

Photo of Kyungsoo, Ivan, Abby from Featherstone Farm, and Azucena (from left to right).



DRIFTLESS AREA'S COMPLEX LANDSCAPES CHALLENGE ORGANIC VEGETABLE FARMERS

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INTRODUCTION

The Driftless Area covers 24,000 square miles at the junction of four North Central States: Minnesota, Wisconsin, Iowa, and Illinois. The name indicates that the region, in comparison to the surrounding areas, lacks glacial deposits (i.e., drifts). Even though the region's glacial history is more complex than the name implies, the name captures the region's strong physiographic identity. Its rugged topography challenges mechanized industrial farming, which is overwhelmingly present in the Midwest. The face of agriculture in the Driftless Area has changed dramatically over the past decades. The region now has become a hub for organic agriculture, driven by changing employment and economic opportunities. Wisconsin, Iowa, and Minnesota fall within the top 10 states with the highest number of certified organic

farms, ranking 2nd, 5th, and 9th, respectively (USDA-NASS, 2019).

Although there is no complete geospatial data of certified organic farms, our mapping of USDA Organic Integrity Database (Figure 1) shows several regional epicenters of organic farms across the country. Within the four states, besides the counties close to Twin Cities, Chicago, and Madison, the Driftless Area stands out with the highest density of certified organic farms. In the Driftless Area, a substantial part of the farm is not suitable for crops because of the steep slopes and flooded valleys. According to the 2017 US agricultural census (2019), acres of harvested crop land as a percent of a farm's acreage is substantially smaller in the Driftless counties in comparison to the surrounding counties. In Minnesota, the Driftless counties show that only 40-79% of the farmland is harvested for crops when the other counties at the same latitude show over 80%. In Wisconsin, this percentage is only 20-39% in the Driftless counties.

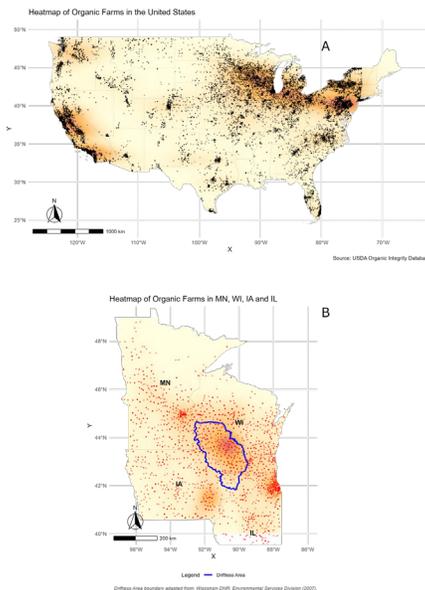


Figure 1. Locations of organic farms in the US (A) and in the four states that intersect in the Driftless Area. The blue line in (B) indicates the boundary of the Driftless Area. Map data from the Organic Integrity Database.

Where complex landscapes reduce harvest area per farm, every inch of land is subjected to careful analyses for its profitability. One of our collaborating farmers commented, "There are some parts of the farm

that make machinery feel less safe, so we're trying to find that balance between the efficiency of large equipment, best soil practices, and safety." Another stated that highly variable soil texture with locations made it difficult to time bed preparation, to utilize ideal crop rotations, and to apply fertilizer at an even rate across the field. Our collaborating farmers emphasized the following topography-affected problems: (i) extremely diverse soil texture, moisture, and organic matter contents that limit timely field preparation, identifying ideal rotations, and fertilizer application, (ii) flooding and saturation of low-lying fields, (iii) distinct micro-climate between the ridge tops and valleys, and (iv) rapid soil erosion across the range of slopes. As the farmers' responses highlight, the Driftless Region is characterized by highly variable conditions, even within individual small farms. Since most research is carried out at a watershed scale, soil research, and risk of erosion in particular, is critically needed at the farm level.

Our research team has received funding from USDA-SARE with a goal of finding ways to increase the profitability of organic vegetable farms and suggesting site-specific management approaches based on the diverse soil-landscape conditions in the Driftless Area. Here we share some basic topography-soil-crop information that characterizes organic vegetable farms in the Driftless Area. If you see this information is relevant to your farms, we encourage you to contact us as we seek to include more farms in our GIS analysis.

WITHIN-FARM VARIABILITY IN SLOPES AND SOLAR RADIATION

We start by quantifying the expected trend that organic vegetable farms in the Driftless Area exhibit significant within-farm and within-fields variability in topography, which challenges on-farm day-to-day management. A slope gradient is a term that tells you the steepness of a hill, with higher percentages indicating steeper slopes. In Figure 2, we show slope gradients in two organic vegetable farms in the Driftless Area as an example. The thick solid lines indicate the watersheds that contain the individual farms, while the dotted lines cultivated fields within the two organic vegetable farms. The comparisons illustrate that relatively flat or minimally sloped lands are selected for vegetable production. For example, about 30% of the watersheds exceed the slope gradient of 15%, while nearly 100% of crop fields have slope gradients less than 15% (Figure 2). This may not be surprising. However, the comparison of the two farms reveals that substantial differences exist between the two organic vegetable farms with respect to the steepness in the fields. Farm A utilizes the relatively flat plateau and valley floor as crop fields, while Farm D has most of its fields on hillslopes between the ridge and valley.

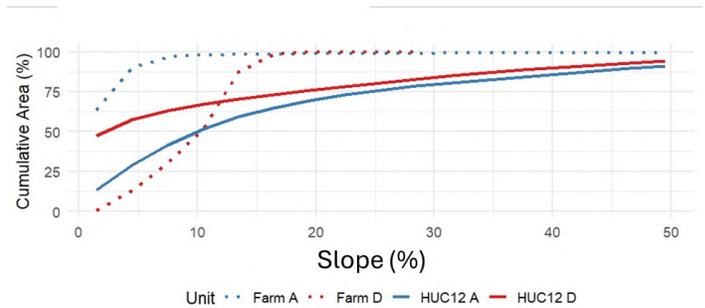


Figure 2. Cumulative percentage of land area by slope gradient. Farm A's crop fields (blue dotted line) and the watershed including the farm (blue solid line), and Farm D's crop fields (red dotted line) and the watershed including the farm (red solid line). Our analyses are not limited to slope steepness. For example, sunny south-facing slopes are considered as having higher soil temperature earlier in the spring than shady north-facing slopes, and such differences will place significant control not only on various soil properties such as soil moisture and organic matter contents but also on crop growth.

To optimize the production potential of different vegetables in complex landscapes, a map of solar radiation within farms could be useful. This logic is comparable to finding optimal locations for solar panels. Figure 3a shows average monthly solar radiation (energy received per square meter of ground surface per day) within four organic vegetable farms in the Driftless Area in comparison to radiation calculated for a flat farm. Except for Farm C, three organic farms receive greater solar radiation than the flat fields because their fields are generally south facing. Also, unlike the flat farm, the four examined organic vegetable farms exhibit a wide range of solar radiation within the farms, illustrating the diverse micro-climate conditions found within those farms (Figure 3b). Lastly, even among organic vegetable farms, considerable differences are found in the solar radiation, and such variabilities depend on the slope gradients and the directions of the slopes (Figure 3b).

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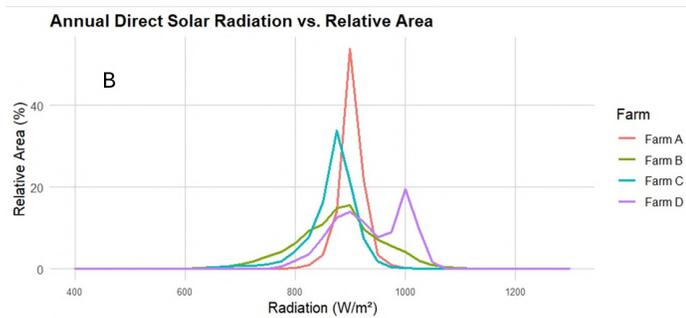
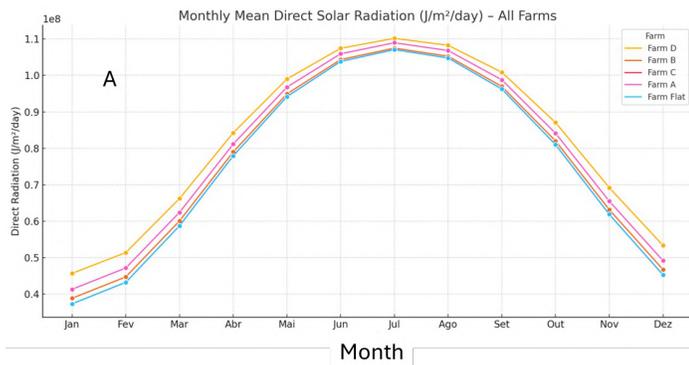


Figure 3. (A) Monthly mean solar radiation in four organic vegetable farms in the Driftless Area vs. a hypothetical farm with a flat topography. (B) Areal percentage of land by annual solar radiation.

WITHIN-FARM VARIABILITY IN SOILS BY TOPOGRAPHY

When looking at soil carbon, nitrogen, and pH, they were all found to greatly differ by the locations within individual farms. However, the direction that topographic locations affects soil properties is unique to individual farms. For example, at Farm A, soil pH was more acidic and variable in the fields on the valley than in the fields on the hilltop (Figure 4 a and b), but this association with topography is opposite in Farm B. At the smaller farms, where farm fields are located on the slopes between the flat ridges and valley floors, soil pH also differed significantly depending on the slope positions, but the direction of the difference was different between the farms. These observations suggest that the relationships between soil properties and topographic positions could be unique to individual farms and are difficult to generalize.

For soil organic matter contents, the highest soil carbon contents were found in the valley fields (2.1 ± 0.04 and $2.1\% \pm 0.02$ in two larger organic vegetable farms) followed by the hilltop fields ($1.6 \pm 0.05\%$ and $1.6\% \pm 0.04$ in the same farms). Soil carbon in the cropping fields located on steep slopes was significantly lower than carbon in hilltop and valley soils. This means that farms where no relatively flat hilltop is available for production, for example very hilly and steep farms, may have lower soil organic matter content than farms that have these flat regions.

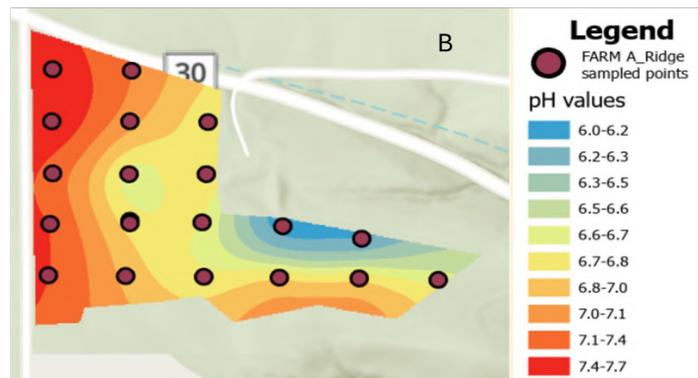
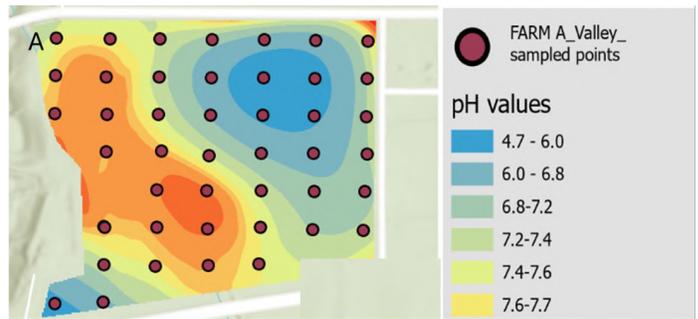


Figure 4. Within-field variabilities in soil pH for hilltop (A) and valley (B) in Farm A.

WITHIN-FARM VARIABILITY IN CROP GROWTH BY TOPOGRAPHY

Ultimately, we would like to develop methods that allow farmers to delineate different management zones based on topography. To meet this goal, we integrated high-resolution (3 meter) satellite remote sensing images with farmer management data and crop productivity for one of our study farms. This task involved extracting the variability in crop productivity from satellite remote sensing images. We examined 2023 satellite data images for 31 fields located in the valley floor and 18 fields located at the hilltop and consulted the farmer management data that includes crop variety, planting date, and management practices.

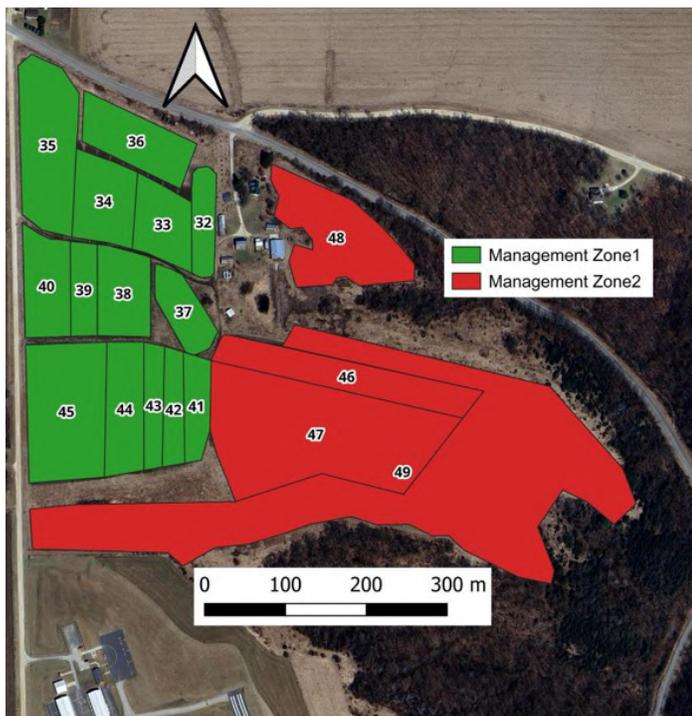


Figure 5. Management zones delineated for the fields in hilltop at a select organic vegetable farm in the Driftless Area.

We found that crop growth had greater variability in the fields located at the hilltop in comparison to the fields located on the valley, which highlights the greater need for delineating management zones at the hilltop. These findings may support sustainable management decisions tailored to specific field conditions, contributing to the success and resilience of organic farming systems in diverse landscapes.

CONCLUSIONS

Our research highlights that organic vegetable farms in the Driftless Area differ from large industrial farms with respect to within-farm topography. We showed that the complex topography in the Driftless Area (Figure 1 and 2) may affect the productivity and management of the organic vegetable farms through subsequent differences in solar radiation (Figure 3), soil properties (Figure 4), and crop growth. Organic farms in the Driftless could benefit by identifying management practices that take advantage of the topographic diversity found in this region (Figure 5). As we continue this North Central SARE-funded research, we would love to develop new collaborations with organic farmers in the Driftless Area, maybe you! If these analyses are relevant to your farm, please contact us. Contact information for researchers is available below.

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REFERENCES

- Organic Integrity Database. <https://organic.ams.usda.gov/integrity/Home> (accessed 2025-06-02)
- USDA-NASS. (2019). Certified organic survey results. Retrieved from www.nass.usda.gov/organics/
- USDA, (2019), 2017 US agricultural census, Summary and State Data, Volume 1 • Geographic Area Series • Part 51, AC-17-A-51

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