Relationship Between Plastic Mulch Use on Farms and Microplastic Content in Soil

Conner Breyer, Elise Girard, Ethan Hayden, Zane Pierson

Advised by: Dr. Chandima Wekumbura

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Abstract

As new methods for soil management become available, it is important to assess potential damages to soil health and plant development. This may be the case for newer technologies such as plastic mulch leading to an increase in microplastic contamination. If prevalent in the soil profile, reduced plant development and disrupting soil structure and hydrological processes such as evaporation may occur. Little research on this topic in relation to Kansas soils has been conducted. Is there a relationship between the usage of agricultural plastic film and the presence of microplastic concentration within the soil profile? Soil samples were collected from ten farms in the Kansas City and Lawrence area. Five of the farms used plastic mulch and five did not. Microplastics were separated from the samples using a wet extraction flotation procedure to separate the less dense microplastic particles from the denser soil particles while collecting the microplastic particles on a filter paper. The filter papers were subject to visual analysis using a microscope to quantify microplastic concentrations.

Introduction

In our state of Kansas, our soil plays a major role in our communities. Roughly 85% of the land is dedicated to agriculture. Popular hobbies such as gardening are common all over the state. That is why the health and quality of our soil is essential for our communities to thrive. However, small pollutants can prevent our soil from reaching its optimal efficiency. Microplastics are small particles of non-biodegradable plastic that contribute to the pollution of our environment and can damage our soil. These pollutants can come from plastic-coated fertilizers, irrigation water, and, commonly, agricultural mulching film. Plastic agricultural films have become a common method for preventing soil erosion, reducing moisture loss, and controlling weeds. Despite these efficiencies, plastic mulches are still known to degrade to smaller particles and become one of several major sources of microplastics in soil profiles. These particles can harm the soil profile, water cycle, and plant development under higher contamination conditions

Microplastics are made up of several different forms of polymers that can have different effects on plant development. Some of these include Polyethylene terephthalate, Polyvinyl chloride, Polyethylene, Polyacrylonitrile, etc. Hydrologic processes allow these polymers to be highly mobile within a soil profile. Once they make their way into the soil, they may break down into different types such as fibers, pellets, fragments, and films. A variety of harmful effects on the environment, plant health, and development can occur depending on the type of polymer present. For example, polyethylene microplastics may cause a substantial decrease in seedling biomass and early root formation (Yuan et al. 2024). Polyethylene is a very common component of agricultural plastic mulching films. Other examples include a decrease in early shoot development and biomass of fruits, which was found to be caused by the presence of polyvinyl chloride (PVC) microplastic concentrations in the soil.

This extends to the structure of the soil itself. The presence of these microplastics after infiltration can damage the structure of the soil body by taking up the necessary pore space. This lower available porosity for water can lead to soils over-saturating more easily, leading to smaller, weaker roots and lower crop yields, and thus lower financial returns for the farmers and gardeners themselves. With soil and plant damage, potential disruptions in the food chain have become more concerning in recent years. This can ripple out more serious environmental problems. Microplastics attract and bind to particles of heavy metals that can alter soil chemistry and increase the concentration of toxic chemicals in the profile. (Garfansa et al. 2025)

With microplastic contamination becoming an increasingly prevalent concern in recent times, understanding plastic mulch's impact on our daily lives is integral to ensure that our environment is protected and soil is performing at the highest efficiency it can be. More research on microplastics' impact on Kansas soil still needs to be conducted. Is there a relationship between the usage of agricultural plastic mulch and the presence of microplastic concentration within the soil profile? To answer this, our group sought to test different soil samples from multiple areas around Kansas under these mulching conditions to quantify the number of microplastics present in each soil and identify trends in concentration amounts from plastic mulching sources. With this information, we may be able to develop better strategies for the prevention and remediation of issues linked with microplastic concentrations in agricultural soil profiles.

Materials and Methods

Sampling Site Selection:

Soil samples were collected from ten farms in the Kansas City and Lawrence area in early August through early October of 2025. Five of the farms used plastic mulch and five did not. The farms chosen were vegetable farms, community gardens, or school gardens. A variety of crops are grown at each farm, mostly vegetable and fruit crops. Soil samples were taken from under plastic mulch as well as from under greenhouses, hoop houses, or high tunnels that are made of plastic. Each of the ten farms had multiple sites where samples were taken from, and five replications were taken from each site.

There were two soil samples taken from the Konza Prairie Biological Site, which has no history of plastic use. The soil samples are expected to have no microplastics and will be used as controls in this experiment.

Soil Sampling Methodology:

Samples were taken from the topsoil (0-15 cm) using a metallic soil auger. The sampling depth corresponded with any rooting depth or management practices. The samples were air dried, sieved with a 2 mm mesh, and stored until analysis.

Microplastic Extraction:

We conducted the microplastic extraction process in sets of 16, with 15 soil samples and 1 reagent blank to use as a control and to test for contamination. As a quality control measure, the extraction was done in a laboratory with glass and metal tools instead of any plastic tools to avoid contamination. Glass flasks, centrifuge tubes, petri dishes, and stirring rods were used as well as white cotton lab coats during analysis and sample manipulation.

The microplastic extraction was done using a wet extraction procedure based on the methodology used in 2019 research by Corradini et al. This method aims to use floatation to separate the plastic particles from the soil samples, since soil particles are more dense than plastic particles.

Dried soil samples were weighed out at 5 ± 0.01 grams in 250 ml conical flasks. Then 20 ml of deionized water was added to each flask. The samples were then stirred at 300 rpm for 30 minutes, allowing the soil to be fully suspended. Samples were transferred into centrifuge tubes and centrifuged for 15 minutes at 2000 rpm. The supernatant was filtered using a Whatman No. 42 filter paper (retention N8 µm). Filtering was done under a vent hood that pushed out any microplastic contamination in the air. 20 ml of sodium chloride (NaCl) 5 M (ρ = 1.20 g cm^{-3}) was added to the precipitate, which was then stirred and centrifuged a second time. The supernatant was filtered through the same Whatman No. 2 filter paper. 20 ml of a concentrated zinc chloride solution (ZnCl2 5 M, ρ = 1.55 g cm^{-3}) was added to the precipitate for a final extraction. The precipitate was once again stirred and centrifuged, then the supernatant was poured through the same Whatman No. 2 filter paper. Filters were allowed to dry under the vent hood and were saved for optical inspection under a microscope.

Microplastic Analysis:

Since there is no standardized method for quantifying microplastics in samples, we used a visual analysis method. After the extraction process, the filter papers were inspected under a microscope at 4x magnification. Photos were captured of 5 random spots on each filter paper. The images were inspected and the microplastic particles in each photo were counted twice. Microplastic particles were counted as those with shiny surfaces, strong colors, and sharp geometrical shapes (Corradini et al. 2019). Synthetic fibers were considered to have smooth sides and strong colors. Particles were classified according to their shape: fibers, fragments (angular and solid), films (flexible and thin), or pellets (rounded and solid). Fragments, films, and pellets are referred to as non-fiber particles.

Data Analysis:

Microplastic data were analyzed in R to compare abundance between mulched and non-mulched sites. To avoid any issues from replications with having multiple samples collected within the same site, data were first grouped at the site level. For each sample, total microplastics (MP) were calculated by summing fibers, fragments, films, and pellets. These totals were then averaged across replicate samples within each site to generate a single value representing microplastic abundance per site. In addition to total abundance, microplastic composition was analyzed by type, where counts of fibers, fragments, films, and pellets were summed within each site and then averaged across sites within each treatment group.

Data distribution was assessed visually using histograms, which showed that microplastic counts were not normally distributed. Because of this, a non-parametric Wilcoxon rank-sum test was used to compare microplastic abundance between mulched and non-mulched treatments. Boxplots were used to visualize differences in site-level microplastic abundance between treatments, while bar plots were used to compare mean microplastic counts by type. All analyses and figures were completed in R.

Results

Microplastic abundance was compared between mulched and non-mulched sites using site-level averages to avoid bias from any replication in each site sample. For each sample, total microplastics (MP) were calculated as the sum of fibers, fragments, films, and pellets, and these totals were then averaged across replicate samples within each site to better represent overall site-level conditions rather than individual sample variation. Analysis found that across sites, mulched treatments generally showed higher microplastic abundance compared to non-mulched treatments (Figure 1).

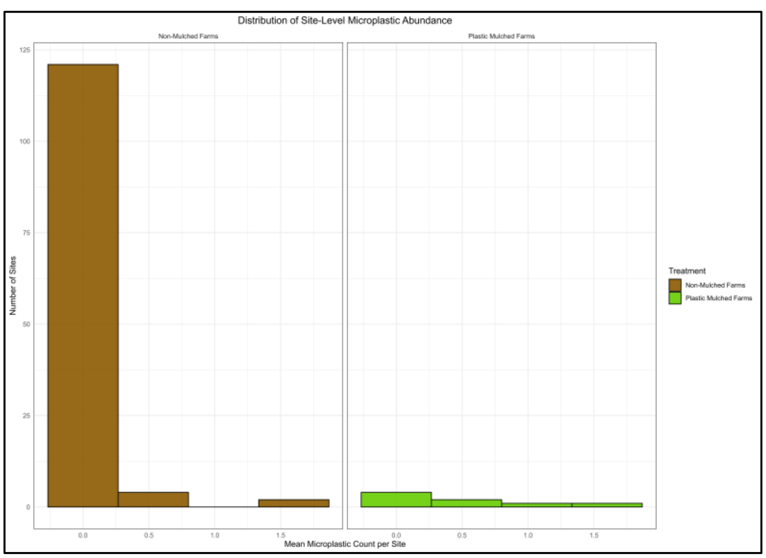

Figure 1. Distribution of microplastic abundance by treatment. Histograms show the distribution of site-level microplastic abundance for mulched and non-mulched treatments.

Most non-mulched farms had low or near-zero microplastic counts, while plastic mulched farms showed a wider range of microplastic abundance, including several sites with substantially higher values. This greater spread indicates increased variability in microplastic accumulation among mulched farms. A Wilcoxon rank-sum test comparing mulched and non-mulched farms found a statistically significant difference in microplastic abundance between treatments ($W = 40$, $p = 0.0183$), with mulched farms exhibiting higher overall microplastic counts. The distribution of microplastic abundance further supported this pattern, as both treatments showed right-skewed distributions characterized by many low values and a smaller number of higher observations (Figure 3).

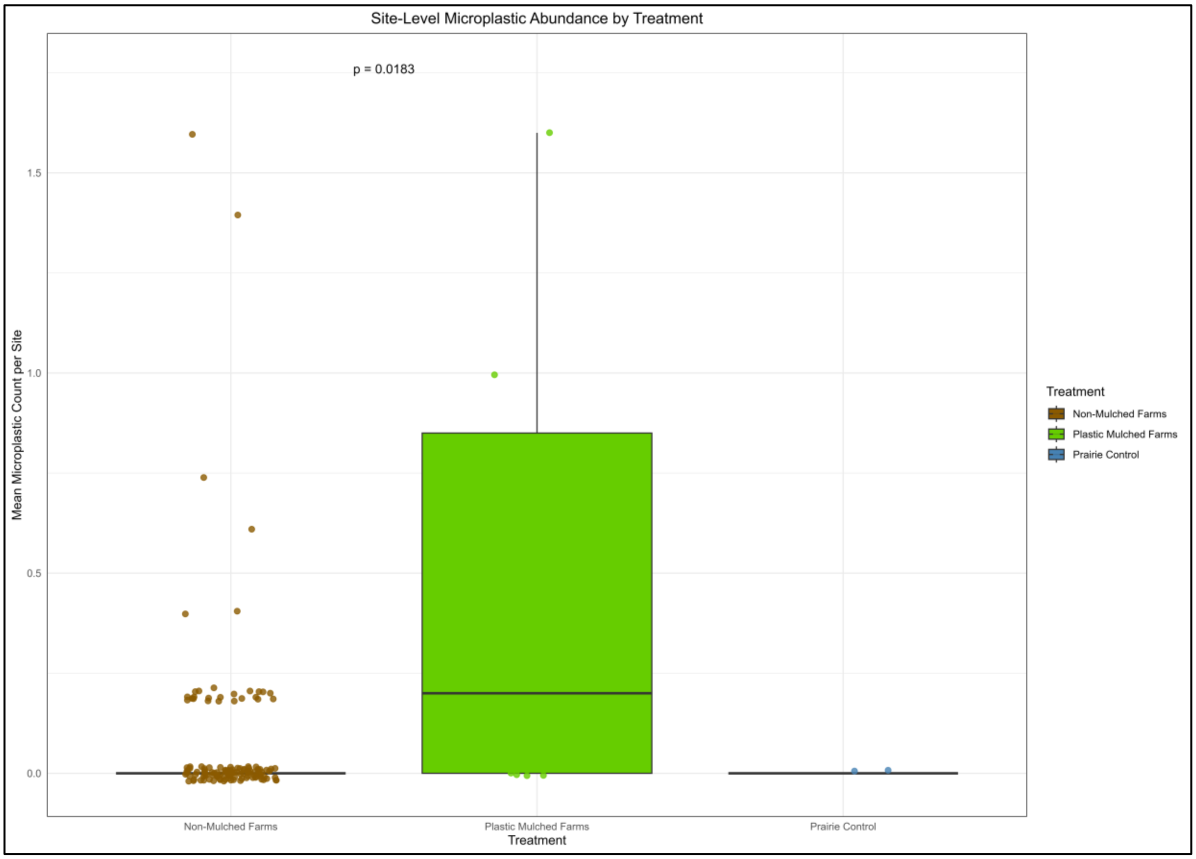

Figure 2. Microplastic abundance by treatment. Boxplot of site-level microplastic abundance for mulched and non-mulched sites, showing higher values and greater variability in mulched sites.

The distribution of microplastic abundance indicates that the data are not normally distributed, with both treatments showing right-skewed patterns characterized by many low values and a small number of higher observations (Figure 1). This distribution supports the use of a non-parametric test. In addition to total abundance, microplastic composition differed between treatments (Figure 3). Mean counts of fibers, films, and fragments were higher in mulched sites compared to non-mulched sites, while pellets were rare or absent in both treatments. Among the different types, films and fibers showed the largest differences between treatments. Overall, multiple microplastic categories exhibited higher values in mulched sites, indicating that differences in total abundance were reflected across several microplastic types rather than a single category.

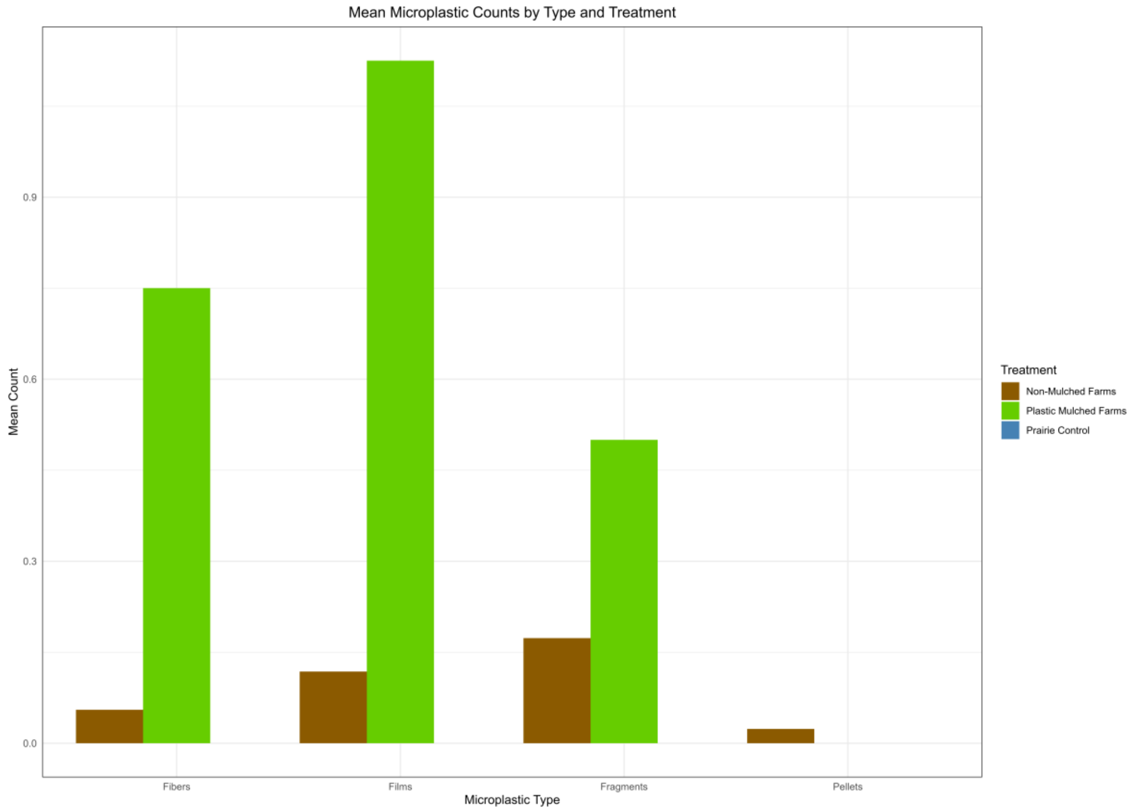

Figure 3. Mean microplastic counts by type and treatment. Bar plot showing mean counts of fibers, films, fragments, and pellets for mulched and non-mulched sites

Discussion:

The observed patterns suggest that mulch use may contribute to increased microplastic presence in soil, particularly through higher levels of films and fibers, which are commonly associated with agricultural plastics. The data analysis between mulched and non-mulched farms showed a significant difference in microplastic abundance, supporting the relationship between plastic mulch use and increased soil microplastic contamination. In addition to higher overall abundance, mulched farms also showed greater variability in microplastic counts, indicating that microplastic accumulation may differ across sites depending on environmental or management conditions. Overall, these results support the idea that plastic mulch can act as a source of microplastic input into agricultural soils and highlight the need for more sustainable alternatives and improved management practices to reduce long-term plastic accumulation in soil systems.

Scope for Future Work/ Next Steps Going Forward

The results of this study emphasize the need for continued research and practical innovation to address the growing issue of microplastic contamination in agricultural soils. While the relationship between plastic mulch use and increased microplastic presence is evident, the long-term implications for soil health, crop productivity, and environmental sustainability need to be further explored. Moving forward, a combination of scientific studies and improved practices will be essential to mitigate these impacts and develop more sustainable solutions.

One important direction for future work is the expansion of research across broader geographic regions. This study focused on a limited number of farms in Kansas, but microplastic accumulation and behavior may vary depending on soil composition, climate, and management practices. Long-term monitoring studies would provide valuable insight into how microplastics accumulate over multiple growing seasons and how they persist or degrade within the soil profile. Ramanayaka's work on the environmental fate of microplastics highlights that these particles, along with associated polymer additives, can remain in soils for extended periods and may undergo slow transformation processes, reinforcing the importance of studying their long-term behavior (Ramanayaka, 2024).

In this experiment, we used soil samples from farms that we did not have control or extensive knowledge of their history of management. This means that we must accept the possibility of microplastics from sources other than plastic mulch being already present in the soil. Potential experiments in the future could be conducted with fields that have more controlled management and only have a history of plastic mulch use.

Advancements in certain techniques also could be a potential next step. While this study utilized visual identification methods, future research could incorporate more precise tools such as FTIR or Raman spectroscopy to accurately identify polymer types and particle sizes. This would allow for a clearer understanding of how specific materials contribute to soil degradation and how plants react as a result. Improved identification methods would also support better comparisons between certain studies and more specific mitigation strategies.

In terms of practical solutions for this issue, reducing the introduction of microplastics into soils is an obvious goal. One promising avenue is the development and adoption of biodegradable mulch alternatives. These materials are designed to break down more completely in soil environments, potentially reducing the accumulation of persistent plastic fragments. However, as suggested by Ramanayaka, even biodegradable plastics may leave behind residues or additives that require further evaluation (Ramanayaka, 2024). Future studies should therefore assess not only the degradation rate of these materials but also their ecological safety and long-term effects on soil systems.

Improved management practices can also play a significant role in minimizing microplastic contamination. Ensuring proper disposal of plastic mulch after use can reduce fragmentation and prevent plastics from being incorporated into said soil. Possibly establishing recycling programs or incentivizing responsible disposal methods may further limit environmental impact. Additionally, reducing the frequency or thickness of mulch application could possibly decrease overall plastic input while still maintaining some of its agricultural benefits.

Another important area of focus is the exploration of alternative agricultural practices that reduce reliance on plastic mulch. Techniques such as organic mulching, cover cropping, and conservation tillage offer potential substitutes that can improve soil moisture retention and weed control without introducing synthetic materials. Comparative studies are needed to evaluate the effectiveness, cost, and scalability of these approaches relative to plastic mulch systems that are already in place. However, further research into the biological and agronomic impacts of microplastics is essential. As demonstrated in the study by Min Yang, microplastics of varying sizes and concentrations can significantly influence soil properties and plant growth, including reductions in biomass and alterations in root development. Expanding this line of research to include a wider range of crops and soil conditions will help clarify the extent of these effects and inform best management practices for maintaining crop productivity.

Essentially, addressing microplastic contamination in agricultural soils will require a rather in-depth approach that combines scientific advancement with practical implementation. By expanding research efforts, improving detection methods, and adopting more sustainable agricultural practices, it is possible to reduce the negative impacts of plastic mulch while preserving the productivity and health of soil systems for future going forward.

Conclusion

The findings of our project and research reinforce the growing concern that agricultural plastic mulch, while beneficial for short-term crop management, contributes to long-term soil contamination through the accumulation of microplastics. By comparing soils from farms that utilize plastic mulch with those that do not, as well as control samples from the Konza Prairie, this research demonstrates a clear relationship between plastic use and increased microplastic presence in agricultural soils. These results support the original hypothesis that plastic mulch application is a significant source of microplastic contamination within the soil profile itself.

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