(Not) Digging Up the Dirt*:*
Examining the effects of organic no-till agriculture on compost nutrient availability and crop yields

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ABSTRACT

As we seek out more sustainable methods of agriculture, no-till, a method that reduces soil erosion, may be a candidate for best practice. We hypothesized that no-till farms would have higher yields due to better ground nutrient content and soil conditions and that compost nutrients would be better maintained. We tested this with special resins that take up nutrients as a plant would, and measuring yields. The yields on the organic no-till farm were indeed significantly greater than those on the non-organic till farm. Which leads us to conclude, that while further research is necessary, early signs are positive for the sustainability of no-till agriculture.

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INTRODUCTION

In the coming decades, we will likely be faced with a rapidly changing climate due to anthropogenic factors such as carbon dioxide emissions (Howden, et al 2007; Houghton et al 1995). To mitigate the most devastating effects of climate change, attention must be paid to all areas of human activity and how they can be more efficient and sustainable. This can happen in a myriad of theoretical ways but, in essence, the goal is either increase sequestration of greenhouse gases or reduce their output or both. Other gases, aside from carbon dioxide, that impact the greenhouse effect include water vapor and nitrous oxide. All three of these can be sequestered in croplands either in the soil or by the plants themselves.

Lands used for agriculture make up approximately half of Earth's habitable lands (Ourworldindata.org 2019). This includes both croplands and lands for cattle grazing, which are substantially greater. Methods of farming these lands vary greatly from crop burning, crop rotation, to organic farming. Depending on the resources available, and the cost of technologies, different locations globally tackle their mass agriculture in different ways. For the purposes of this paper, I will be focusing primarily on agricultural techniques common in vegetable farms in the United States. All of our testing sites were located in New Jersey.

The methods used for agriculture could have a large-scale impact on greenhouse gas emissions, especially if implementable strategies are determined not to have negative effects on profit margins or production. Another important environmental effect to avoid is soil erosion, and this could return to plague farmers with improper management like it did during the 1930s dust bowl experience (Staropoli 2016). Ideally, there would be a management strategy that farmers could use that mitigates these deleterious effects; something that keeps the soil, and the carbon it contains, more firmly in the ground. There's a possibility that the practice of no-till agriculture is the solution to this problem, because dead plant matter that is carbon-rich could stay sequestered underground in a no-till system and preventing soil erosion overall will be beneficial (Trewavas 2004; Rodale Institute 2019).

A common sustainability practice is composting, often taking the form of taking the excess of farms and putting it through aerobic or anaerobic processes, decomposition, and other biological cycles to reclaim nutrients from products that would have otherwise been waste (Haug 1993). All of the farms that we studied used compost in some facet, though each recipe was different.

Even if we make headway to prove that no-till agriculture is more sustainable than typical till agriculture in a myriad of ways, there is still the question of its profitability and its ease of implementation for farmers. The mechanical removal of unwanted plants is a crucial benefit of tilling. In order to implement, no-till farmers would need to utilize methods to manage the negative impacts of weeds and unwanted species. In order to confidently recommend a switch in sustainable methods, we need to determine the extent of these effects. The effect on yields is one area in which farmers have a strong interest. If yields are lower for no-till, this lessens the farmer's incentives to incorporate it. However, no-till does have a positive impact on soil which could in turn improve yields (Trewavas 2004). Therefore, due to the lessened amount of soil loss and run-off and therefore better soil retention, I hypothesize that (1) farmers utilizing no-till agriculture will see an increased amount of nutrients in the soil, not just carbon, and (2) that the crops themselves will yield more because of better soil conditions, specifically compost-added nutrients will be more effective. While we cannot test for it in this experiment, I would also hypothesize fewer emissions from no-till agriculture, due to a sequestering of nitrous oxide, and a lessened need for gas powered CO_2 producing rotor-tilling machines.

BACKGROUND

No-till agriculture is the practice of leaving the soil static, and not using any physical means to churn it in anticipation of growing new crops. There are several methods of doing so, one being the usage of cover crops, to prevent weed growth, then tamping them down and planting the desired crops into the bed of dead cover crop detritus (Rodale Institute 2019). Another method is laying down a mat or tarp that prevents weeds from growing in between the plants. The no-till farm that we studied happen to use a weed-by-hand method, although the cucumber patch in question had a mat for weed control.

METHODS and MATERIALS

1.1 Locations

We collected data from 6 different farms and one garden in the area of central New Jersey. One of the farms had two locations, one in Pennington, NJ and one in Chesterfield Township, NJ. Both were sampled. It should be noted that Chesterfield was the only location sampled from that had the sandy coastal plain soil types. Otherwise, base soils sampled from were clay, or marl: soils on the Trenton piedmont. These locations were chosen on the basis of their participation within a larger study of Princeton area farms. Honeybrook, the farm with locations in Pennington and Chesterfield, was a large-scale organic operation that did in fact till their soil. At the Chesterfield location, we collected data on peppers, onions, and tomatoes. The compost at the Chesterfield location was covered by a felt-like green material. We placed our resin in the furthest pile, punching a hold through the covering. At the Pennington location we measured the growth of their organic corn. Kerr Farm and Kornstand is located in Hopewell, NJ, and is the only non-organic vegetable farm that we sampled from. The crops investigated at Kerr were: peppers, tomatoes, corn, and cucumber. The compost was uncovered and in a pile remote from the main farm. The third farm we visited was Cherry Grove Organic Farm in Princeton, NJ. They use organic till farming methods and have several forms of compost (Unpublished farmer interviews). We got harvest and sensor data from their squash, cucumbers, tomatoes, and placed resins in the squash and two of the composts. The final vegetable farm for resin placement was Orchard Organic Farm in Princeton, NJ. This farm is our instance of a small organic and no-tilling operation. We collected data from their onions, cucumbers, and tomatoes as well as their compost.

The final two farm locations did not grow vegetables for consumption. The Princeton University farm in Princeton, NJ, grew corn and soybeans for non-human consumption and Doublebrook Farm in Hopewell, NJ is a sustainably minded livestock farm. The garden is adjacent to Forbes College in Princeton, NJ, and is a small student-run operation. Forbes garden does have its own compost, however, and we got resin data from that and the row of onions growing there.

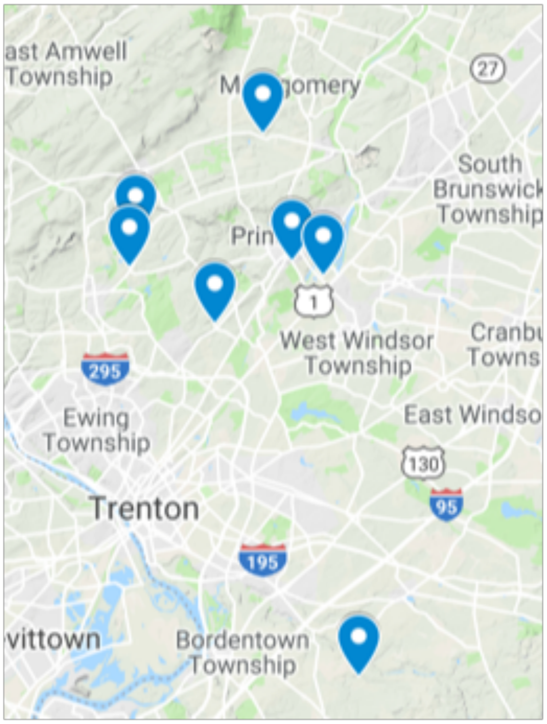


Figure 1. Map of the farm locations. Google maps © 2019.

1.2 UNIBEST AgManager Resins

In order to collect soil data, we obtained Ag Manager Resins from UNIBEST. These resins could act like plants and absorb nutrients over time in the soil. We inserted each resin 6-8 inches deep in the soil of a vegetable row, tying fishing line and a bright string in order to find them for extraction. In vegetable rows, we placed them within a meter of the Arable sensors, or if there was expensive tarp covering the ground, at the very edge of the patch. In compost, they were placed in positions where disturbance was unlikely. It should be noted, however, that at Orchard Organics farms a field hand prematurely removed several resins which then had to be replaced. After 6-8 weeks we removed the resins and sent them to UNIBEST for analysis. The resins are able to act similarly to plants, in that when it rained, the nutrient ions would move through them and be detected and this could later be analyzed in the lab to tell, from a plant's view, what nutrients are available (Ag Manager booklet).

1.3 Harvest measurements and yield

We collected data on the growth of the crops in several ways: first through data collected from the Arable Mark sensors (explained in a later section) and then also through measurements of crop size and weight during its development as well as post-harvest. In meter by meter plots around the sensor we measured the circumference of the vegetables while still on the plant as well as the number of vegetables growing. Later on we measured total yields by getting reports from the farmers as well as measuring the length, circumference, and weight with measuring tapes and scales, once the crops had been harvested.

1.4. Composts

The compost regimens of the two farms we compared are as follows: Kerr farm uses a mulch and leaf compost, a cow manure, and a chicken manure compost, and Orchard uses several “biodynamic preparations” to produce their compost which is a combination of cow manures and vegetable refuse. Typically the Kerr mulch is used on the vegetable patches, however, during this study the chicken manure was the primary compost used (Unpublished interview communications). For both, the method of treatment was a standard spread across the planting area. To improve crop conditions, Orchard also practiced companion planting, where complimentary fixing species grow together and sustain their neighbor.

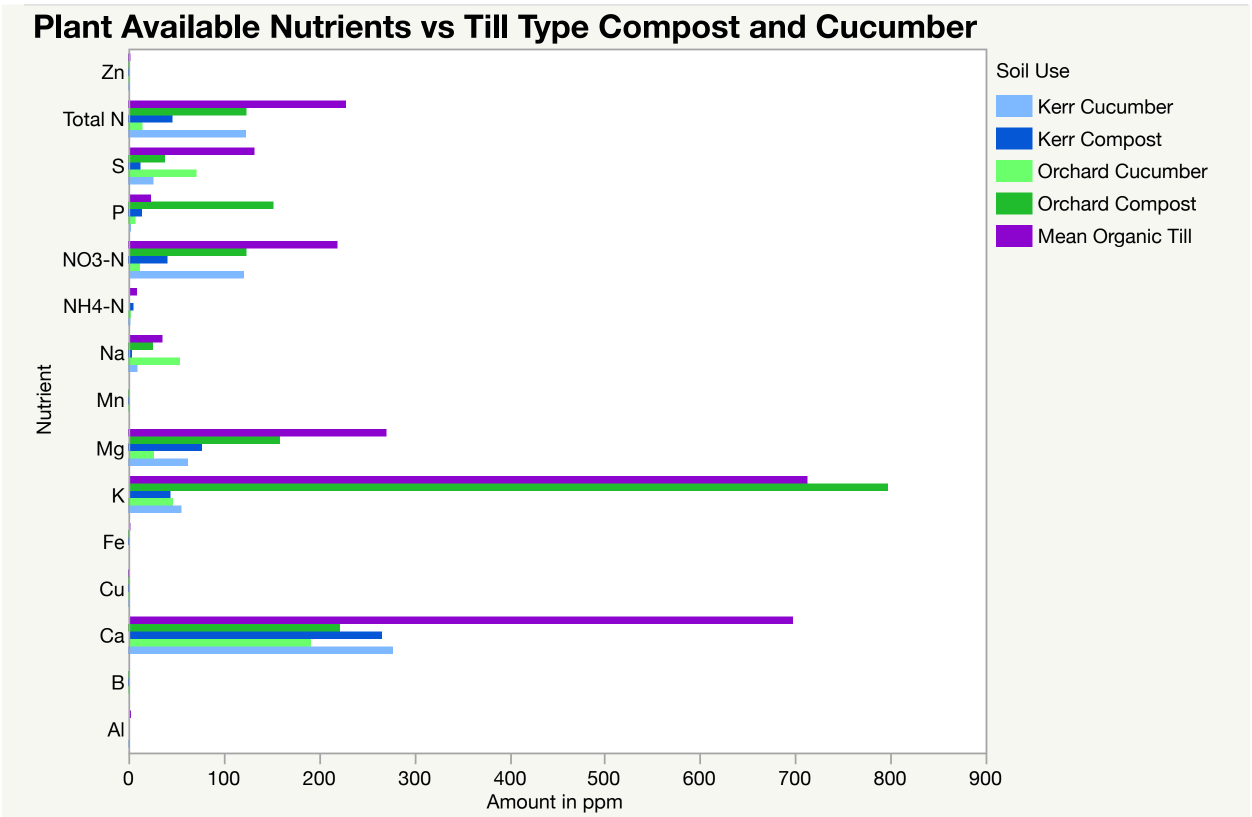
1.5 Arable Mark Sensors

For plant data we used Arable sensor software to monitor photosynthesis, rainfall, temperature, and other growth metrics. The sensors were placed in a row of crops approximately 1-3 meters from the start of the row in order to reduce possible edge effects. As the crops grew, the sensors were raised by adding a second metal pole to the initial pole they had been mounted on.

RESULTS

Wilcoxon tests were performed on the metrics of weight, circumference, and length. The values for weight by till being $W = 4900$, p-value $= 0.006165$, and thus significant. The values for circumference being: $W = 2509$, p-value $= 2.457e-05$, also significant with till having a larger circumference. The values for length were, $W = 6894.5$, p-value $< 2.2e-16$, therefore another significant value.

The resins retrieved data in parts per meter for the following nutrients: ammonium (NH_4), aluminum (Al), boron (B), calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), nitrogen (N), nitrous oxide (NO_3), potassium (K), phosphorus (P), sodium (Na), Sulfur (S), and Zinc (Zn). We included the resin data from the organic till crop farms, Kerr farm (non-organic till), and Orchard farm (organic no-till), as well as the cucumber patches for Kerr and Orchard. Data from the livestock farm and Princeton biodigester were excluded because they did not neatly fit into similar categories.



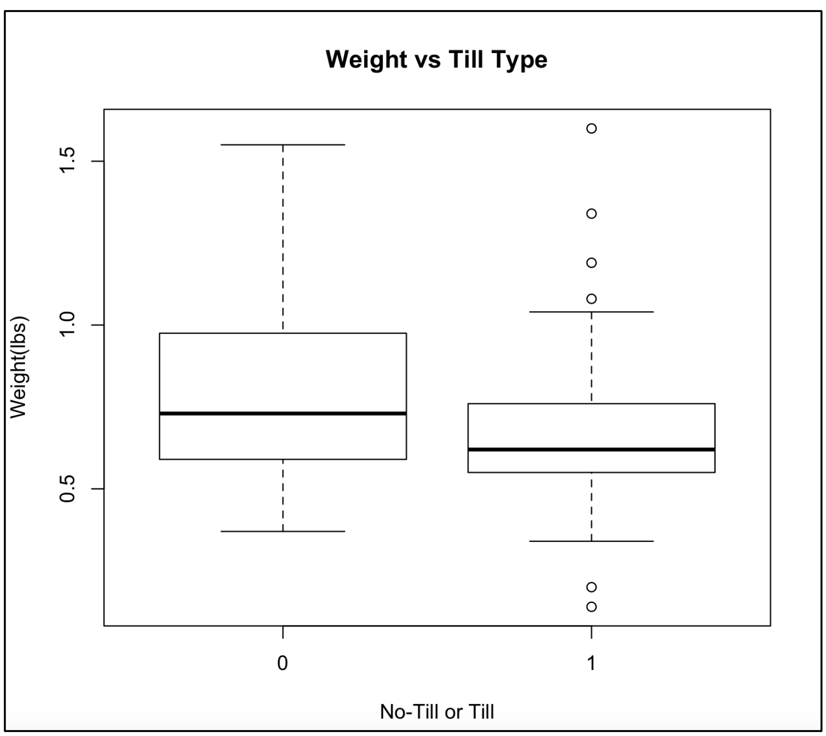


Figure 2 (above). The nutrient concentrations for each type of soil treatment and cucumber plantings in organic no-till and non-organic till environments. The purple represents the average nutrients of the composts of all organic till farms other than Orchard.

Figure 3 (left). The weight differences between no-till (left) and till (right), the weight of the no-till cucumbers was significantly greater.

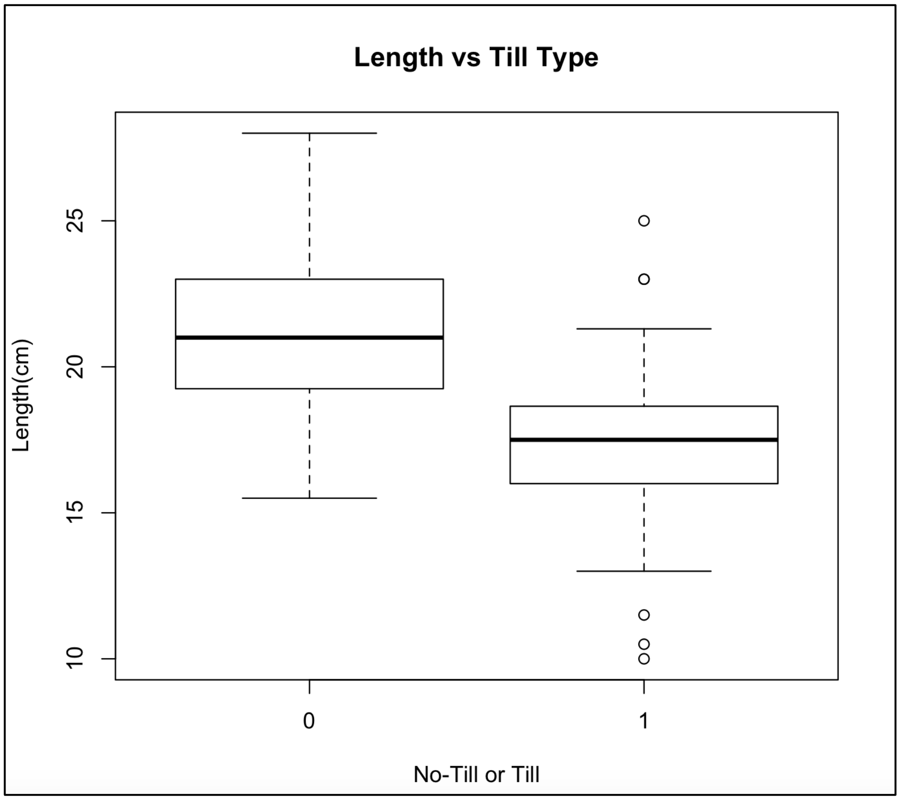


Figure 4. this is the difference in cucumber length for till type, the no-till cucumbers were significantly longer.

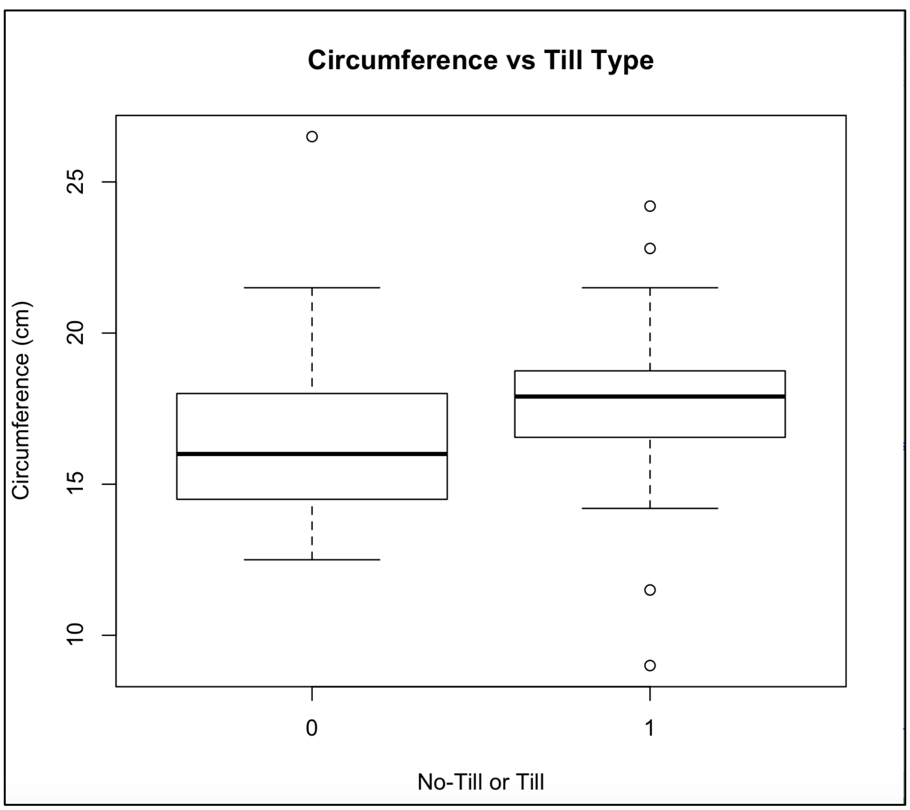


Figure 5. this shows the difference of circumference among till and no-till plots. With the till cucumbers having a larger circumference.

DISCUSSION

The first hypothesis that the practice of no-till agriculture on one farm would improve its soil nutrients over the other farm was not proven to be significant. For one, only two farms were sampled that fit the categories of no-till organic and till non-organic, that had comparable crops growing. Still, the overall nutrient content was very high for the organic composts, but when it came to actual cucumber plots, there were few outstanding differences. In fact, data appears to show a greater amount of nutrients in the till cucumber plot. This could be attributed to the fact that non-organic farms tend to use heavy-duty, non-environmentally friendly fertilizers.

The second hypothesis that no-till would see higher yield rates than till is significant for weight and length, with the circumference being larger for the till cucumbers. However, this rests on the assumption that weight and size are good proxies for overall yield. The biggest problem in assuming this is that it is likely that both these farmers have planted different varieties of cucumber. Unfortunately, we were limited in our ability to study across crop because each farmer strategized their plantings differently. Some grew tomatoes, others grew onions, but the resin data we were able to collect was also dependent on being able to find them again. On most occasions this was possible, but at our organic no-till farm, many of the resins were lost.

CONCLUSION

Our data could benefit from an increased robustness, so that parametric statistical analysis can be performed on it. Unfortunately, due to constraints, we were unable to collect more data. To improve this study, it would be beneficial to reach out specifically to no-till farms. The reason we did not do so here is because we collected this data under the umbrella of a larger ongoing farm project that had partnered with these farms already.

Going forward it will be crucial to examine our farming systems scientifically, because it is through them that we can make a large impact on our climate. It may be too soon to tell whether no-till agriculture is part of that change, but I assert that it is certainly worthy of our investigation.

Proposal for Future Study

To study this further, we propose reaching out to as many no-till farms as possible, and an equal number of till farms. On each farm we place four resins per crop type and compost, then analyze the yields of each farm using a two-way ANOVA. We determine yields not by weight but instead by number produced against average expected yield. Ideally this would be a multi-year longitudinal study so that we could determine the effects of no-till agriculture over time. This could also be done on grazing fields, before and after they have been grazed to determine the effects of grazing animals on soil.

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