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Interaction of weather and field variability on profitability in crop production

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Abstract

The objective of this study was to quantify the often substantial yet somewhat elusive impact of weather, management, and soil spatial variability on within-field profitability in corn and soybean crop production using profitability indices such as profit (net return) and return-on-investment (ROI). We analyzed yield and cropping system data provided by 42 farmers within Central and North Eastern Iowa from 2007 to 2014. The dataset was comprised of 380 site years from 77 fields. Commercial software was used to calculate spatial net return (profit) in crop production, ROI, and standard deviation in profit over time for individual fields. Iowa State University Estimated Costs of Crop Production in Iowa were used to calculate profitability maps. These profitability metrics were then joined with soil attributes (organic matter, drainage, slope), site-specific rainfall, crop rotation and environmental modeling such as soil conditioning index and soil loss by erosion. The relationship between profitability metrics and site-specific field and within-field factors was analyzed for two Iowa landform regions: The Des Moines Lobe and the Iowan Surface. Within both Landform Regions, 10 to 50% of within-field areas had economic losses, especially during 2013 and 2014. We found a higher frequency of economic loss in poorly drained pothole vs. upland areas within the Des Moines Lobe. With each additional inch of May or June rainfall, median field-level profits were reduced by \$45 to \$125 per acre for fields planted to corn. Compared with corn, profitability of soybean fields was unaffected by May rainfall and less affected by June rainfall. The effect of rainfall in eastern Iowa, however, was different than central Iowa, with above normal July rainfall tending to increase profitability by \$45 acre with each additional unit of rainfall. Other than soil drainage, we did not find a significant effect of spatial factors on within-field profitability, indicating the predominance of rainfall and cropping systems. The presented analyses are critical for guiding design and development of future studies that can lead to the creation of risk mitigation tools for farmers.

Introduction

Profitability in crop production is largely driven by crop yield, production costs and commodity prices. The impact of field management, weather and field spatial variability is often difficult to assess for individual fields or for a group of fields within a given geographic area.

According to the Iowa State University Extension and Outreach (ISU, 2007-2015) and United States Department of Agriculture (USDA) National Agricultural Statistics Survey (NASS, 2015), the average corn and soybean prices in 2011 and 2012 generated a profit, whereas the average corn price in 2014 and 2015 generated an economic loss. Although production costs and markets ultimately define revenues, farmers can be smart about managing their fields to optimize ROI by considering three additional factors influential to profitability: weather, field management, and soil characteristics.

When making decisions in precision conservation, it is important to quantify the effects of field management, specifics of cropping systems, soil variability, and weather on temporal and spatial economic outcomes (Muth, 2014, Kyveryga et al., 2012). Quantifying the interaction between weather, crop productivity and field variability is complex. Modern precision agricultural technologies and publically

available spatial data about weather and soils now provide information that enables focus at subfield levels. For example, recent subfield economic analyses studies in Iowa were conducted at the county level or across the entire state to identify portions of land with persistent economic loss. This was done to implement potential alternative conservation practices such as planting perennial grasses to reduce erosion and increase biomass production (Bonner et al., 2014; Brandes et al., 2016). The above mentioned studies used county-based NASS yield estimates for quantifying subfield profitability.

The objective of this study was to use spatial indices for profit (net return) and ROI in corn and soybean production as measures by which to quantify the impact of in-season rainfall and soil characteristics on within-field profitability in two Iowa Landform Regions. The study used field-specific spatial data collected by farmers who participated in statewide on-farm studies in Iowa between 2007 and 2014.

Materials and methods

Central and northeastern Iowa corn and soybean yield data collected between 2007 and 2014 comprising 380 site-years of data from 77 individual farmer fields were used to analyze site-specific crop budget information (Figure 1). Each field had at least three years of spatial yield data. While on average, fields had four years of yield data, some fields had eight consecutive years of data.

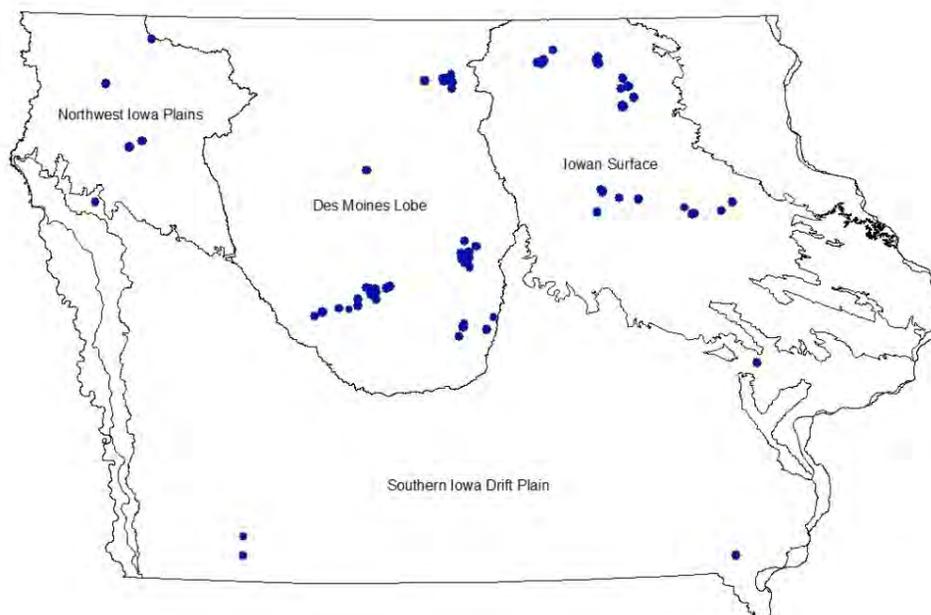


Figure 1. Locations of 91 corn and soybean fields evaluated between 2007 and 2014 across Iowa. Seventy-seven fields in the Des Moines Lobe and Iowa Surface were used in the profitability analyses.

Spatial yield data collected by GPS-enabled yield monitors were provided by farmers. Additional information about field management, field history, and the cropping system were collected as well. While some farmers also provided field-specific crop budget information, our analyses relied on the current and historical cost of production estimates (*Estimated Costs in Crop Production in Iowa*, Iowa State University). The production cost information includes among other items the state-average cost for fertilizer and chemicals, planting, application and harvest machinery, land rent and labor, insurance, and loan interest. Since relative within-field spatial profitability remained constant regardless of budget template, we

employed standard, uniform production costs to eliminate this variable, thereby making differences related to the factors we were studying more apparent.

The Profit Zone Manager (AgSolver, 2015) was used to produce profitability and ROI maps (Figure 2). Standard deviation in profit across all available years was calculated from profit and ROI. (Figure 2C).

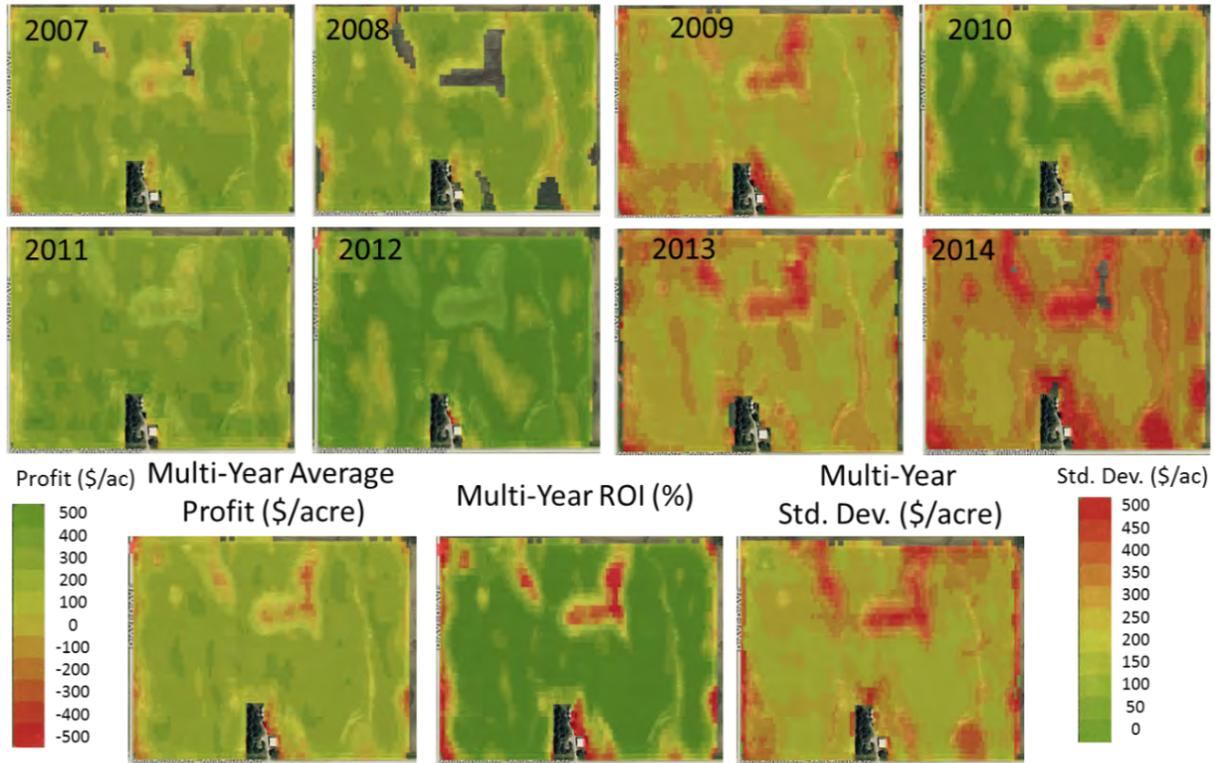


Figure 2. Profitability maps of a field in a typical corn-soybean rotation for eight consecutive years. The maps show within-field profit A) the average profit, B) ROI, and C) profit standard deviation across eight years.

Data processing and statistical analysis

A spatial model was used to overlay spatial data from publicly available sources with the profitability and ROI rasters. Spatial data layers used in the analyses include Soil Conditioning Index, erosion estimates, SSURGO soils (NRCS), elevation and slope (National Elevation Dataset), and LiDAR Pothole and Wetlands rasters (Iowa DNR). Profitability and ROI rasters were converted to vector point files. Spatial data were analyzed at 10 x 10 m resolution. Data were resampled to maintain constant resolution. Each field was spatially joined to monthly rainfall values from the 4 km rainfall estimates in the Iowa Environmental Mesonet database. On average, each field had approximately 19,000 grid cells.

Histograms of profit values were created separately by year and crop rotation (soybean, corn after soybean, and corn after corn) by region, Des Moines Lobe or Iowan Surface.

In addition, for the Des Moines Lobe, analyses were done comparing pothole areas (poorly drained remnants of glaciation) to upland areas. For eastern Iowa, analyses were done comparing crop rotation, soil drainage, and sand content.

Multiple regression analyses were conducted to estimate the contribution of different factors on average profit values across all fields. Cumulative distribution functions of field-level profit means for different categories were estimated using the R statistical software (R Development Core Team, 2015).

Results and discussion

Des Moines Lobe

Fifty-two fields with 270 site years of yield and crop budget data from the Des Moines Lobe landform region (Figure 1) were used to generate field profitability maps for individual years and maps of mean profit and standard deviation across several years (Figure 2).

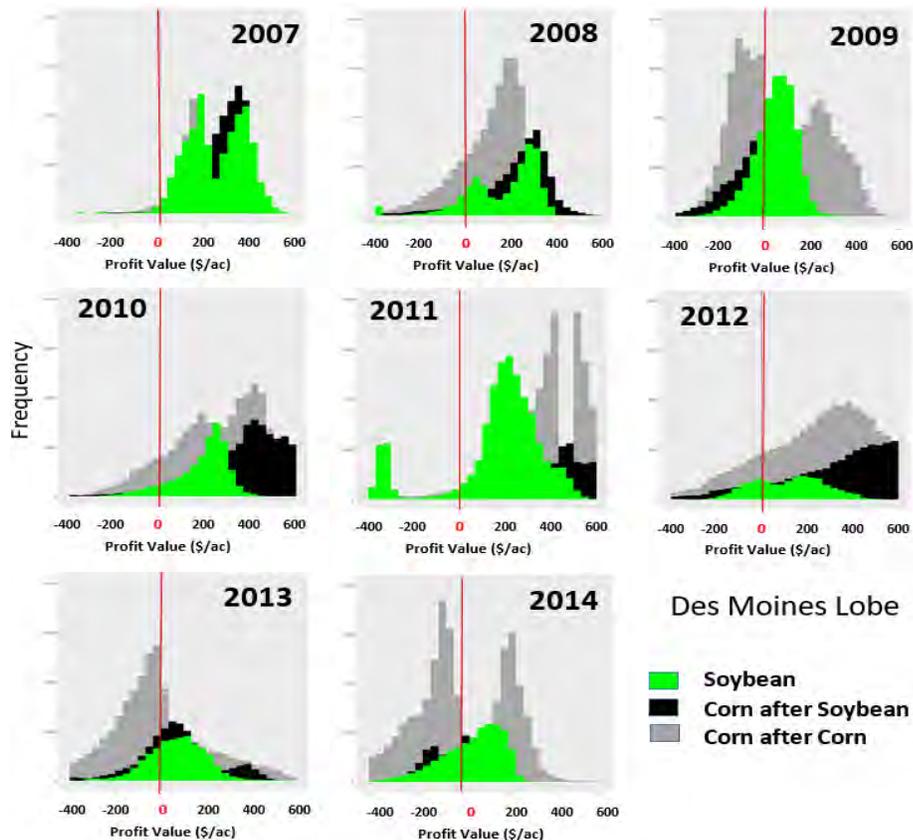


Figure 3. Temporal variability in within-field profit values within the Des Moines Lobe landform region for fields planted to soybean, corn after soybean, and corn after corn between 2007 and 2014.

Distributions of within-field profit values for fields planted to soybean, corn after soybean, and corn after corn for a period between 2007 and 2014 indicate that areas with economic loss ranged from 5% to 45% (Figure 3). The effect of low grain prices and increased land rent prices were more pronounced in 2013 and 2014. The histograms in Figure 3 also indicate bimodal distributions of profit values in some years, including 2008 for soybean and 2009, 2010, and 2014 for corn after corn.

The Des Moines Lobe landform region is characterized by the presence of potholes, which are the remnants of the last glaciation. Although many of the pothole areas have artificial drainage installed, these areas are often flooded and have poor drainage early in the growing season. Cumulative distributions of field-level profit values were generated separately for pothole and non-pothole (upland) areas for fields that had normal spring rainfall (March through May rainfall from 8 to 12 inches) and excessive spring rainfall (>12 inches).

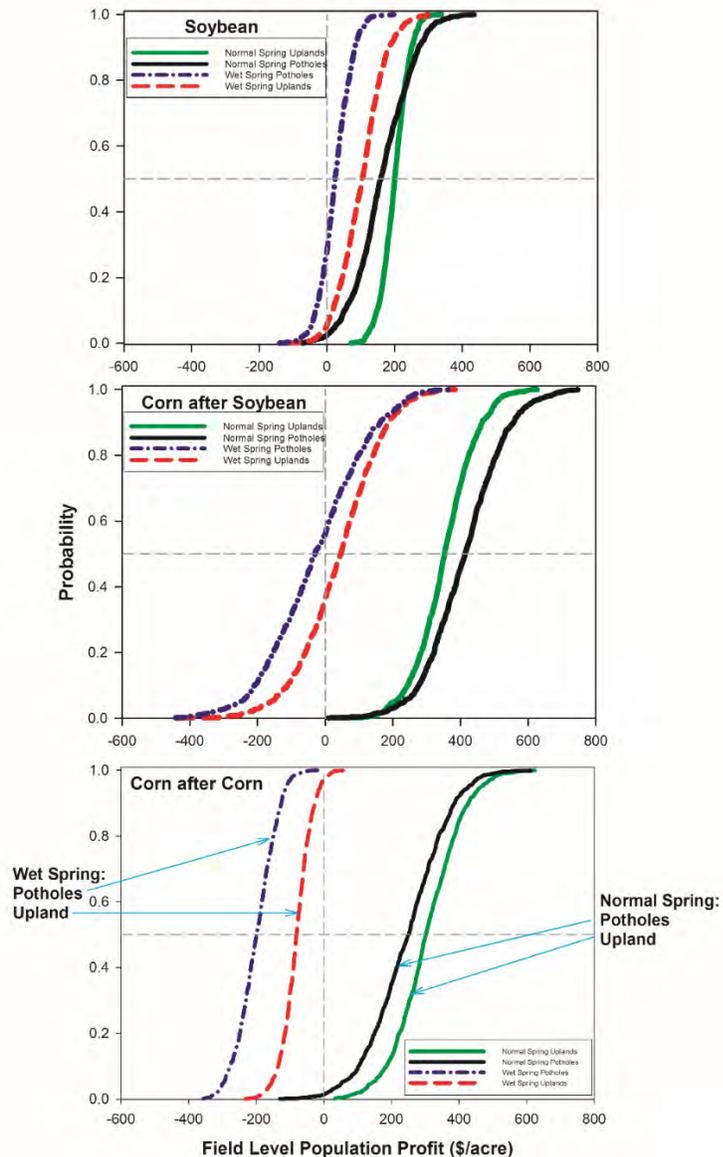


Figure 4. Cumulative distribution functions of field-level profit value for potholes vs upland areas for fields planted to soybean, corn after soybean, and corn after corn within the Des Moines Lobe landform between 2007 and 2014 when spring rainfall was normal (8 to 12 inches) or excessive (>12 inches).

The cumulative distributions in Figure 4 indicate that a corn crop was more likely to be profitable than soybean, and that the field-level profit was substantially reduced in pothole areas compared with upland areas, especially when spring rainfall was excessive. Although soybean fields tended to have a lower profit, they were also less affected by the excessive rainfall and poorly drained pothole areas.

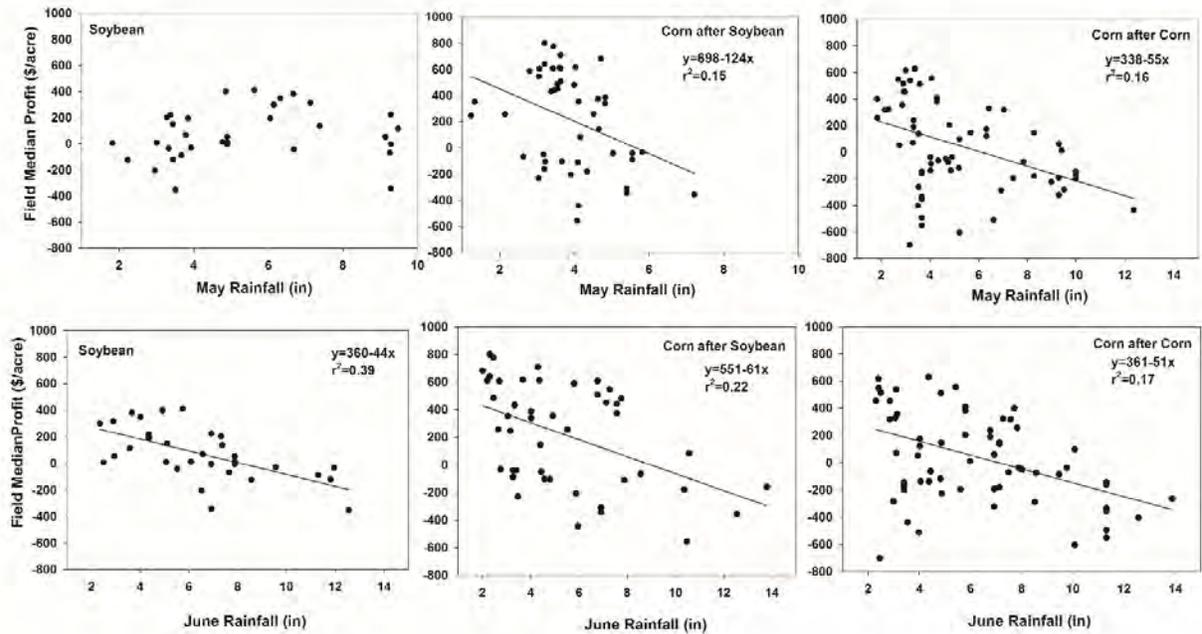


Figure 5. Effect of May and June rainfall on field-level median profits for fields planted to soybean, corn after soybean, and corn after corn within the Des Moines Lobe landform region.

Multivariate analyses of field-level median profit values suggested that early season rainfall was one of the driving factors in reducing profitability within the Des Moines Lobe (data not shown). With each additional inch of May or June rainfall, median field level profit was reduced by \$45 to \$125 acre for fields planted to corn (Figure 5). As shown in Figure 4, compared with corn, soybean fields were unaffected by May rainfall and less affected by June rainfall.

ROI values estimated across soybean and corn fields indicate that in eight of nine years pothole areas had a lower ROI than the upland areas. In 4 of 9 years, pothole areas had economic losses. Only during the drought year of 2012, was ROI higher for pothole areas than for upland areas. These data strongly indicate the need to find management practices or changes in cropping system to reduce economic losses in poorly drained areas (Brandes et al., 2016).

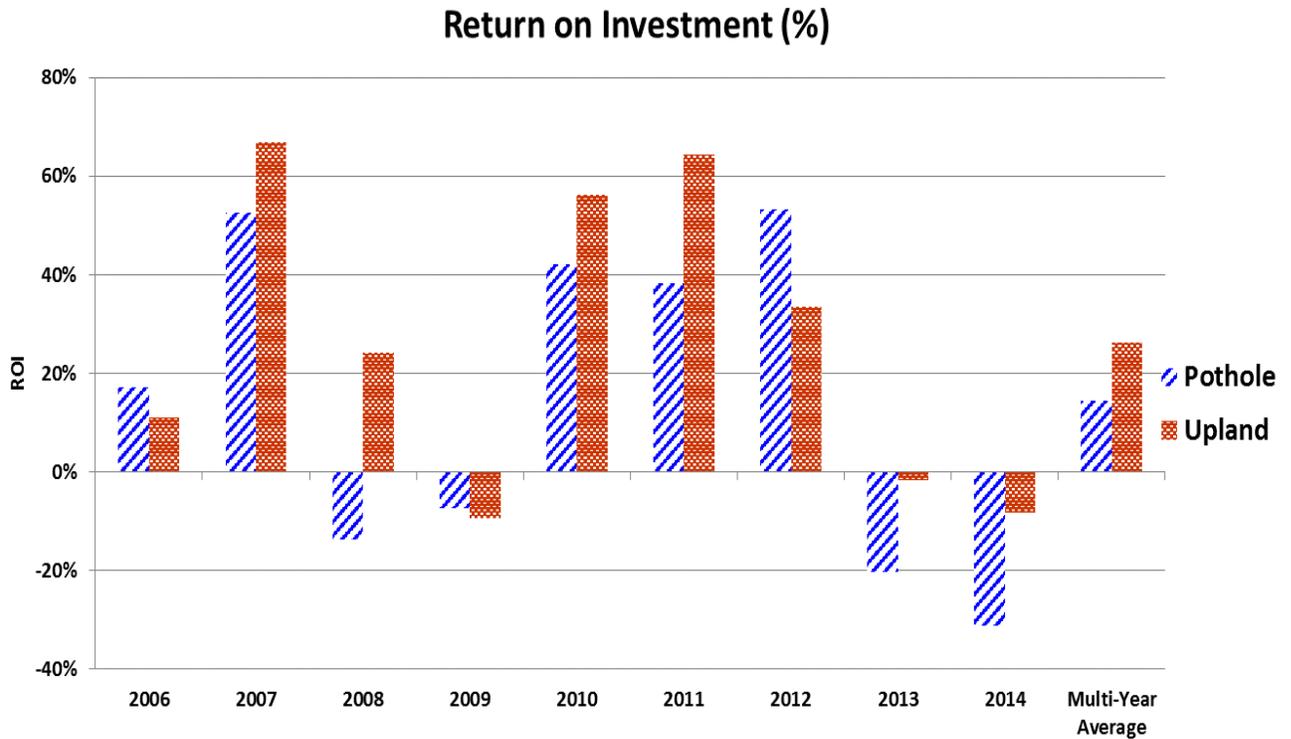


Figure 6. Return on Investment (ROI) for pothole vs upland areas across soybean and corn fields within Des Moines Lobe Landform Region.

Iowan surface

Similar to central Iowa, analyses of 25 fields with 111 site years of data in eastern Iowa (Iowan Surface landform region) showed that substantial portions, up to 50%, had economic loss, especially during 2013 and 2014 (data not shown).

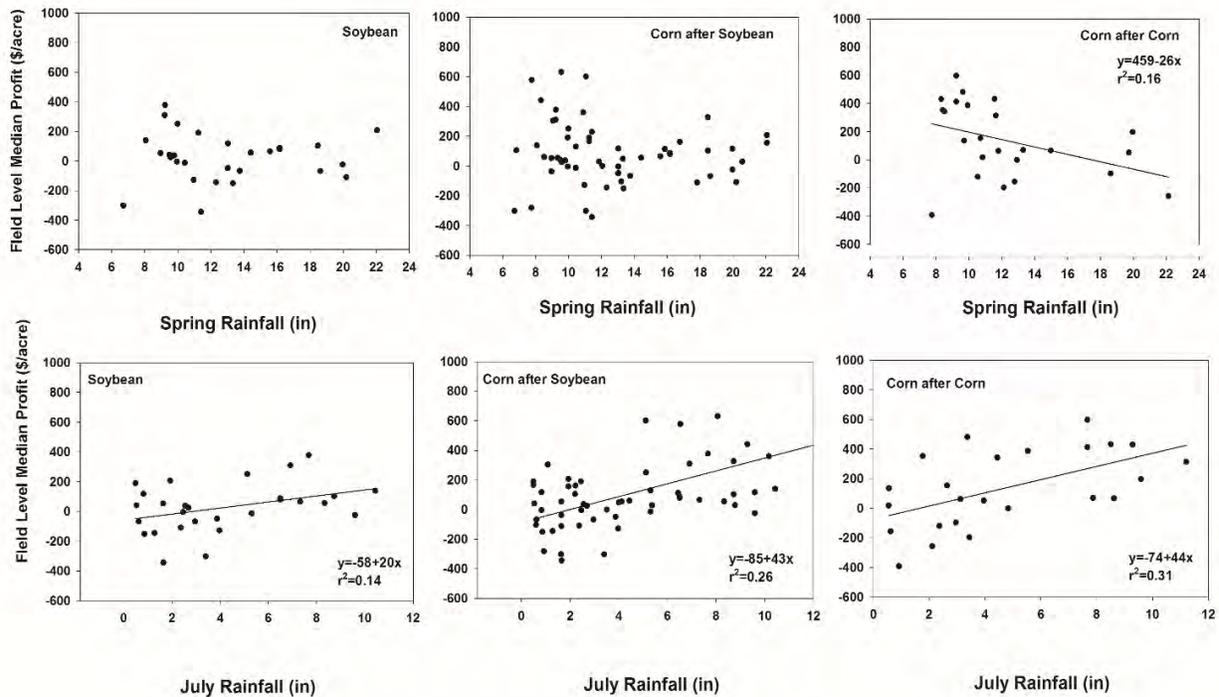


Figure 7. Effect of spring and July rainfall on field-level median profits for fields planted to soybean, corn after soybean, and corn after corn within the lowan Surface landform region.

The effect of early season rainfall, however, was different in eastern Iowa than in central Iowa. Excessive spring rainfall had no significant effect on field level profitability (Figure 7). However, field median profit values tended to increase with above normal July rainfall. This indicates that some of the areas (likely those with sandy soils) ran out water during midsummer and benefited from additional rainfall in July.

The cumulative distribution functions of profit values in Figure 8 suggest that excessively drained within-field areas in eastern Iowa had lower profit compared with the poorly or well drained areas. Some soybean fields, however, tended to be more affected by soil drainage than corn fields.

Analysis of spatial variability in profit, ROI, or standard deviation values across several years suggested that only a small percentage of within field variability could be explained by spatial factors. For example, in several fields, corn suitability rating index (CSR) explained about 16% of spatial variability; drainage, 22%; and soil organic matter explained about 15% of the spatial variability in eastern Iowa. Soils with higher productivity, higher CSR and less excessive drainage tended to have higher profitability, ROI, and lower standard deviation values than those fields with lower soil organic matter and lower productivity.

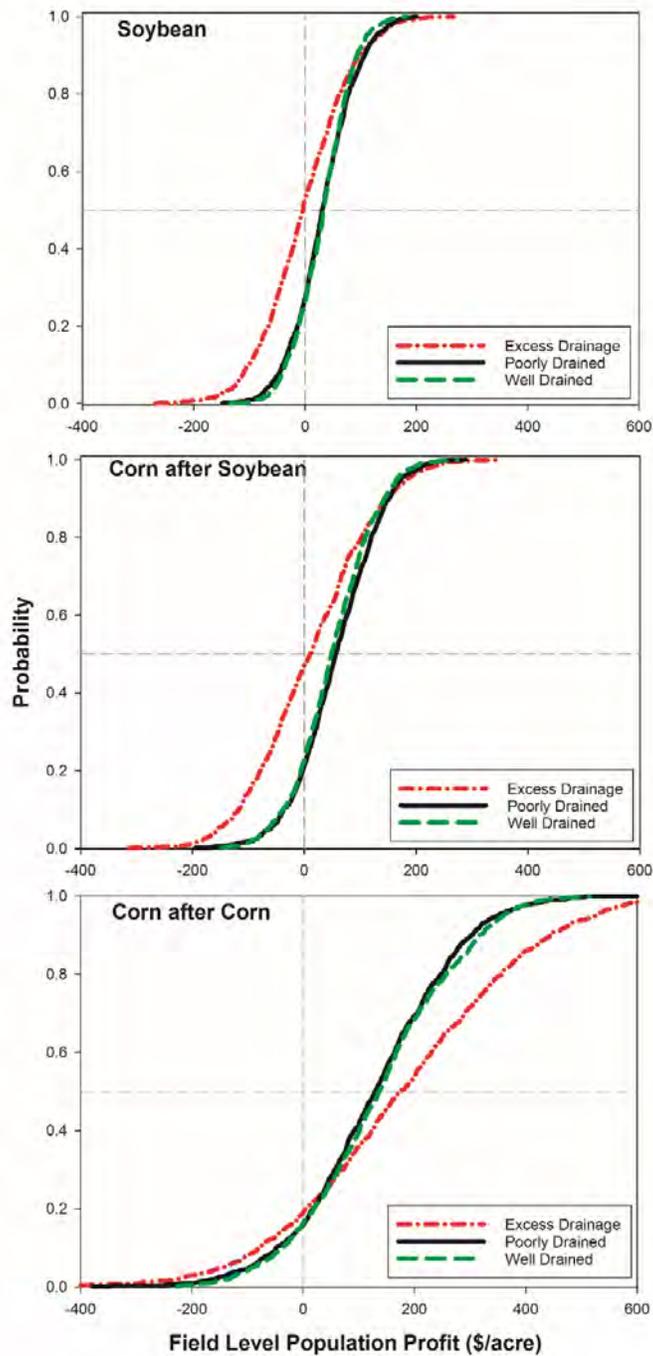


Figure 8. Cumulative distribution functions of field-level profit values for excessively, poorly, and well-drained areas within fields planted to soybean, corn after soybean, and corn after corn within lowland Surface landform region between 2007 and 2014.

Conclusion

Estimated profitability maps and field crop budgets were used to quantify the effect of management, weather, and soil on within-field profitability. Within the Des Moines Lobe, 5% to 45 % of within-field areas had economic loss. Potholes, poorly drained within-field areas, had consistently larger economic losses of between 15% and 75%, with greater losses occurring during a wet spring with more than 12 inches of spring rainfall. While fields planted to corn tended to have higher profitability than those planted to soybean, the corn profitability was more affected by poor soil drainage, especially during wet springs.

During a normal spring, corn fields were more likely to have a larger profit than soybean fields. For the pothole areas, soybean fields were less affected by spring rainfall and had lower economic losses than corn fields. The results indicate that soybean is less affected by excessive moisture and poorly drained soils within pothole areas.

Within the Iowan Surface, approximately half of the within-field areas had economic loss, especially during 2013 and 2014. Excessive drainage had a pronounced negative effect on within-field profitability in soybean compared to corn. The effect of rainfall in the Iowan Surface region, however, was different than within the Des Moines Lobe. Above-normal July rainfall tended to increase profitability in corn fields by \$43 per acre with each additional inch of rainfall indicating that some of the areas (likely sandy or excessively drained) ran out of moisture during midsummer.

This study used spatial corn and soybean yield data and crop budget in conjunction with site-specific rainfall and soil characteristics to identify the degree to which a combination of several factors can be used to help farmers make the best land-use decisions. The presented analyses are critical for guiding the design and development of further studies that can lead to the creation of risk mitigation tools for farmers.

Acknowledgements

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