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Within-Field Profitability Analysis Informs Agronomic Management Decisions in the Mid-Atlantic USA

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Abstract: Yields vary spatially and temporally at the field scale, and recent adoption of yield monitoring has accumulated large amounts of yield data. We assessed within-field spatial patterns of profitability using grower-collected yield data and input cost information for fields in the Mid-Atlantic United States. Three types of profitability pattern categories were identified: economically sensitive, clear profitable–unprofitable zones, and all-profitable. For fields with areas of permanent yield constraints, we demonstrated that the removal of unprofitable areas can increase overall field profitability. The combination of site- and time-specific profitability and yield constraint information can inform future management optimization, including removing field areas from crop production and improving site-specific in-season management strategies.

Arable fields in the Mid-Atlantic region of the United States have high within- and among-field variations in crop performance (Kaul et al., 2005) due to spatially variable soil types and topography, which interact with climate and management factors. To optimize land use in the context of local agroenvironmental conditions, there are opportunities for the application of precision agricultural techniques, such as variable rate soil nutrient applications, pest control, hybrid selection, and variable depth tillage. Because one objective of most growers is to maximize profit, economic incentives are important for encouraging optimized land use (Erickson and Widmar, 2015). However, little research exists assessing economic incentives at within-field scale, and therefore, precisely determining the benefits of management change has been difficult.

Understanding the underlying profitability potential in different areas of agricultural fields allows us to construct area-specific management strategies using information on yield potential and yield constraining factors.

We considered two management interventions to optimize profitability: (i) field areas that are a priori known to be unprofitable and should be considered for alternative use and (ii) field areas that can be made more profitable through improved crop management practices. The objectives of this study were (i) to evaluate the spatial patterns of within-field profitability variations as well as field-average expected profitability for 18 fields in the Mid-Atlantic United States and (ii) to determine opportunities for site-specific management change to increase overall field profitability.

Procedures

The study fields are located in Delaware, Maryland, Virginia, West Virginia, and southeastern Pennsylvania within three physiographic provinces: Coastal Plain, Piedmont, and Blue Ridge (Fenneman, 1938). All of
the selected fields had similar crop rotations: corn (Zea mays L.), soybean [Glycine max (L.) Merr.], and wheat (Triticum aestivum L.) or barley (Hordeum vulgare L.). In some cases, double crop soybean was cultivated following the harvest of small grains. Soil nutrient, pest, weed, and irrigation water management on each field was based on the individual farm's management schemes.

Yield data were collected for corn and soybean with yield monitors on combine harvesters, which were calibrated once per crop season using a calibrated weigh wagon. The calibration process was repeated until the difference between the weigh wagon and the combine weight was below 2%. The fields ranged in size from 5.8 to 46.9 ha, and the number of growing seasons for which digital yield data were available for a particular field ranged from 3 to 12, with a range of 1 to 7 growing seasons for a single crop (Table 1). Six of the 18 fields were irrigated, and the others were rainfed. Postprocessing of yield data was done using the Yield Editor 2.0.7 software (Sudduth and Drummond, 2007) for flow delays, moisture delays, potential overlaps of the harvester paths, and outliers in a localized area. The processed data were then rasterized (6 by 6 m) using the SAGA function (Conrad et al., 2015) within the QGIS environment (QGIS Development Team, 2015).

We calculated site-specific profitability using the following for the fields with available yield data for a single crop ≥ 3:

\[
\text{Probability} = E[\text{Yield}] \times \text{Price} - \text{Cost}
\]

where \(E[\text{Yield}]\) is the expected value of yield (Mg ha\(^{-1}\)), which is the recorded average yield of the individual cell within each field; Price is the average price of a particular crop; and Cost is the average cost of production. We utilized the 10-yr average (2004–2013) price of corn and soybean for the profitability calculation, $169 and $382 Mg\(^{-1}\), respectively (University of Illinois, 2015). The cost of production was determined using the Farm Resource Regions (USDA-ERS, 2000) for 2014 and ranged from $1459 to $1648 ha\(^{-1}\) for corn and $977 to $1080 ha\(^{-1}\) for soybean.

We adopted different scenarios for profitability calculation for both a rented-field scenario and an owned-field scenario, where we subtracted the land rental rate from the total cost. We also estimated the cost of irrigation to be $341 ha\(^{-1}\) (USDA-ERS, 2015), mostly related to the elimination of N fertilizer (Schmidt, 2015). In Field 1, the profitability of soybean under the owned-field scenario was $529 ha\(^{-1}\) compared with $9 ha\(^{-1}\) for corn, and the difference in the cost of production was $583 ha\(^{-1}\). This is in line with a recent analysis where the return from soybean production was $185 ha\(^{-1}\) or more compared with corn in the Mid-Atlantic United States (Schnitkey, 2015). In the Piedmont, the lowest profitability was found in Field 14 ($132 and −$179 ha\(^{-1}\); Table 1). In this region, irrigation effectively improves profitability, which ranged from −$6 to $425 ha\(^{-1}\) (Table 1), even under the rented scenario. This indicates that soil moisture shortage is a major yield limiting factor in this region and that irrigation can achieve positive profits even after taking into account the added cost.

**Soybean**

The profitability with soybean overall was higher than with corn, partly because of the assumed lower cost of production by approximately $500 ha\(^{-1}\) (USDA-ERS, 2015), mostly related to the elimination of N fertilizer (Schmidt, 2015). In Field 1, the profitability of soybean under the owned-field scenario was $529 ha\(^{-1}\) compared with −$9 ha\(^{-1}\) for corn, and the difference in the cost of production was $583 ha\(^{-1}\). This is in line with a recent analysis where the return from soybean production was $185 ha\(^{-1}\) or more compared with corn in the Mid-Atlantic United States (Schnitkey, 2015). In the Piedmont, the lowest profitability was found in Field 14 ($132 and −$179 ha\(^{-1}\); Table 1). In this region, irrigation effectively improves profitability, which ranged from −$6 to $425 ha\(^{-1}\) (Table 1), even under the rented scenario. This indicates that soil moisture shortage is a major yield limiting factor in this region and that irrigation can achieve positive profits even after taking into account the added cost.

### Spatial Patterns of Profitability and Opportunities for Alternative Land Uses

We identified three general categories of within-field profitability patterns: “economically sensitive” (Fig. 1a and 1b), “clear profitable–unprofitable zones” (Fig. 1c and 1d), and “all-profitable” (Fig. 1e and 1f).

The economically sensitive fields were only found in the Coastal Plain region and generally showed high temporal variation in yield pattern due to irregular precipitation and most areas as being, on average, either marginally profitable or unprofitable (Fig. 1a and 1b). This indicates that profitability at a field location strongly depends on the growing season's environmental conditions and the relative prices of inputs and grains. The small margins in profitability suggest that slight improvements in production efficiencies, increased grain prices, reduced input prices, or enhanced localized yields can turn areas from unprofitable to profitable.

In fields with clear profitable–unprofitable zones, areas exist that are either consistently profitable or consistently unprofitable (Field 4; Fig. 1c). The profitable areas presumably have favorable growing conditions, whereas the consistently unprofitable areas of the fields...
experience yield-limiting conditions. The highly profitable areas in these fields have higher-than-field average yield potential, which may warrant increased site-specific inputs like fertilizer.

The consistently low-yielding areas are possibly compacted headlands, areas that experience shading from adjacent woods or wildlife damage, or eroded or poorly drained zones. Since a priori (known prior to growing season) profitability for those field areas is strongly negative, overall field profitability would be enhanced by taking those field areas out of production. Past research has shown that the introduction of herbaceous strips on the field borders can promote wildlife habitats and reduce nutrient losses (Borin and Bigon, 2002) while still allowing equipment turnaround space and minimal effects on the yields of the main crop (Stamps et al., 2008). We evaluated the removal of low profitability areas (less than $−500 ha$\textsuperscript{−1}) from Field 4 (Fig. 1c) and found an increase in overall field profitability from $102 to $157 ha$\textsuperscript{−1}, which can be further increased if conservation subsidies are available. Alternatively, potential yield-constraining factors may be identified and ameliorated to make those field areas profitable, if possible (Oliver, 2010).

Season-specific yield constraints were identified for Fields 9 and 10 (Fig. 1d) from excessive early-season precipitation combined with poorly drained soil for those concave field areas (Soil Survey Staff, 2015). In these fields, unprofitable field areas can also be removed to attain higher overall field profitability. Alternatively, in-season cost-saving decisions may be considered when excessive wetness is experienced, such as foregoing localized sidedress N or pesticide applications.

A third profitability pattern shows all field areas being profitable (Fig. 1e and 1f). This pattern was found for irrigated fields in the Coastal Plain (Fields 6 and 7) and one rainfed field in the Piedmont (Field 15). These are the most preferred conditions, where no additional considerations are warranted and fields can be managed uniformly.

## Conclusions

Field-scale profitability showed higher returns for Piedmont versus Coastal Plain fields under rainfed conditions, but fields in the latter region became more profitable when irrigated. Profitability was also affected by owned versus rented status. Spatially explicit information on profitability and yield constraints can inform future soil and crop management decisions.
such as removing field areas from crop production and improving site-specific in-season management strategies, to improve overall field profitability.

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References


