ENSTU 300: Critical Thinking & Communication in Environmental Studies

# Plastic Film Mulch on Agricultural Fields

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Strawberry Field Photography by Michelle Magdalena from *Edible Monterey Bay (Winter 2020)*

## Introduction

Driving down a California freeway anywhere in an agricultural region, one can see swaths of black and white shiny plastic blanketing the fields of the crops we eat. Can this be good? For the farmer, this mulch keeps moisture from escaping, prevents crops from freezing, and controls weed growth. Despite the convenience for the farmer, the plastic mulch creates a non-renewable, non-recyclable solid waste problem. According to (Bandopadhyay et al., 2018) plastic particles left in the soil can affect plant growth, decreasing the nutrient absorption of the crop. In addition, there are negative impacts on soil microbial communities of the farm fields that use plastic mulch. The life cycle of the plastic mulch has additional greater impacts to ecosystem health. Because the harms of using plastic film seem to outweigh the benefits, the agricultural industry should develop alternative materials and recycling methods to replace the conventional plastic films.

# Background

## History

Humans have been practicing agriculture for thousands of years tilling fields and planting using various methods. Farmers have mulched their crops for centuries using organic material such as straw and other silage to insulate and protect the crop. Before polyethylene was used on agricultural fields, tar paper made its debut in 1924 as a weed suppressant. (Shrefler, et al., 2014) It is only recently that plastic began to be used on farm fields to increase yield, a practice known as plasticulture. In 1938 the first polyethylene prototype was made by the British. From there, the plastic mulch industry took off, dominating other methods of mulching. (Kasirajan, et al., 2012) Polyethylene was used on fields to be a replacement for growing crops under expensive glass greenhouses. For the last forty years, plastic mulch use in agriculture has become commonplace because of the many advantages to the grower. Plastic mulch offers moisture retention, fungus protection, weed suppression, and temperature control. In addition, the mulch keeps soil from damaging the produce.

## Scientific Background

In the Oklahoma Cooperative Extension Bulletin, Brandenberger and Shefler (2014) explain how hay, sawdust, peanut hulls, straw, leaf mold, and compost were the original materials used for crop mulch. However, these natural resources are not abundant enough for large scale commercial farming.
The chemical composition of plastic mulch makes it reliable for farming but difficult to recycle. Contemporary plastic mulches are created from petroleum-based material: carbon, silicon, hydrogen, nitrogen and chloride. Polyethylene (PE) is used for mulch along with polyvinyl chloride (PVC) and ethylene vinyl acetate (EVA). Polyethylene film is made from pellets that can be formed into various shapes and sizes, and the many types of plastic film are flexible, resilient, and odorless. Low density polyethylene mulch film is the thinnest of the plastic films and is most widely used on farm fields (Kasirajan, et al., 2012) The benefits of the film are that it offers protection from weather, insects, and birds, and contains soil fumigants from escaping to the atmosphere. The dark plastic mulch creates a warming effect on the soil under the plastic mulch which helps accelerate plant growth. White plastic mulch reflects light back on the plants, and that has a positive effect on the plant growth. (Shrefler & Brandenberger, 2014)

Several problems result from the use of plastic film on crops. At the end of the crop cycle the plastic is removed from the field. Often the machines used to pull up the film at the end of the crop cycle cannot extract all the bits of plastic that have broken off from the film, and as a result, the plastic may be left on the fields for decades. The fragments negatively affect the topsoil structure and can enter the food chain. Plastic residue left in the soil damages soil health by partially breaking down into chemical components harmful to beneficial soil microbes and the plasticizing chemicals can pollute the soil. (Bandopadhyay et al., 2018)

According to the article *Policy considerations for limiting unintended residual plastic in agricultural soils*, even though low-density polyethylene mulch films provide benefits to the growers and society, plastic fragments left in agricultural soil can pollute not only the fields, but when carried in run-off can pollute marine and riparian environments (Brodhagen et al., 2017).

Pam Krone, the agricultural water quality coordinator for Monterey Bay National Marine Sanctuary, found large amounts of plastic mulch in local watersheds adjacent to agricultural operations. Krone's surveys found that eighty-one percent of plastic waste found around local streams was fragments of agricultural plastic mulch which measured 1.73 pounds per square meter. (Krone et al., 2020)

Another major problem regarding plastic film is the disposal of the plastic film after crops are picked. Plastic mulch is the greatest volume of inorganic waste in commercial agriculture. It is estimated that 126 million pounds of plastic mulch is used annually in the United States alone. (Waste Advantage Magazine, September 2018). It is hard to recycle the plastic due to the remnants of soil and moisture on the film which can account for 60 to 70 percent of the weight of the baled waste plastic material. Due to the process of weathering, the plastic layers can easily rip and disintegrate into tiny pieces so that the material can spread all over the field and the disposal facility. In some areas of the United States, the used plastic mulch can legally be incinerated. Formerly it was being sent off to China, Malaysia or Vietnam, but these countries have stopped accepting it, so it ends up in landfills. (Waste Advantage Magazine, September 2018).

If biodegradable material is used instead of polyethylene plastic mulch, then the farmer can till the biodegradable mulch into the field where soil microorganisms will break it down. (Bandopadhyay et al., 2018)

Scientists have been studying the effects that biodegradable plastic mulch has on soil microorganisms. The effects that biodegradable plastic mulch cover have on the long-term health of the soil and its microorganisms depend on the season and how much of the soil is covered with the biodegradable mulch. Soil microorganisms are more efficient at breaking down the biodegradable plastic mulch under cooler conditions. (Bandopadhyay et al., 2018)

United States standards for biodegradable mulches have yet to be written, but the information is available in Europe. Testing of biodegradable material can be standardized, but since the actual testing for biodegradability of plastic mulch is performed under normal field conditions, it is difficult to assess the degree of biodegradability. Because all soil types are different, plus the settings where the test fields are located are different, it is difficult to predict the performance of biodegradable mulch in all settings. Sunlight is required to biodegrade the mulches, and extreme weather conditions play a significant role in the effectiveness of the mulch to biodegrade. All variables should be included in any given testing site.

Waste products can be utilized to manufacture biodegradable plastic mulch (BPM). Some biodegradable mulches are water soluble, but these mulches are more expensive than the conventional plastic films. Along with starch, cellulose is the most popular biodegradable mulch component. (Ma, et al. 2016)

## Policy Context

The widespread use of plastic mulch on agricultural fields has negative effects on soil health and creates problems of plastic waste disposal after the mulch is removed from the field. Alternatives to conventional plastic films, such as biodegradable plastic mulch offer environmentally sound alternatives to conventional plastic mulch. Three policies concerning film plastic use and disposal and biodegradable plastic mulch qualities and options are presented here.

### Federal Policy

Other than the Organic Foods Production Act, the United States federal law does not have specific laws regulating the specification, use**,** or disposal of plastic mulch on agricultural fields. The Organic Foods Production Act (1990) under the section 6508 *Prohibited crop production practices and materials,* Section C Crop Management, paragraph 2, indicates that plastic mulching must be removed at the end of each harvest season. One of the many negative effects of plastic mulch is that as the mulch gets pulled up from the fields, fragments of the plastic mulch stay behind in the soil, which is the same place where the crops grow. Sunlight breaks down the fragments into mini sizes which will have many more ecological negative impacts. (Hayes & Flury, 2018)

Per Policy Memo 15-1 United States Department of Agriculture Agricultural Marketing Service National Organic Program, biobased biodegradable agricultural mulch film is allowed in organic production. The film must be plant based with no petrochemicals. However, the organic standards exclude Genetically Modified Organisms (GMO) from organic farming and the currently available biobased biodegradable mulch is made from corn or wheat, much of which is GMO, meaning it is not allowed to be tilled into the organic fields after the crop is harvested. "We're looking at it in a bigger way than just, 'Is it biodegrading?' We need to make sure that what we're putting into the soil will have a positive and not a negative effect," said Harriet Behar, chairwoman of the National Organic Standards Board (NOSB), which advises the U.S. Department of Agriculture on organic regulations. (Held, L. 2019)

## International Policy

The European Union has passed legislation in 2018 that standardizes the degree that the biodegradable mulch must disintegrate into the soil. This law is known as European Standard EN 17033: Plastics–Biodegradable mulch films for use in agriculture and horticulture–Requirements and test methods. (EN17033, 2018) The EU standard uses testing under actual field conditions, so it is a more realistic standard. The EU Standard EN 17033 also addresses concerns about soil health known as ecotoxicity. This new legislation is groundbreaking because it is the first law focusing on biodegradable material in soil rather than whether the biodegradable mulch breaks down in a marine or in a compost environment.

This law requires testing for chemicals in the soil, the degree of biodegradability, and the impact on the soil environment. The requirement for chemical testing is more stringent and includes toxicity tests on plants and earthworms. This law also specifies testing for physical variables, such as the amount of light hitting the mulch. The objective of this law is to achieve greater than ninety percent biodegradability outdoors under natural conditions. EN 17033 also includes specific requirements for labeling, such as test reports that go into detail about how tests were conducted, as well as the life expectancy of the product. The law also provides a method to prepare the soil, how to water with the biodegradable mulch on the crops, and how to make holes in the plastic layers so crops can thrive.

According to an analysis of this policy by Douglas Hayes and Marcus Flury, the EN 17033 requires more complete ecotoxicity testing than ASTM D6400. The ecotoxicity tests measure how toxic material from the biodegradable mulch might get into organisms: through soil water, soil gases and soil itself, as ingested by earthworms. Still, Hayes points out, there are multiple questions being asked about the testing described in EN 17033. For example, is the ninety percent biodegradability rate under laboratory testing realistic under average field conditions? The second question researchers are considering is, under the standard, the mulch can be tested in a powder form, but that increases the surface area of the mulch and would increase biodegradability. If the film takes longer to degrade in the soil, the possibility of film fragments escaping in runoff and polluting waterways is higher. The testing is performed under a generic soil type from either forest or agricultural conditions, but the real-life condition on a specific field will vary and be different from the testing facility. (Hayes & Flury, 2018)

## State of California Policy: one of two California assembly and Senate bills discussed in this paper.

The State of California has passed a law concerning composability of plastics including agricultural plastic mulch. California Assembly Bill 2287 Solid Waste (2019-2020) (AB 2287, 2020) is about solid waste management and recycling. Section 3 concerns compostable or biodegradable plastics. The law amends California Public Resources Code (PRC) 4356 and 4357 which describe standards of properties of material that can be labeled compostable or biodegradable. The PRC codes reference American Society of Testing Materials (ASTM) D6400 (Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities) as one standard for biodegradability. The California law references ASTM D6400 which tests under conditions where microorganisms break down material at 122 degrees Fahrenheit. Section 3 also indicates that the Department may adopt the European Standard EN 17033: Plastics–Biodegradable mulch films for use in agriculture and horticulture. The problem with using ASTM D6400 to apply to biodegradable plastic mulch on

fields is that the target temperature of 122 degrees is unrealistic in farm fields where the biodegradable plastic mulch would be tilled into the soil.

### State of California Policy: the second Senate bill

State of California Senate Bill 270 Solid Waste: Single Use carry-out bags (2013-2014) (SB 270, 2014) introduced by Alex Padilla, bans HDPE single use plastic bags. The bill also sets standards for plastic bag recycling. This bill requires store owners not to provide single use plastic bags depending on the store revenues. This bill would also include the sale of reusable recycled material bags for ten cents. The maker of the recycled bags must provide proof to the department that the recyclable bags are in fact recyclable material. This approval must be satisfied with a number of criteria that ensure that the reusable bags contain post-consumer plastic and can be recycled after multiple uses. There needs to be a similar piece of legislation that creates guidelines for biodegradable plastic mulch. While the plastic bag ban does not directly affect agricultural plastic mulch, the origin of the law may lead to guidelines for plastic mulch.

The Reason Foundation Policy Brief 123 by Morris and Christensen provides a critique of the ban. The authors maintain that the ban will have no effect on plastic bags in the ocean or on land as litter, with plastic bags accounting for only 0.6% of visible litter. They also claim that the ban will cause more water use, since paper bag manufacturing uses more water than HDPE bag manufacturing. The analysis says that since HDPE bags are made with natural gas, and the polypropylene substitute bags are made from oil, the ban will result in more oil and coal use. They state that the ban will cost consumers more, and make no difference in municipal solid waste disposal, noting that plastic bags by weight are a small amount of waste going to landfill. They say that plastic bags are no threat to marine animals but decide to focus on fishing gear being a danger to marine life. Moreover, they state that there's a health danger to reusable bags by not washing the bags. The authors state there is a household opportunity cost in washing and organizing the bags.

Similar arguments regarding increases of opportunity costs, user costs, and consumer costs may be made in the future if regulation of agricultural plastic mulch is proposed.

These policies discuss environmental issues related to plastic mulch. The E.U. Policy 17033 provides the United States with ideas worth exploring. Another great bill that has to do with recycling of plastic bags is California Assembly Bill 270 which explains in depth how to reuse plastic bags. Even though this bill does not explicitly describe disposal of plastic mulch, the bill would provide information about how to use mulch in an environmentally sensitive way. Finally, California Senate Bill 2287 sets standards for waste material that can be applied to plastic mulch. The common theme of all three types of legislation is to find environmentally sound alternatives to plastic mulch while the alternatives to conventional mulch has the same benefits to the farmers.

## Stakeholder Perspectives

Plastic mulch use in agriculture has many positive benefits that enhance crop growth but disposing of the plastic mulch after it is used on one crop cycle creates a waste problem in landfills and can pollute nearby watersheds. Plastic fragments left in the field can cause a decrease in soil health and can also migrate to nearby waterbodies in agricultural run-off. This segment of the research will be based upon opinions that stakeholders have on the use of plastic mulch based on their experiences and their values regarding the environment. The stakeholders include a company that collects and recycles agricultural plastic waste, an expert agricultural water quality coordinator representing the Monterey Bay Marine Sanctuary, organic farmers, and the plastics industry. Although the consensus is that plastic mulch is necessary for the agricultural industry, these stakeholders have different opinions of how plastic should be used. Although six stakeholders are listed in the table below, three are described in the text

## Local and International Stakeholders

### Monterey Bay National Marine Sanctuary

In Monterey County, agricultural water quality coordinator for Monterey Bay National Marine Sanctuary, Pam Krone advocates for recycling plastic mulch after use on agricultural fields because massive amounts of plastic waste end up in landfills and some winds up in adjacent water bodies. Krone collected data and shows that 7,941,839 pounds of plastic mulch are used in Monterey County agriculture per year. In a three-year study, Krone collected data from ten streams in agricultural areas of Monterey County, and discovered that, although agricultural plastic comprises just three to five percent of all general plastic use, a surprisingly large amount of agricultural plastics were found on stream banks near agricultural fields. Eighty-one percent of that plastic waste was fragments of agricultural plastic mulch which measured 1.73 pounds per square meter. “I was surprised when I read a study by the Washington State University Study that looked at plastic removal of polyethylene mulch from the field and their study found that about ten percent of the plastic remained in the field after it was removed because it fragmented and broke apart and remained in the soil in the field and didn’t get completely removed. So finding equipment so that we can remove more of that plastic and being super vigilant and looking for plastic…is really important. Second in importance is recycling, making sure that we recycle as much plastic as we can.” (Krone, 2020) This quote demonstrates that Pam Krone has an ecological scientific approach to her analysis. Krone focuses on the amount of plastic pollution with a scientific understanding that uses solid and easy to understand data and uses accurate sampling methods.

Krone’s team also monitored microplastics in local streams and found that the quantity of microplastics in the streams was equal to what the Monterey Bay Aquarium Research Institute found in the Monterey Bay ocean environment. The Monterey Bay National Marine Sanctuary is going to conduct more studies measuring the amount of plastic in nearby watersheds and streams. There is a pilot study underway sponsored by the Monterey Bay Marine Sanctuary, UC Cooperative Extension, and Washington State University involving five growers who are using biodegradable mulch, and Krone hopes to have a larger study next year.

### Revolution Plastics

Revolution Plastics is a plastics manufacturing and recycling company. They make agricultural films, bags, and tubing. Revolution collects agricultural film and other plastic products from the farmer, cleans the dirty plastic and then turns it into post-consumer resin (PCR). Then they turn the PCR into other agricultural plastic products. Revolution processes over 150 million pounds

of agricultural plastic per year and manufactures products that are 97% post-consumer resin. “Those plastics that they’re using, they get really dirty and most recyclers throw their hands up and say, ‘We can’t help you, that’s too dirty, it smells too bad, we can’t handle it.’" said Price Murphy, director of operations for Revolution. “Over 30 years, it took a long time to perfect the process, we were able to create our own process, which was able to wash and clean these materials so we’re able to use them again," said Murphy. "It’s just about the conservation and preservation of natural resources.”. (Stevenson, 2020) “We use our expertise in recycling technology and post-consumer resin to provide green solutions to consumers and communities.” (Calliendo, 29) Part of Revolution’s company is the 125,000 square foot Encore recycling located in Salinas, California. Revolution works with over 400 agricultural operations in California, providing free pick up of used agricultural plastic, working closely with the farmers to make sure that the plastic they collect in specialized trucks is as clean as possible. “A lot of work on the recycling side relies on the willingness of the farmers to play an important part as well.” (Caliendo, 2019) Revolution has partnered with irrigation industry giant, Toro, to recycle drip tubing. Encore is the largest agricultural plastics collection facility in California. Encore makes the post-consumer resin and supplies the plastic bag manufacturing division of Revolution with PCR. Revolution is an example of a utilitarian approach because they are consuming a waste product to produce a more sustainable product with value to the agricultural consumer and to the environment.

### Organic Farmer

Even though organic farmers realize that plastic mulch has benefits to their fields, (As referred to in Table #1 ) the farmers are concerned with the amount of waste and plastic going to the landfill. Also, farmers have a potential opportunity cost to pick up and dispose of the plastic mulch at the end of each growing season when they could be sowing a cover crop instead. Organic farmers would like an alternative to the conventional plastic mulch such as a mulch that can biodegrade in the soil. Drew Norman, an organic farmer who owns One Straw Farms, notes, “it is certainly a better choice than putting dumpsters of plastic in a landfill. In 2014, the USDA's National Organic Program (NOP), which implements and oversees organic regulations, specified that any biodegradable mulch could only be used if it were one hundred percent "bio-based" — that is, made entirely from plant material. Plastic mulch benefits both conventional and organic farmers by conserving water. The water savings achieved by using a system that conserves water by delivering it directly to plant roots through a network are significant enough to justify using the plastic mulch. "The water savings, in gallons per acre, is like 60 percent compared to using sprinklers," said Drew Norman of One Straw Farm. Norman would like to use biodegradable mulch, but it is not allowed under USDA NOP standards. Drew Norman can be characterized as a practical steward of the environment because he cares about the disposal of plastic mulch and he does not want to see the plastic mulch get into the environment after extraction from the fields.

### Biodegradable Plastics Manufacturer

Another significant stakeholder discussed in Table #1 below is plastic and chemical producer BASF who understands that farmers desire a plastic mulch that biodegrades in the soil. While collaborating with Italian farmers who had a major problem with the excess plastic left in the soil from other biodegradable mulches, plus being aware of the mass amount of waste after the conventional plastic mulch is removed from agricultural fields at the end of the growing cycle,

European based BASF came up with a solution for the farmers: Ecovio M biodegradable mulch that can be plowed into the soil after the harvest where the mulch biodegrades, saving time and money. In the promotional video, the BASF representative states, "Partnership is essential to act with foresight." This stakeholder demonstrates practical stewardship of the environment because BASF has designed biodegradable mulch that provides a modern solution to the plastic problem. Zumstein, et al found, using BASF PBAT agricultural film mulch, that it completely biodegrades into CO2 and microbial biomass. (Zumstein et al., 2018) This research could pave the path toward biodegradable mulch use by certified organic growers and approval by the USDA National Organic Program.

The stakeholders realize that plastic mulch is beneficial to farmers, but that there is a solid waste problem after the plastic is removed from the field. These stakeholders' views highlight how plastic mulch collection and manufacturing can be improved. Below is a table highlighting Six stakeholders that have an interest in this matter.

Table 1: Stakeholder Perspectives

| **Stakeholder Group** | **Representative Examples** | **Stakeholder Values*** | **What are the concerns of the stakeholder?** | **What does the stakeholder contribute?** |
|---|---|---|---|---|
| Chemical and plastic manufacturers | BASF<br>Green Dot Plastics | Practical stewards of the environment<br>Utilitarian | Manufactures conventional (PE films) and biodegradable plastics | By producing a superior biodegradable mulch, BASF will eliminate extra plastic particles left in the fields after growing season. Tests and collects data on biodegradable mulch |
| Environmental advocate | (Pam Krone) Monterey Bay national marine sanctuary | Ecological_ scientific evidence | General health of the aquatic ecosystem | Collects plastic pollution data and educates agricultural industry, growers research groups and stakeholders. |
| Plastic industry | Plastics Europe (Trade association) | Utilitarian, | Plastics Europe wants to find alternative to plastic | Plastic Europe would advocate a top sustainable alternative when available. |
| Organic farm | One Straw Farm, Drew and Joan Norman | Practical stewards to the environment | Concerned about the massive amounts of plastic | They don't use Biodegradable Plastic Mulch |

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|---|---|---|---|---|
| | | | film waste in landfills. | because it is not approved by National Organic Standards Board or by the USDA |
| Plastic industry | Revolution / delta | moralistic, ethical concern for nature Utilitarian | landfill capacity and plastic waste, increased reuse from agricultural plastic waste. | Collects agricultural plastic waste (drip tape and plastic mulch) and turns it into another product |

## Discussion

Plastic mulch provides excellent benefits to the agricultural fields and growers, however, the plastic mulch creates a significant waste and pollution problem. Because of these problems, the agricultural plastics industry should develop alternative materials and recycling methods to replace the way conventional plastic film is currently used in the farming sector. To find a solution to this waste problem, three policy options will be explored, and a combination of two solutions will be proposed. A model for one of the solutions is the California Assembly Solid Waste Bill 2287, (AB 2287, 2020), which concerns the recycling of plastic. Another useful model policy references standards for biodegradability of plastic mulch. The United States uses the American Standard for Testing Materials to determine if plastic mulch is biodegradable under conditions of one hundred and twenty-two degrees, which is unrealistic for real-life field applications. (ASTM 6400) A better standard for biodegradability is from the European Union known as European Union Standard 17033 (EN 17033, 2018). This piece of legislation explicitly states that biodegradable mulches must demonstrate that when the mulch decomposes, it must not be toxic to the soil. A final law considered is California Senate Bill 270, (SB 270, 2014) which bans the distribution of high-density polyethylene single use bags. This law does not explicitly describe use of plastic mulch, only single use plastic bags, but it could be applied to the single use of plastic mulch on fields. Using existing laws and policies as guidance, three policy options for solving the plastic mulch waste and pollution problems are:

- Biodegradable mulch
- Mandatory recycling of plastic mulch
- Ban single use plastic mulch

Four criteria illustrated in the policy table below are used to critically evaluate the three policy options listed above. These four criteria are crucial to evaluating the policies because the goal of this paper is to discuss improvements to the disposal of agricultural plastic mulch. Improved policies could prevent plastic mulch from causing a solid waste issue, from migrating into nearby streams and watersheds negatively effecting aquatic life, and work toward protecting soil health. Finally, sustainable policy could make sure that an alternative solution will be an economically feasible option for the entire agricultural sector. The four criteria are:

- Riparian and ocean health

- Waste management
- Soil health
- Agricultural yield and profitability

The policy option table following The discussion has a plus and minus system to indicate whether a given policy satisfies the criteria.

**Riparian and Ocean Ecosystem Health:**
Runoff into nearby streams and watersheds negatively effects aquatic life. (Krone, et al, 2020)

***Policy Option 1: Use Biodegradable Mulch***
Since the certified compostable plastic mulch biodegrades in the soil of the farm field or in an industrial facility for composting, it will not be stored on the fields prior to being disposed in a landfill. When conventional plastic mulch is exposed to sunlight the mulch breaks apart and pieces migrate into adjacent watersheds and eventually make their way to the ocean. Since biodegradable mulch disintegrates into the soil or in a composting facility after a season's use, the tiny plastic particles will not migrate into adjacent watersheds. If biodegradable plastic mulch gets into the adjacent watershed, it will eventually biodegrade in the watershed or ocean as it would in the field or composting facility. (greendotplastics.com)

***Policy Option 2: Mandatory Recycling***
Even though plastic mulch would be required to be recycled, until the plastic mulch goes off the field to the recycling facility, the plastic mulch still could fragment and migrate into watersheds if it is not disposed of in a timely manner. (Krone, et al. 2020)

***Policy Option 3: Plastic film ban***
No plastic mulch runoff will enter water bodies since the mulch would not be permitted to be used on farm fields.

**Waste Management**
Plastic mulch waste disposal in landfills must be eliminated because there is limited space in landfills.

***Policy Option 1: Use Biodegradable Mulch***
Since the plastic mulch biodegrades in the soil of the farm field or in an industrial facility for composting, the plastic mulch would not be sent to the landfill.

***Policy Option 2: Mandatory Recycling***
Since plastic mulch would be required to be recycled, the mulch will not enter the landfill but will be used to make other products such as new plastic film and bags. (Revolution Believe in Better Plastics)

***Policy Option 3 Plastic film ban***
No plastic film would be sent to the landfill.

**Soil Health**
Protecting soil health and soil microorganisms is vital for crops to thrive and grow and protect our food sources. Fragments of plastic mulch can bind to plant roots and prevent uptake of

essential minerals and water. Soil microorganisms can be affected by chemicals from plastic mulch leaching into the soil.

***Policy Option 1: Use Biodegradable Mulch***
Using biodegradable mulch will support the soil community. Since the plastic mulch biodegrades in the soil or at an industrial composting facility into CO2 and harmless chemicals and composted organic matter, it would not harm the soil. In fact, the humus can be used to improve soil. (greendotbioplastics.com)

***Policy Option 2: Mandatory Recycling***
Mandatory recycling can be partially beneficial to soil health. Conventional plastic mulch could still fragment into the field soil as it is being removed from the field after the crop cycle. The fragments can negatively affect soil structure and soil health.

***Policy Option 3: Plastic film ban***.
Since plastic film would not be allowed on farm fields, it would not affect soil structure or soil chemistry, endangering microorganisms. However, forcing farmers to use unproven alternative crop covers could prove to be harmful to soil health in other ways.

**Agricultural yield and profitability**
Plastic mulch is used world-wide to improve crop yield and profitability by saving water, enhancing crop growth, and suppressing weeds.

***Policy Option 1: Use Biodegradable Mulch***
Use of biodegradable mulch instead of conventional plastic mulch will result in greater cost for the product to the farmer. The cost of the biodegradable mulch would likely be more than for conventional plastic mulch. A biodegradable mulch that can be tilled into the soil at the end of the crop cycle would result in labor and cost savings over the time and labor cost of removing the mulch. Waste removal costs would be less. Transport of used mulch to an industrial composting facility would be an added cost.

***Policy Option 2: Mandatory Recycling***
Mandatory recycling will have a neutral effect on agricultural yield and profitability. The plastic mulch will need to be cleaned and transported to the recycler. Recycling would offset waste removal costs. Some recyclers offer free cleaning and pick up**.**

***Policy Option 3: Plastic film ban***
A plastic film would have a strongly negative effect on farm yield and profitability. Farmers would not have all the benefits of plastic mulch.

## Policy Options

Because farmers depend on plastic mulch to farm efficiently, there is a need to find a solution to the plastic waste and pollution problem that will still allow farmers to use an efficient crop cover. The two most appropriate policy options that are recommended are to use compostable biodegradable mulch and when polyethylene plastic mulch is used, recycling of the polyethylene mulch should be mandatory. European policy 17033, (EN 17033, 2018) specifying standards for biodegradable mulch, and the plastics recycling standard, Senate Bill 270 (SB 270, 2014),

provide good examples of policy and standards. Another bill that is preferred is Senate Bill 270, which regards plastic bags, but accommodations are needed to include plastic mulch in the bill.

**Table 2: Policy Options Plasticulture**

| Criteria | **Policy Option 1: Biodegradable Mulch** (based on E.U.17033) | **Policy Option 2: Mandatory Recycling** (based on California AB 2287) | **Policy Option 3: Plastic Film Ban** (based on California SB 270) |
|---|---|---|---|
| **Riparian and Ocean Health-** | +++ | ++ | +++ |
| **Waste Management** | +++ | +/- | +++ |
| **Soil Health** | ++ | +/- | +++ |
| **Agriculture yield and profitability** | +/- | +/- | --- |

**Key:** (Strong) +++ (Medium) +/- (Weak) ---

## Policy Option 1: EU17033 Biodegradable Mulch

Using biodegradable mulch would have a positive effect on riparian and ocean health. There is ample evidence that conventional plastic mulch migrates into rivers, streams, watersheds, and the ocean. (Krone, et al. 2020) When biodegradable mulch decomposes either in the field soil or in a compost environment, the biodegradable mulch will not be transported into nearby streams and watersheds by water run off or wind transport and will not migrate into adjacent watersheds. If biodegradable mulch gets transported into the watershed it will eventually biodegrade into CO2 and harmless chemicals.

Using biodegradable mulch would have a positive effect on waste management. The use of conventional plastic mulch after one use per crop season on agricultural fields presents a waste issue. Tons of plastic mulch are discarded each year in the United States alone. After extraction from the fields, the plastic mulch is transported to the landfill. Until recently, waste plastic had been sent overseas but new foreign policies do not allow export of waste plastic anymore. Since the plastic mulch biodegrades in the soil of the farm field or in an industrial composting facility, it will not be sent to the landfill, so the landfill will have more capacity for other waste.

Biodegradable Mulch would have a positive effect on soil health. Since the biodegradable plastic mulch biodegrades in the soil into CO2 and harmless chemicals, it does not harm the soil. "…Washington State University study that looked at plastic removal of polyethylene mulch from

the field and their study found that about ten percent of the plastic remained in the field after it was removed because it fragmented and broke apart and remained in the soil in the field and didn't get completely removed." (Krone, et al. 2020) When conventional plastic mulch remains in the soil, "leftover conventional plastic mulch film causes the soil quality to deteriorate as it can easily bind and wrap themselves to the roots of new plants. This affects the plants' ability to absorb water and nutrients and ultimately over the longer term, causes lower crop yields." (BASF ecovio.com) Biodegradable mulch will significantly benefit the soil ecosystem health because the biodegradable mulch will disintegrate into the soil after the crop season. Even if the biodegradable mulch takes a long time to decompose in field soil conditions, the biodegradable plastic mulch could be taken to another site or to a composting location or composting facility to decompose. According to Green Dot Bioplastics, the biodegradable mulch takes twelve weeks in a composting facility to biodegrade to ninety percent after 180 days. Ten percent of solid material, which is compost, remains. The remainder of what was the biodegradable mulch is water and CO2. (greendotbioplastics.com) The soil will be much healthier, and this will have a positive impact on crops and soil ecosystems.

Using biodegradable mulch would have a positive effect on agricultural yield and profitability. Farmers report that polyethylene (PE) mulch films are labor intensive and time consuming to remove after the crop is harvested. There is an opportunity cost involved in using PE mulch film, "we have to wait two to three weeks for the leaves to dry up and die down before we remove the PE mulch film completely." (BASF envio.com) Farmers could be plowing in the biodegradable mulch film and putting in their next crop instead of waiting to pull up the film.

While biodegradable plastic mulch could be more expensive and increase farmer's expenses, the labor and time saved plowing in the mulch could offset the added cost of the biodegradable mulch. Farmers point out that there is an added cost of renting dumpsters to dispose of the PE mulch. Farmers can continue to use the same equipment to lay down biodegradable mulch as they use with conventional PE plastic mulch. Farmers can continue to benefit from positive effects of plastic mulch use on crop yields. The incentive to use biodegradable mulch might be encouraged through tax subsidies.

### Policy Option 2: Mandatory Recycling AB 2287

Recycling plastic mulch is possible and is currently practiced by Revolution Plastics, a United States company who collects and recycles PE film into post-consumer plastic products. Recycling of all plastics will need to become more common as our plastic waste becomes overwhelming.

Mandatory recycling of PE agricultural film will have a slightly beneficial effect on riparian and ocean health. Since plastic mulch will be recycled, the bulk of it can be turned into other products, but it still could fragment in the field and migrate into watersheds if it is not disposed of in a timely manner. If collection of the PE mulch for recycling is well managed, it is less likely it will remain in dump piles on the field for long periods of time.

Mandatory recycling will have a positive effect on waste management. Since plastic mulch will be recycled it will not enter the landfill but will be used to make other products. Now, local companies are reusing the plastic mulch for post-consumer use. For example, the Revolution operation based out of Salinas, California, provides the service of picking up and washing the

used plastic mulch from the farmers. Revolution makes other plastic products or new post-consumer plastic mulch out of the discarded plastic mulch. A quote from Revolution's promotional video states, "at Revolution, our Encore production team has diverted more than 150 million pounds of plastic per year, and we have diverted one point five billion pounds of plastic since our founding and turned them back in to sustainable products for you." (revolutioncompany.com) Revolution is a perfect example of how it is possible to recycle plastic mulch into another product and escape the added environmental burden of just dumping the plastic mulch in the landfill.

Mandatory recycling of PE mulch will have a neutral effect on soil health. Mandatory recycling will not significantly benefit the soil ecosystem health because the plastic mulch could still fragment into the field soil when the PE mulch is removed after the crop cycle, negatively affecting soil health.

Mandatory Recycling will have an insignificant effect on agricultural yield and profitability. Plastic mulch will require thorough cleaning so it can be recycled and turned in to another useable product, and it will require transport to the recycler resulting in added expense for the farmer. If a company offers free pickup and cleaning like Revolution does, there will be no added expense or effort for the farmer.

### Policy Option 3: SB 270 Single Use Plastic Film Ban

Even though the plastic bag ban does not directly apply to biodegradable mulch, legislation could provide a law like the plastic bag bill. Having a ban on PE mulch would force farmers and growers to switch to biodegradable plastic mulch.

Banning single use plastic mulch would have a positive effect on riparian and ocean health. No plastic mulch runoff will enter water bodies since it would not be used on farm fields.

Banning single use plastic mulch would have a definite positive effect on waste management since no plastic film would enter the landfill.

Banning single use plastic mulch might have a neutral effect on soil health. Plastic fragments would not be left in the field soil after removal. However, since plastic mulching decreases weed growth, with plastic mulch, farmers do not have to use herbicides to control weeds. Without plastic mulch, farmers might have to rely on herbicides and other chemicals to control weeds, which could damage the soil. Without the plastic mulch cover on the tilled field, there could be increased soil erosion through wind and water transport.

Banning single use plastic mulch would have a strongly negative effect on agricultural yield and profitability. Farmers cannot use their equipment that lays the plastic mulch on the field, which would be a loss of investment in the machinery. Also, a loss of efficiency would result because farmers would not benefit from the positive effects of using plastic mulch on their crops: they would have an added expense in labor for weeding and fungus control. The lack of a membrane on the soil surface could result in crop damage such as rotting strawberries rotting due to soil contact, and soil residue on vegetables. The elimination of plastic mulch on fields would result in increased water use for growing the crop since the plastic mulch helps crops to conserve water by preventing evaporation from the soil.

## Recommendation

Given that farmers depend on plastic mulch to farm efficiently, I recommend a combination of policies. The International European Union policy 17033 defining and supporting the use of biodegradable plastic mulch would be a great approach to the plastic waste problem while providing all the benefits that conventional PE plastic mulch has given. This E.U. Standard requires that the biodegradable mulch be tested under farm field conditions to be sure that the biodegradable mulch is ecologically sound and decomposes effectively with greater than ninety percent biodegradability. I would also propose adopting a bill like California Senate Bill 270, with accommodations geared toward recycling conventional PE plastic mulches. The accommodations to SB 270 would incorporate recommendations to use biodegradable mulch, plus give farmers an incentive to use the biodegradable mulch such as offering subsidies to the growers, only if the biodegradable mulch adheres to US and EU standards for compostable biodegradable mulch. Banning plastic mulch without the government offering a subsidy for using biodegradable mulch would be catastrophic for farmers because they would have added costs for purchasing and composting biodegradable mulch. Mandatory recycling of PE mulch would be expensive for farmers unless there were a commercial or government program free to farmers for recycling PE mulch. Without such a program, farmers may tend to ignore the regulations, without considering the ecological impacts of improperly disposing of their plastic mulch. However, it has been shown that plastics manufacturing companies such as Revolution Plastics have a successful business making post-consumer plastics from used plastic mulch that they are willing to pick up and clean free of charge to farmers. This type of company represents the concept of a circular economy where a product is not thrown away but is reused. While environmentalists may like the idea of banning plastic mulch altogether, the ban would significantly harm farmers because they would not be able to enjoy the benefits of using plastic mulch on their farms, which would have a negative economic impact on both the farmers and consumers. A complete plastic mulch ban without other accommodations would not be recommended.

## Conclusion

Plasticulture has been used to benefit farmers since the early 1960s. Although plastic mulch has numerous benefits to growers and crops, there is a crucial problem with it, which is the waste and disposal of plastic mulch. Some of the negative environmental impacts of the widespread use of polyethylene plastic mulch are plastic run off into nearby streams, watersheds and the ocean, accumulation in landfills, and negative impacts to soil health. Biodegradable plastic mulch is the best type of mulch to use because it will decompose into the soil after being plowed in at the end of the crop cycle or can be taken to a composting facility to decompose. The biodegradable mulch gives the benefits of water conservation, weed control, and temperature regulation. The E.U. Policy 17033 provides ready-made requirements for biodegradable plastic mulch to be tested and used by farmers in the agricultural sector that could be adopted by the United States. Using this biodegradable mulch would be both great for farmers and would significantly benefit waste management and the environment. The stakeholders realize that plastic mulch is beneficial to farmers, but that there is a solid waste problem after the plastic is removed from the field. These stakeholders' views highlight how plastic mulch collection and manufacturing can be improved.

This policy analysis has discussed peer reviewed articles on the effects that conventional plastic mulch has on soil health, the harmful effects plastic mulch has on our environment, and the impacts to waste management. This paper goes on to discuss applicable laws and policy recommendations and criteria to evaluate the three policy options. The paper would be a great benefit to the agricultural industry by recommending a sustainable alternative to conventional plastic mulch.

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