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# Spatial Variation of Protein, Oil and Starch in Yellow Corn

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**Abstract.** *Significant spatial yield variations are known to exist in cornfields with different soil types, topsoil depth and other variables. Similarly, variations might also be found among the highly valued chemical components in corn kernels. This study investigated the spatial variability of protein, oil and starch content of corn from two conventional cornfields and two high oil cornfields. Whole ears were harvested by hand from 20 to 40 randomly selected locations within each field. A DGPS receiver recorded the location of each collection site. Samples were also collected from hauling vehicles with a segmented probe prior to transport from the field and from the grain stream as trucks were unloaded. A commercial NIR instrument was used to measure protein, oil and starch from each sample collected. Representative yield maps were plotted for each type of corn along with protein, oil and starch maps. Results showed significant variations between fields and between sampling locations. Slight variations were also found between truck probe samples from the same field. Oil content was more variable than protein or starch. The sum of protein and oil content was inversely proportional to starch content. Probe samples appeared to provide the most representative results.*

**Keywords.** Value-added, high oil, post-harvest processing, chemical components, feed, seed.

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## Introduction

Many farmers in Kentucky and the Midwest have used yield monitors extensively to determine yield variability of corn and other grains within fields as the crop is being harvested. The value of some specialty crops, such as high-oil corn, is based on the chemical content of the grain. Determining the oil content of a corn crop while it is being harvested or handled for storage would enable farmers, grain handlers or buyers to separate incoming loads into different bins according to their physical properties. Segregation of corn with higher oil content could lead to increased premiums for producers. At a minimum, knowing the oil content during production or handling would allow a producer to target identity preserved markets.

There are a number of options for a producer to determine the oil content of corn during harvest or before binning. This paper investigated two options that may be available to producers in the near future. Case-New Holland (CNH) Advanced Farm Systems (AFS) group has a joint venture with Textron, Inc. to develop a prototype mobile NIR analyzer that has been tested to a limited degree during the last three harvest seasons (http://www.casecorp.com). Their preliminary tests indicate that oil levels for regular field corn can range from about 2.5 to 6.0% and from 5.5 to 8.5% in high oil corn. Protein levels can range from 5.0 to 12.0%.

Market premiums are often based on small increments of each value-added component. For example, high-oil corn producers have typically been offered a premium of 1 cent per bushel for each 0.1% of oil above a 6.0% base level (House, 1999). Hence, precise measurements are essential for both the buyer and seller. As with yield monitors, it is highly unlikely that market values will be determined by measurements from an instrument on a combine, but this information could help producers determine the variability that exists within each field and allow them to make management decisions that affect profitability. This technology may be utilized by producers in conjunction with yield monitors to track the variation within fields, between years, and due to production practices (Morgan, 1999; Needham, 1999).

Some lower-cost stationary NIR instruments are available to measure oil, starch, fiber, kernel density and other intrinsic properties of grain. Representative samples of grain could be taken from trucks, analyzed, and binned according to the results. A number of manufacturers produce stationary NIR instruments that may decrease in cost and be feasible for producers to purchase and operate.

Another option could be an on-line sensor that would be positioned in the dump pit or unloading area to control the flow or grain in the system, such as a distributor on a bucket elevator. Some on-line NIR sensors are available that could be used to control product flow during binning. However, little data is available to evaluate the variability and potential for segregation of corn by oil or protein based on the different strategies. This research was conducted to determine where variations in protein, oil and starch occurred in corn and the feasibility of segregation using NIR sensors.

The objectives of this research were to:

1. Determine the spatial variation of protein, oil and starch in two high-oil and conventional corn fields in Kentucky,
2. Obtain probe samples from trucks before unloading and measure protein, oil and starch to determine variation within loads, and
3. Collect grab samples at one-minute intervals during truck unloading to determine the feasibility of using an on-line NIR sensor in the dump pit area for segregation.

## Materials and Methods

Two conventional and two high-oil cornfields were selected for harvest during the fall of 2001. The conventional fields were located in Shelby County (east of Louisville, KY). No-till production was practiced on the farm and both fields were planted to Pioneer 3335. The first field (SC1) was corn after corn and had relatively high damage level due to cob rot. The second field (SC2) was corn after soybeans and had a lower damage level. The exact damage level in both fields was not determined. Both fields were harvested and sampled on September 18, 2001.

One high-oil cornfield was harvested on September 20, 2001 in Hopkins County (HC) (near Madisonville, KY) that was replanted with W7355 due to flood damage. The second high-oil cornfield was planted in McLean County (MC) (near Calhoun, KY) with the same variety (W7355) and harvested on September 26,2001. Both fields were planted to the same population density (30,000 seeds/ac) and a similar fertility program was applied. The HC field had a conventionally tilled seedbed while the MC field was planted into a no-till seedbed.

Field samples of ear corn were collected by hand in approximately twenty to forty locations as the combine worked in the field. Between four and eight ears were harvested within three rows at each location. Harvest locations were determined using a Trimble® 132 DGPS receiver with satellite correction.

On all farms corn was transferred from the combine into a grain cart, then into semi-trucks with two hopper bottoms. Each hopper was probed twice in the field with a compartmentalized probe with sample cups 8.3 cm long with a 7 cm gap between sample cups. Samples were bagged and labeled individually after collection.

At least three additional grab samples were taken from the flowing grain stream, as each truck hopper was unloaded. Grab samples were collected at approximately one-minute intervals during unloading at all locations.

Field, truck probe and grab samples were transferred to the UK Grain Quality Lab for analysis the same day they were harvested and placed in a freezer upon arrival in the Grain Quality Lab. Whole ears from the conventional cornfields were shelled, blended and analyzed as one sample for each location. In contrast, whole ears of high-oil corn were shelled and analyzed individually from each location. Protein, oil and starch levels were measured with an NIRsystems Model 6500 by Infratec® using the base equations from WinISI (Eden Prairie, MN). The oil calibration equations were expanded with thirty collected samples using the University of Kentucky Regulatory Services solvent extraction method for oil content.

## Results and Discussion

### *Field Samples*

Whole ears from each high-oil corn (HOC) location were shelled and analyzed separately with results averaged for each location in the field. Table 1 summarizes the average and standard deviation of the protein, oil and starch for the four fields sampled. The average protein content was 7.6, 7.3, 7.2, and 8.7% dry basis for fields SC1, SC2, HC, and MC, respectively. At a significance level of 5% the average protein content measurements at random locations in each field were equal for SC1, SC2. HOC in the MC field had significantly higher protein content than corn from other fields that were tested, whereas the MC field had the lowest level of protein.

Oil content was significantly different at each location. The average oil content in the MC field samples was 6.95%, but was 8, 59, and 65 percent lower in HC, SC2, and SC1 fields, respectively. Starch content levels were significantly higher in SC1 and SC2 fields than in HC

and MC fields, however differences in starch content between SC1 and SC2 fields or between HC and MC fields were not significant. The concentration of starch was generally inversely proportional to the sum of protein and oil content.

Table 1. Average values (and standard deviations, dry basis) for protein, oil, and starch content of corn samples collected randomly from each field during the fall of 2001.

| Field Location | Protein % | Oil % | Starch % | Number of Locations |
|---|---|---|---|---|
| Shelby 1 (SC1) | 7.59 (1.49) | 2.41 (0.69) | 74.3 (2.01) | 24 |
| Shelby 2 (SC2) | 7.25 (1.09) | 2.82 (0.55) | 74.5 (1.78) | 22 |
| Hopkins (HC) | 7.19 (1.17) | 6.39 (1.21) | 69.9 (2.97) | 41[1] |
| McClean (MC) | 8.73 (1.54) | 6.95 (1.44) | 69.9 (2.73) | 39[2] |
| Lsd (0.05) | 0.35 | 0.32 | 0.71 | |

[1,2] A total of 279 and 213 ears were analyzed for Hopkins and McLean County, respectively.

The standard deviations for oil content were greater in the two high-oil cornfields (MC and HC) than in the conventional cornfields. Intuitively, if ears from each location were analyzed and averaged, the average oil content was identical to that found from the analysis of individual ears. However, the standard deviation of the oil content was lower (0.83 and 0.85 for HC and MC, respectively). Maps showing yield, protein, oil and starch for the MC and SC1 fields are shown in Figures 1 through 4 and Figures 5 through 8, respectively.

### *Probe Samples from Trucks in Fields*

Table 2 shows the average and standard deviation of the protein, oil, and starch content of samples collected with the compartmentalized probe from all trucks used in each of the four fields of study. All truck beds had two hopper-bottom sections for rapid unloading by gravity. Approximately 44 samples were collected from each semi-truck (two probe samples from each hopper with eleven individual compartments for each probe). The protein, oil, and starch content were determined for each compartmentalized sample. The average protein content was 7.2, 7.3, 6.7, and 8.9% in SC1, SC2, HC, and MC fields, respectively. As with hand-harvested samples, protein levels in SC1 and SC2 fields were essentially equal, significantly higher than in the HC field and significantly lower than the MC field.

More variation was found with oil content, which was 8.0% in the MC field and 11, 66, and 74 percent lower in HC, SC2, and SC1 fields, respectively, and is comparable to the differences found in hand-harvested samples. Similarly, oil concentrations were significantly different in each field. Starch content levels were essentially equal in both SC fields and significantly lower in the HOC fields. As with hand-harvested samples, starch content was inversely proportional to the sum of protein and oil content.

Table 2. Average values (and standard deviations, dry basis) of protein, oil, and starch content of corn collected with a compartmentalized probe from loaded trucks in each field.

| Field Location | Protein % | Oil % | Starch % | Number of Samples |
|---|---|---|---|---|
| SC1 | 7.21 (0.52) | 2.06 (0.66) | 76.1 (2.26) | 103 |
| SC2 | 7.33 (0.60) | 2.69 (0.92) | 75.8 (2.61) | 118 |
| HC | 6.68 (0.79) | 7.14 (0.95) | 71.5 (3.43) | 190 |
| MC | 8.95 (0.60) | 8.04 (0.75) | 66.5 (1.58) | 240 |
| Lsd (0.05) | 0.15 | 0.20 | 0.61 | |

Average values and the standard deviation of the protein, oil and starch samples by truck number and hopper in the MC field is shown in Table 3. The average oil for the field was 8.0% (Table 2), yet this value varied between 7.5 and 8.8% for probe samples collected from each hopper and between 7.6 and 8.6% for combined probe samples from each truckload. Table 3 also shows that significant differences in average protein, oil and starch levels were observed between some truckloads.

Table 3. Average values (and standard deviations, dry basis) for protein, oil, and starch content from HOC samples collected from each truck and hopper location at the MC field.

| Truck Number | Hopper Location | Protein % | Oil % | Starch % |
|---|---|---|---|---|
| 1 | Front | 8.90 (0.52) | 7.48 (0.72) | 67.4 (1.42) |
| | Back | 9.47 (0.54) | 7.75 (0.72) | 66.5 (1.42) |
| | Avg. | 9.18 | 7.62 | 67.0 |
| 2 | Front | 9.60 (0.54) | 8.00 (0.68) | 66.3 (1.34) |
| | Back | 8.96 (0.56) | 7.81 (0.70) | 66.6 (1.47) |
| | Avg. | 9.28 | 7.91 | 66.5 |
| 3 | Front | 8.62 (0.56) | 8.16 (0.67) | 66.2 (1.37) |
| | Back | 8.42 (0.58) | 8.29 (0.64) | 66.2 (1.29) |
| | Avg. | 8.52 | 8.22 | 66.2 |
| 4 | Front | 8.62 (0.58) | 7.86 (0.64) | 66.2 (1.27) |
| | Back | 8.65 (0.57) | 7.98 (0.70) | 67.0 (1.36) |
| | Avg. | 8.64 | 7.92 | 66.6 |
| 5 | Front | 9.04 (0.59) | 8.35 (0.67) | 66.5 (1.38) |
| | Back | 9.21 (0.59) | 8.76 (0.66) | 65.7 (1.37) |
| | Avg. | 9.13 | 8.55 | 66.1 |
| Lsd (0.05) | Avg. loads | 0.21 | 0.27 | 0.63 |

### *Grab Samples as Trucks Unload*

Table 4 shows the average and standard deviation of protein, oil, and starch content for grab samples taken, as trucks were unloaded. At least three samples were collected from the grain stream at approximately one-minute intervals as each hopper was emptied. The average protein content was 7.6, 7.8, 7.0, and 8.7% for SC1, SC2, HC, and MC fields, respectively. The average oil and starch contents were essentially equal for corn from fields SC1 and SC2 as well as for loads from the two HOC fields, HC and MC, which concur with samples collected by previously described methods. Average oil values were significantly lower from SC1 and SC2 fields compared to HOC fields HC and MC, which was expected. Conversely, average starch values were significantly higher in fields SC1 and SC2. As previously noted, starch content was inversely proportional to the sum of protein and oil content.

Table 4. Average values (and standard deviations, dry basis) for protein, oil, and starch content for collective grab samples of corn from trucks used at each location.

| Field Location | Protein % | Oil % | Starch % | Number of Samples |
|---|---|---|---|---|
| SC1 | 7.61 (0.26) | 3.18 (0.76) | 73.0 (1.20) | 25 |
| SC2 | 7.77 (0.46) | 3.23 (0.44) | 72.4 (1.33) | 20 |
| HC | 7.04 (0.44) | 7.21 (0.56) | 69.9 (1.34) | 18 |
| MC | 8.72 (0.38) | 7.34 (0.59) | 67.0 (1.70) | 24 |
| Lsd (0.05) | 0.26 | 0.35 | 0.82 | |

In the two no-till fields of conventional corn (SC1 and SC2) oil content was higher in SC2. The SC1 field was planted to a corn-after-corn crop rotation and had a significant amount of cob rot damage. The SC2 field was in a corn-soybean rotation and had a lower level of damage. No significant differences in protein and starch content levels were found between these fields regardless of the sampling method. However, oil content was found to be different with field and probe samples but not with grab samples.

Oil levels were significantly higher in high-oil cornfields than in conventional cornfields, as expected. Between the two HOC fields, all three sampling methods showed that the MC location had a significantly higher percentage of protein and oil. The HC field was replanted due to flood damage relatively late in the growing season that may have reduced the oil content relative to the MC field. Starch levels were not significantly different between field and grab samples but were significantly lower with probe samples in the MC field.

Ideally all three sampling methods would predict the same protein, oil, and starch content. However, all three components varied considerably according to the sampling method. The probe results (Table 2) appeared to give the most representative samples. Each hopper of the truck was probed twice using a compartmentalized grain trier with eleven divisions. This provided the most representative sample because grain was mixed by the combine during harvest, by transport into a grain cart, and by a second transport into the truck.

## Conclusions

Some differences in protein, oil and starch were found between the fields selected in this study. More work is needed to determine whether there might be an economic incentive to segregate grain loads as they are delivered from the field. Such a system would need to be designed to minimize the amount of time required to sample and analyze each load so that the hauling vehicle could return to the field quickly enough to maintain high harvest efficiency. Otherwise, additional hauling vehicles may be needed in the operation.

### *Acknowledgements*

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# Appendix

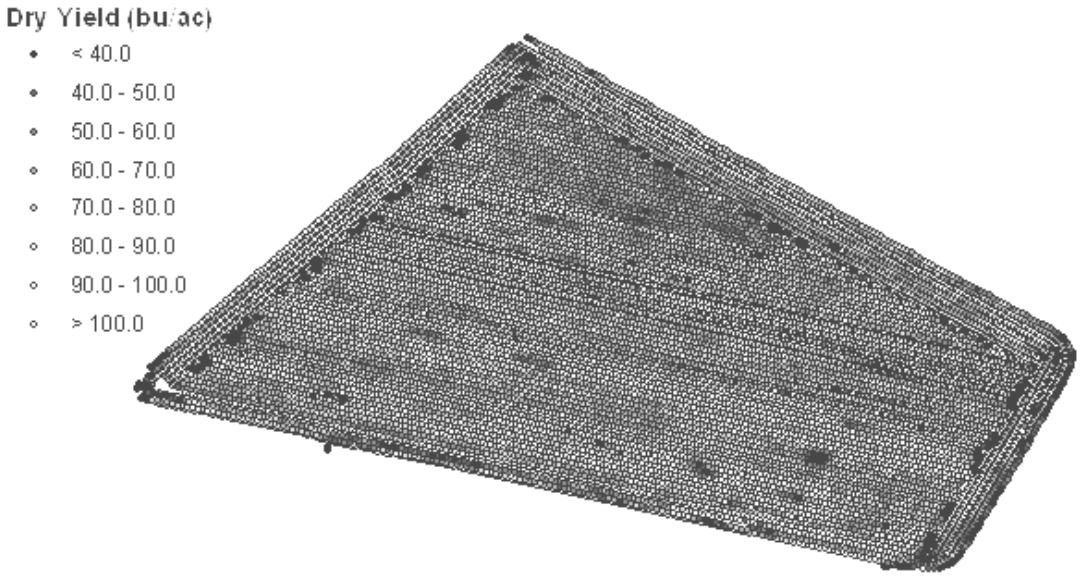


Figure 1. Yield map for high-oil cornfield in Hopkins County, KY.

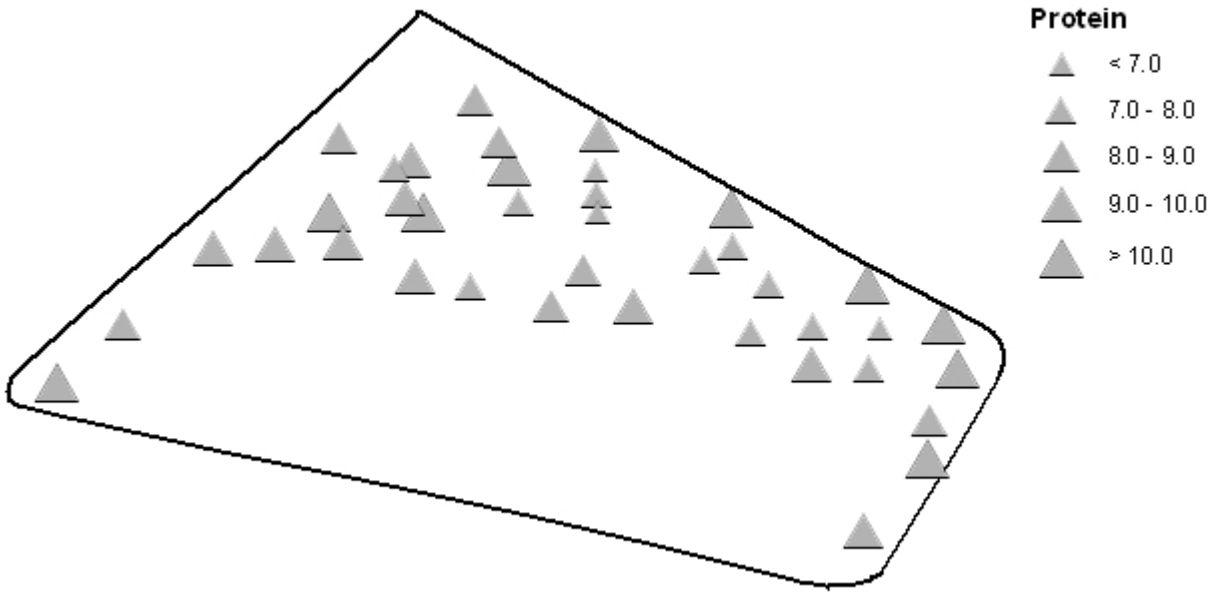


Figure 2. Map of sample locations in Hopkins County field with results of protein analysis.

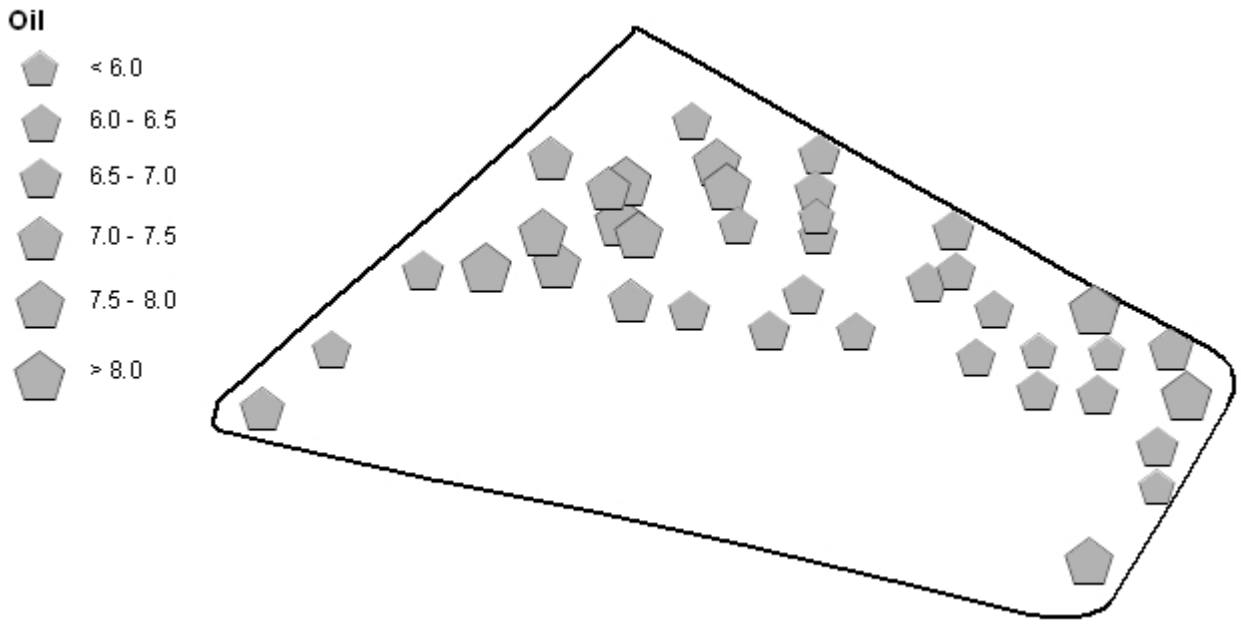


Figure 3. Map of sample locations in Hopkins County field with results of oil analysis.

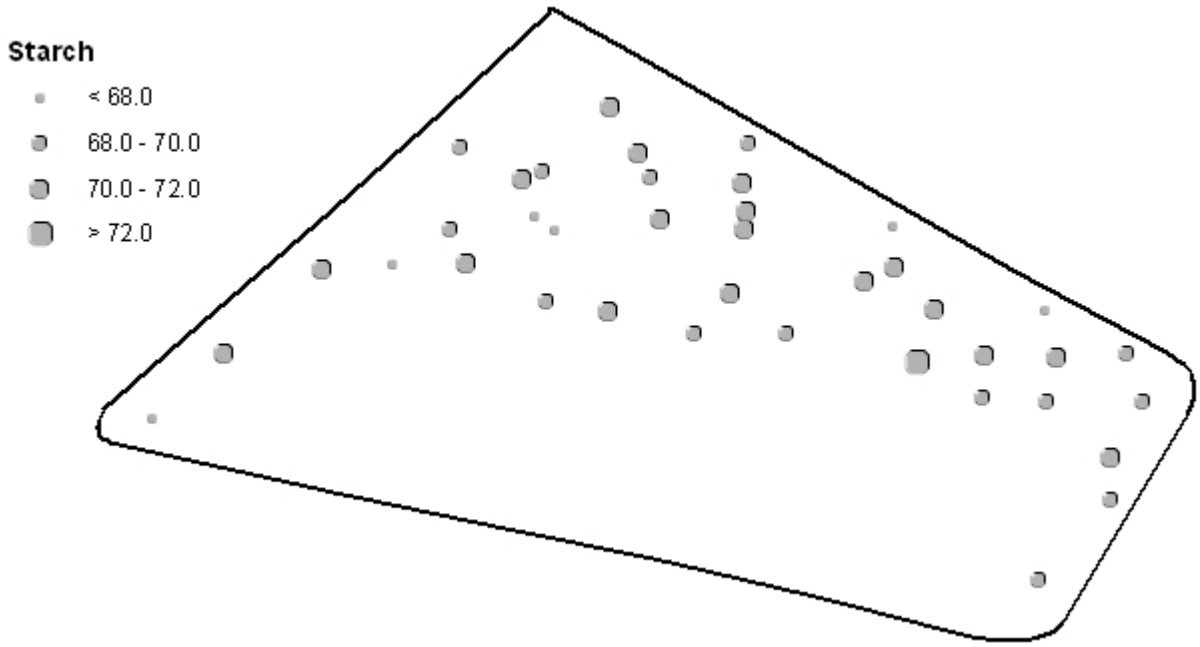


Figure 4. Map of sample locations in Hopkins County field with results of starch analysis.

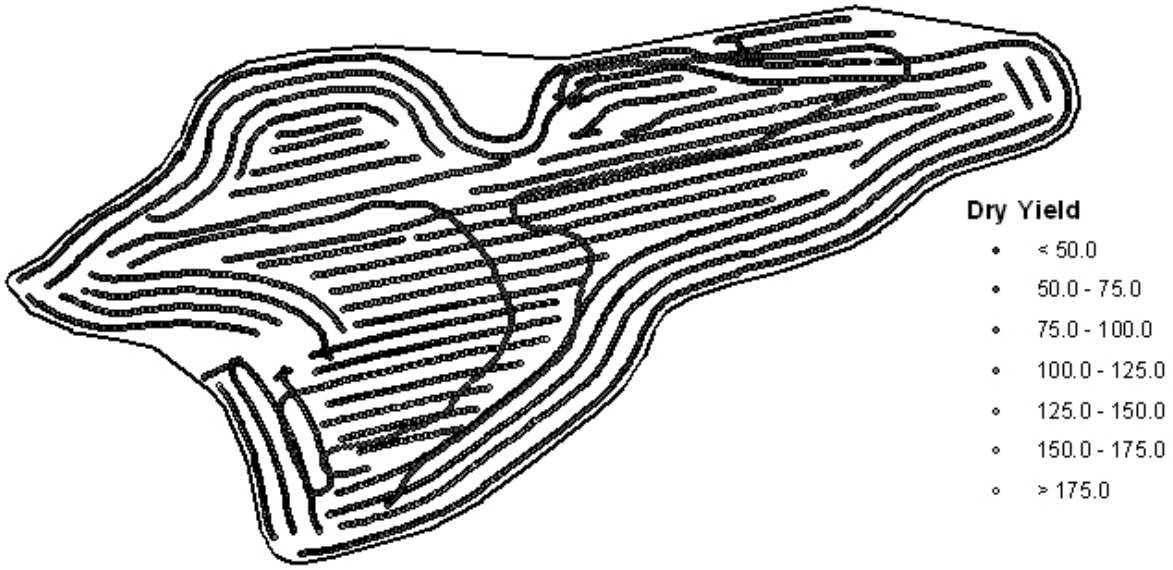


Figure 5. Yield map of cornfield SC1 in Shelby County, KY.

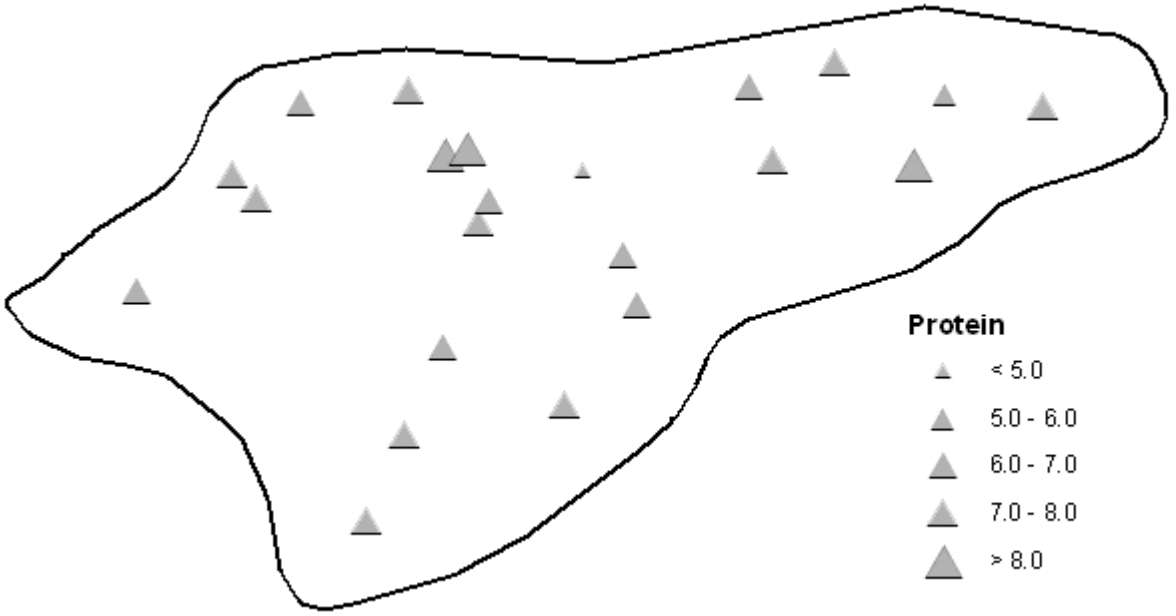


Figure 6. Map of sample locations in Shelby County field SC1 with results of protein analysis.

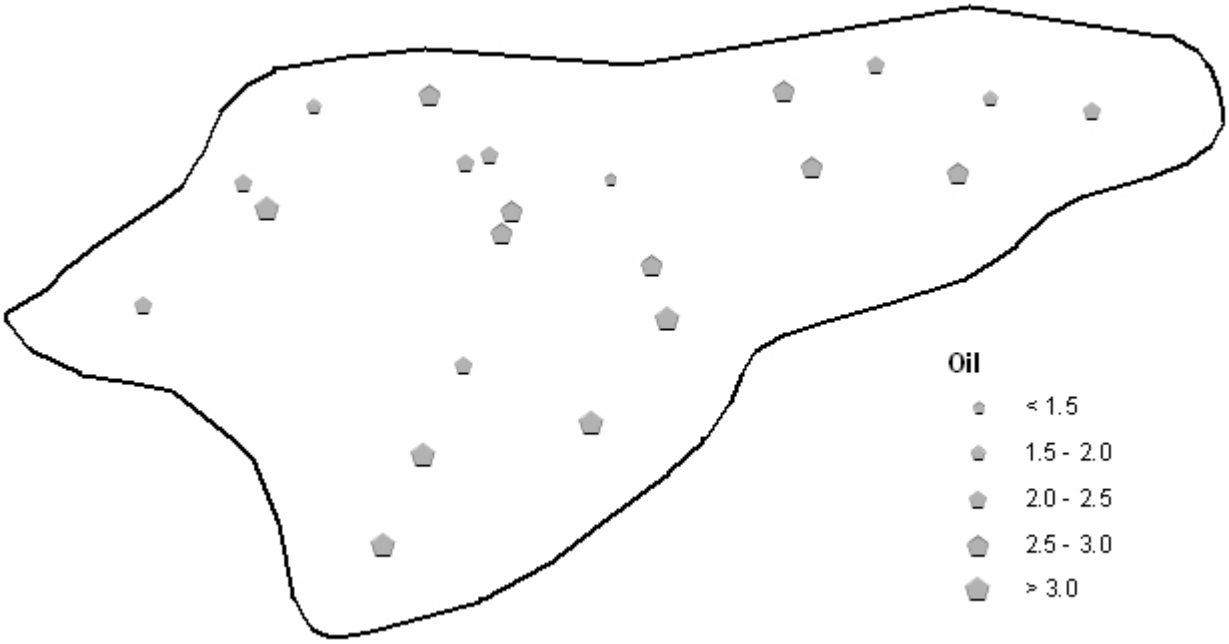


Figure 7. Map of sample locations in Shelby County field SC1 with results of oil analysis.

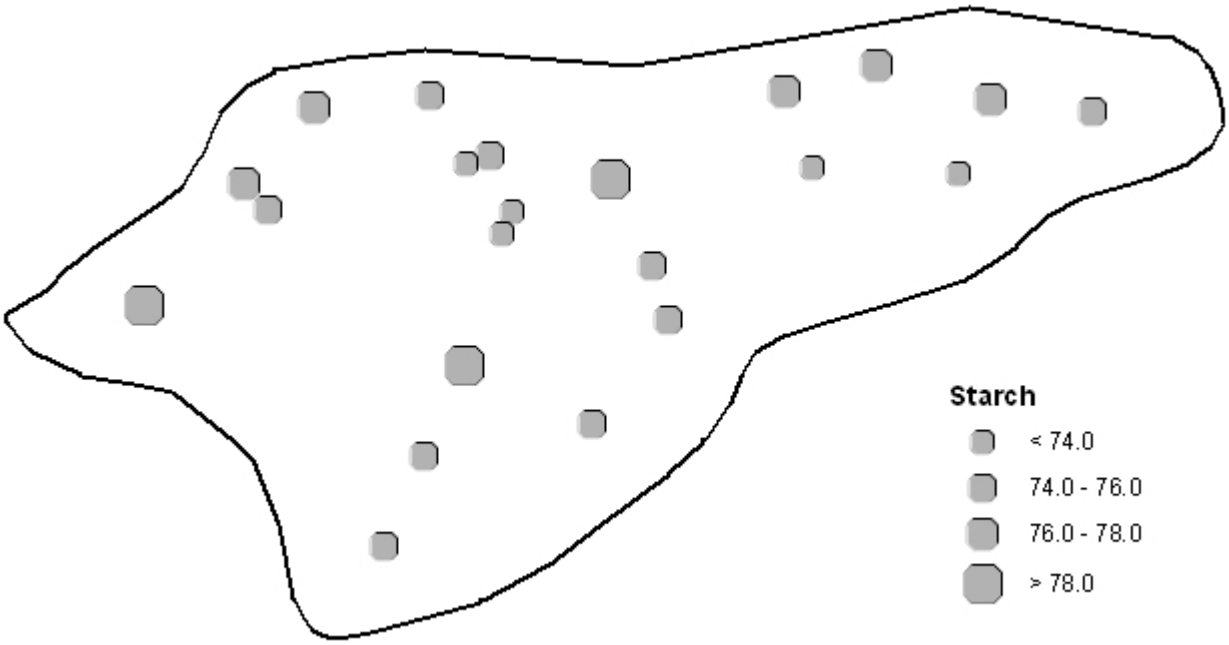


Figure 8. Map of sample locations in Shelby County field SC1 with results of starch analysis.