Introduction

Most fertilizer recommendation programs contain these crucial steps: 1) collecting representative soil samples; 2) conducting accurate and precise laboratory analysis; and 3) using a well-calibrated fertilizer recommendation model to estimate fertilizer recommendations. The first step...collecting a soil sample...may seem simple, but it is not. And obtaining an accurate and representative soil sample is important because it is the basis for fertilizer recommendations from soil test results.

A representative soil sample is one that adequately portrays the nutrient content of the area sampled. There are several excellent papers that review various aspects of soil sampling protocols (Kitchen et al., 1990; Blackmer et al., 1991; Buchholz, 1993; Skopp et al., 1995; Clay et al., 1997; Franzen and Cihacek, 1998; Franzen, 1999; Fleming et al., 1999; Franzen and Kitchen, 1999; Ferguson and Hergert, 2000; Clay et al., 2002; Chang et al., 2003; Clay et al., 2004). These papers recommend that a soil sampling protocol should consider how the fertilizer is applied, that at least 12 to 20 cores should be combined into a single sample, and that individual samples should be collected from sub-field areas where differential management occurred. As a rule, the more soil nutrient variability within the sampling zone the more difficult it is to obtain a representative sample. In other words, if the nutrient concentrations of a sampling area are highly variable, then obtaining a representative sample is very difficult.

Clay et al. (2002) proposed four specific guidelines for soil sampling fields impacted by prior management. First, producers need to keep track of where fertilizers containing immobile nutrients are band-applied. Application of this type may cause small-scale variability for many years after application. To avoid over-sampling fertilizer bands, sampling protocols for fields with residual bands should be followed. Second, sample areas where animals were confined separately from the rest of the field. Third, whenever possible avoid soil sampling guess rows (i.e., edge rows of planter passes). Fourth, recommendations are improved by including at least 15 to 20 individual cores in a composite sample. If the residual bands are present, and the placement is unknown, then the number of samples per composite may be closer to 30. In many situations, the importance of sampling old homesteads separately from the rest of the field is underestimated. The first step in precision nutrient management should be to identify and sample old homesteads or animal confinement areas separately from the rest of the field.

Materials and Methods

Soil samples (0 to 6 in. depth) from at least a 200 by 200 ft. grid were collected from fields located in eastern South Dakota and north-central Missouri (Clay et al., 2002). South Dakota samples were analyzed for Olsen-P, while Missouri samples were analyzed for Bray-1 extractable-P (Brown and Rodriguez, 1983). Parent materials in the South Dakota sites were glacial till or loess, while at the Missouri site the soil...
was weathered loess with a well defined claypan. Elevation, latitude and longitude, and apparent electrical conductivity surveys were conducted in all fields (Johansen et al., 2001; Lund et al., 1999; Kitchen et al., 2003). Evidence at the site or historical photographs obtained from the USDA-FSA offices were used to identify old homesteads. For comparative purposes the 80% confidence interval for a composite sample containing 20 individual cores was determined. The mean and standard deviation were both calculated using Microsoft Excel (Microsoft Corporation, Seattle, Washington).

**Results and Discussion**

Sampling protocols that consider historical management are important, particularly in fields where farm animals were confined or fed. Soil samples taken within these areas may have elevated P and potassium (K) levels for decades after the animals have been removed. These samples will influence both the composite core sampling requirement (variance or standard deviation) and the soil nutrient concentration. For example, a survey of 13 grid soil sampled fields showed that excluding the old farmsteads from the composite sample decreased P concentration and the confidence intervals associated with composite sample (Table 1). High confidence intervals can result in accurate fertilizer recommendations. These results were attributed to very high soil nutrient concentrations in the area of the old homesteads and that excluding these areas from a composite sample reduced the nutrient variation within the remaining sampling zone (Figure 1).

**Table 1. The influence of excluding the old farmstead from a whole field composite sample on P soil test results and 80% confidence interval.**

<table>
<thead>
<tr>
<th>Location site #</th>
<th>Soil test P 80% CI for</th>
<th>20 cores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farmstead Included</td>
<td>Excluded Included</td>
</tr>
<tr>
<td>South</td>
<td>ppm</td>
<td>ppm</td>
</tr>
<tr>
<td>1</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Dakota</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Missouri</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>

Not including the homestead area in the composite sample improved the precision (80% confidence interval) by as much as 97%. These results show that the first step in collecting reliable soil samples for fertilizer recommendation is to identify and sample old farmsteads separately from the rest of the field and that the fertilizer recommendation may be compromised if these areas are not excluded.

After old homesteads have been identified and sampled separately, the resulting fertilizer recommendation will be improved. Another consideration is management changes over time. Most fields have been managed differently than current management (Figure 2). In much of the U.S. Midwest prior to 1960, fields sizes were typically 40 acres or less. Aerial photographs show that, over time, larger fields were created by combining small fields (Figure 2). It is difficult to provide guidance on which historical management practices should be considered and which ones can be ignored. An assessment must be conducted on a field-by-field basis.

Figure 1. A 1956 USDA-NRCS aerial image collected from a South Dakota field and a soil P contour map based on soil samples collected in 1995. Current images show that the farmsite has been removed from the field.

Figure 2. A sequence of aerial images collected between 1939 and 1990 from a Missouri field.

If the field shown in Figure 2 is subdivided based on the 1982 rotational sequence (Figure 3), the resulting analysis shows sub-field areas A, B, C, and D have soil test P values of 10, 8, 11, and 20 parts per million (ppm) P, respectively. If the fertilizer recommendation for this field was based on a whole field sample (mean 12 ppm), then
area B would be under-fertilized and area D would be over-fertilized. It is important to point out that sampling the four sub-field zones separately increased the sampling requirement. Prior to sub-dividing, a manager needs to ask the question: Is the value of the spatial information worth the cost of data collection and analysis?

Summary and Conclusion

A consequence of larger farms has been the loss of farmstead sites. In many cases, these sites have been put into crop production. For example, in Brookings County, South Dakota a random survey of 384 quarter sections in aerial photographs collected in 1950 and 1990 showed that the number of quarter sections with building sites decreased from 218 to 180 over the 40 years. Given the number of management changes that have occurred in production fields over the past 100 years, it is difficult to provide step-by-step guidance for developing sampling protocols that account for historical management. When considering immobile soil nutrients like P and K, farmers and agricultural consultants need to realize that fields maintain a memory.

Factors that should be considered when developing soil sampling protocols include: locations of historic homesites, fence lines, farming directions, crops, consolidation of fields, roads, abandoned railroads, stock ponds, and feedlots.

Understanding historical changes in management is important because row crops often received more fertilizer and lime than pastures and manure was typically applied to fields close to the farmstead. Human-induced effects have a lasting impact on soil test results. Isolating areas impacted by historical management prior to soil sampling is paramount for developing reliable crop nutrient plans.

Acknowledgments

Funding for the research discussed in this paper was provided by USDA-CSREES-406, United Soybean Board, North Central Soybean Board, South Dakota Corn Utilization Council, South Dakota Soybean Research and Promotion Council, USDA-ARS, and the National Aeronautics and Space Administration (NASA).

References


Figure 3. A 1982 aerial photo showing how polygons were drawn around four areas with different historical management practices. Two farmstead areas on the south end of the field were removed and the field divided as it was cropped in 1982.


This Site-Specific Management Guideline was prepared by:

**Dr. David E. Clay**  
Professor, Soil Science  
South Dakota State University  
Brookings, SD 57007  
605-688-5081  
E-mail: david.clay@sdstate.edu

**Dr. C. Gregg Carlson**  
Professor, Soil Science  
South Dakota State University  
Brookings, SD 57007  
605-688-5081  
E-mail: carlson.gregg@ces.sdstate.edu

**Mr. J.L. Kleinjan**  
Research Associate  
South Dakota State University  
Brookings, SD 57007  
605-688-5105  
E-mail: jonathan.kleinjan@sdstate.edu