Food and Agriculture
Organization of the
United Nations

BIOECONOMY

A short overview of regulatory and market-based instruments for the management of plastics used in agriculture

ENVIRONMENT
AND NATURAL
RESOURCES
MANAGEMENT

WORKING
PAPER

102

ISSN 2226-6062

BIOECONOMY

ENVIRONMENT
AND NATURAL
RESOURCES
MANAGEMENT

WORKING
PAPER

102

A short overview of regulatory and market-based instruments for the management of plastics used in agriculture

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 2024

Required citation:
FAO. 2024. *A short overview of regulatory and market-based instruments for the management of plastics used in agriculture.* Environment and Natural Resources Management Working Paper, No. 102. Rome. https://doi.org/10.4060/cd2610en

ISSN 2226-6062 [Print]
ISSN 2664-6137 [Online]

ISBN 978-92-5-139139-6

Contents

Acknowledgements

This publication was prepared by Giulia Carcasci, Agricultural Plastics and Sustainability Specialist, Office of Climate Change, Biodiversity, and Environment (OCB), Food and Agriculture Organization of the United Nations (FAO). It incorporates inputs from an earlier draft developed by Karen Raubenheimer, University of Wollongong, and Liu Yulu, National University of Singapore. The author expresses gratitude for the extensive comments, inputs, and revisions provided by Carmen Bullon, Legal Officer (FAO); Pierre DeLepinau, Senior Policy Advisor, Plastics in Agriculture (FAO); Alexandre Meybeck, Senior Technical Advisor, Natural Resources and Sustainable Production Stream (FAO); Teemu Viinikainen, Development Law Service (FAO); and Huimin Zhang, Environment Team (FAO).

The report was prepared under the overall leadership of Kaveh Zahedi, Director, OCB (FAO), and with the guidance of Lev Neretin, Environment Team Leader, OCB (FAO).

Executive summary

Plastic pollution is a critical issue that has prompted calls for global action. The Food and Agriculture Organization of the United Nation's (FAO) first assessment of plastics in agriculture highlighted the need for intersectoral collaboration and improved governance.[1] In December 2022, the FAO Council endorsed recommendations to address knowledge gaps on plastics in agriculture and requested the development of policy instruments, taking into account Members' past and ongoing efforts as well as developing countries' needs and challenges.[2]

FAO[3] estimates that annually, 12.5 million tonnes of plastic are utilized in plant and animal production, with an additional 37.3 million tonnes in food packaging. Plastics enhance agricultural productivity by increasing yields, extending growing seasons, reducing the use of chemicals and water, and improving climate resilience. However, their extensive use also generates substantial environmental, economic, and social costs, primarily due to soil pollution which can negatively affect plant, animal and human health.

This paper outlines regulatory and market-based instruments that can be employed to manage plastics sustainably in agriculture. A number of tools can be designed to reduce the environmental impact of plastics by encouraging recycling, reuse, and the adoption of sustainable alternatives. Regulatory instruments include product bans or phase-outs, restrictions on certain agricultural practices, the promotion of plastic alternatives, and the introduction of standards for product design. Market-based mechanisms include extended producer responsibility (EPR) schemes, taxes and fees, and plastic credits.

The paper emphasizes a comprehensive application of the 6Rs framework—Refuse, Redesign, Reduce, Reuse, Recycle, and Recover—to manage plastics in agriculture. It presents examples of instruments that have been implemented or proposed in various contexts, providing policymakers with a suite of options to address the challenges of plastic pollution in agrifood systems.

Although various instruments are available to manage plastic use, their effectiveness hinges on context-specific implementation and enforcement. As the field of plastic management is rapidly evolving, ongoing research and engagement of all relevant stakeholders in decision-making processes are essential to refine these instruments and tackle the environmental challenges posed by plastics in agriculture.

1 **FAO**. 2021. *Assessment of agricultural plastics and their sustainability. A call for action.* Rome. https://doi.org/10.4060/cb7856en

2 **FAO**. 2022a. Report of the 171st session of the Council of FAO. https://www.fao.org/3/nl148en/nl148en.pdf

3 **FAO**. 2021. *Assessment of agricultural plastics and their sustainability. A call for action.* Rome. https://doi.org/10.4060/cb7856en

Chapter 1. Introduction

The use of plastics in agrifood systems is pervasive. The Food and Agriculture Organization of the United Nations (FAO) estimates that every year 12.5 million tonnes of plastic products are used in plant and animal production, and an additional 37.3 million tonnes in food packaging (FAO, 2021). The crop production and livestock sectors are the largest users, accounting for 10 million tonnes per year, followed by fisheries and aquaculture with 2.1 million tonnes, and forestry with 0.2 million tonnes. The benefits of using plastics in agriculture include increased yields and production efficiency, alongside reduced food loss and waste. However, agricultural plastics also incur high environmental, economic and social costs, primarily from increased pollution. FAO's first assessment on plastics used in agriculture included a call for global action for improved intersectoral collaboration and governance to address plastic use throughout agrifood systems (FAO, 2021).

In December 2022, at its 171st Session, the FAO Council (FAO, 2022a) endorsed the recommendations of the 28th session of the Committee on Agriculture (COAG28) and:

- encouraged FAO to undertake further scientific and evidence-based assessments related to the distribution, benefits, trade-offs and risks of plastics for agricultural use and their alternatives, to address knowledge gaps on plastics in agriculture, and requested the development of policy instruments, taking into account Members' past and ongoing efforts as well as developing countries' needs and challenges;
- underscored the need for improved intersectoral collaboration and governance to address plastic use throughout agrifood systems, and recommended FAO to continue to address knowledge gaps, including through inclusive participation of Members and consultations with relevant stakeholders, and subject to the evidence-based assessment referred to in subparagraph k) to develop, within FAO's mandate, a Voluntary Code of Conduct on the sustainable use of plastics in agriculture;
- encouraged FAO to support deliberations of the intergovernmental negotiating committee (INC) on plastic pollution to develop an international legally binding instrument on plastic pollution established by the United Nations Environment Assembly Resolution End plastic pollution: Towards an international legally binding instrument (UNEP/EA.5/Res.14) with guidance on the issues of plastics used in agriculture.

FAO's work on the sustainable management of plastics in agriculture is aligned with the FAO's Strategic Framework 2022–2031, and its Programme Priority Area on Bioeconomy for Sustainable Food and Agriculture.

This document provides examples of instruments that are or could be used by countries to promote a more sustainable use and management of plastics in agriculture. It outlines the main issues related to plastics used in agriculture (Section 1.1), describes the methodology applied in preparing this paper (Section 1.2), presents examples of regulatory instruments (Section 2), and market-based mechanisms (Section 3).

1.1 CHALLENGES OF PLASTICS USED IN AGRICULTURE

The increased use of plastics benefits modern agriculture, enhancing productivity, extending growing seasons, reducing chemical and water use, improving nutrient uptake, and helping farmers adapt to climate change. At the same time, data suggest that a significant amount of plastic products used in agriculture becomes waste or is leaked to the environment, while only a small fraction is recycled (Hofmann *et al.*, 2023). Often farmers do not have the capacity for selection, application, and retrieval needed for adequate plastic management, nor do they have access to sound environmental end-of-life services and infrastructure. Plastics can degrade into micro- and nanoplastics, which pose an increasing concern given their potential to accumulate in food chains and their negative impacts on plant growth and soil health, with impacts on food safety, food security and human health still poorly understood.

Even with an efficient collection system in place, various substances, materials, and products used in terrestrial agriculture can still pose a risk of environmental contamination. Below is a non-exhaustive list of examples from FAO, 2021, and references therein:

- Oxo-degradable plastics do not meet biodegradable mulch standards and pose a risk with regard to the release of plastic fragments and microplastics.
- Burning polyvinyl chloride (PVC) films and pipes in fields – a common practice in many countries – can release hazardous chemicals listed as persistent organic pollutants under the Stockholm Convention.
- The application of sewage sludge as a fertilizer on agricultural soils can be a significant source of microplastic pollution (UNEP, 2022).
- Plastic mulch is commonly used for a single cropping season, which can range from three to nine months. When left in the soil after use, it degrades into micro- and nanoplastics, potentially impacting soil health and ecosystems as well as yields after continuous use.
- Fertilizers with non-biodegradable polymer coatings and PVC-coated seeds contribute directly to microplastic pollution in the soil.

Plant support twines made from non-biodegradable materials can become entangled with plant residues, compromising opportunities for recycling.

© FAO/Cristina Aldehuela

In FAO's first assessment (FAO, 2021), alternatives and interventions were identified to improve the circularity and sound management of agricultural plastics based on the 6Rs (Refuse, Redesign, Reduce, Reuse, Recycle, and Recover). The 6R criteria provide a hierarchical framework that can be applied to product design, manufacturing, use, and end-of-life management of plastics used in agriculture to transition from a linear to a circular economy. If the 6R approach cannot be applied, safe disposal in a sanitary, engineered landfill should be considered the next most sustainable option. Open burning should be avoided due to its potential to generate greenhouse gases, persistent organic pollutants (POPs), and other harmful emissions.

TABLE 1. The 6R approach

	Definition	Example
REFUSE	Intentionally avoiding use of the product.	Not using labels and stickers on single fruit items that are packaged in a larger retail box.
REDESIGN	Modifying a product in order to enhance its retrieval and waste management options; the redesign is intended to maintain/enhance the current agricultural benefit and/or health and safety performance the product.	Using thicker gauge mulch films to enhance retrieval from the field following use.
REDUCE	Minimising the quantity of plastic products used to deliver the same benefit, resulting in reduced need for raw materials, less plastic waste produced per batch of product and fewer amounts of plastic waste that need to be collected for recycling or disposal.	Adopting a stronger polymer for twines, allows a thinner cross-section.
REUSE	Intentionally switching from using single-use plastics to more durable items that can be reused a number of times along the value chain, thus reducing the quantities of plastics used.	Adopting reusable, reconditionable insulated boxes for transporting fish.
RECYCLE	Reprocessing plastic waste into new materials or products of the same or lower quality.	Recycling broken plastic crates or used containers into secondary materials such as plastic pellets.
RECOVER	Extracting energy from plastics; it should only be carried out if the previous 5Rs cannot be applied for technical or economic constraints and life assessments indicate it is more sustainable than landfilling.	For mixed plastic residues, such as thin films contaminated with organic residues, soil and chemical products.

Source: **FAO.** 2021. *Assessment of agricultural plastics and their sustainability. A call for action.* Rome. https://doi.org/10.4060/cb7856en

Management options must be evaluated within specific applications and contexts, using holistic methodologies based on a life-cycle approach.[4]

According to the particular context and agricultural sector, potential strategies include adopting farming or fishing techniques that prevent plastic usage; phasing out the most harmful plastic items; replacing specific plastic products with natural or biodegradable alternatives; promoting reusable plastic items; introducing waste management protocols; establishing extended producer responsibility collection schemes; and promoting financial measures and incentives to induce behavioural shifts along the supply chain.

4 An overview of possible policy options by application, with appraisal of appropriateness and viability, can be found in WRAP (2023).

1.2 OBJECTIVE AND METHODOLOGY

This paper presents examples of types of instruments that can be applied by national governments at national and subnational level to address the management and improve the sustainability of plastics used in terrestrial agricultures, and promote the use of less polluting alternatives.

They are gathered here in two broad categories: regulatory instruments, aimed at producing the desired change through the enforcement of laws and regulations, and market-based policy instruments, which use economic incentives to enhance product design and promote sustainable behaviors and practices.

The objective of this paper is to offer a concise overview with concrete implementation examples of the extent and variety of regulatory and market-based instruments utilized by policymakers to tackle plastic pollution. These instruments should be considered as a suite of possible options that policymakers could employ, though the effectiveness of the implementation or enforcement of these instruments may vary across different countries and agricultural sectors, based on their own specific contexts and circumstances.

Some of the instruments presented have already been used in the agricultural sectors. Others are not specific to the agricultural sector, but can be applied to address plastics used in agriculture or target the related pollution. When evidence was found that specific instruments have been used to address agricultural plastics or related pollution, this is indicated in the document.

The paper focuses on instruments which can be implemented by governments, and it does not analyse good agricultural practices which would result in a more sustainable use of plastics. These include, for example, crop rotation to reduce the need for plastic mulch, the promotion of rental and leasing schemes for agricultural services and products,[5] among other solutions. In addition, this paper does not analyse governments and industry investments in waste management infrastructure and operations, including incentives for plastic recycling.

The instruments discussed in this paper are derived from a desk review of those used to manage plastics in primary agriculture production, as well as those from other sectors that could be applied to address plastics used in agriculture. The order of presentation does not imply any hierarchy or priority. It is crucial to acknowledge that this field is rapidly evolving, and the examples provided are not exhaustive. The primary objective of this paper is to stimulate further discussion on the most effective instruments for addressing plastic pollution in agrifood systems, rather than offering a comprehensive list of all available options for tackling environmental challenges related to plastics in agriculture.

Table 2 summarizes the instruments presented in the paper, indicating the type (regulatory or market based), and their relation to the 6R management options.

5 Reusable Transport Packaging, Inc is a US-based company that provides farms with a rental service for plastic bulk agriculture containers, see RTP (2024).

TABLE 2. Measures to improve the sustainability of plastics used in agriculture

	Instrument	Regulatory or market based	6R management option
1	Product bans and phase outs	Regulatory	Refuse
2	Application of biosolids to lands	Regulatory	Refuse
3	Plastic alternatives and substitutes	Regulatory	Refuse; Redesign
4	Minimum recycled content	Regulatory	Reduce; Redesign
5	Product design for sustainability	Regulatory	Reduce; Redesign; Recycle
6	Product standards	Regulatory	Reduce; Redesign; Recycle
7	EPR schemes	Market-based	Recycle
8	Taxes and fees	Market-based	Reduce; Redesign
9	Environmental cross-compliance	Market-based	All
10	Plastic credits	Market-based	Redesign; Recycle

Source: Authors' own elaboration.

Chapter 2. Regulatory instruments

Regulatory instruments to drive a more sustainable management of plastics used in agriculture include measures to ban hazardous substances, products and practices, or to mandate the use of more sustainable substances, products and practices, including through standards for product design.

2.1 PRODUCT BANS AND PHASE-OUTS

Restrictions on the import or production of plastic products aim to reduce the quantity of these products introduced to the market, and are an increasingly common instrument (UNEP, 2018). In addition to restrictions on domestic manufacture or retailing, restrictions could include controlling both the import and export of such products (Diggle and Walker, 2022).

These types of command-and-control instruments have been particularly common for regulating production and consumption of single-use plastics. UNEP (2018) carried out an analysis of the countries that regulate the manufacture, import, sale, use and disposal of single-use plastics and microplastics. On plastic bags, the study reports that although interventions vary considerably, the most prevalent type of regulation is the ban on free retail distribution, which 83 countries have introduced. The second most common measure is manufacturing and importation bans, adopted by 61 nations. In addition, 27 countries introduced some type of ban on single-use plastics (either on specific products, materials, or production levels).

In the case of plastics used in agriculture, bans, phase-outs or restrictions could be implemented for those products with a high risk of leakage into the environment, and for which viable alternatives are already available.

Plastic pollution impacts on livestock

Plastic pollution poses threats to livestock and animal health. A study commissioned by the National Environment Management Agency (Lange *et al.*, 2018) revealed that 50 percent of livestock slaughtered in Nairobi's abattoirs had consumed plastic bags. This was among the reasons for the ban on single use plastic bags in Kenya.

Implementation of product bans for plastics used in agriculture

Oxo-degradable plastics do not meet current biodegradable mulch standards and pose contamination risks, including the release of plastic fragments and microplastics in soils. The European Union has banned their use, and China has a non-binding guidance on their use (Ellen MacArthur Foundation, 2017; FAO, 2021).

Fertilizers with non-biodegradable polymer coatings contribute directly to microplastic pollution in the soil. The European Union's Fertilising Products Regulation 2019/1009 (European Union, 2019a) includes a restriction on the marketing of non-biodegradable polymer coated fertilizers. These restrictions should enter into force in 2026 in all European Union Member States (Fertilizers Europe, 2023).

In Bangladesh, the Mandatory Jute Packaging Act, 2010, requires using jute bags for a list of bulk commodities such as rice, sugar, and fertilizers. The law has been expanded to include more products, and mandates jute packaging for the preservation and transportation of 17 commodities throughout Bangladesh (ELAW, 2024).

2.2 RESTRICTIONS ON AGRICULTURAL PRACTICES: THE CASE OF THE APPLICATION OF BIOSOLIDS TO LANDS

Biosolids are semi-solid by-products of wastewater treatment that are rich in nutrients but commonly contain micro- and nanoplastics. Depending on the processes used, pre-treatment, primary, secondary, and tertiary treatment stages of wastewater can decrease presence of microplastics in wastewater by an estimated 6 percent, 68 percent, 92 percent, and 96 percent respectively (Blair *et al.*, 2019). Irrespective of the processes used to remove microplastics from wastewater before release, microplastics will sink into the residual sludge (Milojevic, N. and Cydzik-Kwiatkowska, A., 2021). The application of biosolids as fertilizer to improve agricultural soils has inadvertently resulted in the release of micro- and nanoplastics into the environment. Microplastics present in biosolids originate from both household and industrial waste streams, including contaminated solids and wastewater. Mitigating this issue requires the establishment of treatment protocols and the implementation of maximum residue limits for microplastics in sludge.

The application of biosolids as fertilizer on agricultural soils is part of the broader issue of plastics generated, consumed, and disposed of, during primary agricultural production processes. This provides a rationale for governments to consider regulating or restricting the use of biosolids in agriculture. Such restrictions could focus on limiting the concentrations of microplastics and other contaminants present in biosolids applied to agricultural lands.

Biosolids' regulations in the European Union

The European Union introduced the Sewage Sludge Directive (86/278/EEC) in 1986 to protect humans, animals, plants, and the environment by limiting heavy metal concentrations in soil while promoting the use of sewage sludge in agriculture. The directive sets limits for seven heavy metals in sludge used for agriculture, and prohibits sludge applications that exceed these limits (European Union, 2022). A 2014 evaluation confirmed the directive's success in increasing sludge use and reducing environmental harm (European Commission, 2014). By 2018, all European Union Member States had implemented the directive, often with stricter limits (European Union, 2018). Ongoing discussions are now focused on integrating the directive into the circular economy framework (European Commission, n.d.).

2.3 PLASTIC ALTERNATIVES AND SUBSTITUTES

One of the solutions to tackle the problems related to plastic pollution lies in the identification, piloting and scaling up of plastics alternatives and substitutes. In this sense, the last years have seen a growing number of initiatives addressing material-shift towards substitutes to plastics throughout value chains, and especially in relation to biodegradable and biobased plastics.

UNCTAD (2023) differentiates between plastic substitutes and plastic alternatives based on their composition. Plastic substitutes refer to natural materials sourced from minerals, plants, animals, marine, or forestry origins that possess properties similar to plastics but do not include fossil fuel-based or synthetic polymers. These substitutes are often biodegradable, compostable, or erodible. Plastic alternatives, on the other hand, include bio-based plastics[6] and biodegradable plastics. Unlike plastic substitutes, they focus more on innovative polymer materials that aim to reduce greenhouse gas emissions and can be either recyclable or compostable. Biodegradable plastics are those that can be decomposed by the action of living organisms.

Both plastic substitutes and alternatives can be used to replace conventional, fossil-based plastics used in the agricultural sector. Plastic substitutes and biodegradable plastics can help reduce the need for off-site management of agricultural plastic waste, as well as cutting plastics and microplastics pollution in agricultural systems.

Biodegradable agricultural plastics products can replace non-biodegradable polymers in the production of various products. They are particularly suitable for items that are difficult to retrieve and have a high risk of littering, such as elastration bands, mulch films, and polymer-coated fertilizers, as well as for products that tend to become entangled in plant residues, such as support twines, plant clips, and tree guards and shelters.

However, caution is recommended, as the science around the potential negative impacts from the degradation of biodegradable plastics is still evolving. There are concerns that intermediate degradation products, incomplete degradation and release of additives could cause environmental harm (Filiciotto & Rothenberg, 2021; EIA, 2023b; Wei *et al.*, 2021). Furthermore, evidence shows that degradability of specific products is often related to environmental conditions, and additional research is needed to better understand the mechanisms of polymer degradation under various environ-mental conditions (Chamas *et al*, 2020).

6 FAO (2021) defines bio-based plastics as *"Plastic polymers that are derived from plant based raw materials. These materials can be specifically grown crops (e.g. corn starch), by products from crop production (e.g. bagasse from sugar cane) or specifically grown algae. Not all bio based plastics are biodegradable or compostable. Bio based polymers are generally blended with fossil based polymers to produce a plastic product"* (p. 124).

Implementation of plastic substitutes and alternatives in agriculture

In the Philippines, a project has replaced Expanded Polystyrene (EPS) fish boxes with biodegradable cold storage boxes made from discarded coconut husks. These "coconut coolers" offer similar performance at a competitive price while reducing ocean plastic pollution by 50 tonnes annually. Each cooler replaces a dozen disposable EPS boxes, saving costs for small-scale traders (UNDP, 2023).

According to UNCTAD (2023), studies on paper mulch have shown that it keeps soil cooler than plastic mulch, making it more suitable for cooler-season crops. Other types of mulch, like bio-based spray-on mulch made from agricultural residues, are still undergoing testing. Organic mulches, such as straw, strip tilling, compost mulch, woodchips, and wool mulch, offer similar benefits to plastic mulch and can aid in pest management. Additionally, Elizade University in Nigeria, in partnership with the Council for Scientific and Industrial Research (CSIR) in South Africa, is working on a project to develop biodegradable mulch films using locally sourced natural polymers like starch.

2.4 PRODUCT DESIGN AND STANDARDS

According to OECD (Watkins *et al.*, 2019), the design phase of a product determines 80 percent of its environmental impact, as key decisions made at this stage directly affect its end-of-life management, including durability, recyclability, reusability, and reparability. It also influences the reduction of harmful substances and the use of recycled raw materials. By implementing eco-design product standards, these design choices can be regulated, allowing for more effective management of the product when it reaches the waste stage.

The adoption of better designs for agricultural plastic products would promote appropriate extended use of products, as well as increase the options for reuse and recycling of plastic products used in agriculture. Some examples of product standards that are particularly relevant for agriculture are analysed in the following paragraphs.

2.4.1 MATERIALS WITH A MANDATED MINIMUM RECYCLED CONTENT

The introduction of mandatory minimum levels for the use of recycled materials in the production processes is a form of product standard that can contribute to the sustainable use of plastics in agriculture. Setting requirements for the proportion of recycled content in plastic products could enhance circularity, increase demand for recyclables, and encourage investment in recycling infrastructure.

Mandated minimum recycled content has been tested in non-agricultural packaging plastic products. The European Union Directive on single-use plastics entered into force in 2019, introducing mandatory recycled content of 25 percent in polyethylene terephthalate (PET) bottles from 2025, and 30 percent in all bottles from 2030 (European Union, 2019b).

It should be noted that the presence of recycled content should not compromise critical performance standards of the product. For example, the overriding performance standard for a pesticide container is to safely contain, and maintain the quality, of its contents. The light transmission and durability of greenhouse films are critical to their performance, and including recycled materials in their manufacture could adversely impact their performance. For food contact materials, the incorporation of recycled plastics could compromise their performance and food safety through the potential transfer of hazardous chemicals and pathogens (FAO, 2022b).

Implementation of minimum recycled content

According to Plastics Europe (2024), the recycled content rate for the agricultural sector is 37.5 percent. APE Europe (2020) estimates that silage sheets, stretch films, flexible irrigation pipes, small tunnels and mulch films for horticulture already include 10–40 percent of recycled material. No recycled agricultural plastic waste is currently used for mulch films, greenhouses and nets. Agricultural plastic products can also incorporate high quality recycled material from other sectors: plastic recyclers interviewed by Hann *et al.* (2021) suggested that a minimum of 25 percent recycled content is possible in most agricultural plastic products. Pallets are mostly made from wood, but those made from plastics could be good candidates for recycled plastics, and similarly plastic crates could be made from recycled plastics. In France, the converters committed in 2018 to increase the percentage of recycled content in new products from 19 percent to 25 percent by 2025 (APE Europe, 2020).

2.4.2 PRODUCT DESIGN FOR SUSTAINABILITY

Products can be redesigned to improve their lifespan, reuse, repurposing, retrieval, or recyclability. This is particularly applicable to greenhouse covers, mulching films, irrigation drip tape, tree guards and shelters, ear tags, insulated fish crates and boxes, bale films and nets.

Reuse should be strictly understood as the reuse of the product for its intended original purpose as a distinction from repurposing (to a different use). Repurposing is often conflated with reuse, but should be carefully and separately considered. In instances where plastics have been exposed to hazardous materials, repurposing potentially exposes the new users to those hazards. An example is the use of greenhouse films as roofing material in dwellings.

Being robust and well designed, empty pesticide containers are often repurposed for the storage of other commodities, including food. Such practices pose risks to human health and the environment, due to the nature of the residual content of emptied pesticide containers (FAO, 2021). The International Code of Conduct on Pesticide Management (FAO and WHO, 2014) and its supporting technical guidance documents sets voluntary standards for the design and management of pesticide containers to protect users and the environment from unnecessary exposure.

Any repurposing should be regulated to ensure that the product is safe and appropriate for the new purpose and will be managed in a safe and circular way at the end of its repurposed life. Repurposing can potentially extend the use of a plastic product to a point where it poses a high risk of degradation into microplastics.

The European Union has implemented since 2009 a regulatory framework fostering eco-design for a range of products (European Union, 2024a). Similar examples of applications of eco-design regulations include the European Union Packaging and Packaging Waste Directive (European Union, 2015), the upcoming Plastic Packaging and Plastic Waste Regulation (European Union, 2024b) and the Single-Use Plastics Directive (European Union, 2019b). The former aims to prevent the production of certain kinds of packaging waste, and promote reuse and recycling of packaging, with the goal of reducing the need for final disposal of packaging waste.

Implementation of product design sustainability

To promote the use of a better quality, thicker plastic mulch to improve options for reuse, collection and recycling, the Chinese Ministry of Ecology and Environment and the National Development and Reform Commission (NDRC) imposed a ban on the production and sale of polyethylene agricultural mulch films with a thickness of less than 10 µm (Chinese Academy of Agricultural Sciences, 2020). The NDRC also aims to support pilot programmes for the recycling of waste from plastics used in agriculture. In the European Union there are proposals to impose a standard with a minimum thickness of 25 µm.

In Brazil, pesticides producers voluntarily phased out the use of polyethylene terephthalate (PET) in favor of high-density polyethylene (HDPE) for pesticides containers, in an effort to enhance the recycling process.

2.4.3 PRODUCT STANDARDS

Certified standards play a crucial role in ensuring the reliability and environmental performance of biodegradable materials for agricultural applications. These standards provide guidelines for testing and certifying the biodegradability of materials under specific conditions, helping to regulate the use of biodegradable plastics and other alternatives in agriculture. Adhering to such standards ensures that materials break down efficiently, without leaving harmful residues in the environment, such as microplastics or toxic chemicals.

Standards for biodegradable and compostable products are complex, partly because of variations in definitions, testing criteria, and testing environments. Table 3 summarizes some of the biodegradable and compostable agricultural products and standards.

As discussed in section 2.3, significant data gaps remain on the impacts of biodegradable plastics on the environment and agricultural soils.

TABLE 3. Examples of standards for biodegradable and compostable agricultural products

Sector	Items	Standard	Test environment
Farming	Mulch films	EN 17033	Soil
	Clips	EN 17033	Soil
	Ropes and twines	EN 17033 EN 13432	Soil Industrial composting
	Pheromone dispensers	EN 13432 ASTM D6400	Industrial composting
	Plant pots	EN 13432 ASTM D6400	Industrial composting
Fisheries	Nets	ASTM D6691 ASTM D7991	

Source: Adapted from **FAO.** 2021. *Assessment of agricultural plastics and their sustainability. A call for action.* Rome. https://doi.org/10.4060/cb7856en, and references within.

Chapter 3. Market-based instruments

Market-based instruments are designed to encourage desired behavioral changes by providing economic incentives. These incentives are effective when there is an opportunity to choose a product design or process that pollutes less, or to reduce consumption of the higher-polluting option when no suitable alternative exists (Ten Brink et al., 2009). This can apply to consumer choices on products and practices, as well as producer decisions on materials and business models.

Examples of market-based instruments include extended producer responsibility (EPR) schemes, taxes on virgin plastics, deposit-return schemes, advanced disposal fees, plastic credits, and environmental cross-compliance. Many of these schemes aim to make producers financially and/or operationally accountable for the end-of-life management of their products.

Depending on the design of the scheme, the goal may also be to encourage more sustainable product design choices (Kaffine and O'Reilly, 2015). Market-based instruments can incentivize environmentally responsible design by allowing products that meet specific design criteria to qualify for lower fees or exemptions under the scheme.

The instruments presented in this section are categorized as market-based since their compliance mechanism relies mainly on a monetary incentive. However, it is important to note that, in most cases, these instruments require support from regulatory measures to ensure their effective implementation by the private sector.

© FAO/Stefanie Glinski

3.1 EXTENDED PRODUCER RESPONSIBILITY (EPR) SCHEMES

A common approach to addressing plastic pollution is the use of "Extended Producer Responsibility" (EPR) collection and management schemes. As described by the Organisation for Economic Co-operation and Development (OECD, 2016), such schemes aim to "make producers responsible for the environmental impacts of their products throughout the product chain, from design to the post-consumer phase."

This paper discusses three types of EPR systems: take-back schemes, advanced disposal fees, and deposit/refund systems.

EPR collection schemes

EPR collection schemes may be voluntary or mandatory, and are typically regulated by governments and administered by producers individually or through a collective producer responsibility organization (PRO). FAO (2021) identified that the majority of current EPR schemes for plastics used in agricultural production were voluntary, many of which were initiatives of the pesticide industry to manage empty containers[7]. It also recommended that EPR schemes in the agricultural sector be mandatory to ensure that all plastic products were covered by the scheme, and to improve collection rates. Voluntary schemes often achieve lower collection rates, tend to cover a smaller product range, and target products and geographic areas with a greater profit potential.

EPR schemes can target various types of plastic products. Examples of those used in the production stage of agrifood systems are found covering mulch films, greenhouse films, bale wraps, bags and containers for inputs (e.g. pesticides, fertilizers, feed and hygiene products), twines and nets (FAO, 2021).

Advanced disposal fees

Advance disposal fees (ADFs) are a non-refundable levy imposed on individual products at the point of sale, representing a form of EPR. Traditionally, ADFs cover the costs associated with managing the end-of-life processing and disposal of a product. This can be particularly relevant for countries lacking revenue sources to manage increasing volumes of waste. ADFs can target multiple points of the value chain; fees can be imposed upon producers/importers – reflecting the costs of disposal of the products they place on the market – or retailers. The fees may end up being passed on to consumers through price increases. If ADFs are differentiated based on the marginal disposal costs of the embedded materials (e.g. by the weight of polymers), then they provide producers with both source reduction (limit waste generation) and green design incentives. Where a label or invoice identifies the additional fee charged for disposal, consumer choice may also be influenced, leading the purchaser to potentially avoid plastics products that are difficult or expensive to recycle, and which attract a higher ADF. A common example is the visible ADF charged in many countries on plastic bags.

7 For an additional review of some of the EPR schemes in place globally for plastics used in agriculture, see WRAP (2023).

ADFs could be included in the price of all conventional plastics products used in agriculture. If related policy responses are in operation, these price-based policies may be more appropriate to plastic products which are not suitable for rental/lease schemes, such as bale films and nets, fishing nets and ropes, plastic ties, ropes and twines, and bale twine. ADFs are also highly applicable to plastic packaging used in the mid- and downstream phases of agrifood systems.

Deposit-return schemes

Deposit-return schemes are commonly used to boost the collection of consumer packaging, particularly polyethylene terephthalate (PET) beverage bottles, and are part of the broader concept of EPR. In these schemes, a deposit fee is added at the time of purchase, and refunded when the consumer returns the used product. Deposit-return schemes can be driven by industry initiatives or required by regulations.

This report did not find any deposit-return schemes connected to the use of agricultural plastics in primary production, but they could be employed for semi-permanent and single-use agricultural plastic products. These could include pesticide containers, EPS boxes, plant pots, seedling plugs, bags for feed, fertilizer containers, tree guards, crates for harvesting, and ear tags. Deposit schemes for bags for feed will call for a change in bag design, whereas those for EPS boxes, plant pots, and seedling plugs will require improvements to the strength and durability of these products.

According to WRAP (2023), deposit-returns may be suitable for bottles, drums, canisters, sprays, and livestock tags. This is based on their potential for reuse, provided proper cleaning processes are followed, and aims to minimize environmental loss.

Implementation of EPR schemes across the world

The "Campo Limpo" in Brazil is a legally mandated scheme run by the PRO inpEV on behalf of Brazil's pesticide manufacturers and importers. The scheme has been operating since 2002, and in 2023 it received more than 53 000 tonnes, recycling 97 percent of collected containers (inpEV, 2023). The success of the Brazilian scheme is primarily due to the legal obligation on the pesticide industry to finance it, and on farmers to deliver their used pesticide containers to the reverse logistic collection scheme. The scheme is enforced through a tracking system that links farmers' purchases of pesticides to the return of the empty containers (FAO, 2021).

The A.D.I.VALOR system in France, which manages both packaging and non-packaging agricultural plastic waste, was established on a voluntary basis through close collaboration and a public agreement between the national government and the agricultural sector, including farmers and industry (A.D.I.VALOR, 2024).

DrumMUSTER is a voluntary product stewardship scheme in Australia, involving suppliers and manufacturers of agricultural and veterinary chemicals. Producers of these chemicals pay a fee on products introduced in the market. The funds collected are used to reimburse local councils and community groups for inspecting containers and supporting the program's operations. Additionally, processors receive reimbursement for collecting and recycling these containers into new products (DrumMUSTER, 2024).

3.2 TAXES AND FEES

Taxes and fees can serve as market signals to reduce the use of specific products, materials, or chemicals. Generally, a tax raises the price of a product, thereby encouraging a decrease in its use. When promoting more sustainable plastic design from a polymer perspective, taxes can be imposed to discourage the use of certain polymers. Additionally, taxes can be levied on products deemed less environmentally sustainable compared to available alternatives.

Some countries have established a tax on the use of virgin plastics packaging to reduce the generation of new plastic and the increased pollution associated with it. The tax could be paid by producers, both national manufacturers and importers, of products made with virgin plastic. Taxing virgin plastics increases the cost of using virgin plastic in the production of plastics products, improving the competitiveness of recycled content and bio-based materials. Taxation measures could also encourage the adoption of alternatives, foster reuse and recycling of plastics used in agriculture, and raise funds for needed investment in recycling and waste management infrastructure.

Implementation of taxes on plastic use

Between 2000 and 2018, Denmark imposed a tax on certain soft PVC products containing phthalates for items like pipes, flooring, cables, and rainwear. Products using alternative softeners are taxed at reduced rates, providing an incentive for manufacturers to avoid phthalates (Watkins *et al.*, 2019).

An example of a virgin plastic tax regulation can be found in the 2022 Plastic Packaging Tax in the United Kingdom of Great Britain and Northern Ireland (National Archives, 2022). The tax applies to plastic packaging manufactured in or imported into the United Kingdom of Great Britain and Northern Ireland which does not contain at least 30 percent recycled plastic. The tax came into force on April 2022 and was charged at a rate of GBP 200 per ton from April 2022, and GBP 210.82 per ton from April 2023. Silage wrap used in agriculture was initially supposed to be targeted by the tax, but it was ultimately not included (EIA, 2023a; CIPA, 2023).

© D. Whaley

3.3 ENVIRONMENTAL CROSS COMPLIANCE

Environmental performance of agricultural production may be improved by developing interactions between agricultural policy instruments and environmental policy measures. Environmental cross compliance is an example of this, whereby environmental conditions must be met before income support payments (i.e. subsidies) are granted, or to avoid a reduction or withdrawal of these payments (European Commission, 2023). The guide to cross compliance in England 2022 defines cross compliance as "*a set of rules which farmers and land managers must follow on their holding if they are claiming certain rural payments*" (Rural Payments Agency, 2022).

In the European Union, through conditionality (formerly known as cross-compliance), farmers are encouraged to meet standards for public, plant, and animal health and welfare. To receive income support, they must adhere to a set of basic rules, including maintaining good agricultural and environmental conditions (European Commission, 2023).

In addition, the European Union also actively supports the fruit and vegetables sector through its market-management scheme (European Commission, n.d.). Producer Organizations (POs) are groups of fruit and vegetable growers which can establish an operational fund to support their operational program. This fund can be partially financed through European Union financial assistance, which is typically capped at 50 percent of the total operational fund. A minimum of 10 percent of the expenditure in the operational programmes must be allocated to environmental initiatives that go beyond mandatory environmental standards. European Union Countries with recognised POs must draw up a national framework for environmental actions as part of their national strategy for sustainable operational programmes. European Union countries with recognized POs are required to establish a national framework for environmental actions as part of their broader national strategy for sustainable operational programs.

Implementation of cross compliance

In Wales, cross compliance has been used to promote compliance with the application of sewage sludge to agricultural lands. Although microplastics are not specified in the *Cross Compliance Verifiable Standards 2024* (Welsh Government, 2024), farmers are required to obtain a permit before the discharge of any non-hazardous pollutants such as sewage sludge (GAEC 3, standard 3.2).

In France, certain criteria are recommended for Producer Organizations (POs). One such measure involves sending plastic and packaging waste for recycling, with the additional costs associated with recycling—compared to cheaper alternatives like landfilling or incineration—being covered. Another measure promotes the use of plant-based, biodegradable, or reusable mulching films, again with the higher costs, in contrast to non-reusable, non-biodegradable plastic films, also being accounted for (FranceAgriMer, 2023).

3.4 PLASTIC CREDITS

Similar to carbon credits, plastic credits are tradable permits or certificates that represent the offset of the plastic footprint of a business, coming from the consumption of plastics, or the generation of plastic waste.

For example, one credit may be representative of one ton of plastic waste recycled or collected from the environment. These credits are transferable, and are generated by entities that collect or recycle plastics. Commonly, they are purchased by manufacturers or consumers, but also by investment firms that trade the credits.

Credit schemes have come under criticism for lack of effectiveness and for allowing producers that purchase credits to continue with harmful environmental practices (for a comprehensive list of risks, see WWF, 2021). Plastic credits could be employed to enhance the collection, recycling and disposal of any plastic waste used in agriculture, and would be of particular interest for products for which no other more sustainable option is available (such as reduction, or replacement with more sustainable materials).

Implementation of plastic credits

The Verra Plastic Waste Reduction Program (Verra, 2024) sets out requirements for new or scaled-up collection and recycling projects that can quantify their impact to generate plastic credits. Credits are issued for the additional amount of plastic waste collected from the environment and managed in a responsible manner (e.g., recycled, landfilled or incinerated with energy recovery).

Within this programme, GreenCollar (2021) is tackling plastic waste generated by plastic banana covers used in Far North Queensland, in Australia. The project is currently focusing on the collection of plastics on the participating farms, which are estimated to create around 300 tonnes of waste yearly. Phase two, which should begin in 2024, will create new facilities to recycle plastic banana covers.

In Colombia, the company MAYCO recycles plastic waste originated in banana plantations. Through this project, MAYCO seeks to upscale and improve the capacity of their recycling plant, adding new plastic types (PP and HDPE) to its current process. The recycled plastic will then be used in the manufacturing of new items for several sectors, including the agricultural sector (Verra, 2024a).

Chapter 4. Concluding remarks

This paper presents a range of instruments that can be used to improve the management of plastics in agriculture, including bans and restrictions, economic instruments, extended producer responsibility, and other measures. It outlines the key aspects of each instrument with examples.

Addressing the complex and specific challenges intertwined with the use and management of plastics in agriculture necessitates a multifaceted approach and, most of the time, a sectoral approach specific to the agricultural sector. This involves not only reducing the use and enhancing the circularity of plastic products but also mitigating their environmental impacts. Specifically, both upstream measures, aimed at reducing the quantity of plastics introduced into the market and improving their durability or recyclability; and downstream measures, aimed at preventing plastic leakage into the environment, can be implemented to achieve effective results in improving the sustainability of plastics used in agriculture and their alternatives.

A thorough evaluation of the benefits and drawbacks of different regulatory interventions is still needed. Therefore, it is crucial that legislations on agricultural plastics are based on baseline assessments, lifecycle analyses, and extensive consultations with relevant stakeholders. Solutions will need to be assessed case by case, using a holistic approach that takes into account all relevant dimensions of sustainability.

As pointed out in UNEP & WRI (2020) and OECD (2022), policymakers should also consider the success of hybrid approaches that combine multiple policies tailored to the specific context of the country to effectively address the sustainable management of plastics used in agriculture. Effective regulation may require targeting various consumer behaviors and addressing multiple lifecycle stages of agricultural plastics. Combining waste collection, product replacement, and educational campaigns can create a more comprehensive policy than a single instrument. National and subnational initiatives may need to complement each other to ensure coherent policy. Policymakers should also evaluate the implementation timeframe, considering gradual approaches for ambitious measures like total bans.

In essence, the attainment of substantial progress in the enhancement of plastics' sustainability within agricultural mandates a comprehensive strategy. This field is rapidly evolving, with new models and best practices continually emerging. In the meantime, this paper can serve as an initial steppingstone for facilitating discussions regarding the formulation and deployment of policies by governments, catalysing proactive measures to grapple with the challenges posed by the proliferation of plastic pollution in agriculture and beyond. The diversity of instruments presented here can spark dialogues aimed at sculpting an effective and adaptable roadmap to address the intricate intersection of plastics and agriculture.

References

A.D.I.VALOR. 2024. Organization history. In: A.D.I.VALOR. [Cited 9 August 2024]. https://www.adivalor.fr/en/filiere/presentation/historique.html

APE Europe. 2020. *The European Plasticulture Strategy - a contribution to an european agri-plastic waste management.*

Blair, R.M., Waldron, S., Gauchotte-Lindsay, C. 2019. Average daily flow of microplastics through a tertiary wastewater treatment plant over a ten-month period. *Water Research*, Volume 163, 114909, ISSN 0043-1354. https://doi.org/10.1016/j.watres.2019.114909

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J.H., Omar, M.A., *et al*. 2020. Degradation Rates of Plastics in the Environment. ACS Sustainable Chemistry & Engineering. 8, 9, 3494–3511. https://pubs.acs.org/doi/10.1021/acssuschemeng.9b06635

Chinese Academy of Agricultural Sciences & Ministry of Agriculture and Rural Affairs. 2020. *Management of Agricultural Plastics in China: the Plastic Mulch Film - a report for FAO.*

CIPA. 2023. *Plasticulture – the magazine of plasticulture professionals.*

Diggle and Walker. 2022. *Environmental and Economic Impacts of Mismanaged Plastics and Measures for Mitigation.* https://doi.org/10.3390/environments9020015

DrumMUSTER. 2024. In: DrumMUSTER. [Cited 9 August 2024]. https://www.drummuster.org.au

ELAW. 2024. Plastic Law. In: *The Environmental Law Alliance Worldwide (ELAW).* [Cited 9 August 2024]. https://elaw.org/plastic

Ellen MacArthur Foundation. 2017. *Oxo-degradable plastic packaging is not a solution to plastic pollution, and does not fit in a circular economy.*

Environmental Investigation Agency (EIA) UK. 2023a. *Cultivating Plastic Part 1 - Agriplastics and the UK grocery retail supply chain.*

Environmental Investigation Agency (EIA) UK. 2023b. *Cultivating Plastic Part 4 - Caution with regards to the adoption of potential agriplastic alternatives.*

European Commission. 2014. Ex-post evaluation of certain waste stream directives: Final report. Neuilly-sur-Seine. https://ec.europa.eu/environment/pdf/waste/target_review/Final%20Report%20Ex-Post.pdf

European Commission. 2023. Common agricultural policy. In: European Commission. [Cited 7 Aug 2024]. https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/conditionality_en

European Commission. n.d. Sewage sludge. In: European Commission. [Cited 25 July 2024]. https://ec.europa.eu/environment/topics/waste-and-recycling/sewage-sludge_en

European Commission. n.d. Fruit and vegetables. In: European Commission. [Cited 12 September 2024]. https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/fruit-and-vegetables_en

European Union. 2009. Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast) (Text with EEA relevance). In: EUR-Lex. [Cited 25 July 2024]. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125&locale=en

European Union. 2015. Consolidated text: European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. In: EUR-Lex. [Cited 25 July 2024]. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01994L0062-20150526

European Union. 2018. Report from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions on the implementation of eu waste legislation, including the early warning report for member states at risk of missing the 2020 preparation for re-use/recycling target on municipal waste. In: EUR-Lex. [Cited 25 July 2024]. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1537873850842&uri=COM:2018:656:FIN

European Union. 2019a. Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019R1009

European Union. 2019b. Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (Text with EEA relevance). In: EUR-Lex. [Cited 25 July 2024]. https://eur-lex.europa.eu/eli/dir/2019/904/oj

European Union. 2024a. Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC (Text with EEA relevance). In: EUR-Lex. [Cited 12 September 2024]. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L_202401781#:~:text=REGULATION%20 (EU)%202024/1781%20OF%20THE%20EUROPEAN%20PARLIAMENT%20AND%20OF%20THE

European Union. 2024b. European Parliament legislative resolution of 24 April 2024 on the proposal for a regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC. In: Publications Office of the European Union. [Cited 12 September 2024]. https://op.europa.eu/en/publication-detail/-/publication/a1424b75-03a8-11ef-a251-01aa75ed71 a1/ language-en#:~:text=European%20Parliament%20legislative%20 resolution%20of%2024%20 April%202024%20on%20the

FAO. 2021. *Assessment of agricultural plastics and their sustainability. A call for action*. Rome. https://doi.org/10.4060/cb7856en

FAO. 2022a. Report of the 171st session of the Council of FAO. https://www.fao.org/3/nl148en/nl148en.pdf

FAO. 2022b. *Thinking about the future of food safety - a foresight report*. Rome. https://doi.org/10.4060/cb8667en

FAO & WHO. 2014. *International Code of Conduct on Pesticide Management*. https://www.fao.org/pest-and-pesticide-management/pesticide-risk-reduction/code-conduct/en

Fertilizers Europe. 2023. Policy priorities: Microplastics. In: Fertilizers Europe. [Cited 25 July 2024]. https://www.fertilizerseurope.com/circular-economy/micro-plastics/

Filiciotto, L., & Rothenberg, G. 2021. Biodegradable plastics: Standards, policies, and impacts. *ChemSusChem*, *14*(1), 56-72.

FranceAgriMer. 2023. Programmes Opérationnels (PO) relevant de la PAC 2014-2022. In: FranceAgriMer. [Cited 12 September 2024]. https://www.franceagrimer.fr/filiere-fruit-et-legumes/Accompagner/Dispositifs-par-filiere/Organisation-commune-de-marche-et-aides-communautaires/OCM-Fruits-et-legumes/Programmes-Operationnels-PO-relevant-de-la-PAC-2014-2022

GreenCollar. 2021. Case study: Peeling the Lid off the Banana Plastic Industry. GreenCollar. https://greencollar.com.au/bananas-plastic-industry/ (Accessed 23 August 2023).

Hofmann, T., Ghoshal, S., Tufenkji, N., Adamowski, J. F., Bayen, S., Chen, Q., ... & Wilkinson, K. J. 2023. Plastics can be used more sustainably in agriculture. *Communications Earth & Environment*, *4*(1), 332.

inpEV. 2023. Relatório de Sustentabilidade 2023. inpEV - (Instituto Nacional de Processamento de Embalagens Vazias). https://www.inpev.org.br/relatorio-sustentabilidade/2023/index.html

ISO. 2021. Plastics — Organic recycling — Specifications for compostable plastics. ISO Standard, No.17088. Geneva, International Organization for Standardization. https://www.iso.org/standard/74994.html

Kaffine, D. & O'Reilly, P. 2015. *What Have We Learned About Extended Producer Responsibility in the Past Decade? A Survey of the Recent EPR Economic Literature.*

Lange, N. C., Inganga, F., Busienei, W., Nguru, P., Kiema, J., & Wahungu, G. 2018. The prevalence of plastic bag waste in the rumen of slaughtered livestock at three abattoirs in Nairobi Metropolis, Kenya and implications on livestock health. *Prevalence*, *240*(1051), 991.

Milojevic,N., & Cydzik-Kwiatkowska, A. 2021. Agricultural Use of Sewage Sludge as a Threat of Microplastic (MP) Spread in the Environment and the Role of Governance. *Energies 2021*, 14, 6293. https://doi.org/10.3390/en14196293

National Archives. 2022. The Plastic Packaging Tax (General) Regulations 2022. In: Legislation.gov.uk. [Cited 25 July 2024]. https://www.legislation.gov.uk/uksi/2022/117/contents/made

OECD. 2016. *Extended Producer Responsibility: Updated Guidance for Efficient Waste Management*. OECD Publishing, Paris. https://www.oecd-ilibrary.org/environment/extended-producer-responsibility_9789264256385-en

OECD. 2022. *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*. OECD Publishing, Paris. https://doi.org/10.1787/de747aef-en

Plastics Europe. 2024. *The Circular Economy for Plastics: A European Analysis*. https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/

Rural Payments Agency. 2022. *The guide to cross compliance in England 2022*. https://assets.publishing.service.gov.uk/media/61b21acb8fa8f5038358c1c9/Guide_to_cross_compliance_in_England_2022.pdf

Reusable Transport Packaging (RTP). 2024. Rental Product. In: Reusable Transport Packaging. Petersburg. [Cited 25 July 2024]. https://reusabletranspack.com/product-category/rental-products/

Ten Brink, P., Lutchman, I., Bassi, S., Speck, S., Sheavly, S., Register, K., and Woolaway, C. 2009. Guidelines on the Use of Market-based Instruments to Address the Problem of Marine Litter. *Institute for European Environmental Policy (IEEP), Brussels, Belgium, and Sheavly Consultants, Virginia Beach, Virginia, USA.*

UNCTAD. 2023. *Plastic pollution. The pressing case for natural and environmentally friendly substitutes to plastics.*

UNDP. 2023. Cohort 1: Marine pollution reduction. In: UNDP Ocean Innovation Challenge. [Cited 25 July 2024]. https://www.oceaninnovationchallenge.org/ocean-innovators#cbp=/ocean-innovations/fortuna-coconut-coolers

UNEP. 2018. *Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations.*

UNEP. 2022. *Plastics in Agriculture – An Environmental Challenge*. Foresight Brief 029. Nairobi.

UNEP & WRI. 2020. *Tackling plastic pollution: Legislative Guide for the Regulation of Single-Use Plastic Products.*

U.S. Congress. 2020. Break Free From Plastic Pollution Act of 2020. In: Congress.gov. Washington, D.C. [Cited 25 July 2024]. https://www.congress.gov/bill/116th-congress/house-bill/5845

Verra. 2024. Plastic Program Details. In: *Verra*. [Cited 9 August 2024]. https://verra.org/programs/plastic-waste-reduction-standard/plastic-program-details/#verra-registry

Verra. 2024a. MAYCO SOLUCIONA BananaPlastRevive Colombia: Sustaining Lives, Preserving Nature. In: *Verra*. [Cited 9 August 2024]. https://registry.verra.org/app/projectDetail/PWRP/4762

Watkins, E., Schweitzer, J. P., Leinala, E., & Börkey, P. 2019. *Policy approaches to incentivise sustainable plastic design*. OECD.

Wei, X.-F., Bohlén, M., Lindblad, C., Hedenqvist, M., & Hakonen, A. 2021. Microplastics generated from a biodegradable plastic in freshwater and seawater. *Water Research 198.* https://doi.org/10.1016/j.watres.2021.117123

Welsh Government. 2024. Cross compliance: verifiable standards 2024. Cardiff. https://www.gov.wales/cross-compliance-verifiable-standards-2024

WRAP. 2023. *Review of Plastics in Agriculture.* https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=21145

WWF. 2021. *WWF Position: Plastic Crediting and Plastic Neutrality.* https://c402277.ssl.cf1.rackcdn.com/publications/1429/files/original/newWWF_Position_on_Plastic_Crediting_and_Plastic_Neutrality_.pdf?1611957221

Office of Climate Change, Biodiversity and Environment (OCB)
www.fao.org/in-action/sustainable-and-circular-bioeconomy
Bioeconomy@fao.org

Food and Agriculture Organization of the United Nations
Rome, Italy

ISBN 978-92-5-139139-6 ISSN 2226-6062

9 789251 391396

CD2610EN/1/10.24