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A Comparative Analysis of Farming Tactics on Corn Production Using Novel Longitudinal Remote Sensing Techniques

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INTRODUCTION

Farming methods that optimize plant health and growth while minimizing harmful environmental impact are essential to feeding a growing world population with increasingly limited agricultural space. This study experimentally investigates the effects of three different farming tactics—soil nutrient amendment, weed control, and deer mitigation—on corn growth; we also present a unique approach to UAV remote sensing and multispectral GeoTIFF analysis for longitudinal studies. All combinations of the three farming tactics, each with two variations, were applied to eight cross-sections of an approximately 4 acre Princeton University cornfield (*Zea mays*).

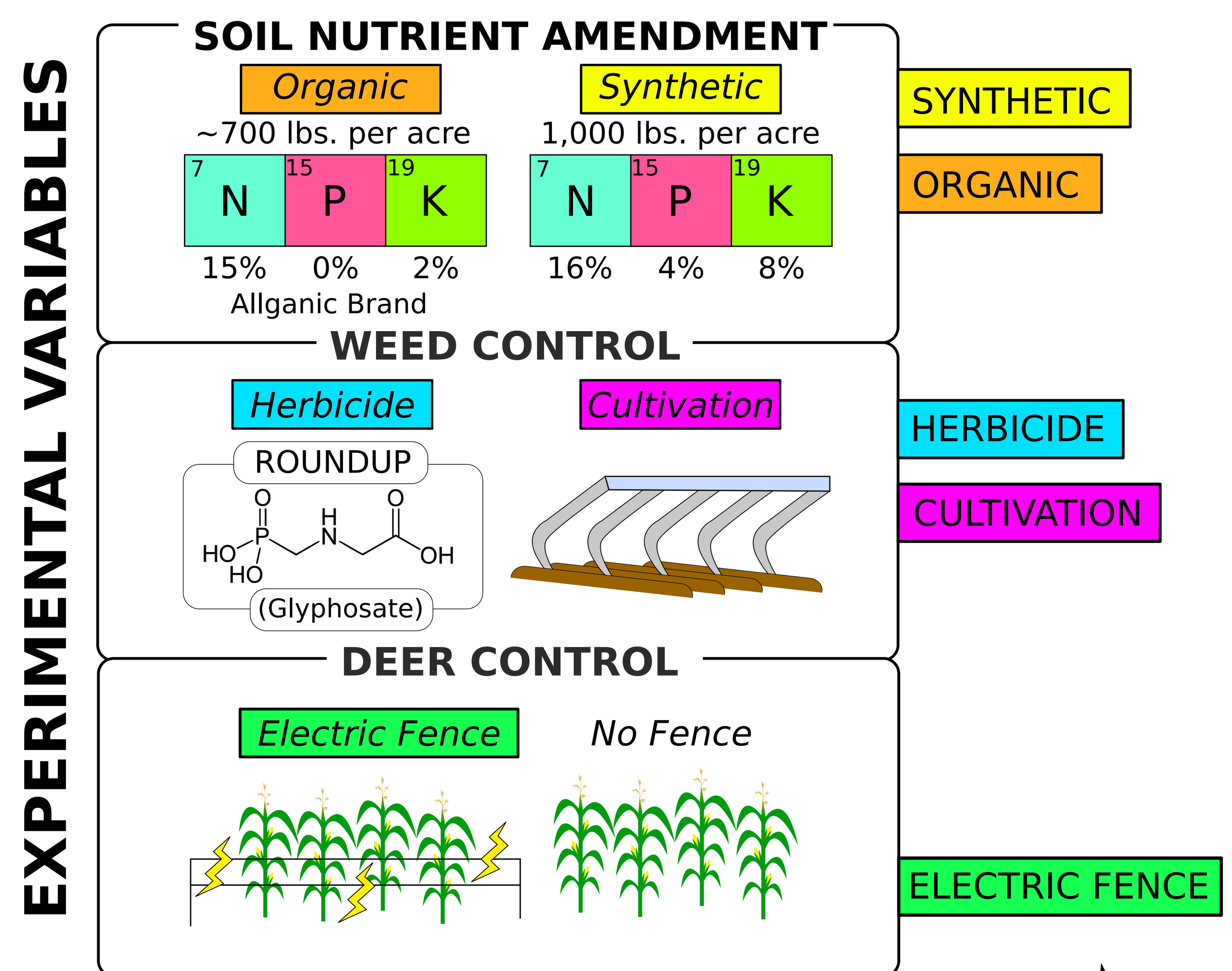


Figure 1: Farming tactics applied in different combinations to eight cross sections of the cornfield.

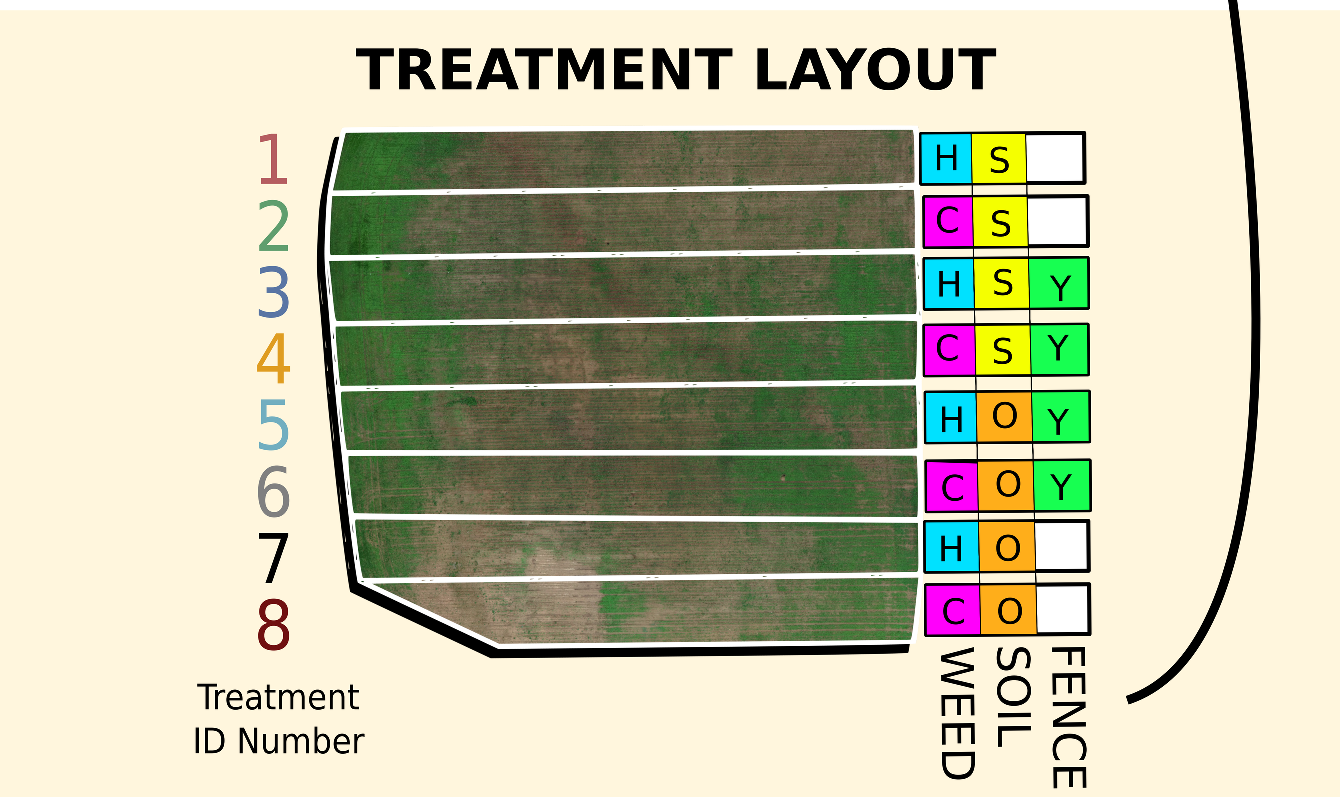


Figure 2: Princeton corn field divided into eight 15x150m sections. Letters and colors in a grid to the right illustrate combinations of treatments applies to the different cornfield sections. "Fence" refers to deer control treatment (above); "Soil" refers to soil nutrient amendments (above); "Weed" refers to weed control treatment (above).

METHODS

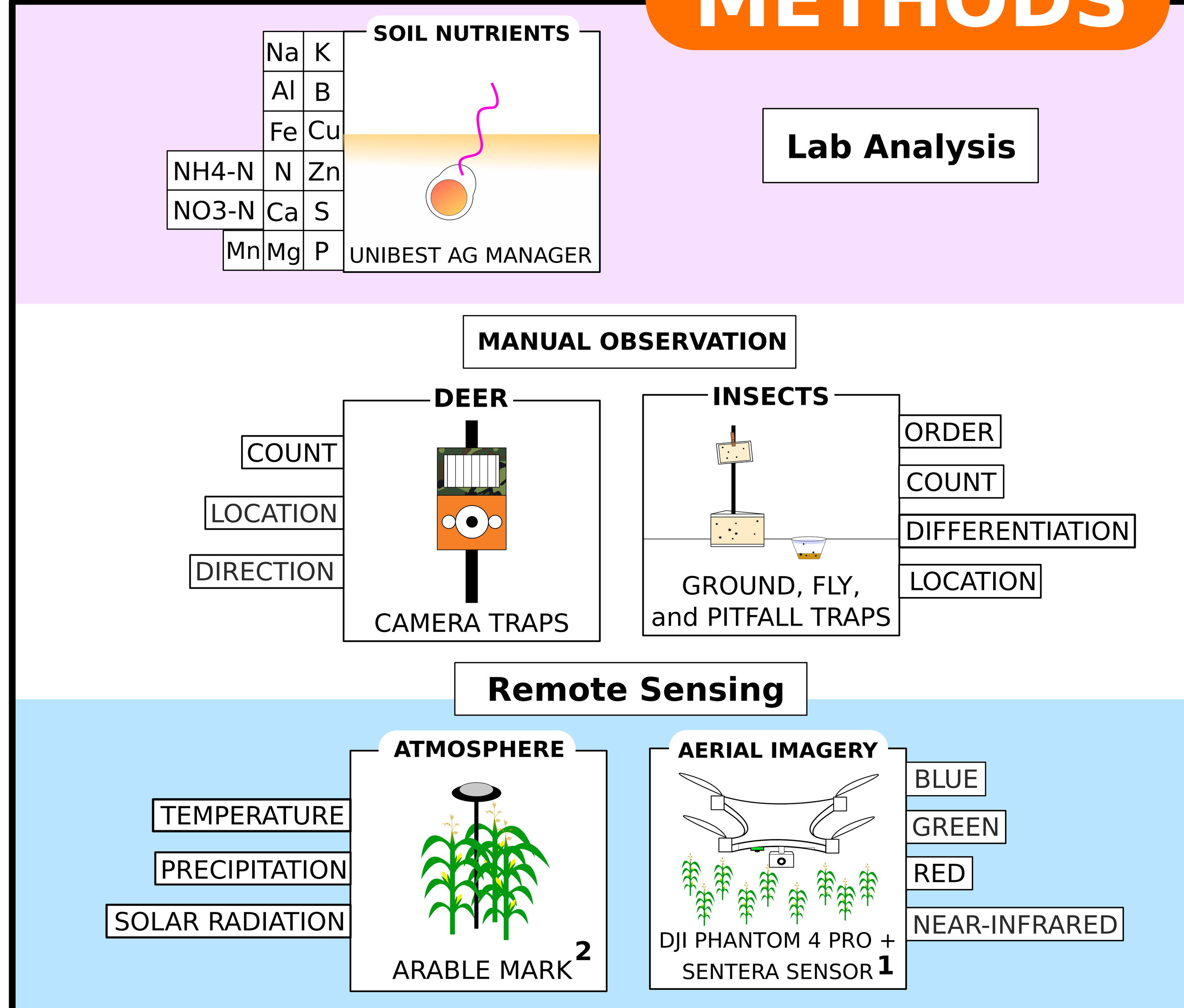


Figure 3: Observed variables include insect biodiversity, deer presence, atmospheric conditions, soil nutrients and RGB and NIR aerial imagery of the corn field.

NORMALIZED DIFFERENCE VEGETATION INDEX

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}}$$

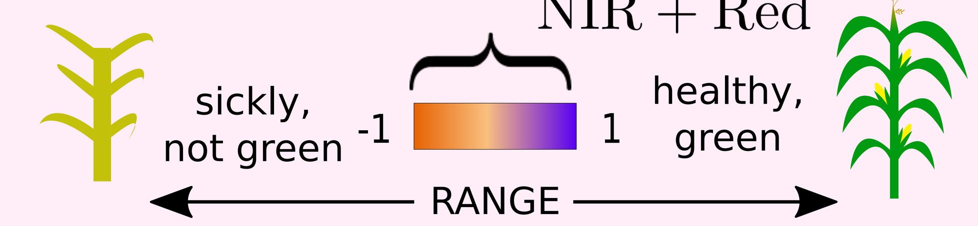
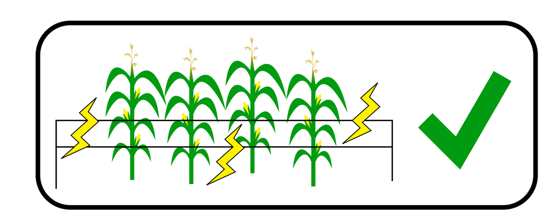


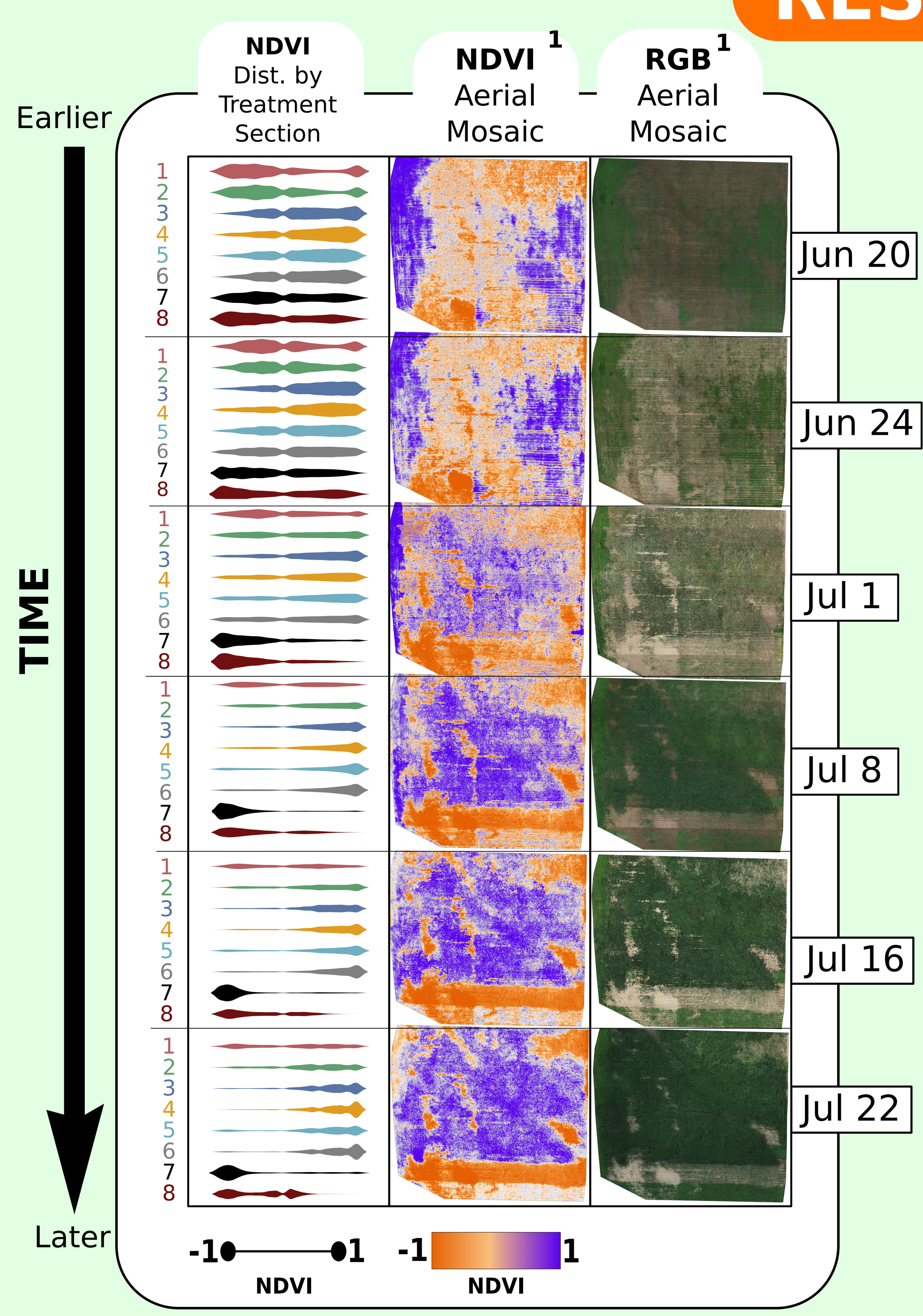
Figure 4: Normalized Difference Vegetation Index (NDVI) is mesaure of the quality of a plant's reflectance and optically guages evapotranspiration and photosynthetic rate. Images of green, healthy plants have NDVI ~ 1, and dirt or snow has NDVI ~ -1.

CONCLUSION

Preliminary regressions across all treatment plots suggested that both synthetic fertilizer and electric fencing had significant positive impacts (coeffs. > 1, $p < 0.01$) on NDVI over organic fertilizer and no fencing, respectively. This analysis took deer pressure, atmospheric conditions, and insects into account. However, we noticed that treatment sections 7 and 8 did inordinately poorly (Figure 7, left column). A new regression only including those treatment sections within the electric fence was run to test for fertilizer, and this yielded a negative coefficient and insignificant p-value ($p = 0.059$) for synthetic fertilizer over organic fertilizer. Because we saw a change in significance and direction of correlation when controlling for treatments 7 and 8, we were unable to confidently conclude that synthetic fertilizer outperformed organic fertilizer. We were also unable to conclude that herbicide outperformed cultivation with any regression. However, a test on electric fence across only the synthetic fertilizer treatment sections (1-4) had both positive and significant ($p < 0.01$) results, so we felt confident to conclude that electric fencing did have a significant positive impact on plant health.



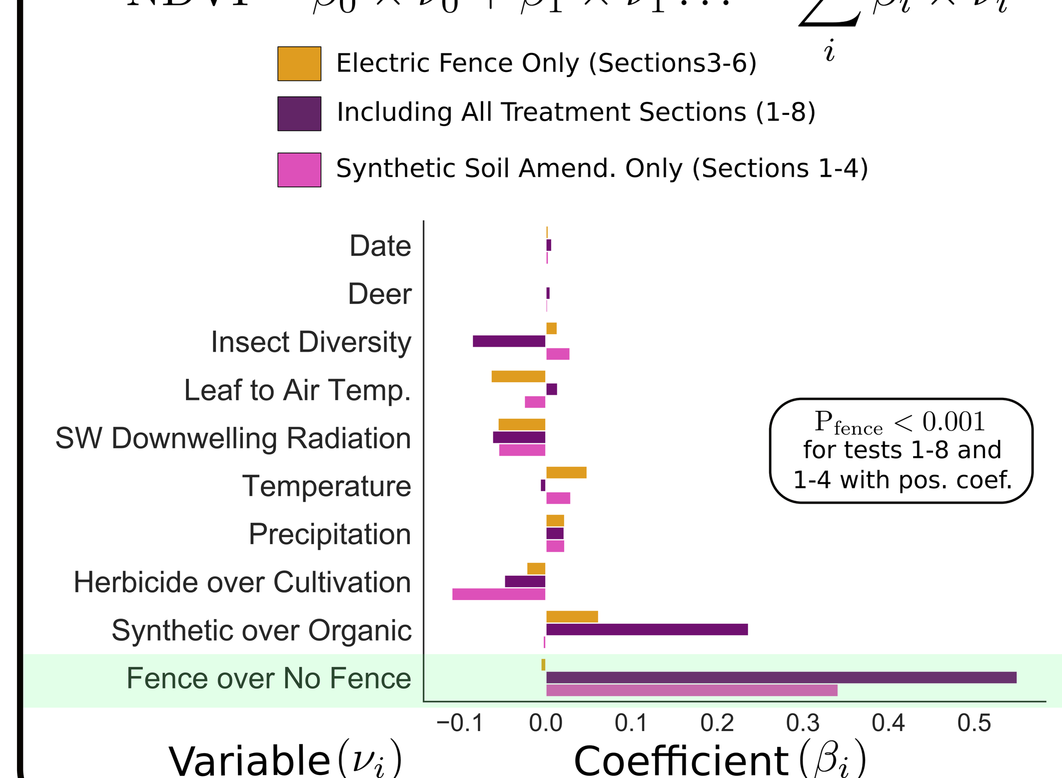
RESULTS



(LEFT) Figure 5: (LEFT) NDVI distributions for each treatment section; (CENTER) NDVI across farm over time; (RIGHT) RGB image of farm over time for comparison with NDVI image.

Results of Robust Multi-Linear Regression **on NDVI** as a Proxy for Plant Health

$$\mathrm{NDVI} = \beta_0 \times \nu_0 + \beta_1 \times \nu_1 \ldots = \sum_i \beta_i \times \nu_i$$



(TOP) Figure 6: Multivariate robust regression models using Huber's T norm for mean NDVI with dummy variables representing treatments. Three tests were run: the first, with all treatment sections included. Latter tests excluded sections 7 and 8 to control for their inordinate negative contribution.

DISCUSSION

Our conclusions draw questions about the power of synthetic fertilizers and herbicides. In our experiment, neither outperformed their sustainable counterpart (organic fertilizer and cultivation, respectively). It is worth expanding comparisons between these farming tactics to a greater diversity of crops over a longer period of time to see if our small-scale and short-term results can be replicated on a larger scale. If so, it may be financially and environmentally advantageous for small and large farms alike to transition to these sustainable methods. Our longitudinal remote-sensing techniques, including Python GIS scripting for easy bulk NDVI analysis of geographically defined field subsections, can make such larger experimentation possible. The biggest hurdle to performing these experiments is acquiring high-resolution RGB and NIR imagery for the NDVI computation.

Acknowledgements

1. NDVI and RGB Aerial Mosaics were created using Sentera FieldAgent desktop software; NIR photography taken using Sentera Single-Sensor, Sentera Inc.
2. Arable Mark is a product of Arable LLC.

Thank you to the farmers who care for the University cornfield. Thank you to the farmers who care for all of us.

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