

# Historic and present agricultural land use and its effect in plastic debris in a semi-arid agricultural region of southern Puerto Rico

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Finca Atabey

## Introduction

- Plastic pollution in the environment has reached exceptionally high levels due to its durability, affordability, and widespread use in commerce, industry, and agriculture (1).
- Since the 1940's, plastics have been used in agricultural soils to regulate temperature, maintain humidity and decrease weed growth (2). In the 1970's, the use of plastic covers and drip irrigation was introduced on the southern semi-arid region of Puerto Rico by *April Agro* (3).
- Finca Atabey, a multi-crop farm on the southern semi-arid municipality of San Isabel was established in 2000. Plastic covers were initially used in establishment of the perennial crop rows (avocado trees; *Persea Americana* var. *Butler*). For annual crops, (pumpkin plants; *Cucurbita moschata* var. "Taina Dorada"), plastic cover is methodically used, as it is systematically and intentionally applied over the soil. Since 2023, biodegradable plastics have been used for pumpkin harvest.
- Over time, wind, heavy machinery, or UV irradiation have and will continue to disintegrate both types of plastic covers into macro, meso, and microplastics. Mechanical tillage can integrate these particles into various soil layers, contributing to soil pollution with plastic debris, which can significantly affect crop growth and soil health (4).

## Objective

- Evaluate the legacy of plastic debris in the soil resulting from long-term plastic use and analyze their quantity and size based on crop and depth variability.

## Questions

- Does the long-term use of plastics result in a quantifiable legacy of plastic debris in the soil? Do significant differences exist in the quantity and size of plastic debris based on perennial and annual crop row management? Does soil depth influence the quantity and size of plastic particles?

## Hypothesis

- Finca Atabey's soils will exhibit high plastic concentrations due to prolonged non-biodegradable plastic use. Pumpkin fields will show greater concentrations and size variability of plastics with minimal depth variability from mechanical tillage. Avocado fields superficial layers will contain higher concentrations and size variability.

## Methodology



Figure 1. Coordinates. a) Santa Isabel in Puerto Rico; b) Finca Atabey in Santa Isabel; and c) Finca Atabey, a multi-crop agricultural farm in Santa Isabel, Puerto Rico. From Google Earth.

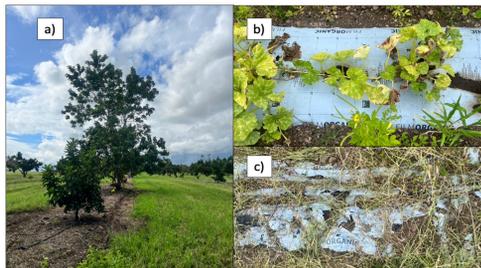


Figure 2. Types of crop sampled. a) Avocado field; b) Pumpkin field, biodegradable plastic; c) Pumpkin field, fragmented biodegradable plastic.

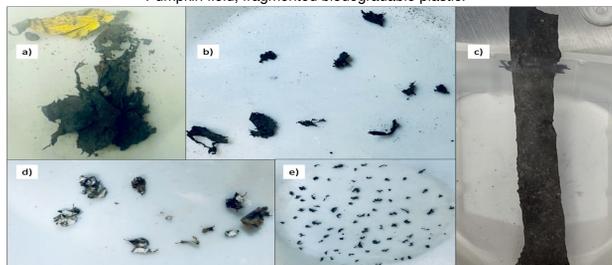


Figure 3. Types of plastic debris found. a) Non-biodegradable microplastics > 4.75 mm; b) Non-biodegradable microplastics 2.00 - 4.75 mm; c) Non-biodegradable plastic debris (114.04 mm); d) Biodegradable microplastics 2.00- 4.75 mm; e) Non-biodegradable microplastics 1.00 - 2.00 mm.

## Methods

- Soil samples (10) were collected from two soil depths, 0 -15 cm and 15- 30 cm, for two different crop fields: avocado and pumpkin field (Figure 1 and 2). In total 40 samples were analyzed for plastic concentrations.
- All samples were stored in a forced air oven at 60°C for 48 hours to dry. Samples were weighted to obtain the soil weight with plastic debris.
- Each dried sample, individually, were transferred through sifters with meshes of various sizes, 4.75 mm, 2.00 mm, and 1 mm, where sizes were determined (Figure 3).
- Magnifying tools and precision lab tweezers were used to extract plastic particles in each mesh size and quantify them.
- Samples of plastic debris collected were weighted to determine the percentage of contribution of plastic per soil sampled.
- The plastic type: **biodegradable (BD)** and **non-biodegradable (NBD)**, was determined by their difference in color: BD = white, NBD= darker or colorful appearance.
- Statistical analyses were carried out using **JMP® Pro 17 Statistical Package** and **RStudio**, were descriptive, inferential, and explanatory analysis were made. T-tests were also performed.

## Results and Discussion

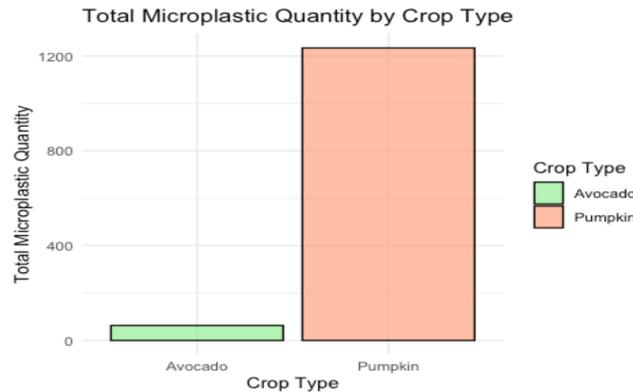


Figure 4. Histogram for the total quantity of microplastics per crop type: avocado and pumpkin.

- The long-term use of non-biodegradable plastic in Finca Atabey's soil results in a quantifiable legacy of plastic debris in the soil.
- The legacy of plastic debris in the pumpkin field was higher (**1,234 plastic particles**), than that of the avocado field (**63 plastic particles**).

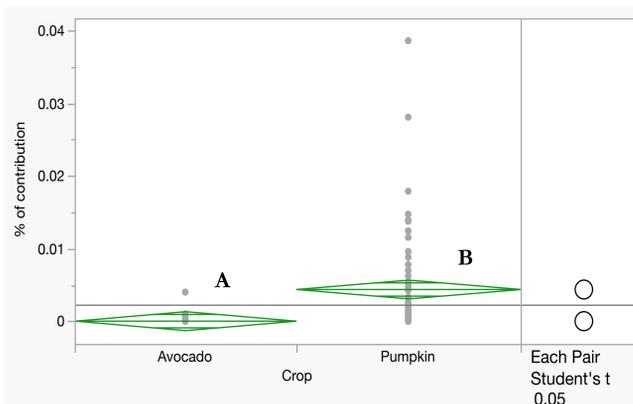


Figure 6. Percentage of contribution of microplastics for crop type: avocado and pumpkin. Levels not connected by the same letter are significantly different.

- The percentage contribution of microplastics by crop type: avocado and pumpkin field, was **significantly different** (p-value < 0.05; t Ratio= 4.696).
- Non-biodegradable and biodegradable microplastics had a higher contribution in the pumpkin field, as its soil is managed annually by tillage for crop production.

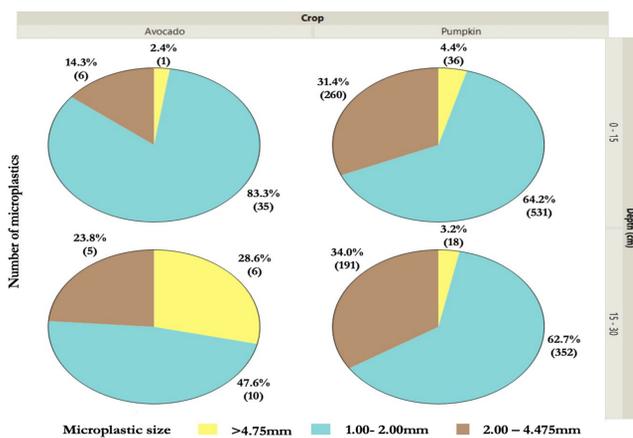


Figure 8. Number of microplastic by size, crop, and depth.

- No significant differences were found in quantity and size between depths per crop type.**
- There is a greater presence of smaller microplastic (**1.00- 2.00 mm**) in both depths per crop type. This indicates that plastics do not disappear from the soil but instead continue to degrade into finer particles.

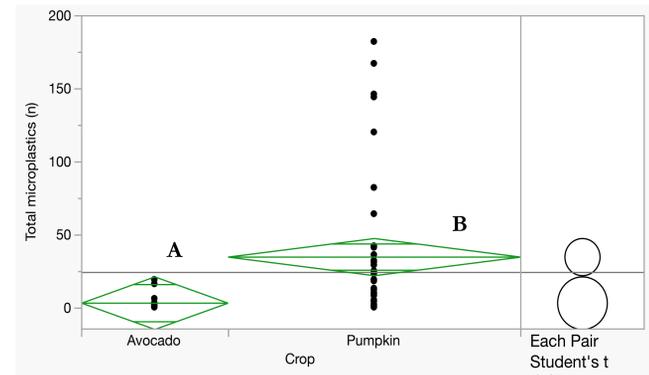


Figure 5. Total microplastics for crop type: avocado and pumpkin. Levels not connected by the same letter are significantly different.

- There were **significant differences** in the total microplastics found by crop type: avocado and pumpkin field (p-value < 0.05; t Ratio = 2.864).
- In the avocado field, plastic cover and tillage were applied once, during the preparation and planting of the juvenile avocado trees. In annual crops, the plastic cover is left in the field and incorporated into the soil by fragmentation from tillage for the next planting.

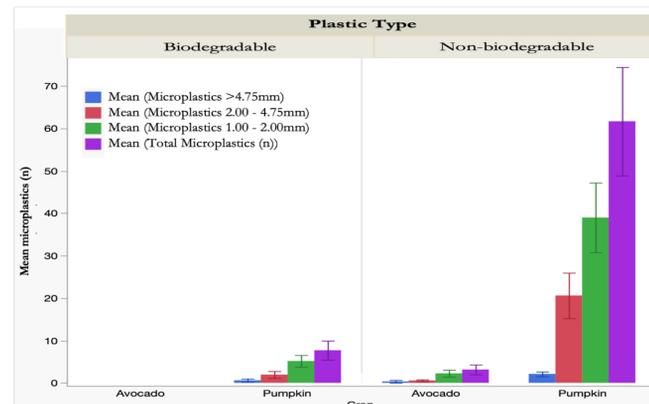


Figure 7. Number of plastic pieces by crop type: avocado and pumpkin and by plastic type: Biodegradable and Non-biodegradable.

- The number of microplastic pieces of all sizes from non-biodegradable plastic was **significantly higher in the pumpkin field** compared to the avocado field. No biodegradable plastic cover was applied to the avocado field.
- Biodegradable microplastics have degraded rapidly since their introduction than non-biodegradable microplastics in the pumpkin field.

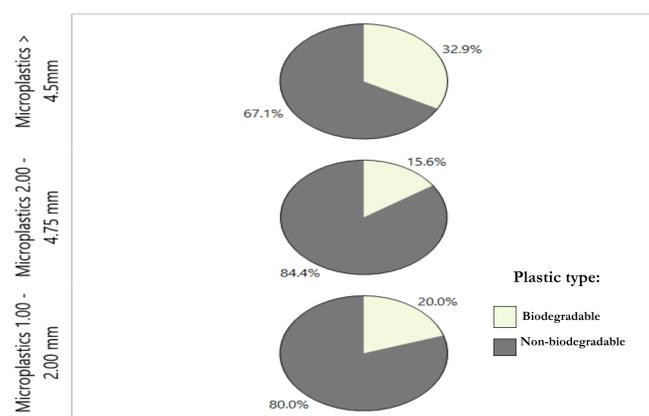


Figure 9. Percentage of plastic type: biodegradable and non-biodegradable, per size studied (>4.75 mm, 2.00-4.75 mm, and 1.00-2.00 mm) in the pumpkin field.

- The **total sum (annual + perennial crops)** of non-biodegradable microplastics accounted for **89.4%** of which **85%** was found in the pumpkin soil.
- The **biodegradable** input of microplastics accounted for **10%** of the total.

## Conclusions

- Historic use of non-biodegradable plastic cover for both annual and perennial crops can contribute to a measurable legacy of microplastics in the soil.
- Biodegradable plastic covers offer a better alternative to non-biodegradable plastics for agricultural use, as they degrade at a faster rate and contain fewer harmful substances.
- In arid and semi-arid regions, the legacy of plastic debris in agricultural soils can pose a challenge by altering the soil's water-holding capacity, potentially affecting crop development.
- Understanding pollutant dynamics in agroecosystems can inform strategies to reduce plastic concentrations, and therefore, safeguard soil health, crop quality, and overall ecosystem integrity.

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## References and Contact Information

