodegrade or biodegradable waste that has been improperly discarded enter the waste stream, leading to the mixing of polymers. Additionally, there is concern about the overuse of biodegradable plastics, which could still result in these materials entering the environment and acting as pollutants.

Under the question on assessing what products and mechanisms may add microplastics to agricultural soils, there was no consensus among the stakeholders on whether the use of biodegradable plastics contributed to microplastics build-up or not. Respondents agreed that materials considered biodegradable should be fully biodegradable and that their degradation should mean that there is no remaining micromaterial in agricultural media. Some noted that with current biodegradable agricultural plastics, polymers can still enter the environment, behaving like microplastics do. However, other respondents claimed that soil biodegradable, and compostable materials (as those certified as EN 1733 or ISO 23517) do not release persistent microplastics since microbes can metabolize what remains from these plastics.

Another concern noted by respondents is that some products or materials labelled bio-based or biodegradable plastics are structurally identical to fossil fuel-based plastics, meaning that when they enter the environment, they persist in it for the same amount of time, and are therefore not an improvement from fossil-fuel based plastics. Similarly, bio-based and biodegradable plastics can contain harmful chemicals often found in fossil-fuel based plastics, including per- and polyfluoroalkyl substances (PFAS), organophosphate esters, and plasticizers that pose threats to human and environmental health upon exposure across a products life cycle.

Other issues mentioned by respondents included threats to the environment from harvesting material for bio-based plastic such as soil depletion (particularly from monoculture), land use changes, and the competition with land for food production. Finally, the existing biodegradable or bio-based plastics that do meet all the criteria that would make them viable alternatives are rarely commercially available at scale or at cost, presenting an additional challenge to transitioning to these under current conditions.

Options for products, applications, and source materials

Respondents recommended that the VCoC prioritize the transition to biodegradable or bio-based plastics in products, applications, and sectors that have the highest rates of environmental leakage, are challenging to regulate under policies like extended producer responsibility (EPR) or voluntary schemes, are difficult or typically not collected for recycling, and are costly to collect.

Respondents provided examples of specific applications that could have the highest impact if they transitioned to bioplastics: these include mulch films, hooks, fishing gear, coating for controlled release fertilizers, threads, clips, nets, shelters, row covers, stickers, pots, bags, and rope. They also recommended using compostable biodegradable plastics, cardboard, or other bio-based materials for food packaging when possible. Respondents recommended prioritizing biodegradable materials that have high biodegradability rates and minimized environmental impacts. Finally, respondents suggested suitable materials to produce bio-based polymers: paper, peat, rice husks, straw, leaves, wood chips, cellulose, potato or corn starch, sugar cane, cassava, corn, soy, jute, bamboo, hemp, wheat, sugar beet, castor oil, wood fibre, coconut, sisal, chitosan, starch-based flocculant aids, and algae.

Alternative practices and nature-based solutions to reduce plastic use

Thirty respondents recommended the use of nature-based solutions to reduce the use of plastics in agriculture. Many of such practices have been developed and employed in Indigenous Peoples' and traditional communities, and respondents highlighted the importance of including this knowledge in the development of the VCoC.

The most commonly cited nature-based solutions are: crop rotation to avoid the build-up of diseases and pests in soils, thus reducing the dependence on pest-reducing products like nets and mulching films; and the use of cover cropping (for example with ryegrass or fescue) to retain soil nutrients and reduce the need for plastic mulching and weeding. Both practices may also reduce the need for pesticides and herbicides. One respondent mentioned the Indigenous Peoples' practice known as *Coivara*, a form of slash and burn agriculture, which eliminates the need for synthetic fertilizers and pesticides, or plastic alternatives to these. Other nature-based solutions cited are organic farming, organic mulching, intercropping, agroforestry, regenerative livestock farming, integrated crop protection, and permaculture. According to the respondents, such practices, when and where studied, have reported environmental, climate, and economic benefits.

The VCoC may support the use of nature-based solutions by encouraging their use, identifying crops and conditions where such practices can be suitable, and facilitating knowledge transfer among and between stakeholders.

Respondents also noted other alternative practices that can be used to reduce reliance on plastics or reduce the risk that plastics degrade into and enter the environment as microplastics.

These include:[7]

- Replace single use plastic wrapped hay bales with bunker silos, or other reusable or storage systems.
- Use precision technology that uses water and fertilizer more efficiently, remove weeds, apply chemicals and remove mulch.
- Use vertical cultivation of crops or hydroponics.
- Employ reusable containers, personal protective equipment (PPE), syringes (in veterinary practices) where possible.
- Use durable plastic or glass covers for greenhouses.
- Use clay mixtures instead of plastic-based dam lining in pond aquaculture.
- Apply microbiomes or worms that feed on plastic in soils contaminated with plastics.

1.3 Selection criteria for balancing trade-offs with plastics and plastic alternatives

Fifty-seven respondents noted opportunities associated with reducing reliance on fossil-based plastics and transitioning to alternatives, including boosting local and national economies while reducing reliance on imported products. At the same time, there are numerous and complicated tradeoffs in doing so across sectors. Trade-offs and considerations were primarily focused on concerns related to cost, food security, and carbon footprint. These tradeoffs and impacts often vary along timescales: for example, there may be short term economic benefits with using certain products, at the expense of long-term soil health. According to respondents, consideration of these tradeoffs should be included in decision making criteria.

Socioeconomic trade-offs

Respondents acknowledged the clear utility of plastics in agricultural systems, emphasizing their key features such as lightness, resistance, durability, versatility, and affordability.[8] Some respondents highlighted the benefits of using plastic in agriculture, including reduced labour requirements, long service life, compatibility with existing machinery and infrastructure, and packaging that ensures quality, freshness, and extended shelf life[9] – advantages that may not be fully replicated by alternatives. Additionally, they noted that transitioning to alternatives does not guarantee the complete elimination of fossil fuel-based plastics, meaning that alternatives and plastics may coexist within the same system, posing a risk of mixing in waste management infrastructure.

Respondents frequently emphasized that the use of alternative materials should not negatively impact global food security, nutrition, or food safety (for example through food contamination or preventable food losses), particularly highlighting that food production is often critical for developing economies.

[7] These claims have not been fact-checked for accuracy and may not be substantiated by scientific evidence.
[8] This section analyses the stakeholder's responses to Question 7: *What guidance should the VCoC include to balance the benefits and trade-offs of plastics and their alternatives?*
[9] Countering this perspective, one respondent noted that the consumers' focus on the exterior aspect of produce, which is often relying on the use of plastic packaging, contributes significantly to both food and plastic waste.

In addition, respondents recommended that a shift towards growing crops for bio-based plastics should not impact the cost effectiveness of food production, noting the historical tendency of primary producers to shift to cash crops, including rape seeds for biofuel production, at the expense of food production.

According to respondents, interventions, alternatives, technologies (including biodegradable materials) are perceived by the community of practice to be costlier than conventional agricultural plastics. At the same time, the costs of externalities (for example from climate impacts, pollution, remediation, human health) of agricultural plastics are not internalized, and therefore unproportionately borne by some, most especially vulnerable communities in the Global South, future generations, as well as the broader nature and environment. As such, when considering trade-offs related to cost, several stakeholders highlighted how all costs should be compared with the externalities related to the full plastic life cycle.

Overall, respondents noted that plastic alternatives should have comparable costs for users, including the cost of retrieval, disposal, and waste management. Costs of an alternative can also come in the form of labour costs (such as the cost of use and retrieval of an alternative product) and may be prohibitively high, according to a small number of respondents. Alternatively, the use of biodegradable products that do not need to be retrieved from the environment may save some labour costs on production operations. The VCoC could include guidance on where there are cost savings associated with the use of alternative materials and how EPR or government subsidies can help more equitably distribute the costs associated with transitioning to alternatives.

A small number of respondents discussed the social impacts associated with the use of agricultural plastics that should be considered as negative tradeoffs. Noting that there are human rights violations documented in the plastics industry, alternatives should be assessed for human rights related issues such as worker safety, job security, and gender equality. One respondent suggested identifying and comparing the social impact associated with the entire life cycle of plastics (e.g. the release of toxic fumes from burning plastics) to determine the overall impacts associated with conventional approaches.

Climate and environmental trade-offs

There are several environmental considerations, or externalities, across the life cycle of agricultural plastics that vary between conventional products and alternatives and substitutes.

Stakeholders have noted that alternative materials are not necessarily more sustainable. Some respondents noted that the production of bio-based plastics may contribute to land use changes and deforestation due to cultivation needs. Such threats in Indigenous Peoples' areas or in proximity to other vulnerable groups may constitute environmental justice violations. Land use change, due to cultivation of materials to develop bio-based plastics, can also impact food production and food security. There is also an associated carbon footprint to produce plastics used in agriculture, both for fossil fuel-based plastics and alternatives.

Respondents mentioned several environmental benefits associated with the use of fossil fuel-based plastics in agriculture, including: plastic mulch film can reduce soil erosion, control weed growth, preserve soil moisture, and reduce fertilizer loss (which has important water quality and water pollution implications); drain pipes prevent agricultural runoff; plastic irrigation in drip irrigation systems, vertical farming, and hydroponics ensures efficient distribution of water and may have carbon benefits when compared to metal pipes that lose water; and polymer coated fertilizers regulate nutrient release, nitrous oxide emissions, ammonia volatilization, and nitrate leaching.

On the other hand, respondents noted that plastic leachate in soil can also harm humans, soil, and environmental health. Respondents mentioned the harms associated with the application of fossil-fuel based plastics in agriculture, citing their negative impact on the environment, soil, and biota upon degradation in the environment. Many respondents questioned whether alternatives will have those same impacts.

2. Recommendations to improve the sustainability of plastic life cycle

2.1 Design and reuse of agricultural plastics

Respondents frequently highlighted that global recycling and reuse rates for agricultural plastics are very low, a situation many find highly concerning. The VCoC could enhance the sustainability of agricultural plastics by identifying and sharing information on which products and applications are suitable for reuse and recycling, and where elimination is feasible. Recommendations included developing and promoting standards and guidelines for product design, utilizing labels, and providing education for stakeholders on the proper use of products. Respondents noted several existing pilot projects and programmes focused on the reuse and sustainable design of agricultural plastics, listed in Appendix 4. However, although some of these programmes were described as being focused on reuse, researchers discovered that they were, in fact, recycling programmes. A common confusion appears to be related to the lifespan of certain plastic products: multi-year products may be labeled as reusable because they are not single use, yet there is currently no established system for collecting these plastics for reuse. Another source of confusion may be that the industry sometimes labels recycling programmes as reuse programmes, since the polymer itself is reused.

Design of agricultural plastics, guidelines, and standards

Respondents were supportive of the development of guidelines and standards to better regulate the life cycle management of plastics used in agriculture, including regarding the use of chemicals.[10] Respondents noted that while guidelines should be in accordance with common sustainable waste management hierarchies, they should also be contextual, and based on variables associated with geography, climate, agricultural application, availability of recycling options, and type of industry. Some respondents suggested that standards should be co-developed with the agriplastics industry, and include directions regarding safe installation, use, retrieval, and disassembly.

Regarding standards and guidance for product design, respondents noted that materials used should be designed to be reusable and durable**.** In particular, many respondents noted that mulching film should be above a certain thickness, to enable collection and deployment many times without fragmentation, and that should be included in standards. However, there was no consensus among respondents on what that thickness should be, ranging from 25 microns (as suggested by standard EN 13655) to 50 microns. A respondent also emphasized the importance of developing product design guidance on the use of recycled, biodegradable, and compostable materials.

[10] This section analyses the stakeholder's responses to Question 6: *How could the VCoC improve the sustainability of plastics used in agriculture through guidance on products reusing, repurposing, standards, and design?* While the question did not directly address plastics recycling, we have included the stakeholders' responses that addresses recyclability as part of plastics design. Those responses that consider waste management and recyclability are addressed in section 2B.

As mentioned by respondents, guidelines on product design should include recommended material thickness, should discourage the use of mixed plastic (e.g. different polymers or colors) which hinders the likelihood of plastic being recyclable, and more broadly should refer to existing European standards on designing for recyclability. Another consideration was the use of highly detectable colors for agricultural plastics to facilitate their automatic or manual retrieval.

Beyond the development of these guidelines, respondents stressed the importance of complementary education and outreach efforts aimed at producers, and noted the need to balance environmental considerations with food safety and nutrition in the development of standards or guidelines.

Some respondents also pointed out the economic opportunities that could arise from implementing design standards, including for example the development of industries related to reverse logistics, recycling, reselling, waste processing, and chemical recycling.

Furthermore, respondents suggested that guidelines on product design should include instructions on product labelling; labels can provide information on reuse and the composition of polymers and chemicals. This would promote transparency and raise awareness among users.

Products considered suitable for repair and reuse

Respondents identified several types of agricultural plastics that could be suitable for repair and reuse, including pots, crop covers, rigid containers, agricultural or fishing nets, intermediate bulk containers, crates, personal protective equipment, veterinary syringes, barrels, and irrigation tubing. Additionally, used pipes and fittings can be repurposed as supports for trellises or protective structures for plants.

For the reuse of plastic products to be effective, standardization is necessary to ensure interoperability – such as uniformity in sizes, dimensions, and thickness of items intended for reuse – and to enable the tracking of these items as they move through a system. Guidelines or requirements for reuse in this sector should include instructions on sanitization, disinfection, cleaning, solarization, and the number of reuse cycles, considering that fragmentation may occur with repeated use. These guidelines should also support the inclusion of LCAs.

To facilitate the effective deployment and scaling of reuse systems, respondents emphasized the importance of pilot programs and education initiatives for farmers, potentially through extension services.

However, some respondents expressed concerns about the feasibility of reuse systems for certain agricultural plastics, noting that some items, like mulch film, are too large to be efficiently incorporated into a reuse system.

2.2 End-of-life management and EPR schemes

Seventy-three respondents shared their perspectives on end-of-life management for agricultural plastics, including the role of Extended Producer Responsibility (EPR) in facilitating and financing waste management. They recommended that the VCoC promote the development of technical capacity on these issues through guidance on waste management, including EPR, emphasizing that such guidance must be tailored to and relevant across different contexts and capacities. Although respondents agreed that the VCoC should support and enable EPR, there was no consensus on which plastic materials and applications are most suitable for EPR mechanisms. More broadly, respondents highlighted the need for financing and suggested that responsibility for this could be shared among various stakeholders, including governments, the plastics industry, food producers, and other private sector actors. They also noted that multiple financing mechanisms, such as take-back schemes, could be employed. Additionally, respondents stressed the importance of transparency and traceability mechanisms to monitor the end-of-life management and fate of

Contextual considerations

Many respondents recognized that contextual factors significantly impact the feasibility and effectiveness of EPR schemes and various end-of-life management approaches.[11] For instance, the costs associated with waste management can vary for different stakeholders dealing with waste, including farmers, fishers, local governments, civil society and more and prescriptive measures that are not tailored to specific contexts may result in inequitable outcomes in areas with limited capacity. As a result, there was consensus that the VCoC should acknowledge these differences and the unique challenges faced by agricultural systems globally. Additionally, respondents suggested that the VCoC should promote regional or national evaluations of capacity and existing legislation related to agricultural plastics waste management.

One frequently cited contextual consideration is the scale and density of agricultural production in a given area. For example, some farms are small or located in remote areas with low farming density, where access to waste management or waste collection is either limited or prohibitively expensive compared to other regions. Consequently, an EPR scheme in such areas would need to secure substantial financing to support the collection and management of agricultural plastics.

Some respondents suggested that EPR schemes should be established at the national level, as some countries already have developed relevant schemes that can be adapted to local conditions. However, others noted that there may be certain products or applications for which a global EPR scheme could be feasible. Such a scheme might improve compliance and participation from multinational corporations, which otherwise face varying EPR requirements across different countries and regions.

[11] This section analyses the stakeholder's responses to Question 8: *What guidance should the VCoC include on the end-of-life management of agricultural plastic waste, including through Extended Producer Responsibility (EPR) schemes?*

Financial considerations for end-of-life management

Regardless of whether financing comes through EPR or another mechanism, addressing agricultural plastics end-of-life management will incur financial costs. To ensure effective waste management, favorable economic conditions must be established to facilitate participation. It is crucial to define who bears these costs and the methods of payment to develop effective guidance on these actions.

Opinions among respondents varied on how to facilitate financing for end-of-life management and who should bear these costs. Some believed that farmers and food producers should not be responsible for these expenses, while others felt that they should. Additionally, some respondents suggested that governments should fund collection systems, whereas others proposed that the private sector, encompassing the entire value chain, should cover these costs.

Opinions on how to finance end-of-life management varied as well. Some suggested implementing cash-for-return schemes, where participants are rewarded for returning used plastics. Others proposed using tax instruments, such as adjustable taxes and tariffs, or providing tax exemptions to reward low plastic use. There was also support for modulated fees for products made from recycled content or designed for recyclability. Additionally, some respondents believed that governments or other entities should provide free or convenient national take-back systems to facilitate collection and delivery, thereby encouraging participation in these programmes. Subsidies for preferred products were also suggested as a potential financial mechanism.

Respondents also noted that recycling agricultural plastics often faces limitations due to contamination, lack of available infrastructure, and emerging evidence that recycling practices release microplastics and may have health implications for people working in those industries. Such challenges would need to be considered and addressed even if financing was secured for waste management.

Extended Producer Responsibility

Extended Producer Responsibility comprised the largest portion of the answers to questions about end-of-life management. EPR is a policy framework that coordinates and convenes producers (which can be defined in many ways) to pool together resources to collectively finance responsible product stewardship. While EPR often is used to finance end-of-life management, it can also be designed to support education and awareness, dissemination of best practices, certifications, promote innovations, establish reuse systems, develop a platform for coordination, support reverse logistics, and enable reduction through eco-design, among other interventions. There are already several legally binding and voluntary EPR schemes for agricultural plastic that can serve as references. Stakeholders suggested that the VCoC may encourage the establishment of EPR schemes, and provide guidance on how to develop effective EPR programmes.

On EPR policy design

In considering how to design EPR, respondents noted the importance of including into EPR policies the principles of shared but differentiated responsibilities between stakeholders. While all respondents agreed that EPR should at a minimum include fossil-fuel based plastics, there was no consensus regarding which products or applications should be covered under EPR, and whether biodegradables or other alternatives should be included or exempt from EPR policies. Some respondents believe that alternatives or substitutes should be exempt, while others claim they should be included and regulated under different pricing mechanisms (such as eco-modulated fees).

Some respondents argued that it should be targeted towards plastics that have an established end-of-life market (e.g. PET), while others believe it should target those that currently have no end-of-life market.

Some policy instruments that could be financed by EPR include incentives for responsible stewardship, take-back schemes for plastics, tax incentives, access to more favorable credit conditions, and eco-modulation depending on the sustainability of a product (as determined by LCAs).

Respondents noted that EPR should be designed with inputs from all stakeholders, including the producers, distributors, agricultural associations, importers, farmers, recyclers, informal waste sector. A producer responsibility organization, or PRO, was the only mechanism suggested to organize stakeholders. Respondents noted that through a PRO, EPR can ensure integration and standardization across all stakeholders. Other perspectives from respondents included that EPR for agricultural plastics could be part of a broader agricultural policy, needs to be tailored to regional or national contexts, should be regularly monitored, or audited by a neutral third party, based on principles of circularity rather than linearity, and ensure compliance (via enforcement, licensing systems, incentives, and penalties).

Other end-of-life management options and considerations

- Some respondents expressed support for increasing the use and regular application of recycled content agricultural plastic products, e in plastics used for, noting that this could help drive the recycling market. They mentioned several policy instruments that could boost the demand for recycled plastic, both in general and specifically for agriculture. These include green public procurement, financial incentives or disincentives (such as a VAT tax proportional to the percentage of plastics used in agriculture), EPR schemes to stabilize volatile recycling markets, setting targets for recycled content.
- Four respondents discussed energy recovery a potential end-of-life waste management as option for agricultural plastic waste.[12]
- Two respondents emphasized the importance of proper storage mechanisms for farmers, noting that waste can accumulate even with adequate collection infrastructure in place.
- Two respondents mentioned best practices related to the export of agricultural plastic waste.
- One respondent suggested recycling agricultural plastic waste into other products, such as flip-flops or buckets.[13]

[12] Across the scientific community, material recovery is generally considered a better form of recycling that energy recovery. There are, however, cases where energy recovery can be considered an improved end-of-life management.

[13] This is often considered downcycling in the scientific literature.

3. Research and knowledge gaps related to plastics and microplastics in agriculture

3.1 Knowledge gaps on human health and socioeconomic sustainability

Sixty-two respondents identified knowledge gaps across 17 different but overlapping themes, including environmental and socioeconomic impacts, implications for food production, and human, animal, and soil health. In addition to research gaps, respondents emphasized the need to standardize assessments for determining and evaluating risks to support evidence-based and informed decision-making. While some of the research questions and gaps identified by respondents may already be addressed by existing information, this information may not be widely or effectively disseminated. The VCoC can play a role in facilitating new research as well as in inventorying and disseminating existing research.

Human health and food security

The most commonly highlighted knowledge gap in this area is the impact of microplastics and chemicals on food safety and human health, including how microplastics accumulate in food through environmental transfers.[14] Respondents suggested developing a comprehensive microplastics risk assessment tool to evaluate the impacts of microplastics and plastic chemicals on human health, in support to decision-making for policy development. Additionally, respondents noted knowledge gaps regarding the impact of plastic recycling and reuse on human health, as recycling processes can expose workers to plastic chemicals, chemicals used in the recycling process, and microplastics from manual handling.

Some stakeholders also identified knowledge gaps concerning the impacts of plastic pollution on food security, particularly in relation to agricultural soils. Specifically, they pointed out uncertainties about how macroplastics in the environment might alter water flows in rivers, irrigation systems, and soil health, and the subsequent effects on agricultural production systems. Related questions include the impact of microplastics on crops and livestock, especially regarding yield and productivity.

Economic, social, and cultural impacts

Addressing the management of plastics used in agriculture may have social, economic, and cultural impacts, including benefits and costs, that are not yet well understood. Several respondents identified knowledge gaps regarding the impact of transitioning to biodegradable plastics, or adopting other practices that reduce the use of plastics in agriculture. Without further research, especially on socioeconomic and gendered inequalities, there may be unintended consequences or tradeoffs.

[14] This section analyses the stakeholder's responses to Question 13: *What are key research gaps around plastics used in agriculture, and how can the VCoC recommend addressing them?*

Furthermore, given the ubiquitous use of agricultural plastics today, several respondents noted that there are existing knowledge gaps on alternative forms of agriculture where there is less or no use of plastics (i.e. agroecology, permaculture, indigenous Peoples' and traditional knowledge practices), and especially in relation to the long-term benefits of these practices. Furthermore, some stakeholders asked what the cost of inaction is, that is, what the socioeconomic and environmental cost of not regulating agricultural plastics will be to the current and future generations.

The stakeholders suggested that the VCoC could encourage the collection of data from farms already utilizing more sustainable practices, to understand costs and benefits, including experiences with and perceptions of costs and benefits according to farmers.

3.2 Knowledge gaps on environmental sustainability

Plant and animal health

Many of the stakeholders noted large knowledge gaps and concerns regarding the impact of agricultural plastics, including primary and secondary microplastics, on plants, animals, ecosystems, and the broader environment. While there is a growing amount of research, several respondents highlighted concerns regarding how plants absorb and accumulate microplastics, and how this affects plant growth. Others pointed out knowledge gaps concerning how the ingestion of plastics impact animal health, including their reproductive systems.

Soil health

Many respondents noted remaining knowledge gaps about the impact of microplastics from conventional fossil-fuel based and biodegradable plastics on soil and soil health. More specifically, respondents noted knowledge gaps regarding the effect of microplastics (including biodegradables) on soil organisms (e.g. mesofauna, biodiversity), moisture, porosity, nutrient cycling, bio-geophysical processes, and microbial activity. Other research topics related to microplastics include the quantification of microplastics that are generated from use of plastics in agriculture, and the quantification of microplastics coming from sewage sludge, biogas, digestates, compost, and animal fodder. To support such quantification, one respondent noted the need for standards on the characterization of microplastics.

Chemicals

Respondents highlighted the need for more information about chemicals in both conventional and biodegradable plastics used in agriculture, as well as their fate, accumulation, and persistence. Respondents noted knowledge gaps related to the degradation of these additives in the environment, as well as the risk associated with exposure to both individual chemicals and chemical cocktails from agricultural plastics.

3.3 Knowledge gaps related to plastic use and plastic waste management

Biodegradable plastics and other conventional plastic alternatives

Definitions regarding biodegradable plastics and other alternatives to conventional plastics were emphasized as a large knowledge gap. Respondents suggested the VCoC should play a role in developing, standardizing, disseminating, and demystifying these definitions. Other knowledge gaps identified are related to the degradability of biodegradable plastics under various conditions and environments; the effectiveness, and quantifiable social, economic, and environmental benefits of biodegradable plastics and other alternatives, including their carbon footprint.

Waste management and mismanagement

Respondents highlighted research and knowledge gaps regarding waste generation and management of plastics used in agriculture. Some of these research questions were focused on describing trends, such as the quantification of waste generation associated with agricultural plastics and identification of which practices have the most detrimental impacts. Other questions were oriented towards the feasibility, effectiveness, and best practices associated with current waste management including identifying which agricultural plastics are recyclable and how are they recycled, what are existing preventative solutions, what is the policy landscape and known impacts of policies (including those overseeing trade of agricultural plastics), and case studies of effective solutions. Other research avenues were focused on solutions that are less common or still in development, including how to treat sewage sludge that has microplastics, how to best incorporate recycled content into new agricultural plastics, and how to develop reuse systems for agricultural plastics. Finally, some stakeholders noted concerns with the lack of knowledge on how to develop proper waste streams for conventional and for biodegradable materials or alternatives to plastic, so that these do not contaminate the rest of the waste stream.

Use of agricultural plastics

Respondents highlighted that there is a lack of data on the different agricultural plastic products and their usage. They suggested that the VCoC should facilitate the development of inventories for agricultural plastic, to better understand how much agricultural plastic is placed on the market, how much is used, and how this varies across regions and sectors. In addition, one respondent noted the lack of available information on the actual necessity of agricultural plastics and which types of plastic products can be eliminated without affecting agricultural production.

4. Policy recommendations

Respondents offered various views on potential financial incentives that could be included in the VCoC and how financial instruments can internalize externalities. They highlighted that policy frameworks for plastics and agricultural systems can support and enable financing, technical assistance, and trade systems by integrating circularity principles; can develop, mandate, and enforce limits and standards, and ensure effective monitoring. However, the current policy landscape is fragmented. The VCoC could serve as the connective tissue to better align existing policies to enable the needed supportive policy environment.

Financing, according to respondents, could involve direct support to the most vulnerable stakeholders in the agricultural plastics value chain. They also suggested that the VCoC should encourage economic disincentives to discourage practices such as landfilling and the use of fossil fuel-based plastics. Additionally, respondents suggested that the VCoC encourage technical assistance, particularly regarding sustainable practices and the necessary training (e.g. upskilling) to implement them effectively.

There was also discussion on how trade policies, along with the development and enforcement of product standards, should be leveraged to improve monitoring of the trade in agricultural plastics and waste, and to promote a transition to sustainable practices. Furthermore, stakeholders expressed support for the VCoC to provide guidance, requirements, and standards for developing and enforcing regulations on plastics in agriculture. Most respondents focused on the need for regulatory and enforcement guidance for fossil fuel-based plastics rather than biodegradable alternatives.

Broadly speaking, respondents believed that effective regulation must come from the highest political levels, be explicit and accountable, and enable measurement and monitoring. They recommended that the VCoC develop guidance for decision-makers and legislators on the use of plastics in agriculture.

4.1 Enabling policy environment

Respondents agree that a supportive and enabling policy environment for the sustainable management of agricultural plastics needs to be established at all levels of government—subnational, national, and international.[15] However, the current policy landscape for both plastics and agricultural systems is fragmented, with significant gaps in regulation and enforcement.

Several stakeholders argue that policies should be crafted to integrate most, if not all, plastics used in agriculture into circular economy models. This could involve promoting circular economy principles and restricting the import of agricultural products that do not comply with established standards.

[15] This section analyses the stakeholder's responses to Question 11 (*What financial incentives, priorities for technical assistance and trade measures could be included in the VCoC?*) and Question 12 (*How could the VCoC provide guidance on efficient regulatory and enforcement mechanisms?*). This section also includes suggestions on best practices and information from question 8 concerning waste management, and regulatory solutions suggested under question 9 on microplastics.

In addition, there is a need to mandate end-of-life solutions for agricultural plastics through, for example, EPR schemes. Moreover, some respondents suggest that laws and regulations should establish and enforce targets, which could drive industry innovation and attract investment. These regulations should also support public education and capacity building, ensuring that SMEs have access to accreditation and standards. Enhancing infrastructure for recycling and end-of-life management is another critical area where laws and regulations can make a significant impact.

Several respondents also highlighted the role policies can play in supporting nature-based solutions. For instance, policies could provide incentives for farmers to dedicate portions of their land to maintaining traditional crops and agricultural practices that minimize or eliminate the need for plastics. Additionally, these policies could encourage the adoption of Indigenous Peoples' agricultural practices that inherently do not rely on plastic use.

Ensuring policy coherence

Respondents also suggested that, to the extent practicable, the VCoC should recommend agricultural plastic policies to align with existing policies, to ensure coherence across different regulatory frameworks. They named several specific policies and regulations, which include the forthcoming legally binding instrument on plastic pollution, the EU REACH regulation, the EU Fertilizing Product Regulation, the Circular Plastics Alliance, and Indigenous Peoples' customs.

Other relevant policies mentioned include standards from various agencies,[16] as well as other FAO Codes of Conduct on responsible fishing, and pesticides and fertilizers management. Additionally, respondents highlighted the importance of aligning with the EU Sustainable Reporting Directive, the Rotterdam Convention (which pertains to Prior Informed Consent), Annex XVII to Regulation EC 1907/2006 (concerning microplastics in fertilizers), MARPOL Annex V, and trade regulations from the WTO (World Trade Organization).

Information disclosure

The discussion among respondents highlighted the importance of regulatory requirements and enforcement provisions concerning information disclosure by manufacturers, distributors, and associations. They proposed that certain types of information should be required for disclosure, either publicly or to designated authorities. This information could include the tonnage of materials used, types of polymers or plastic resins, chemical composition, trade details, point of sale, point of waste generation, associated carbon footprint, and product certifications.

One respondent suggested that governments could require a standardized code (such as Harmonized System – HS or International Organization for Standardization – ISO) for products, which would enable the collection and sharing of data across the product's life cycle, and enable tracking of traded goods. This approach would also facilitate better labeling practices.

In a similar vein, some respondents emphasized the role of farmers and food producers in the disclosure and reporting of their use and waste generation of agricultural plastics. They suggested that farmers should be required to report their plastic usage and waste production.

[16] Such as from CENELEC (European Committee for Electrotechnical Standardization), ASABE (American Society of Agricultural and Biological Engineers), and ASTM International.

4.2 Financial instruments

Direct support for sustainable practices, waste management, and innovation

Respondents suggested a range of financial instruments to support the adoption of sustainable practices. These include:

- subsidies, including for adequate waste management;
- low interest loans (e.g. green loans) or the granting of credit lines;
- insurance premium reductions;
- tax reductions;
- financial support for ecolabelling and training; and
- economic incentives for the removal of microplastics and macroplastics already in the environment.

There was no consensus on which financial instruments were preferred among the stakeholders. Some stakeholders suggested that financial support should be prioritized for small-scale farmers, Indigenous Peoples' groups, women, and other vulnerable groups. Some respondents also considered support for the purchase of certified biodegradable materials, however, others did not believe that financial support should be given for biodegradables given remaining uncertainties.

In addition to supporting producers, government actions on agricultural plastics should also include financial support for improved national collection systems and recycling facilities, stabilizing volatile recycling markets, enabling compliance monitoring and evaluation of implementation, and incentivizing financial institutions investing in circularity and sustainable agriculture. Further, the stakeholders suggested the VCoC could encourage government to finance innovation, research and development (for example via a fund) to enhance recycling technologies, biodegradable alternatives, and new products.

Several stakeholders listed practices that can be the specific target for subsidies or incentives. These include innovative methods that reduce plastic use (for example, vertical cultivation of crops and conservation tillage practices), encourage eco-design, encourage the replacement of conventional fertilizers, pesticides, and seeds with botanical fertilizers and cultural methods for pest control. Additionally, they suggested that incentives could extend to broader plastic policies beyond agriculture, including improved waste management, bans on frequently littered plastic items, and restrictions on the manufacture and sale of products at risk of creating microplastics pollution.

Economic disincentives

The stakeholders suggested that the VCoC can encourage several economic disincentives that can promote sustainable practices. These are varied and include:

- variability in tariffs (for trade): e.g. lower tariffs for products that are aligned with standards or certified as biodegradable, and higher tariffs for products considered not sustainable;
- taxes on fossil fuels, fossil fuel-based plastics, and uncertified bioplastics;
- fines and penalties for non-compliance; and
- landfill levies, charging to dispose of waste.

Many stakeholders listed specific practices to be considered for economic disincentives and prohibitions regulated with fines and penalties. These include among others: mixing of soils (or sludge, or biogas digestate) contaminated with microplastics with clean soil; the use of intentionally added microplastics; and the use of oxo-degradable plastics.

Structuring of financial mechanisms

Respondents emphasized the importance of structuring financial mechanisms based on well-defined criteria related to the use and waste generation of plastics in agriculture. These criteria could include the weight of collected plastic, the reduction in waste generation, the use of alternative materials, or the risk associated with plastic, as determined by credit rating agencies.

They also highlighted the need for guidance to clearly define the roles and responsibilities of all relevant stakeholders. This guidance should be regularly updated and widely disseminated to ensure transparency and accountability. Furthermore, respondents stressed that equitable financial responsibility for the entire life cycle of agricultural plastics needs to be carefully considered and incorporated into policy guidance. This includes addressing the question of who should bear the costs of implementing regulations designed to manage agricultural plastics effectively.

4.3 Technical assistance

General suggestions regarding technical assistance

Respondents were supportive of the VCoC encouraging coordinated technical assistance measures to enhance the sustainability of plastics in agriculture, covering topics such as:

- technologies and harvesting techniques (e.g. precision farming) that reduce the use of plastics and chemicals in agriculture;
- training for alternative and new skills (e.g. upskilling) for farmers and plastic producers;
- training of staff in ministries of agriculture, livestock, fisheries, environment, and other relevant ministries, on the sustainable management of plastics in agriculture;
- the development and use of decision support systems;
- responsible end-of-life management;
- technologies and machinery to recover plastics that have entered the environment, and how to pool resources and assets to support them;
- training on definitions and standards, including the ones associated with bioplastics;
- transfer of knowledge between private sector actors to share information about new technology and new products, including biodegradable and bio-based alternatives;
- routine microplastic monitoring in soil, water, compost, sewage sludge, fertilizer and more; and
- outreach and educational material on sources and impacts of microplastics on human and environmental health.

Respondents recommended that technical assistance be tailored to specific locations and contexts, and be developed in coordination with local research initiatives. This assistance could be organized and facilitated through existing organizations, initiatives, and public-private partnerships. Additionally, respondents emphasized that technical assistance should prioritize SMEs (small and medium-sized enterprises) over large companies. However, industry or innovation bodies that have successfully implemented solutions should also provide technical assistance, sharing insights on those solutions and their outcomes.

Enabling best practices for improved end-of-life management

Specifically regarding EPR and improved end-of-life management, the stakeholders provided a rich overview over how the VCoC could include best practices, guidance, and training on EPR and end-of-life management more broadly. Their recommendations include:

- Develop a list of prohibited or discouraged end-of-life management practices, such as illegal dumping and open burning.
- Develop guidance on monitoring and surveillance methods.
- List which materials are easy to recycle, have a long-life span, and are readily available.
- Provide information about the destination of agricultural plastics after their use.
- Develop decision trees or matrices to detail end-of-life options and support decision making for each product.
- Develop guidance on collection, cleaning, recycling, reuse, and disposal to multiple stakeholders, including government (e.g. explain how to remove mulch films from soils best), tailored to each sector.
- Create a website with a central repository of information on actions that are already being done.
- Provide training and capacity building for workers in the sector (e.g. farmers, fishermen) specifically, in coordination with municipalities, extension authorities, and well-established. programmes across the UN system (e.g. Clean Seas Program)
- Develop guidance and clear knowledge on how to use labels on packaging.
- Share benefits of transitioning to sustainable practices, including avoidance of plastics.

Twenty-two respondents spoke of the value of traceability tools to support compliance and mandatory or voluntary data reporting, as well as to better monitor and control the use and end-of-life management for plastics used in agriculture. Respondents cited both widely used and novel techniques that can enable such transparency, including microchips in fields, barcodes, QR codes, tag, and Radio Frequency Identification (RFID) on plastic products. Some respondents suggested such mechanisms be supported, developed, and enforced regionally or globally, or as a part of standards that are developed for plastics used in agriculture. Information stored and transmitted via traceability mechanisms includes plastic type, chemicals in the product, expected use, date of manufacture, country of origin, maximum end use, allowable usages, safe use, references to best practices or recommendations for responsible end-of-life management, and where it ends up for recycling. A centralized information system, website, database, or repository was recommended as the place to track the movement of agricultural plastics through their life cycle.

Respondents emphasized that the VCoC should call for and facilitate engagement and collaboration including with informal sector, public and private sectors, across the entire value chain, including global and transnational actors owing to the trade of agricultural plastic products and waste, and across sectors as plastic waste from agricultural plastics can be used by other industries and vice versa.

4.4 Trade measures

Trade measures to ensure international harmonizations and avoiding free riders

Given the global trade of plastic products and waste, respondents noted that policies must be applied to regulate trade of plastics, such that harmonization, standardization, industry compliance, and transparency are ensured, and to prevent free riders or certain countries from being disproportionately impacted by actions to address plastic.

Many respondents noted that limits, bans, or tariff policies on the import of low-quality materials, or materials that do not adhere to international standards, can lead producers to prefer products that do adhere to standards. According to respondents, such standards should take into consideration the sustainability of production, use, and end-of-life management. In addition, trade policy can support technical assistance and technology transfer across countries to improve access to services that reduce plastic use, or enable proper end-of-life management across jurisdictional boundaries.

To support trade policies for sustainable agricultural plastics management, respondents suggested that the VCoC could promote the development of guidelines to achieve international harmonization of traded products, focusing on areas such as product labeling, licensing, and design. Additionally, respondents recommended the creation of a global register for manufacturer, which would help manufacturers understand the appropriate labeling requirements for products destined for international markets, ensuring compliance with various regulatory standards.

In addition, the VCoC may encourage the development, in collaboration with relevant authorities, of HS codes specifically for agricultural plastics, including alternatives and substitutes. These HS codes would allow border agents to better differentiate between types of agricultural plastics, making it easier to enforce regulations. The new codes could also be incorporated into tools like the UNCTAD Control Measures Tool, enhancing the effectiveness of trade policy in promoting sustainable agricultural plastics.

4.5 Guidance on standards, labelling and regulations

Development of and guidance on standards

Respondents recommended that the VCoC may encourage the creation of standards for products that are based on a number of criteria, such as durability, recyclability, thickness (when relevant), safe use, quality, environmental impact, and food quality and safety. Furthermore, respondents were clear that standards need to be developed for all stages of the life cycle for products and should also include chemicals. In addition, standards should be developed for recycling and traceability mechanisms, for example standards on best practices for end-of-life management of plastics, and technical standards for product design that minimize microplastic release to the environment. Respondents noted that the VCoC could encourage enforcement through product standards, for example through import controls or inspections.

With regards to guidance on compliance monitoring and enforcement, respondents recommended that the VCoC provide guidance on how member states can enforce global standards and conduct compliance monitoring (including through a framework or methodology for recordkeeping), as well as guidance on how labels can be used as an enforcement mechanism.

One respondent encouraged the VCoC to endorse and provide guidance on the concept of Prior Informed Consent as an enforcement mechanism for ensuring that standards are reviewed upon product importation.

Finally, the stakeholders recommended standard measurements to fill knowledge gaps, conduct risk assessments and support evidence-based decision making. Standardized protocols need to be developed, defined, and widely shared, for issues including measuring biodegradability and detecting microplastics. Protocols should be tested to ensure they are relevant for all regional and sectoral contexts as they may differ.

Guidance for product registration

In addition to developing guidance for harmonized standards, respondents recommended developing guidance for harmonization of product registration and licensing. One respondent recommended that the developers of the VCoC refer to pesticide licensing registration protocols, which are developed by and for producers, importers, distributors, and users alike.

Several respondents recommended that the VCoC complete the following activities:

- developing information documents (e.g. databases or info sheets) on specific products and their end-of-life pathways that governments can use in decision making;
- fostering and encouraging multisector collaboration on coordination in the development of standards; and
- establishing (or encouraging the establishment of) a certification process to identify the best products.

Guidance on product and polymer labelling

Respondents held that regulatory measures can be used to encourage or mandate the labelling of all plastics used in agriculture, and the VCoC can develop guidelines on what should be labelled, and how. One respondent suggested that the VCoC should develop a global register or database for correct labelling for all products. Respondents encouraged labelling to be clearly written, legible for the public, and not greenwashing. Respondents had many suggestions for what information should go on labels, including:

- conformity to standards and certifications that have been received;
- usage instructions and guidelines for proper end-of-life management for the given area;
- education for consumers on reuse and recycling;
- definitions for any terms on labels (e.g. green, organic, recyclable);
- adherence to or compliance with the VCoC (or other policy instruments); and
- recycled content, durability, reusability, repairability, recyclability.

Guidance on regulations and infrastructure

The other category of guidance that respondents suggested VCoC could develop was related to policy design and requirements for policies across the life cycle of agricultural plastics, noting that there may already be relevant published reports on this topic. This includes guidance (and one respondent even suggested instruction manuals for governments) on EPR schemes, the use of biodegradable applications in specific applications (e.g. a suggestion of which alternatives should be allowed), collection systems, the development of recovery targets for agricultural plastics, which materials or applications should be prohibited or restricted, labelling requirements and when to use rewards or penalties. Guidance would be, at least partially, developed from case studies on best practices and effective outcomes.

5. VCoC structure, implementation arrangements, and stakeholder inclusion

5.1 The VCoC structure

The question regarding the structure of the VCoC was presented to respondents with suggested options, and most respondents adhered to these suggestions, favoring one over the other. While there was no consensus on the specific categories for structuring the VCoC, the majority agreed on the need for a higher-level umbrella structure that provides relevant guidance for all sectors, followed by themed chapters or categories. Among those who responded, 22 supported a subsector approach, 10 favored an approach organized by specific aspects, and 10 supported either a combination of the two options or proposed an entirely new structure. Respondents emphasized that the guidance should be flexible enough to accommodate countries with varying levels of authority to regulate agricultural plastics.

Umbrella structure organized by sector

For those supporting a structure organized by sector, respondents outlined an umbrella structure with guidance applicable to all sectors, and then sector-specific (crop production, fisheries, forestry, livestock, aquaculture) guidelines, followed by even more tailored guidelines for subsectors beneath those sectors.[17] Some respondents supportive of this approach recommended that subsectors be organized by medium (e.g. soil, freshwater, saltwater), which can allow for more tailored guidance regarding the use of for example biodegradable plastics (as these are certified to degrade in different media). Others supported subsectors be organized by product or crop type (e.g. cereal, vegetable). Respondents believed that corresponding councils and committees would then be organized by subsectors.

Structure organized by aspect

Those in favor of structuring the VCoC by aspect suggested themes such as EPR, licensing, labeling, single-use plastics, and nature-based solutions. One respondent also proposed organizing based on the different end-of-life pathways for agricultural plastics.

Other structure recommendations

A small number of respondents recommended a combination of the two, whereby the first category is organized by sector and then the subcategory following is by aspect. Perspectives that were less frequently mentioned in the consultation include focusing solely on terrestrial plastics used in agriculture (e.g. crops) rather than aquatic and marine sources (e.g. fishing and aquaculture). Others emphasized the importance of ensuring that this VCoC, where appropriate, references and expands upon existing VCoCs, such as the one on marking of fishing gear.

[17] This section analyses the stakeholder's responses to Question 15: *Which structure would be more efficient in targeting all agricultural subsectors?*; and Question 16: *Which stages of the agrifood value chains should be covered by the VCoC?*

The scope of the VCoC and related agrifood value chain stages

Thirty-six respondents agreed that all stages of the agrifood value chain, including food packaging, should be covered by the VCoC. They emphasized the importance of including various stages of agricultural plastic use, such as production, processing, distribution, land preparation, consumption, and post-consumption activities (e.g. storage, waste management, composting, biogas, animal fodder). Additionally, they stressed the importance of including the entire food packaging value chain, which encompasses production, transport, marketing, distribution, and end-of-life management. Respondents advocated for this comprehensive scope for the VCoC due to the interconnectedness of plastics across these stages, noting that a broad approach is crucial for ensuring circularity.

Sixteen respondents advocated for a more targeted and narrow approach, focused primarily on plastics used directly in agricultural systems that become waste within the agricultural system. Two respondents pointed to existing packaging laws in the EU and Australia as reasons to avoid creating duplicate or redundant policies. Some of these respondents also suggested a phased or targeted strategy – initially focusing on plastics used in the food production sector, followed by food packaging. Others proposed narrowing the scope even further to address only plastics with known effects on food production or those that represent the largest sources of plastic use along the value chain.

5.2 Implementation arrangements

Many respondents expressed significant expectations for the VCoC. While some acknowledged its voluntary nature – particularly industry and waste management representatives who appreciated the flexibility it allows for contextual adaptations – a notable number of respondents suggested that certain aspects could contribute to strengthening national legislation and informing binding agreements. The following sections summarize the content suggested by respondents for technical committees. These suggestions include elements that can be integrated into the VCoC while maintaining its voluntary nature, as well as aspects that could contribute to strengthening national legislation and informing future legally binding agreements.

Representation and design of the technical committees

To support the development and implementation of the VCoC, technical committees could be structured to align with the overall structure of the VCoC. Respondents provided recommendations for both the principles that should guide the design of these committees and their preferred structure.[18]

In terms of representation, respondents emphasized the need for broad and inclusive stakeholder participation. This includes relevant practitioners and experts, representatives from Indigenous Peoples' communities and other groups with traditional knowledge, all users of plastics in agriculture, government entities, the private sector,[19] the research community,[20] civil society, and UN

[18] This section analyses the stakeholder's responses to Question 14: *What technical aspects should be regularly reviewed to keep the Code up to date, and how could the Technical Committee(s) be structures to best review these aspects?*

[19] Conversely, one participant was opposed to participation from individuals with political backgrounds or who represent multinational companies.

[20] Disciplines mentioned were technology, chemistry, soil science, crop science, engineering, and health science.

agencies. Additionally, respondents highlighted the importance of ensuring geographic representation and achieving gender balance, particularly in senior positions within technical committees that may have hierarchical structures.

Other key design elements suggested for these technical committees include ensuring their independence, maintaining transparency in membership selection, and developing policies to prevent conflicts of interest. Recognizing that members of these committees may not frequently interact, respondents also recommended creating structures that build trust and encourage engagement. Some respondents supported the alignment of technical committees with regional governance frameworks, while others favored the formation of national-level committees to better gather data and align with national policies.

Monitoring and review

Respondents expressed strong support for the periodic review of the VCoC to ensure it remains current and effective for compliance monitoring. They recommended that feedback mechanisms be integrated into the VCoC's design and implementation. Such reviews could be facilitated through regular audits conducted by third parties.

Several respondents suggested that country-level reviews or audits be conducted to systematically track key information. This would include monitoring existing national policies, assessing the effectiveness of these policies, and tracking waste generated and pollution entering the environment from country.

Respondents also recommended forming technical committees to review, provide guidance on, and monitor various aspects or principles related to the VCoC. These aspects include waste management and end-of-life considerations, extended producer responsibility, biodegradables, food safety, distribution of plastics and microplastics in agriculture, human health, the use of plastics, agricultural policy, the precautionary principle, and the polluter pays principle.

To ensure regular reporting and updates, stakeholders suggested the development of a knowledge-sharing platform for the submission of new information. One respondent proposed the creation of a science-policy panel to review and incorporate these updates. The types of information to be collected and updated on such a platform would include data on plastic use, research on microplastics and their impact on human health and the environment, technological developments, and best practices for sustainable agricultural plastics management.

There was no consensus on how technical committees should be formed to monitor implementation, though generally respondents agreed that all levels of government should be engaged to ensure wide reach of communication, engagement, and implementation.

5.3 Ensuring meaningful stakeholder inclusion

Respondents strongly encouraged the engagement of stakeholders throughout the process of developing the VCoC. Among the 61 respondents who addressed this question, many identified specific stakeholder groups that should be included. Additionally, 30 respondents highlighted practices and principles to ensure that engagement is inclusive, such as aligning with ongoing initiatives that have already established communication with stakeholders, like the negotiations for the legally binding instrument on plastic pollution.

Respondents emphasized that stakeholder engagement serves multiple purposes, including policy development, knowledge transfer, and tracking and monitoring measures implemented by different actors. They advocated for engagement processes that begin early, occur frequently, and maintain transparency with the public.

However, many respondents also pointed out that, while the consultation via the FSN Forum is a positive first step, it is insufficient for meaningful stakeholder interaction and inclusion into the VCoC design and development. Several respondents stressed the importance of specifically targeting practitioners and stakeholder groups in the Global South, where access to digital and formal processes, such as participation in the FSN Forum, is more limited. This focus, they argued, is crucial for the successful development and adoption of the VCoC.

Inclusive approaches

Thirty respondents emphasized that the VCoC should promote multistakeholder engagement that is inclusive and representative of all life cycle stages, guided by principles such as inclusion, pluralism, participatory equality, autonomy, the common good, environmental justice, and human rights.[21] Another respondent specifically advocated for the inclusion and promotion of Indigenous Peoples' knowledge, particularly in the production of substitutes and alternatives.

In addition to fostering engagement within the process for developing the VCoC, respondents recommended aligning and ensuring coherence with other ongoing and relevant initiatives at local, regional, and international levels, including the forthcoming legally binding instrument on plastic pollution. For instance, EPR policies and existing extension programmes offer established platforms for stakeholder engagement that have already built trust among stakeholders. One respondent suggested that the FAO coordinate a multistakeholder action agenda or forum, as called for by UNEA resolution 5/14.

Participants noted that stakeholder engagement serves several crucial purposes, including promoting collaboration, sharing best practices for monitoring and reporting, driving comprehensive sector-specific global strategies, and hosting consultations, workshops, and participatory forums. Engagement also plays a key role in capacity building and providing training and educational sessions. To ensure equitable outreach, multiple communication channels should be utilized, and resources should be allocated specifically to monitor and report on the outcomes of engagement. Regular and early engagement was highlighted as essential for maximizing the benefits of stakeholder involvement.

[21] This section analyses the stakeholder's responses to Question 10: *How to ensure (and what guidance is needed for) meaningful engagement of all relevant stakeholders in the development and implementation of the VCoC?*

These include key players in agriculture and food production, such as farmers, food producers, foresters, fishers, and agricultural technical centres and universities; government bodies at all levels – regional, national, and municipal – along with standard setters, FAO representatives, and other UN agencies; plastic manufacturers, retailers, distributors, equipment manufacturers, installers, and supermarkets, as well as plastic importers; wastewater treatment practitioners, end-of-life operators, the recycling industry, and waste pickers; civil society, community groups, cultural interpreters, anthropologists, youth, and women; healthcare professionals, scientific community and food safety experts.

Respondents emphasized the importance of tracking and mapping all relevant stakeholders across the life cycle of products, possibly through a system or directory, identifying each group's role and responsibility in achieving sustainability in the use of plastics in agriculture. They suggested that the VCoC may encourage the development of a directory of stakeholders to facilitate knowledge sharing, by working with individual sectors to map the value chain and identify all stakeholders involved. One respondent highlighted that such mapping could also aid in the development of more targeted EPR schemes.

Communication and information sharing

To enhance engagement and transparency, one respondent suggested that VCoC review processes should be made public and include input from all stakeholders, as there is significant information that can be both collected from and shared with stakeholders. Respondents suggested various forms of communication and media to connect with stakeholders, such as meetings and workshops, virtual communication channels, roundtables, interviews, local radio, training sessions, open-air campaigns, and publications. A concerted and sustained effort using these diverse methods is essential to build and maintain the stakeholder network, ensure access to information for all parties, demonstrate accountability, monitor engagement, and uphold a commitment to transparency.

Respondents cited examples of existing, certified platforms that can be leveraged or serve as models for structuring stakeholder engagement. These include the High-Level Panel of Experts of the UN Committee for World Food Security and the UN One Planet network's 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns (10YFP).

Other considerations on stakeholders' engagement

Several considerations were suggested regarding the design and maintenance of stakeholder engagement processes. One respondent emphasized the importance of understanding the needs and experiences of all stakeholders, noting that it is crucial for policymakers to grasp these needs as well. Respondents also highlighted the longstanding use of plant-based materials in agriculture by Indigenous Peoples, stressing that their knowledge and practices should be recognized and included in discussions on the topic. Additionally, the importance of considering contextual, regional, and cultural differences among stakeholder groups was noted, as these factors can influence how different sectors are able to engage. One respondent pointed out that there is already considerable active work in this area, and that these existing efforts should be acknowledged, leveraged, and integrated into the broader engagement strategy.

Concluding remarks

This report has reviewed the stakeholder responses gathered through the consultation launched by the FAO via the FSN Forum. The consultation aimed to collect opinions and experiences from stakeholders to inform the development of the FAO – led Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture. The consultation engaged 108 stakeholders, representing a diverse range of backgrounds, including academia, industry, farm associations, and government representatives.

This report has summarized stakeholders' opinions on problematic agricultural plastic products and polymers, as well as various plastic alternatives and substitutions, including biodegradable plastics. Stakeholders shared their views on improving sustainability and reducing environmental impacts throughout the entire plastics life cycle, from design to end-of-life management.

Significant input was provided on existing knowledge gaps, particularly regarding socioeconomic and environmental sustainability. Stakeholders expressed concerns about the lack of data on the long-term effects of current agricultural plastic usage, as well as uncertainties related to economic costs and inequalities associated with plastic alternatives and waste management.

Additionally, respondents offered a range of policy recommendations, including regarding financial instruments, technical assistance, awareness – raising initiatives, trade measures, and guidance on standards, labeling, and regulations. Lastly, stakeholders were invited to suggest how the upcoming VCoC and its related technical committees should be structured, as well as which stakeholders should be engaged in the process and how.

At a broad level, stakeholders expressed differing views on the issue of agricultural plastics. Some respondents emphasized that the primary concern is waste management and the mismanagement of plastics in soil and the environment. Others framed the problem as a broader challenge to planetary health, where the current production, use, and end-of-life management of agricultural plastics threaten the health and vitality of current and future generations, animals, ecosystems, and human health.

There was also a divergence in opinions on solutions to the environmental challenges posed by conventional plastics. Some respondents supported the use of biodegradable and bio-based plastic alternatives, seeing them as viable solutions. However, others were skeptical about these alternatives, advocating instead for systemic changes, including altering agricultural practices. These respondents cited uncertainties about the degradation rates of biodegradable plastics and the potential impact of bio-material production on food supplies, advocating for the application of the precautionary principle.

While most stakeholders underscored the importance of preserving food security and nutrition, they differed in their views on how conventional and biodegradable plastics affect them. Some, particularly those from large-scale industries in the Global North and from rapidly growing countries in the Global South worried that reducing agricultural plastic usage could jeopardize food security in the face of increasing global demands. Conversely, other respondents argued that the current reliance on agricultural plastics in industrial food production is unsustainable, compromising soil health and the broader environment, which could ultimately threaten food production in the medium to long term.

Stakeholders' differing perspectives also surfaced in their views on the scope and content of the VCoC. Respondents who prefer biodegradable and bio-based alternative products recommend that

the VCoC promote these as favorable alternative products in the shift away from conventional plastics, and identify which products or applications are well suited for these alternatives. Others advocated for the VCoC to focus primarily on improving end-of-life measures, viewing conventional agricultural plastics as the preferred choice and recommending that the VCoC support the development and alignment of EPR policies. Another group of stakeholders advises applying the precautionary principle, recommending that the VCoC should not endorse specific alternative products, but rather provide strong guidelines for environmental and sustainability assessments, including incorporating LCAs into the development of standards for alternative products and polymers.

As the development of the VCoC progresses, FAO will need to take these diverse stakeholder experiences and opinions into account, addressing the challenges and concerns expressed. Stakeholders emphasized the need for an inclusive and transparent process, with particular attention to marginalized groups, gender equality, and the recognition of Indigenous Peoples' and traditional knowledge practices worldwide.

Appendix 1. Consultation text

Call for submissions:

Towards the development of a Voluntary Code of Conduct on the sustainable use of plastics in agriculture

Template for submissions (maximum 2000 words in total)

In the context of the development of the Voluntary Code of Conduct on the sustainable use of plastics in agriculture (VCoC), FAO's Office of Climate Change, Biodiversity and Environment (OCB) invites you to submit your feedback on the questions below, and to share good practices and lessons learned on the sustainable use of plastics and agriculture and their alternatives.

You are welcome to respond to any of the below questions, as per your interest and expertise. Your responses, alongside the feedback we gather during our ongoing webinar consultations, will help inform the first full draft of the VCoC.

You can provide your feedback by answering questions in any of the six UN languages (English, French, Spanish, Russian, Arabic and Chinese).

To take part in this Call for submissions, please get registered or login to your account on the FSN Forum website; and upload the completed submission form on the dedicated webpage. For any technical support regarding downloading or uploading the submission form, please send an email to fsn-moderator@fao.org.

The Call for Submissions is open until November 7, 2023.

1. Proponent (name and surname; email address; country)
2. Name of organization and organization type: Academia and research, Government; IGO; Independent Consultant; NGO, Private Sector, PRO; Standard Setting; Trade association (if applicable)
3. Gender (Female; Male; Other; Prefer not to say)
4. Reducing problematic plastics

Some plastic materials and products used in agriculture are unnecessary, avoidable, problematic, or short lived. A VCoC could recommend their banning, reducing or phasing out. Examples include products made of polyvinyl chloride (PVC); oxo-degradable plastics; non-biodegradable polymer coated fertilizers; mulching films; and bale film and nets.

Which plastics polymers, substances or products the VCoC could recommend banning, reducing or phasing out?

5. Alternatives and substitutes

Solutions to improve the sustainability of plastics used in agriculture include adopting agricultural practices that avoid the use of plastic, or substituting plastic products with other materials, including biobased and biodegradable alternatives. For example, some fishing gear components could be biodegradable; plastic mulch could be substituted with cover crops in some applications.

What guidance should the VCoC include on plastics alternatives and substitutes?

6. Reuse and sustainable design

Some plastic products are necessary and cannot be replaced by alternative practices or materials. In some cases, their lifespan can be increased by promoting reuse and repurpose. In addition, labeling, product standards and design can reduce the environmental impact of plastic life cycle: for example, mandatory plastic mulch thickness can ensure its retrieval and prevent the generation of microplastics.

How could the VCoC improve the sustainability of plastics products used in agriculture through guidance on products reusing, repurposing, standards and design?

7. Selection criteria

Trade-offs may become evident when assessing a fossil-based plastic product against an alternative. For example, many biodegradable products are more expensive than their fossil-based counterparts. Plastic products and their alternatives should be assessed and compared across their life cycle and for all dimensions of sustainability including food security, food safety and nutrition. Management options should be assessed for each particular application and in specific contexts.

What guidance should the VCoC include to balance the benefits and trade-offs of plastics and their alternatives?

8. End-of-life and EPR schemes

After its intended use, it is paramount that plastic waste is retrieved and is not left contaminating the environment. Waste collection, recycling and disposal can be driven by the establishment of Extended Producer Responsibility (EPR) schemes. In addition, it is important to address the issues of illegal dumping and open burning. MARPOL Annex V and LC/LP already addresses illegal dumping and disposal of plastic waste from sea-based activities. Traceability mechanisms can also support compliance and enforcement activities.

What guidance should the VCoC include on the end-of-life management of agricultural plastics waste, including through Extended Producer Responsibility (EPR) schemes?

9. Microplastics

Micro and nano-plastics pollute agricultural soils and oceans, and are harmful to ecosystems, animals and potentially human health. Sources of microplastic pollution in agriculture include sewage sludge application, the use of non-biodegradable polymer coated fertilizers, seeds and pesticides, and the use of non-biodegradable dolly-rope.

How could the VCoC support the reduction of microplastics pollution in agriculture?

10. Stakeholder engagement

Multistakeholder engagement is necessary to promote active and meaningful participation in the development and implementation of the VCoC. The VCoC may target a broad range of stakeholders including governments; manufacturers, installers, distributors of plastic products or their alternatives; farmers, foresters and fishers; Indigenous Peoples, youth, and waste collectors, recyclers and disposers, both from the formal and informal sectors.

How to ensure (and what guidance is needed for) meaningful engagement of all relevant stakeholders in the development and implementation of the VCoC?

11. Financial instruments, technical assistance and trade

The VCoC could recommend incentives for financial institutions to create instruments (e.g. EPR schemes) to promote circular economy of plastics in agriculture. Technical assistance could support assessments, development of alternatives, skills and capacity building. Trade policies can support a more sustainable management of agricultural plastics by restricting or banning the import of plastic products that do not respect products standards.

What financial incentives, priorities for technical assistance and trade measures could be included in the VCoC?

12. Regulatory and enforcement mechanisms

Good practices to support regulatory and enforcement mechanisms that could be included in the VCoC include: product registration, product licensing, product standards, licensing of actors in the supply chain, licensing users of plastic products, traceability mechanisms, and labelling with usage and end-of-life management instructions.

How could the VCoC provide guidance on efficient regulatory and enforcement?

13. Research and knowledge gaps

Research gaps need to be addressed to inform effective policies for the sustainability of plastics used in agriculture, including among others: the impacts of macro, micro and nano plastic pollution on soil, plants and animal health, food safety and human health; the effectiveness of biodegradable plastics and alternative materials; the economic viability and farmers perception around these options.

What are key research gaps around plastics used in agriculture, and how can the VCoC recommend addressing them?

14. Implementation arrangements

Typical FAO Codes of Conduct provide an overarching framework under which more detailed guidelines, standards and tools are developed. It is important that Codes of Conduct are kept up to date with the latest policy, scientific and technological developments. Codes of Conduct are supported by technical committees that meet regularly to review developments, recommend improvements and new subsidiary guidance.
What technical aspects should be regularly reviewed to keep the Code up to date, and how could the Technical Committee(s) be structured to best review these aspects?

15. Structure of the VCoC

Different options for structuring the VCoC exist to ensure it efficiently targets all agricultural subsectors (crop and livestock, forestry, fisheries and aquaculture). For example, the VCoC could focus primarily on terrestrial agriculture, and include fisheries and aquaculture only by cross-referencing existing policies and guidelines. Alternatively, the VCoC could have an umbrella structure valid for all subsectors, followed by specific guidelines for different subsectors (crop and livestock, forestry, fisheries and aquaculture). Finally, the VCoC could have an umbrella structure valid for all subsectors, followed by guidelines on specific aspects (including for example,

durable/single use products, licensing, labelling and EPR Schemes).

Which structure would be more efficient in targeting all agricultural subsectors?

16. Agrifood value chains stages

The VCoC could encompass different stages of the agrifood value chains. It could target plastics used solely for primary agricultural production; it may also include plastics used for agrifood storage, transport, processing and distribution; and finally, it may include the entire agrifood value chain from production to consumption, including consumer packaging.

Which stages of the agrifood value chains should be covered by the VCoC?

17. Good practices and lessons learned

Good practices for the sustainable management of plastics and their alternatives can be found in all regions of the globe. Please leave below any information regarding specific applications, good practices, lessons learned, and innovative approaches on the management of plastics in agriculture and their alternatives.

18. Links and additional comments

Appendix 2. Methodology and codebook

The results of the consultation were analysed by two researchers (Baann and Karasik) using the qualitative analysis software NVivo. Using inductive coding methods, the first researcher (Baann) reviewed one response per stakeholder group and developed "grouped themes" corresponding to respondent's behaviours, perspectives and beliefs. These themes served as an initial codebook for analysing the content of all consultation responses, and they were adjusted throughout the process of analysis. Table 1 reports the codebook. The first researcher then coded all the relevant content according to the "grouped themes." For qualitative analysis, a second researcher (Karasik) used NVivo to extract the content coded for every individual theme under each question. The content allowed a side-by-side analysis of each respondent's perspective on a given topic, allowing the researcher to qualitatively characterize trends and identify points of consensus or disagreement among participants on a given topic.

Table 1. Codebook used for content analysis

Research Question 4 – Problematic plastics: Which plastics polymers, substances or products the VCoC could recommend banning, reducing or phasing out?
Assessment framework
Case by case
Elimination feasibility
LCA
Link to INC
Pollution risk
Polymers
ABS
Brittle
Chemicals
PE
PET
Polycarbonate
Polystyrene
Polyurethane
PP
PVC
Practices
Infrastructure
Lack of awareness
Mulching
Processing practices
Products
Biodegradable plastics
Containers
Decorative plastics
Fishing gear
Food stickers
Haybale silage film
Microplastics
Nets

- Non-biodegradable plastics
- Non-recyclables
- Oxo-degradable plastics
- Polymer coated products
- Products that cannot be collected
- Single use
- Thin mulching films
- Tunnels n greenhouse
- Woven products

Research Question 5 – Plastic alternatives: What guidance should the VCoC include on plastics alternatives and substitutes?

- Alternative practices
  - Clay vs plastic lining
  - Glass greenhouses
  - HDPE vs PVC pipes
  - Hydroponic irrigation vs driptape
  - Precision machinery
  - Repair and maintenance
  - Silo vs haybales
  - Vertical farming
- Biodegradable plastics
  - Materials
  - Product development
  - Standard and controls
  - Yes
- Nature-based solutions
  - Practices
  - Products
  - Why
- Other

Research Question 6 – Plastic design: How could the VCoC improve the sustainability of plastics products used in agriculture through guidance on products reusing, repurposing, Plastic standards and design?

- Design
- Practices
- Recycling
- Reduction
- Reuse

Research Question 7 – Trade-offs: What guidance should the VCoC include to balance the benefits and trade-offs of plastics and their alternatives?

- Carbon footprint
- Chemicals
- Cost
- Ecosystem impacts
- Erosion
- Food and nutritional security
- Food waste
- Human rights
- Land use for alternatives
- Local conditions
- Long term vs short term
- Mix conventional and bioplastics
- Plastic qualities in practice

- Polymer coating
- Waste infrastructure
- Water usage

Research Question 8 – End-of-life management: What guidance should the VCoC include on the end-of-life management of agricultural plastics waste, including through Extended Producer Responsibility (EPR) schemes?

- Contamination in recycling
- Downcycling
- Energy recovery
- EPR
- Export
- Farm diversity
- Financial instruments
- Improve integration
- Info and best practice
- PRO
- Prohibit mismanagement
- Recycled content requirements
- Recycling programmes
- Traceability
- Waste storage

Research Question 9 – Microplastics: How could the VCoC support the reduction of microplastics pollution in agriculture?

- Biodegradable plastics
    - None
- Consequences
- How
- Solutions

Research Question 10 – Stakeholder engagement: How to ensure (and what guidance is needed for) meaningful engagement of all relevant stakeholders in the development and implementation of the VCoC?

- Acknowledgement
- Certification
- Communication
- Inclusive approaches
- Mapping
- Public vs private
- Stakeholder support

Research Question 11 – Circularity instruments: What financial incentives, priorities for technical assistance and trade measures could be included in the VCoC? Circularity instruments

- Financial instruments for circularity
- Intl inclusive avoid freeriders
- Nature-based solutions
- Supportive policy environment
- Technical assistance

Research Question 12 – Regulations: How could the VCoC provide guidance on efficient regulatory and enforcement?

- Cost distributions
- Farm practice info
- Guidelines
- Info-labels
- Information disclosure
- LCA

Other regulatory instruments
Requirements and standards
Triple washing

Research Question 13 – Knowledge gaps: What are key research gaps around plastics used in agriculture, and how can the VCoC recommend addressing them?

Alternative products
AP use
Biodegradable plastics
Chemicals
Economic cost-benefit
Effect on plants and animals
MP effects on humans
MP in soil
Policy analysis
Pollution
Prevention measures
Recycling
Socio-cultural
Standardize MP research
Trade
Tradeoff assessments
Waste generation and management

Research Question 14 – VCoC Technical committee: What technical aspects should be regularly reviewed to keep the Code up to date, and how could the VCoC Technical Committee(s) be structured to best review these aspects?

Developing economies
EoL regulations
Inventories
Knowledge update
Microplastics
Monitoring and review
National or regional bodies
Plastic alternatives
R&D
Risk
Thematic structure

Research Question 15 – Sectorial structure: Which structure would be more efficient in targeting all agricultural subsectors?

Clear objectives and definitions
Existing FAO VCoC
General framework
Other
Subsectorial guidelines
Who

Research Question 16 – Agrifood chain: Which stages of the agrifood value chains should be covered by the VCoC?

Agrifood production
Downstream consumers
Downstream packaging and transport
Other
Upstream inputs

Research Question 17 – Good practices: Good practices for the sustainable management of plastics and their alternatives can be found in all regions of the globe. Please leave below any

information regarding specific applications, good practices, lessons learned, and innovative approaches on the management of plastics in agriculture and their alternatives.

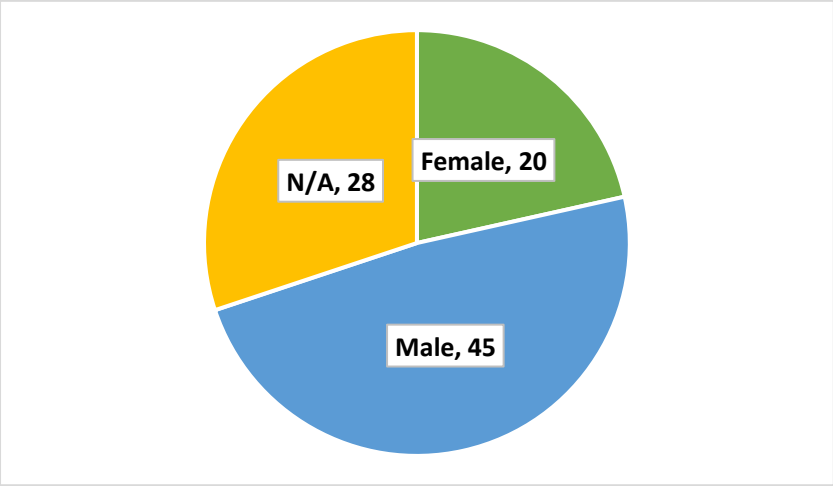
- Farm practices
- Information and awareness
- Life cycle
- Participatory practices
- Pilot scheme tests
- Technology

Appendix 3. Quantitative analysis of respondents

The population included 93 analysed responses out of the total 108 received and listed in the FAO inventory. Among the 108 responses, four were identified as AI-generated answers (based on similarities in sentence structure noted by researchers and verified using two AI-detection tools, GPTzero.me and Copyleaks.com), and 7 were categorized as duplicates. Additionally, 18 respondents did not answer the questions directly, instead providing general statements (16 respondents) or links to published material (2 respondents). After excluding the AI-generated and duplicate responses, the final number of responses used in the qualitative analysis was 93, from 48 countries.

As shown in Figure 1, under a third of all respondents chose not to disclose their gender identity. Among those who did, there were more than twice as many male respondents as female respondents.

Figure 1. The gender breakdown of respondents



Source: Authors' own elaboration

As shown in Table 1, of the 93 respondents, close to a third are from Europe, followed by Asia and Africa. The regions with the least representation were Australia Pacific (3 respondents) and North America (7 respondents).

Table 1. The geographic breakdown of respondents

Region of respondent	Number of respondents
Africa	18
Asia	21
Australia Pacific	3
Europe	33
Latin America	11
North America	7

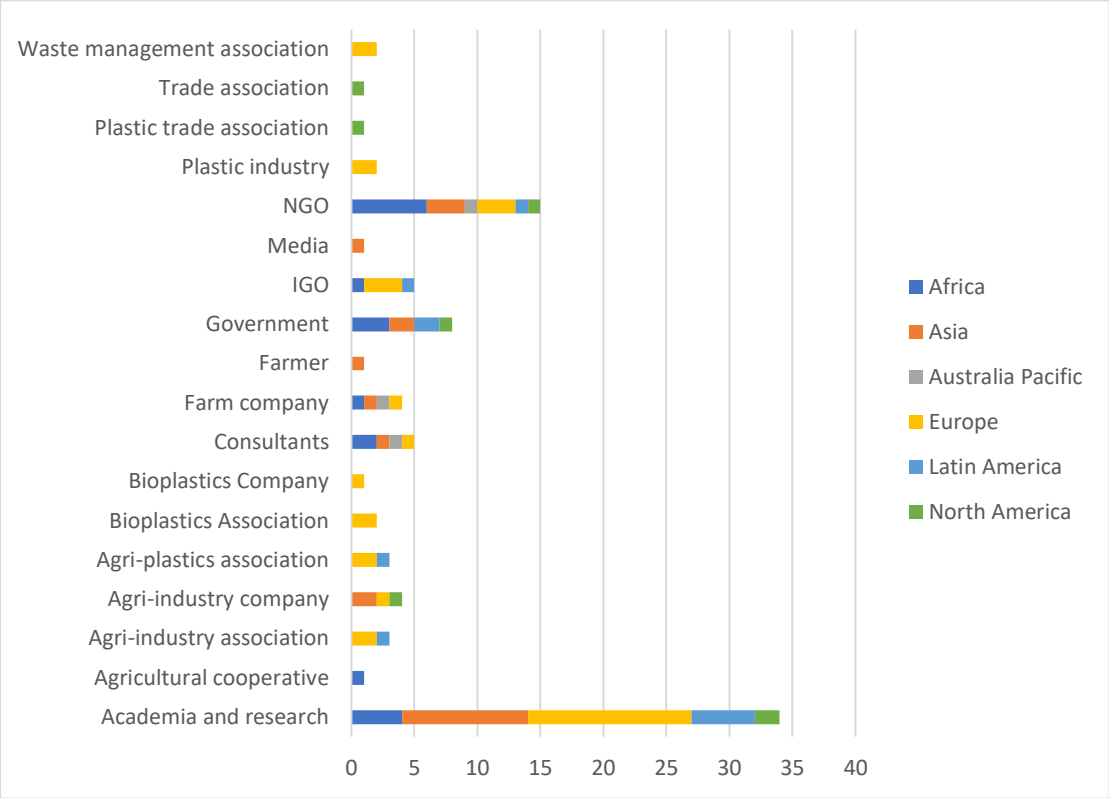
As shown in Table 2, 16 stakeholder groups were represented in the consultation, with over half of the respondents coming from academia or civil society organizations. Several respondents also represented specific industry sectors, including the plastics and biodegradable plastics industries.

Table 2. Stakeholder group distribution

Stakeholder Group	Number of respondents
Academia and research	34
Agricultural cooperative	1
Agri-industry association	3
Agri-industry company	4
Agri-plastics association	3
Bioplastics Association	2
Bioplastics Company	1
Consultants	5
Farm company	4
Farmer	1
Government	8
IGO	5
Media	1
NGO	15
Plastic industry	2
Plastic trade association	1
Trade association	1
Waste management association	2

In assessing the respondent distribution by organization and region, certain sectors appear to be underrepresented in specific regions, as detailed in Figure 2. For example, the bioplastics sector in this sample is represented solely by respondents from Europe. To achieve a more balanced and representative distribution, additional stakeholder engagement efforts could be targeted to include underrepresented groups from different regions as necessary.

Figure 2. Stakeholder groups regional distribution



Source: Authors' own elaboration

Stakeholders' complete responses were evaluated across three broad questions. The first question asked whether stakeholders believed that agriculture could operate without the use of plastics, with 34 respondents answering "no" and 31 answering "yes". The second question focused on what stakeholders considered to be the main problem with plastics, with pollution (35 respondents) and planetary health (25 respondents) emerging as the primary concerns. This divergence is also evident in the final broad question, which assessed how stakeholders believed plastics could become more sustainable. Here, 22 respondents advocated for improved end-of-life management, 22 supported a more holistic life cycle assessment approach, and 21 favored biodegradable or bio-based solutions.

Results from the qualitative coding of three broader questions based on the stakeholders' complete response are the following:

1. Can agriculture operate without plastics? 31 respondents coded as **yes,** 34 respondents coded as **no**
2. What do they consider the main problem with plastics?
    a. **Pollution** (35 respondents)
    b. **Planetary health** (25 respondents)
    c. Lack of **awareness and compliance** (5 respondents)
    d. **Mismanagement** (5 respondents)
    e. Low **recycling** rates (1 respondent)
    f. Tradeoffs for **food security** (1 respondents)
3. What is the main way to make plastics use more sustainable?
    a. Improved **End-of-life management** (22 respondents)
    b. Use **life cycle assessments** for decision making (22 respondents)
    c. **Biodegradable** solutions (13 respondents)

d. **Bio-based** solutions (8 respondents)
e. Increase **awareness and compliance** (4 respondents)
f. **Prevent loss** to the environment (3 respondents)
g. Improve the **quality** of plastic products (2 respondents)

Table 3. Quantitative coding results for each question

Question 4: Which plastics polymers, substances, or products the VCoC could recommend banning, reducing, or phasing out?					
Products	Number of Respondents (46 total)	Practices	Number of Respondents (21 total)	Polymers	Number of Respondents (32 total)
Oxo-degradable plastics	29	Mulching	19	PVC (Polyvinyl Chloride)	19
Polymer coated products	22	Processing practices	2	Polystyrene	10
Non-biodegradable plastics	8	Infrastructure	1	Chemicals	5
Haybale silage film and nets	9	Lack of awareness	1	Brittle	4
Fishing gear	5			PE (Polyethylene)	4
Products that cannot be collected	4			PP (Polypropylene)	2
Non-recyclables	3			ABS (Acrylonitrile butadiene styrene)	1
Containers	2			PET (Polyethylene terephthalate)	1
Single use	2			Polycarbonate	1
Tunnels greenhouse	2			Polyurethane	1
Biodegradable plastics	1				
Decorative plastics	1				
Food stickers	1				
Microplastics	1				
Woven products	1				
Thin mulching films	0				
Assessment framework to be used for elimination	Number of Respondents (48 total)				
LCA	33				
Pollution risk	14				
Case by case	11				
Link to INC	6				
Elimination feasibility	5				
Question 5: What guidance should the VCoC include on plastics alternatives and substitutes?					
Plastic alternatives	Number of Respondents (63 total)				
Biodegradable plastics	48				
Nature-based solutions	30				
Alternative practices	8				
Other	6				
Question 6: How could the VCoC improve the sustainability of plastics products used in agriculture through guidance on products reusing, repurposing, standards and design?					
Plastic design	Number of Respondents (65 total)				
Design	43				
Recycling	33				
Reuse	30				

Reduction	16
Practices	4
Question 7: What guidance should the VCoC include to balance the benefits and trade-offs of plastics and their alternatives?	
Trade-offs between plastic use and alternatives	Number of Respondents (57 total)
Food and nutritional security	24
Cost	22
Carbon footprint of plastic and alternatives	16
Land use for alternatives	12
Plastic qualities in practice	10
Erosion from soil work	8
Ecosystem impacts of using plastics and alternatives	8
Chemicals used for alternatives	6
Water usage when not using plastics	6
Food waste when not using plastics	5
Human rights violations associated with alternatives	4
Long term vs short term benefits	4
Polymer coating reduce overfertilization and pesticide use	3
Waste infrastructure is incomplete	3
Local conditions prevent general advice	2
Mix conventional and bioplastics in recycling streams	1
Question 8: What guidance should the VCoC include on the end-of-life management of agricultural plastics waste, including through Extended Producer Responsibility (EPR) schemes?	
End-of-life management considerations	Number of Respondents (73 total)
EPR	42
Information and sharing best practice	27
Traceability	22
Prohibit mismanagement	20
Farm diversity	17
Financial instruments	14
Recycling programmes	13
Recycled content requirements	12
Improve integration	9
Energy recovery	4

PRO	4
Export	2
Waste storage	2
Contamination in recycling	1
Downcycling	1
Question 9: How could the VCoC support the reduction of microplastics pollution in agriculture?	
Microplastics	Number of Respondents (61 total)
Solutions	40
How it enter environment	25
Biodegradable plastics	12
Consequences	8
Question 10: How to ensure (and what guidance is needed for) meaningful engagement of all relevant stakeholders in the development and implementation of the VCoC?	
Stakeholder engagement	Number of Respondents (61 total)
Inclusive approaches	30
Mapping	25
Communication	19
Certification	11
Acknowledgement	9
Public vs private	6
Stakeholder support	4
Question 11: What financial incentives, priorities for technical assistance and trade measures could be included in the VCoC?	
Instruments	Number of Respondents (60 total)
Technical assistance	25
Intl inclusive avoid freeriders	19
Supportive policy environment	18
Nature-based solutions	3
Question 12: How could the VCoC provide guidance on efficient regulatory and enforcement?	
Regulations	Number of Respondents (62 total)
Requirements and standards	33
Info-labels	29
Guidelines	23
Other regulatory instruments	16
Farm practice info	15
Information disclosure	15
Cost distributions	3
LCA	3
Triple washing	1
Question 13: What are key research gaps around plastics used in agriculture, and how can the VCoC recommend addressing them?	
Knowledge gaps	Number of Respondents (62 total)
Microplastics in soil	26
Biodegradable plastics	22
MP effects on humans	17
Economic cost-benefit	16
Alternative products	15
Effect on plants and animals	15
Socio-cultural	12

Waste generation and management	9
Standardize MP research	8
AP use	6
Chemicals	5
Pollution	5
Recycling	5
Policy analysis	3
Prevention measures	3
Trade	2
Tradeoff assessments	2
Question 14: What technical aspects should be regularly reviewed to keep the Code up to date, and how could the Technical Committee(s) be structured to best review these aspects?	
Technical committees	Number of Respondents (51 total)
Monitoring and review	28
Knowledge update	17
R&D	11
Developing economies	10
Inventories	9
EoL regulations	6
National or regional bodies	6
Plastic alternatives	4
Risk	4
Microplastics	2
Thematic structure	1
Question 15: Which structure would be more efficient in targeting all agricultural subsectors?	
Sectorial structure	Number of Respondents (54 total)
Subsectorial guidelines *	42
Who	19
General framework	10
Other	5
Existing FAO VCoC	3
Clear objectives and definitions	1
* The coded category sub-sectorial guidelines were later sub-coded into the different forms of umbrella-structures.	
Question 16: Which stages of the agrifood value chains should be covered by the VCoC?	
Agrifood chain	Number of Respondents (59 total)
Downstream consumers	36
Agrifood production	21
Downstream packaging and transport	7
Other	2
Question 17: Good practices and lessons learned	
Good practices	Number of Respondents (29 total)
Information and awareness	11
Farm practices	8
Pilot scheme tests	8
Life cycle	7
Participatory practices	4
Technology	1

Appendix 4. Good practices, standards and additional resources listed by respondents

This appendix summarizes the good practices and lessons learned listed by the respondents, in addition to relevant projects, standards, and additional resources (Questions 17 and 18).

Twenty-nine respondents offered additional inputs, many of which included best practices for crop production. These suggestions often emphasized ways to reduce the use of plastics in agriculture, prevent them from entering the environment, or extend their useful life. Respondents also mentioned several existing frameworks and programmes that could provide best practices and recommendations for the VCoC, most of which focus on recovering and recycling agricultural plastics and using biodegradable plastics on farms.

List of good practices from respondents

- "Tuck in the tail" of the silage haybale film that is often torn off by wind and weather.
- Use a heat-tool to cut woven covers so that the cover does not fray.
- Do not store plastic waste outside.
- Use bulk fertilizer to avoid packaging of inputs to the farm.
- Replace silage with hay in cattle production as a way to reduce plastic use.
- Use cover crops or crop diversification to replace some functions of the plastic film.
- In irrigation systems for trees, to cover the holders of the pipe screw by high quality polyethylene materials.
- Organic mulches are good alternatives for plastic mulch, but there are some tradeoffs to consider.

List of programmes and projects from respondents

- FAO Andean Landscapes project installed 10 strategically located boxes to allow farmers to return empty containers.
- EACEA (an agro-consulting company) has recently launched a Voluntary Programme to Recycle agriplastics. In addition, and to support implementation and uptake, they have developed guidelines for end-of-life tracking, treatment on the field, collection, and recycling.
- An agreement in Italy between Assobioplastiche (Italian association of biodegradable and compostable plastics) and Federbio (Italian organic farming federation) demonstrates an opportunity to consolidate resources to facilitate participation, allowing producers to pool resources to use soil biodegradable mulch films and fund an evaluation of the program.
- A similar agreement in Mallorca, Spain between APAEMA (Association of organic producers of Mallorca) and MAFT (Mallorca Preservation Foundation) have enabled the substitution of conventional plastic films with soil biodegradable films for organic vegetables.
- ADI VALOR is a voluntary EPR scheme for agricultural plastics in France.

- In the Environmentally Friendly Farmer Card Project, funded by the Antalya Metropolitan Municipality in Turkey, producers who return empty pesticide packages will be provided with special cards to access solar-powered smart agricultural packaging collection vending machines located at various points. At the time of submission of this consultation, the respondent noted that there were plans to exchange collected points for rewards.
- In Canada, all provinces have developed Environmental Farm Plans (EFPs) and some organizations, like the Dairy Farmers of Canada have made EFPs mandatory for all members. The EFP is a voluntary assessment that a farm undergoes with the goal to increase environmental awareness. Upon completion, farms are then eligible for grants or cost-sharing opportunities.
- The Blue Line System, a programme in Ecuador, has piloted in the Port of Cascais for collection of fishing gear in a port has installing the “Ecoponto do Pescador,” or Maritime Ecopoints.
- IBM researchers have created a new technology called "VolCat", represented by a catalytic chemical process that can transform PET waste into a substance that can be fed directly into plastic manufacturing machines to obtain new products.
- A voluntary producer responsibility organization, Finnish Agricultural Plastics Recycling Ltd, formed in 2023 with 10 companies, will be piloting a recycling scheme for agricultural plastics beginning in August 2024. The new initiative plans to phase in recycling programmes for bale wraps, silage film, silo covers, baler string and twine, and net wrap.
- Recycling companies and irrigation products manufacturers in South Australia have collaborated to establish a recycling programme for the plastic drip tubes used to irrigate vineyards. In 2019 the programme recycled an estimated 200 tons of used drip tube.
- The ERDE Initiative, a German PRO with an existing silage and bale wrap recycling programme expanded nationwide collection to the plastic film used in asparagus production in 2021. In 2022, the initiative recovered 38,000 tons of farm plastics in, achieving a 41 percent recycling rate of asparagus and a 68 percent recycling other farm plastics. The initiative has committed to a recycling rate of 60 percent of asparagus film and 75 percent of bale and silage wrap by 2026.
- The Irish Farm Films Producers Group have made the return of farm plastics for recycling more convenient for farmers with over 200 bring centres nationwide. Many of these centres are at retail outlets or cooperatives that the farmers likely already frequent.

List of standards from respondents

- EN 13432.[1] Packaging. Requirements for packaging recoverable through composting and biodegradation.
- EN 14995. Evaluation of compostability.
- EN 17033. Plastics – Biodegradable mulch films for use in agriculture and horticulture – Requirements and test methods.
- ISO 14855. Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions – Method by analysis of evolved carbon dioxide.
- ISO 23517. Soil biodegradable materials for mulch films for use in agriculture and horticulture – Requirements and test methods regarding biodegradation, ecotoxicity and control of constituents.
- ISO 17556. Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved.[2]
- Any existing green and sustainable chemistry guidelines.[3]

[1] This is a harmonised European standard linked to the European Directive on Packaging and Packaging Waste (94/62/EC). It allows for the presumption of conformity with essential requirements of the Directive. It has been translated and implemented in all the European Member States

[2] Other standards that were not recommended by respondents but may be relevant are ISO 18606 "Packaging and the environment – Organic Recycling" and ISO 17088 "Specifications for compostable plastics"

[3] Existing standards or definitions of Green or Sustainable Chemistry were not included in responses. Green Chemistry refers to 12 guiding principles that aim to minimize chemical pollution at the source by minimizing the synthesis and use of hazardous substances (US EPA) (Yale). The UN Industrial Development Organization (UNIDO) launched a global Green Chemistry initiative in 2017, and in 2022, the UN Environment Assembly adopted UNEPs 'Green and Sustainable Chemistry: Framework Manual'. While often used interchangeably with green chemistry, sustainable chemistry focuses more broadly on circular economy and systems-based approaches to improving chemical pollution and processes.

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