June 2024

Improved End-Of-Life of Plastic Mulches

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Life Cycle Assessment for Soil-Biodegradable Plastic Mulch

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Summary

Soil-biodegradable mulch (BDM) is an alternative to polyethylene (PE) mulch. BDM, especially BDM that contains starch, has environmental benefits including reduced energy use and greenhouse gas emissions.

Presenter Notes

These notes provide information for presenters for this slide presentation that describes the life-cycle assessment of soil-biodegradable mulches (BDMs). Numbers in the text correspond to the slides in the presentation. Information in this document is based on a number of reviewed publications, some of which are listed in the "Resources" section.

1 This presentation explores the environmental impact associated with the production, use, and end-of-life of soil-biodegradable mulch (BDM) and plastic mulch through a comparative life cycle assessment.

2 The term 'life cycle assessment (LCA),' also known as 'life cycle analysis,' refers to a structured, systematic, comprehensive, and iterative method used to evaluate the environmental impact associated with the stages of a product system's life cycle. The life cycle stages of mulch films include raw material extraction or production, film production, field application, and removal, disposal, or recycling.

LCA is structured, involving well-defined stages such as goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and results/interpretation. It is systematic because these stages follow a defined order, comprehensive as it covers the entire life cycle of a product, and iterative because any identified limitations or data availability issues often require revisions or refinements to the initial goals or scope.

3 While there is not yet widespread adoption of soil-biodegradable mulch (BDM), BDM, especially BDM that contains starch, displays significant environmental advantages throughout its entire life cycle and is recommended as an alternative to PE mulch.

USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

This material is based upon work that is supported by USDA SCRI award 2022-51181-38325. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

A comparative LCA involves a rigorous comparison between the environmental burdens associated with two products, from raw material production/extraction to mulch production, use, and end-of-life. The raw material stage involves the production or extraction of mulch film feedstocks, e.g., corn, starch, succinic acid, terephthalic acid, and other raw materials such as bauxite, barite, phosphoric acid, etc. The mulch manufacturing stage involves raw material processing into mulch film, which can include fermentation, polymerization, film extrusion, injection molding, etc. The use stage is when the mulch films are laid on crop fields. The end-of-life stage involves the fate of mulch waste after crop harvest. This can include the direct tillage of BDM into the soil or the collection of PE mulch for landfilling, incineration, and recycling.

4 Notably, the material manufacturing stage of mulch film production represents a dominant portion of the overall environmental impact. BDM manufacturing displayed promising environmental benefits specifically reduction in greenhouse gas emissions and non-renewable energy consumption compared to petrochemical-based counterparts. But BDM can display notable negative environmental impacts such as eutrophication and land occupation (for production of feedstocks), in addition to acidification and ecotoxicity. These will be explained in the following slides.

5 Environmental impact varies depending on factors such as life cycle stage, end-of-life strategy, fertilizer application, polymer blends, additive content, film thickness, and climate.

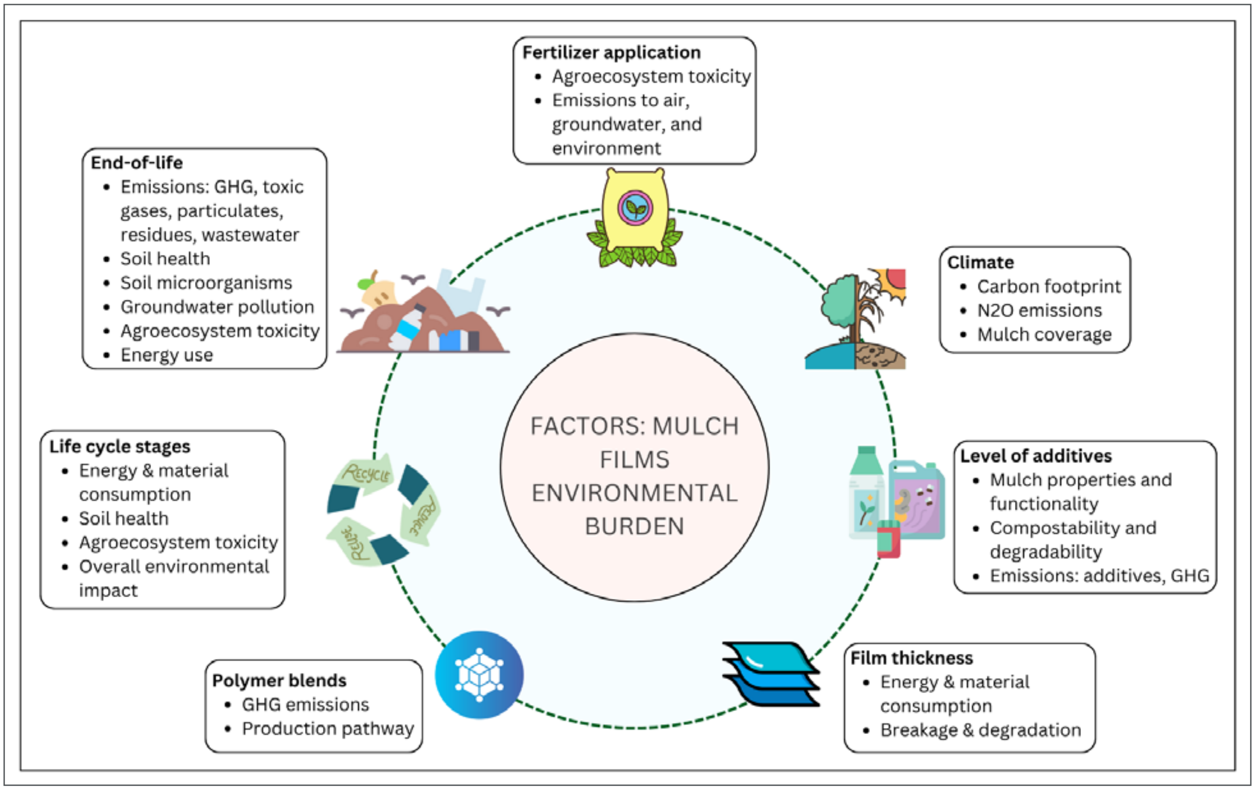

Figure 1. *Factors affecting environmental burdens associated with mulch films.*

- **Life cycle stage:** Specific life cycle stages disproportionately contribute to the environmental impact of both BDM and PE mulch. The manufacturing stage stands out as a dominant contributor to energy and material consumption. Crop yield is often comparable for both BDM and PE mulch use stages. Additionally, plastic residues left after harvest pose critical toxicity risks to soil health, plants, humans, and other organisms that ingest them.

- **End-of-life (EOL) strategy:** Common EOL strategies for PE mulch include landfilling, recycling, incineration, on-site stockpiling, and burning. BDM is usually tilled into the soil or composted, although composting is more expensive. For PE mulch, priority should be given to material, heat, and energy recovery while minimizing waste streams such as toxic wastewater and particulate matter.

    - Direct incineration of mulch wastes with impurities results in the generation of greenhouse gases (GHGs) such as CO_2, SO_2, and NO_2. Mulch waste burning with impurities releases pollutants like dioxins, particulate matter, CO, polycyclic aromatic hydrocarbons (PAH), and furans. Leaching of toxic substances into the soil from

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landfills causes land and groundwater pollution. Microplastics formed by the breakage of stockpiled mulch waste deteriorate soil health and reduce the functional diversity of soil microorganisms. Washout of adsorbed agrochemicals from plastic wastes, triggered by irrigation or rainfall, into soil and groundwater causes environmental toxicity and eutrophication. Runoff of toxic wastewater into water bodies from mulch washing during recycling causes agroecosystem toxicity.

- **Fertilizer application:** Fertilizer production and excessive applications contribute to eutrophication, acidification, and GHG emissions. Growers should optimize fertilizer applications to only apply what is needed and assimilated by the crop.

- **Polymer type:** The composition of plastic polymers in polymer blends significantly affects environmental burdens by influencing the overall production pathway. Consequently, the manufacturing environmental impacts vary significantly from one BDM product to another. Increasing starch content and reducing polybutylene adipate terephthalate (PBAT) and polybutylene succinate (PBS) contents in co-polymer blends is encouraged for environmental sustainability.

- **Level of additives:** Mulch additives play a crucial role in enhancing film properties and overall functionality. Minimizing additive use in BDM production is recommended, as additives may reduce compostability and degradability.

- **Mulch thickness:** The manufacturing of thicker films requires higher energy and raw material consumption. Also, thicker films are less prone to breakage with reduced plastic fragmentations, and have higher strength, making them suitable for recycling.

- **Climate:** In semiarid regions experiencing heavy rainfall, it is advised to avoid the use of mulch due to the significant increase in net global warming potential (GWP) and carbon footprint compared to scenarios with no mulch. Conversely, climates with drier seasons during key times of crop production and/or cooler soil temperature conditions are more likely to benefit from the effects of mulches on soil microclimates.

6 The post-use environmental impact can nullify the benefits of other life cycle stages, as observed with PE mulch films, which pose additional environmental and economic burdens due to removal, disposal, and end-of-life. Therefore, it is essential to adopt suitable EOL strategies that minimize environmental impact.

For BDM, complete degradation within a short time is necessary to reduce mulch residue in the soil. EOL strategies that recover energy and/or material, such as recycling and incineration, should be practiced. While recycling is a preferable option for used PE mulch, currently this is not an option as there are no facilities. Ultimately, reducing plastic residue in the soil is crucial for maintaining soil health. Growers should optimize the use of agrochemicals to minimize post-harvest chemical migration into the soil and water bodies. Additionally, efforts to reduce wastewater emissions from mulch waste washing should be prioritized.

This project is supported by USDA SCRI award **#2022-51181-38325**.

Resources

These information resources provide background information and additional information to help you have a more thorough understanding of this topic.

ISO. **ISO 14044:2006 Environmental Management — Life Cycle Assessment — Requirements and Guidelines 2006**. https://www.iso.org/standard/38498.html

Life Cycle Assessment of Bio-Based Plastics: Concepts, Findings, and Pitfalls. https://onlinelibrary.wiley.com/doi/10.1002/9783527827589.ch13

Life Cycle and Environmental Cycle Assessment of Biodegradable Plastics for Agriculture. http://link.springer.com/10.1007/978-3-662-54130-2_7

Recycling, Disposal, or Biodegradable-Alternative of Polyethylene Plastic Film for Agricultural Mulching? A Life Cycle Analysis of Their Environmental Impacts. https://linkinghub.elsevier.com/retrieve/pii/S0959652622045231

A Critical Review of Biodegradable Plastic Mulch Films in Agriculture: Definitions, Scientific Background, and Potential Impacts. https://www.sciencedirect.com/science/article/pii/S0165993623004788

Barriers and Bridges to the Adoption of Biodegradable Plastic Mulches for US Specialty Crop Production. https://www.cambridge.org/core/journals/renewable-agriculture-and-food-systems/article/barriers-and-bridges-to-the-adoption-of-biodegradable-plastic-mulches-for-us-specialty-crop-production/EE78FE877DFD201AADF92734231BED69.

Risk and Uncertainty of Plastic Mulch Adoption in Raspberry Production. https://www.cambridge.org/core/journals/renewable-agriculture-and-food-systems/article/risk-and-uncertainty-of-plastic-mulch-adoption-in-raspberry-production-systems/2C3B6AA1E4842AE9A903AAFDC902D65C.

Additional Information

Visit **https://smallfruits.wsu.edu/plastic-mulches/** for more information about BDMs in fruit and vegetable crop production systems. You can also find us on social media!

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