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Collecting Data from a Permanent Grid Sampling Frame via a Mobile Mapping Instrument

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EXECUTIVE SUMMARY

In recent years, the National Agricultural Statistics Service (NASS) has made strides to improve its data collection processes and to evaluate a number of cost-saving initiatives. The June Area Survey (JAS) is one of the largest annual surveys NASS conducts and is based on an area frame. This is also NASS's only survey collected via in-person interviews using pencil and paper. Frame construction and face-to-face data collection efforts are expensive and time-consuming processes. It has been proposed to replace the area frame with a permanent grid sampling frame.

The sampling units for the JAS are segments of land. In the segment creation process, segment borders follow physical features on the ground (i.e., an edge of a field, a road, a river, etc.). Fitting segment boundaries to physical features is a manual and laborious process, with overall annual costs of approximately 2.6 million dollars. One way to lower the labor costs for this survey is through the use of a permanent frame requiring limited manual adjustments. The proposed grid frame has roughly equal-sized units and shaped areas called grid cells. This frame is based on the Public Land Survey System's (PLSS) one-square-mile sections in the 30 states in which the PLSS is the primary surveying method. In these 30 states, roads are often aligned with the PLSS section lines. However, exceptions to this rule and gaps in PLSS coverage exist. In states where land surveying is based on alternate systems (non-PLSS states), a grid frame with one-square mile sections would be generated using ESRI's ArcGIS software.

Because grid cells do not necessarily follow the infrastructure on the ground and often cut across fields, a mobile mapping instrument was developed to automatically calculate acreages of surveyed fields. A team of researchers from NASS and Iowa State University's Center for Survey Statistics and Methodology developed the prototype mobile mapping instrument in 2012. The instrument was designed to operate on an iPad and can be used to collect data for either grid cells or JAS segments.

This paper describes the results of research initiated to test collecting data using grid cells utilizing the mobile mapping prototype instrument. Enumerators (field interviewers) in North Carolina, Pennsylvania, and South Dakota visited with farm operators during the summer of 2014. A random sample of 20 grid cells was selected in each state. South Dakota was selected because it is based on the PLSS system. Because North Carolina and Pennsylvania are not based on the PLSS system, a fishnet was created using ArcGIS software and grid cells were selected. Enumerators identified a total of 917 tracts, which are unique land operating arrangements (457 agricultural and 460 non-agricultural). Enumerators delineated all the tracts and attempted to conduct interviews with farm operators for all tracts with agriculture. Within each agricultural tract, they delineated the field boundaries for any kind of agriculture in the specified field. In addition, they were asked to record any challenges while enumerating the grid cells, time spent with and without the farm operator, and any issues related to the use of a mobile mapping instrument such as connectivity and glare associated with the iPad.

Results indicate that the lack of physically identifiable boundaries for grid cells presented a substantial problem to enumerate and increased respondent burden as additional operators had to be contacted to complete a survey form based upon a very small portion of a field. Another lesson learned is that the average time it took enumerators to draw off the fields with the mobile mapping instrument was not reasonable for the approach to work operationally.

The best practices to enhance usability of the mobile mapping instrument is to simplify the design. Many enumerators in rural areas do not have high speed Wi-Fi in their homes; therefore, it is important to be mindful of connectivity limitations. Sophisticated GIS features may not be practical due to connectivity requirements. Further, enumerators need to have a higher level of technical expertise than with the current operational procedures. Future efforts should continue to obtain feedback from enumerators on instrument enhancements and to test the instrument in all possible environments.

In conclusion, the use of grid cells as an enumeration unit for the JAS is not feasible for NASS. However, the mobile mapping instrument is still a promising tool for modernizing the agency data collection activities. Because the instrument can be used with both grid cells and JAS segments, research should continue with the application being on JAS segments. One way to reduce the time taken to enumerate segments is to provide segments with pre-delineated field boundaries. Information from the Farm Service Agency Common Land Units, imagery from the National Agricultural Imagery Program (NAIP), and topology maps could be used to create the segment pre-delineated field boundaries.

RECOMMENDATIONS

1. Do not use grid cells as an enumeration unit to collect data for the JAS.

2. Provide enumerators with JAS segments with pre-delineated field boundaries using sources such as Farm Service Agency's Common Land Units, imagery from the National Agricultural Imagery Program (NAIP), and topology maps among other sources.

3. Implement the following instrument and training modifications:

    a. Store all required imagery on the same server as the instrument.

    b. Test the instrument in all possible environments.

    c. Make the following enhancements to the instrument:

        i. Increase the width of the segment border to distinguish it from roads.

        ii. Retain the vertices of the incomplete polygon when a split fails.

        iii. Add a pan tool to allow enumerators to navigate around the imagery without selecting.

        iv. Clarify warning messages to indicate the number of fields involved in a merge and the reason a merge failed.

        v. Ignore slight finger movements when a button is pushed.

        vi. Display the calculated GIS acres for each field at the bottom of the Section D form.

    d. Remove the following features from the instrument:

        i. Option to double tap to complete a split.

        ii. The geo-location feature.

        iii. Menu requiring the selection of the type of other crop.

    e. Incorporate more role-play practice exercises that mimics live interviews during field enumerators training.

    f. Reinforce the use of the iPad's airplane mode and the invert colors options.

4. Investigate new devices and screen protectors as they come on the market to further address the issue of screen visibility on the iPad.

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Abstract

The National Agricultural Statistics Service (NASS) conducts the June Area Survey (JAS), which is based on an area frame. Segments of land comprise the sampling units for the JAS. Building and constructing an area frame is expensive and time consuming. The agency is evaluating the use of a permanent grid sampling frame as a cost-saving initiative. The proposed grid frame would include sample units having roughly equal-sized and shaped areas called grid cells. The grid cells would be stratified by agricultural intensity and content and then a stratified random sample drawn. A challenge associated with this proposed approach is that only a portion of an agricultural field may lie within the selected grid cells whereas currently sampled segments have boundaries that follow roads or other physical features. Because of the presence of partial fields, mobile mapping technology may be critical for proper identification of the areas to be included in a sampled grid cell. Using mobile mapping technology would also allow for replacing the aerial photo and paper questionnaires, thus modernizing NASS's data collection efforts and improving data quality. To test the concept of permanent grid cells in conjunction with the mobile mapping instrument, enumerators (field interviewers) in North Carolina, Pennsylvania and South Dakota visited with farm operators during the summer of 2014. For each sampled grid cell, the enumerators completed an evaluation form to obtain information on a variety of issues including 1) those associated with the grid concept, 2) use of a mobile mapping instrument, 3) connectivity and 4) visualization problems associated with the iPad (e.g. sun glare). This report documents the challenges faced, as well as the lessons learned, from collecting data using grid cells with the mobile mapping prototype and discusses future instrument enhancements.

Key Words: Mobile Mapping, Area Frame Survey, GIS, Data Collection, Interface Design

1. Introduction and Background

In recent years, the National Agricultural Statistics Service (NASS) is making strides to improve its data collection processes and to evaluate a number of cost-saving initiatives. The June Area Survey (JAS) is one of the largest annual surveys NASS conducts and is based on an area frame. This is also NASS's only survey solely collected via in-person interviews using pencil and paper. Frame construction and face-to-face data collection efforts are expensive and time-consuming processes. It has been proposed to replace the area frame with a permanent grid sampling frame. The sampling units for the JAS are segments of land. In the segment creation process, segment borders are adjusted to follow physical features on the ground (i.e., an edge of a field, a road, a river, etc.) (Cotter et. al, 2010). Determination and preparation of segments are labor-intensive and expensive with overall costs around 2.6 million dollars per annum. The proposed grid frame has roughly equal-sized units and shaped areas called grid cells which require very limited manual intervention. The grid frame is based on the Public Land Survey System's (PLSS's) one-square-mile grid cells in the 30 states in which the PLSS exists. In these 30 states, roads are often aligned with the PLSS section lines. However, exceptions to this rule and gaps in PLSS coverage exist. In states where land surveying is based on alternate systems (non-PLSS states), a grid frame with one-square-mile grid cells can be generated using ESRI's ArcGIS software. Figure 1 illustrates the grid frame concept (outlined in yellow) compared with a JAS segment (outlined in red).

Figure 1: Grid cell (outlined in yellow) vs. JAS segment (outlined in red)

Because grid cells do not necessarily follow the infrastructure on the ground and often cut across fields, a mobile mapping instrument was developed to use Geographic Information Systems (GIS) technology to calculate the acreage of fields surveyed. In 2012, a team of researchers from NASS and Iowa State University's Center for Survey Statistics and Methodology developed a prototype mobile mapping instrument called Geographic Information Running Area Frame Forms Electronically (GIRAFFE) (Gerling et. al, 2015). The instrument is designed to operate on an iPad and can be used to collect data for either grid cells or JAS segments. A series of studies were needed to evaluate whether or not NASS could implement the permanent grid frame operationally. Phase I was the actual development of the instrument in 2012. The objective of the 2013 study (or Phase II) was to determine whether the mobile mapping instrument's calculated GIS acreages were comparable to the acreages reported by farmers during the JAS before moving forward with testing grid cells. Enumerators (field interviewers) were provided the completed aerial photos from previously collected data and tasked with replicating the field boundaries within the mobile mapping instrument. Results indicated that there was strong agreement between JAS farmer reported and GIS acreage (Boryan et. al, 2017). Based on this result, this study was initiated to test collecting data using grid cells with the mobile mapping prototype instrument (Abreu et. al, 2015; Lawson et. al, 2015). This paper documents the challenges faced as well as the lessons learned from collecting data using these grid cells and describes future instrument enhancements. Before discussing the study and the results, it is necessary to understand NASS's area frame and the JAS (Section 2); the origins of the permanent grid sampling frame (Section 3); and the features and functionality of the mobile mapping prototype instrument (Section 4).

2. NASS Area Frame Construction and the June Area Survey

NASS's JAS is based on an area frame, which ensures complete coverage of all land in the U.S. First, all land in a state is stratified using GIS technology, such as satellite imagery, aerial photography, and geo-referenced crop-specific land cover data known as the Cropland Data Layer (CDL) (Boryan et al., 2014). This step is a manual process where Primary Sampling Units (PSUs) are digitized (electronically identified using GIS software) based on physical boundaries and other features on the ground (i.e. railroads, roads, etc.) and classified into the defined strata for a state. A sample of PSUs is selected and smaller, similar-sized segments (each about a square mile [640 acres]) of land are delineated within selected PSUs. Segment boundaries follow natural boundaries that can be easily identified outdoors, such as roads, ditches, edges of fields, rivers, tree lines, etc. This "tweaking" of boundaries is a labor-intensive process. In general, staff divide a PSU of four square miles into four segments, one-square mile each. Next, one segment is randomly chosen from within each sampled PSU (see Figure 2). This process avoids segment delineation for non-selected PSUs, thereby saving resources. In the current sampling scheme, the JAS replaces the oldest 20% of the segments with new segments rotated in each year. Eight staff working year-round are required to select the incoming rotation for the sample. A state receives a completely new area frame approximately every fifteen years. This on-going process takes twenty-five staff with salary and benefits totaling about 2.6 million dollars and another 100,000 dollars in equipment, software, printing, and mailing of materials. (See Cotter et. al 2010 for further details on the JAS design).

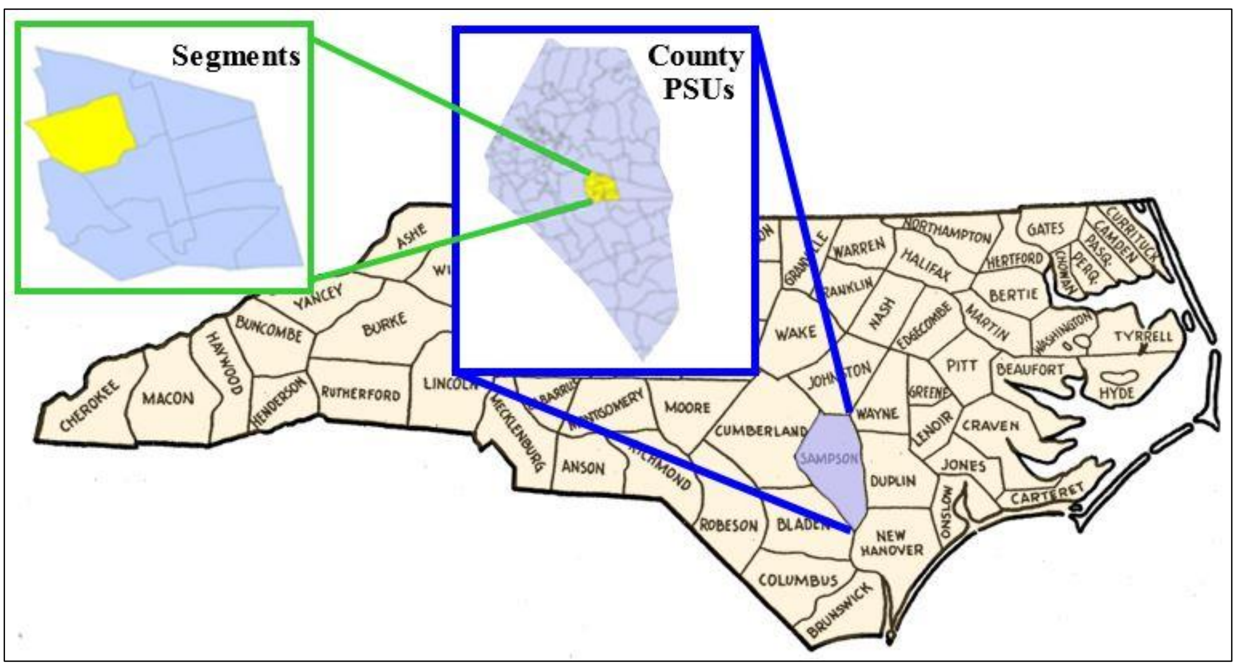

Figure 2: NASS area sampling frame for North Carolina

JAS segments (outlined in red in Figure 3) are pre-screened during the month of May prior to the June data collection period. During pre-screening, enumerators divide each segment into separate tracts of land that represent each unique operating arrangement. Each tract is assigned a letter and drawn in blue on the aerial photo (Figure 3). Tracts are then screened for agricultural activity of which about 42,000 of them are classified as agricultural tracts. JAS data collection is conducted during the first two weeks of June. At this time, enumerators return to only the agricultural tracts and conduct interviews using the JAS questionnaire, which collects detailed agricultural information about the operator's land, both inside and outside the segment. Enumerators complete a separate paper questionnaire for each agricultural tract operation within the segment. Farm operators identify all field boundaries (outlined in red in Figure 4) on the aerial photo and report acreage and the crop planted or other land use of each individual field (pasture, woods, wasteland, etc.).

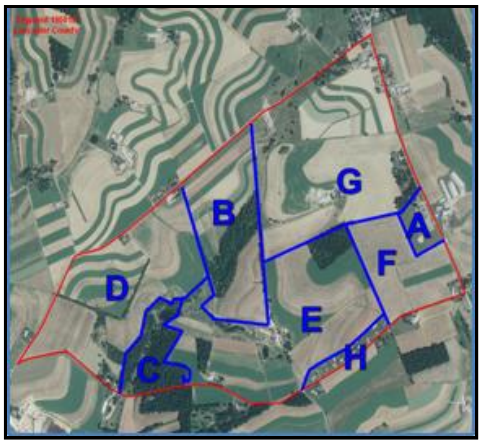

Figure 3: The area outlined in red is the segment. Tracts are outlined in blue and labeled with letters.

Figure 4: Tracts are outlined in blue and labeled. Individual fields are outlined in red within the tracts and labeled with numbers.

3. Theoretical Grid Sampling Frame

NASS is exploring the concept of a permanent grid area frame to replace the area frame segments as a cost-saving initiative. The permanent frame sample units are roughly equal size and shape (one-square mile) and are called grid cells. The permanent grid frame concept can be based on the PLSS when it is available (USGS, 2016). PLSS is a surveying method used over large parts of 30 states in the United States to spatially identify parcels of land, especially in rural and undeveloped areas. Land is divided into (mostly) rectangular areas ranging from a 24-mile by 24-mile quadrangle down to a one-mile by one-mile square grid cells (See Figure 5). In Figure 6, states included in the PLSS are identified in blue. Figure 5 illustrates PLSS section lines over a National Agricultural Imagery Program (NAIP) aerial photo (USDA FSA, 2015). In Figure 5, the PLSS section lines are closely aligned with physical features on the ground. However, even in PLSS states, section lines do not perfectly match with roads, railroads or rivers causing fields to be split. In non-PLSS states, a grid frame can be generated using ESRI's ArcGIS software. In this case, the grid cell lines do not have any correlation with physical features on the ground. In the end, the United States can be divided into roughly one-mile by one-mile square grid cells. This can reduce the resources required in the preparation for the JAS. The sampling process can then be automated to handle stratification and sample selection of these grid cells using NASS's current methods. The enumerator can then be responsible for collecting all agricultural data within the defined grid cells.

Figure 5: Public Land Survey System (PLSS) section lines overlaying the NAIP imagery

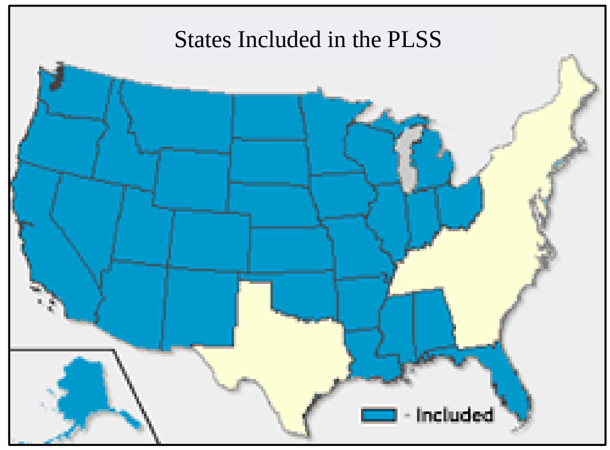

Figure 6: States included in the Public Land Survey System (PLSS)

A challenge with grid cells is that fields may not be fully contained within a grid cell boundary. In these instances, information must be collected for just the portion of the field that lies within the grid cell. In Figure 7, the pink boundary identifies the middle of the road, while the red line shows the actual grid cell boundary. In this case, the enumerator must collect information on the portion of land to the south of the road (labeled as "Partial Field" in Figure 7). It may be difficult for an agricultural operator to report the acreage correctly viewing a printed aerial photo. Thus, having a mobile mapping instrument that uses GIS technology to automatically calculate the acreage can be used to eliminate the need for farm operators to report acreage for land within the grid cell. An overview of the mobile mapping instrument and all its features is described in the next section.

Figure 7: Partial field identified at the left bottom corner of the grid cell

4. Prototype Mobile Mapping Instrument

Development of the prototype mobile mapping instrument began in 2012. The instrument is an offline-capable web application designed to run within the Safari browser on an iPad. A substantial amount of the JAS data collection takes place in rural areas that tend to have intermittent signal; therefore, it is essential that the instrument be able to operate without an Internet connection. Prior to data collection, enumerators run a cache routine to store the required imagery in the iPad's memory. The instrument has two main parts (Figure 8). The left side of the screen contains the aerial imagery and the right side of the screen displays general field information that replaces the Section D (Appendix A) part of the paper questionnaire.

Tracts and fields are delineated on digital imagery in place of the paper aerial photo. Detailed field information is captured in a streamlined electronic version of the Section D questionnaire. Field boundaries are captured as polygons with the Section D data linked as attributes.

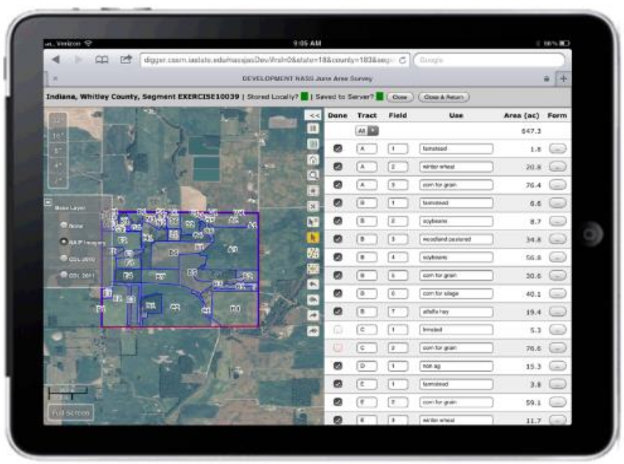

Figure 8: Mobile mapping instrument

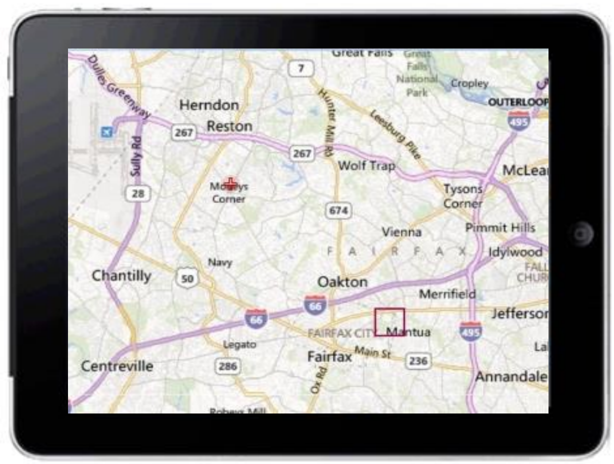

Figure 9: Geolocation feature

If a wireless broadband connection is available, the instrument transmits a copy of the data to the web server as it is entered or modified by an enumerator. Otherwise, the data remains stored locally on the iPad. All data are automatically transmitted to the web server whenever a wireless broadband connection is available. Up-to-date traffic light symbols are displayed to indicate if the data has been stored locally on the iPad, saved to the server, or both.

The instrument contains a wide range of GIS tools and features. Enhancements are made each year to improve usability. A sophisticated geolocation feature was added to the prototype instrument in 2014 to help the enumerators orient themselves in relation to the segment or grid cell (Figure 9).

4.1 Aerial Imagery Part of the Instrument

The aerial imagery part of the instrument displays a red segment or grid cell boundary overlaid on digital imagery on the left side of the screen which can also be run in full screen mode (Figure 10). The digital imagery is obtained from the National Agricultural Imagery Program (NAIP), which acquires aerial imagery during the agricultural growing seasons in the continental U.S. Typically, this digital ortho-rectified aerial photography is available to governmental agencies and the public within two to four months after acquisition.

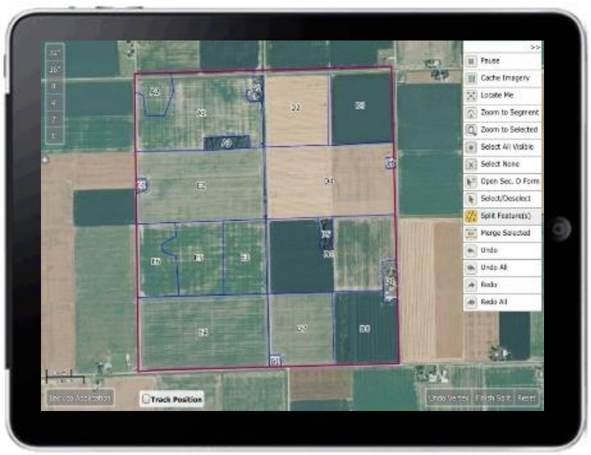

Figure 10: Instrument shown in full screen mode

Figure 11: Displays the CDL in place of NAIP imagery

The instrument is capable of presenting additional resource material using Web Map Service overlays. This allows the ability to replace the NAIP imagery with another layer, such as roads or the Cropland Data Layer (CDL) (Figure 11). The CDL is an annual crop specific land cover product, depicting more than one hundred unique crop categories across the nation. NASS derived this cropland area monitoring program via remote sensing (satellite data) using a supervised land cover classification approach. The national CDL product (Boryan et. al, 2011) is available on NASS's CropScape web portal at http://nassgeodata.gmu.edu/CropScape.

The majority of the functions are performed within the aerial imagery part of the instrument using the various tools created within OpenLayers. OpenLayers is an open-source JavaScript mapping library and provides basic web and GIS functionality.

In the JAS enumeration process, enumerators use a blue grease pencil to outline tracts and a red grease pencil to outline fields on the paper aerial photo. The process within the mobile mapping instrument requires "splitting" a segment or grid cell into tracts and fields instead of outlining them. The polygons representing each of the fields are created by using the split feature tool. Splitting ensures that all land parcels are included within the segment or grid cell boundary.

The split tool is integrated into a toolbar on an OpenLayers map in the instrument. The map allows a loaded segment or grid displayed over NAIP aerial imagery to be repeatedly split into component tracts and fields. A merge tool is used for updating/correcting errors made when splitting. Several additional tools are part of the OpenLayers map, including zoom tools, selection tools, and undo/redo buttons to make it more user friendly. The mobile mapping instrument has touch screen pinch zooming capabilities, but also includes buttons to quickly zoom to preset levels.

4.2 Instrument's Electronic Section D Form

The right side of the mobile mapping instrument's main screen (Figure 12) displays the calculated GIS acreage along with general information about all of the polygons or fields that have been delineated on the aerial imagery. A button to the right of each field is used to open the electronic Section D form (Figure 13).

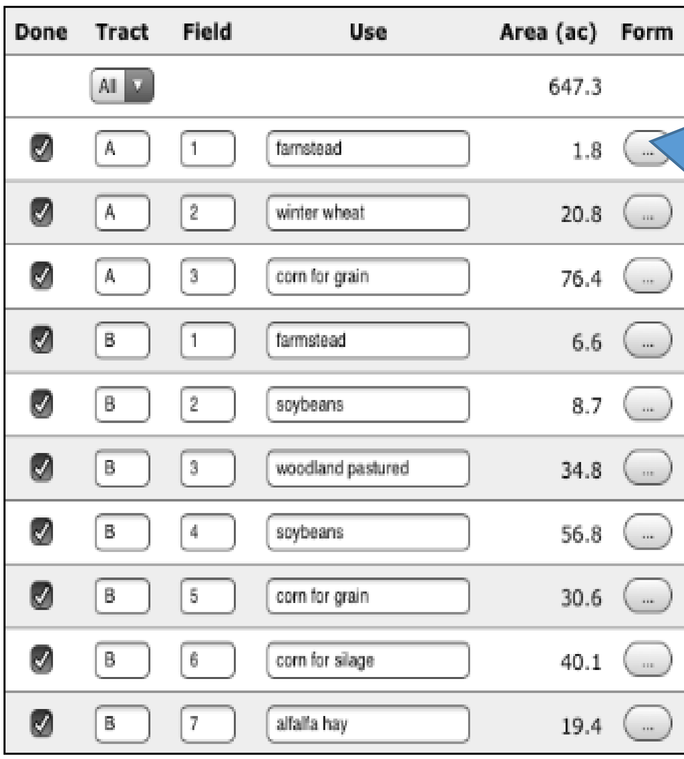

Figure 12: The right side of main screen displays the calculated GIS acreage and general field information

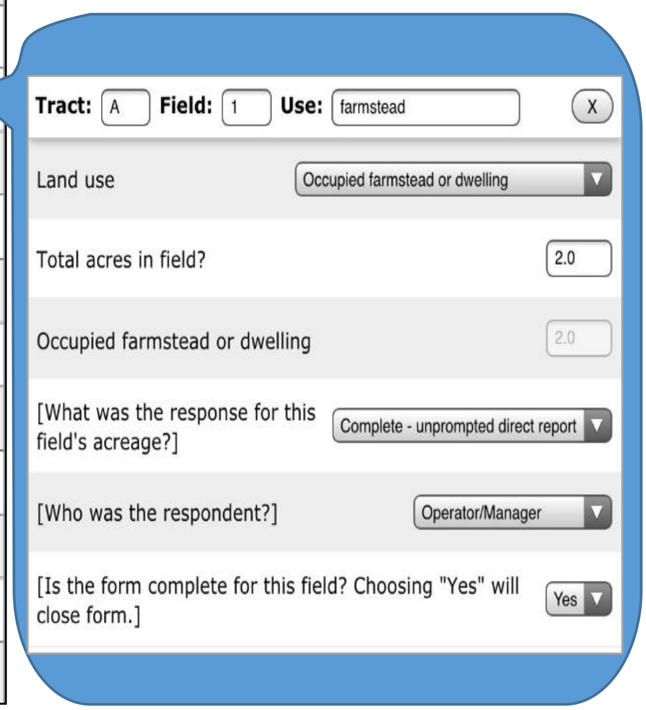

Figure 13: A view of the opened Section D form for the first field in the table

The mobile mapping instrument provides a highly-optimized version of the paper Section D form. The specific details for each field are captured in a survey-like format containing drop-down menus and basic edit checks. Skip rules and validation logic are specified per-question dynamically. This effectively reduces the complex paper table as shown in Appendix A to a handful of questions that relate to the specific crop or land use (Figure 14).

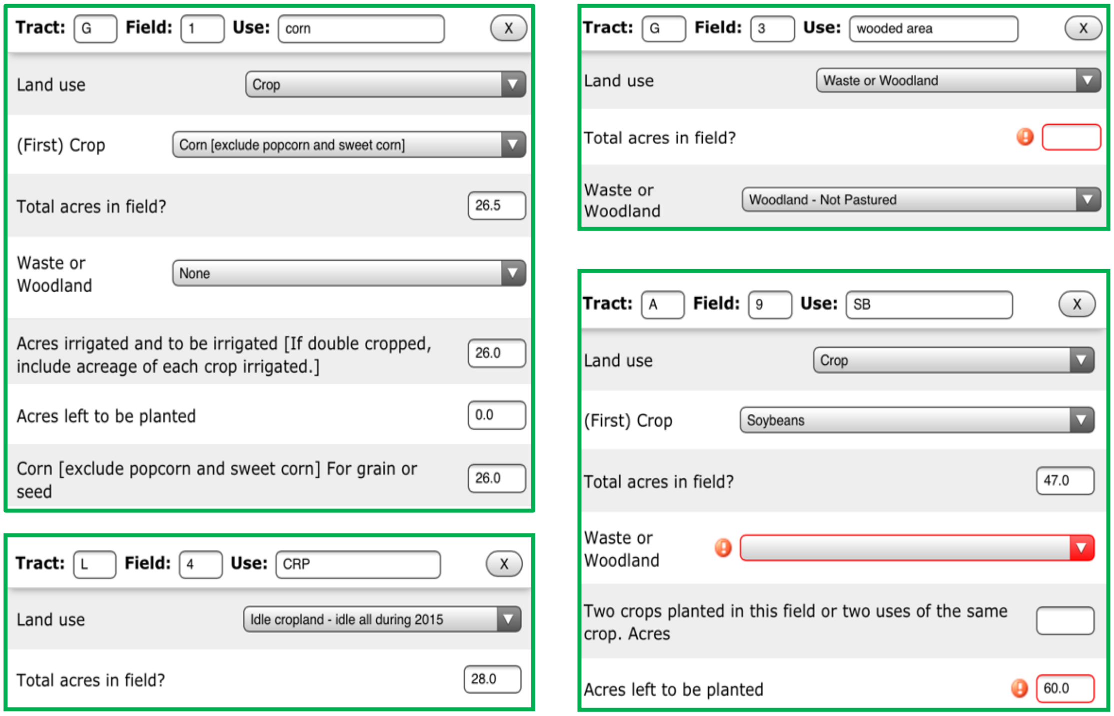

Figure 14: Skip rules facilitate streamlined questions specific to each crop or land use. Indicators pinpoint missing information and any data inconsistencies found during basic edit checks.

5. Phase III Study - Field Data Collection & Results

This study was conducted to evaluate whether grid cells could replace JAS segments as the data collection unit for the survey and to identify any issues of collecting data electronically using a mobile mapping instrument instead of pencil and paper procedures. During the summer of 2014, enumerators in North Carolina (NC), Pennsylvania (PA) and South Dakota (SD) visited with farm operators to test the concept of grid cells in conjunction with the mobile mapping instrument. A random sample of 20 grid cells was selected in each state. South Dakota was selected because it is based on the PLSS. Because North Carolina and Pennsylvania are not based on the PLSS, a fishnet was created using ArcGIS software, and grid cells were selected. Figure 15 shows the location of the grid cells in each of the participating states.

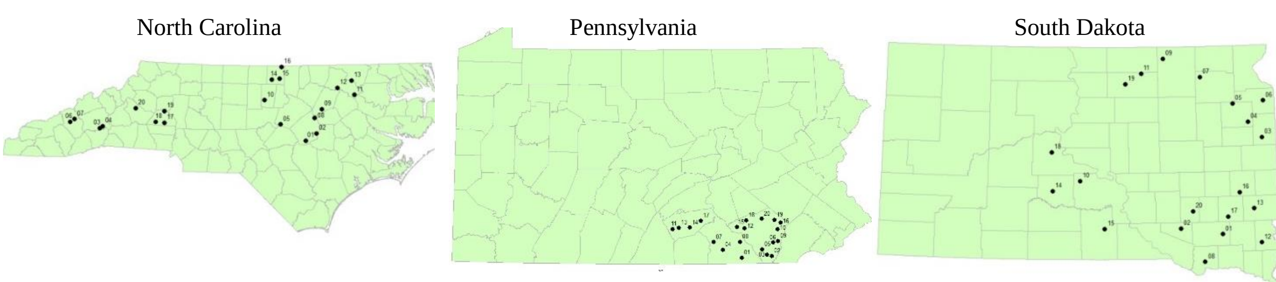

Figure 15: Sampled grid cell locations in participating states

Enumerators identified a total of 917 tracts of land representing unique operating arrangements. Each tract was screened for agricultural activity based on questions on the screening questionnaire. Of these, there were 457 classified as agricultural and 460 as non-agricultural. Enumerators delineated all of the tracts and attempted to conduct interviews with the operators for all tracts with agricultural activity. Enumerators were asked to complete a questionnaire for each grid cell as shown in Appendix B. The form collected information on a variety of issues including 1) those associated with the grid concept, 2) use of a mobile mapping instrument, 3) connectivity and 4) visualization problems associated with the iPad (e.g. sun glare). In addition to providing a yes/no response, enumerators were asked to supply additional information for positive responses. This enabled proper determination of the exact cause of the issue encountered. Table 1 shows the total counts of agricultural and non-agricultural tracts by state. Table 2 displays the interview results for the agricultural tracts by whether an interview was completed, refusal, or estimated (i.e., no contact).

Table 1: Agricultural and Non-Agricultural Tracts by State

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Agricultural Tract	136	36.3	239	54.4	82	79.6	457	49.8
Non-Agricultural Tract	239	63.7	200	45.6	21	20.4	460	50.2
Total	375	100.0	439	100.0	103	100.0	917	100.0

Table 2: Completed, Partial and Estimated Agricultural Tract Interviews by State

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Complete Live Interview	86	63.3	171	71.5	66	80.5	323	70.7
Refusal Partial Interview	18	13.2	11	4.6	3	3.7	32	7.0
Estimated (No Contact)	32	23.5	57	23.9	13	15.8	102	22.3
Total	136	100.0	239	100.0	82	100.0	457	100.0

Enumerators were asked to record their experience and any challenges encountered while enumerating the grid cells by indicating ‘yes’, ‘no’ or ‘sometimes.’ In addition, they explained any issues they encountered. Table 3 displays the results of the question pertaining to challenges the enumerators faced while enumerating the grid cells.

The results shown in Table 3 indicate that enumerators encountered issues more than 20% of the time in all three states. Non-PLSS states were expected to report numerous issues due to the lack of physical boundaries, but enumerators in South Dakota (a PLSS state) answered 'yes' 21.8% of the time versus 12.2% in North Carolina and 4.7% in Pennsylvania, which are non-PLSS states. The primary problem in South Dakota was that the grid cells were very close to the infrastructure on the ground but slightly shifted causing numerous partial fields. As an example, in Figure 16, the South Dakota grid boundary does not align exactly with the road. As a consequence, the edges of fields are excluded from the left side of the grid cell and small portions of fields are included on the right side of the grid cell. In these cases, enumerators were required to contact additional operators and to complete a survey form based upon a very small portion of a field.

Table 3: Did You Encounter Any Issues While Enumerating the Grid Cells?

	North Carolina (non-PLSS)		**Pennsylvania (non-PLSS)**		**South Dakota (PLSS)**		**All 3 States**	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Yes	14	12.2	9	4.7	17	21.8	40	10.4
Sometimes	20	17.4	29	15.2	4	5.1	53	13.8
No	81	70.4	153	80.1	57	73.1	291	75.8
Total[1/]	115	100.0	191	100.0	78	100.0	384	100.0

1/ There were 73 no-response to this question that are not included in the total. Counts by state: NC-21, PA-48 and SD-4.

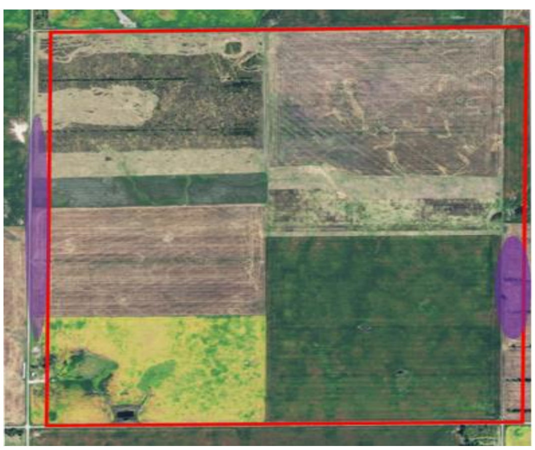

Figure 16: South Dakota grid cell with partial fields highlighted in purple

Figure 17: Grid cell in Pennsylvania with difficult boundaries. Ovals show grid boundary cutting across multiple fields.

The goal of the Phase II research (Boryan et. al, 2017) comparing reported acres to GIS calculation of acres was to determine whether asking farm operators the acres for split fields could be eliminated. While enumerating the grid cells (Phase III), the enumerators reported that farm operators had difficulty estimating acreage for just the part of the field inside the grid cell boundary. Pennsylvania and North Carolina enumerators indicated that their main issue was identifying clear boundaries for the grid cells (See Figure 17). In addition, they also reported that grid cell boundaries cut across numerous crop fields.

Once enumerators contacted farm operators, they identified and delineated the fields and collected the crop-specific data on the Section D portion of the instrument. Table 4 displays the number of fields per tract by state and all states combined. Pennsylvania has more tracts than both South Dakota and North Carolina. It is important to note that this was a result of the counties that were available for sampling in Pennsylvania. This is not representative of all the counties in the state. Figure 18 shows an example of the number of fields delineated for each state. This helps depict how many more fields needed to be delineated in Pennsylvania as compared to the other two states.

Table 4: Number of Fields per Tract by State

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
1 Field	41	30.1	44	18.4	24	29.3	109	23.9
2 Fields	19	14.0	51	21.3	16	19.5	86	18.8
3-4 Fields	28	20.6	47	19.7	14	17.1	89	19.5
5-7 Fields	23	16.9	28	11.7	13	15.8	64	14.0
8-10 Fields	8	5.9	32	13.4	8	9.8	48	10.5
Over 10 Fields	17	12.5	37	15.5	7	8.5	61	13.3
Total	136	100.0	239	100.0	82	100.0	457	100.0

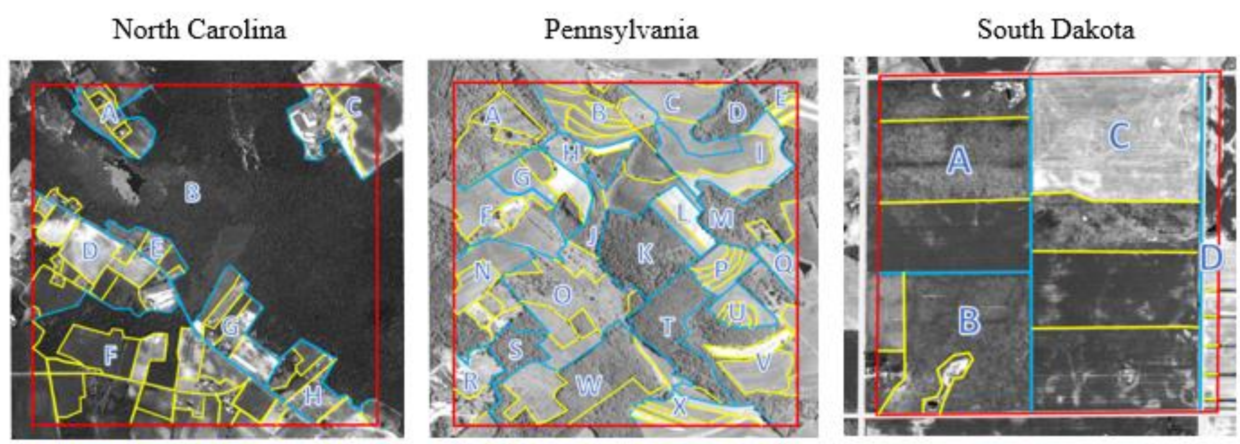

Figure 18: Examples of grid cells in NC, PA and SD. Letters represent each tract or unique operating arrangement. Tract boundaries are shown in blue and fields within each agricultural tract are shown in yellow.

Because limiting burden on farm operators is essential to NASS, the study focused on gaging how long it took enumerators to collect data using grid cells utilizing the mobile mapping instrument. The time spent with each farm operator was examined for each state. Figure 19 describes the enumeration times spent with the farm operator for each of the three states. The black vertical line represents the mean enumeration time with the farm operator for that particular state.

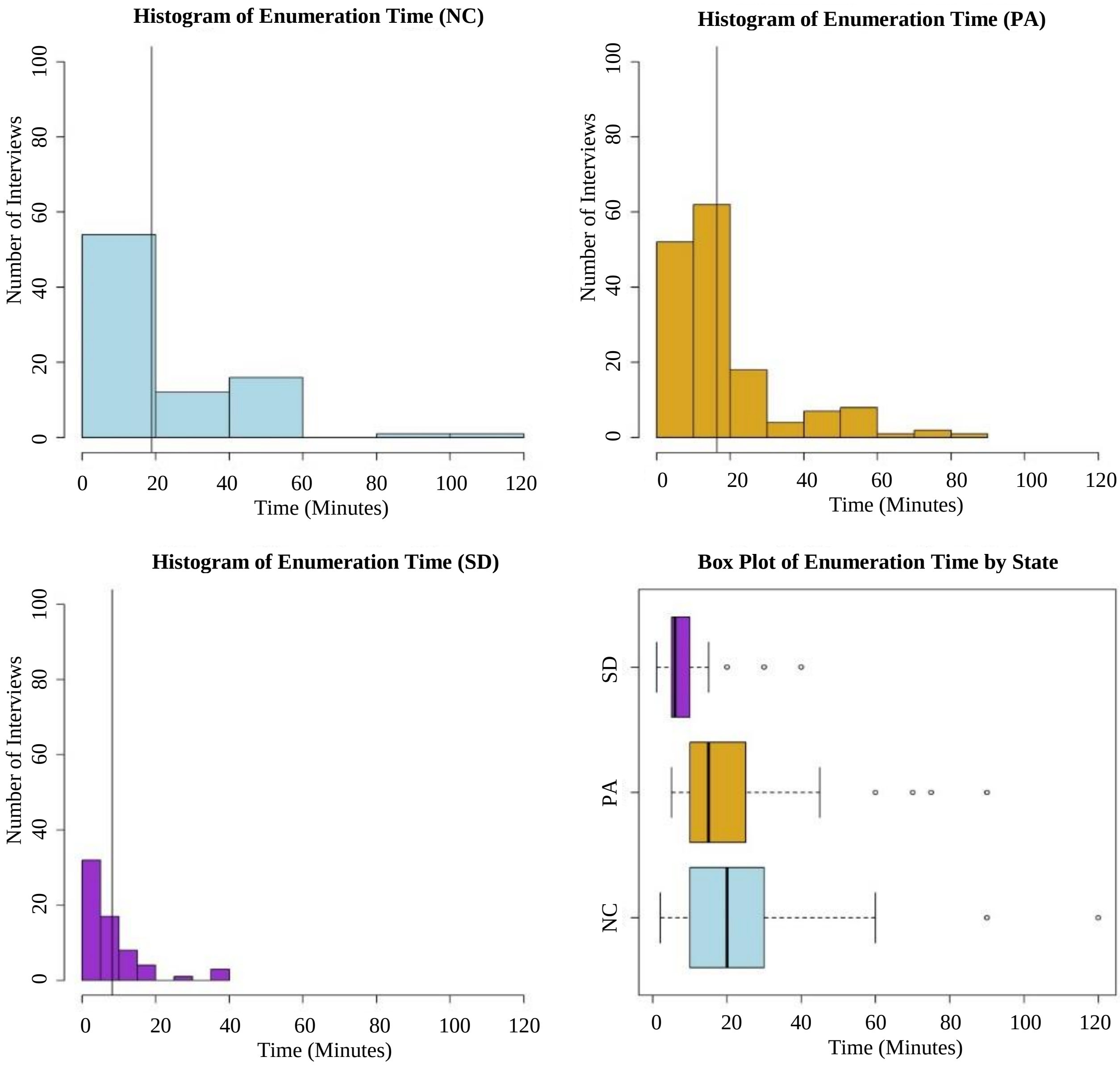

Figure 19: Interview time in each state taken to input data into the mobile mapping instrument.

Based on a one-way analysis of variance, the mean time enumerators spent with the farm operator (see Table 5) was not the same for all states ($p < 0.0001$). Fisher's Least Significant Difference was then used to conduct pairwise comparisons between states (see Table 6). Only those times for which an interview was completed with a farm operator were included in the analysis. The mean enumeration times with farm operators differed significantly between North Carolina (non-PLSS) and South Dakota (PLSS) and between Pennsylvania (non-PLSS) and South Dakota (PLSS). The mean interview times did not differ significantly between North Carolina and Pennsylvania. The average time taken to conduct an interview in South Dakota is significantly less than that for the other two states. The variability of this time is also significantly smaller in South Dakota than for the other two states. This indicates that it was faster and easier to conduct interviews in the PLSS states as compared to the non-PLSS states.

Table 5: Summary Statistics for Enumeration Time Spent with the Farm Operator for Each State

State	Number of Interviews	Mean Time (minutes)	Standard Deviation (minutes)
North Carolina	84	24.5	20.1
Pennsylvania	155	20.8	16.8
South Dakota	65	9.7	8.8
All 3 States	304	19.5	17.3

Table 6: P-values for Two Sample T-test Comparing Enumeration Times Spent with the Farm Operator for Each Combination of Two States

	***P*-values**		
	North Carolina	**Pennsylvania**	**South Dakota**
North Carolina	NA	0.156	< 0.0001
Pennsylvania	0.156	NA	< 0.0001
South Dakota	< 0.0001	< 0.0001	NA

Linear regression was used to examine the potential association between the number of fields in a tract and enumeration time. Although the correlation was not strong ($R^2 < 0.35$ for all states), the enumeration time did tend to increase as the number of fields within a tract increased. The estimated slopes from the linear regression coefficients (coefficient associated with fields) from each state are shown in Table 7. The estimated increase in the number of minutes, on average, for each additional field within a tract was 1.7, 1.5, and 0.6 minutes for North Carolina, Pennsylvania, and South Dakota, respectively; all of the slopes were significantly different from 0. A plot of the enumeration time versus the number of fields in the tract is shown in Figure 20 along with regression lines for each state.

Table 7: Coefficients and R^2 Values for Regression of Enumeration Time vs Number of Fields

	North Carolina	**Pennsylvania**	**South Dakota**
Beta (Fields)	1.7	1.5	0.6
***p*-value**	<0.0001	<0.0001	0.0012
R^2	0.34	0.25	0.13

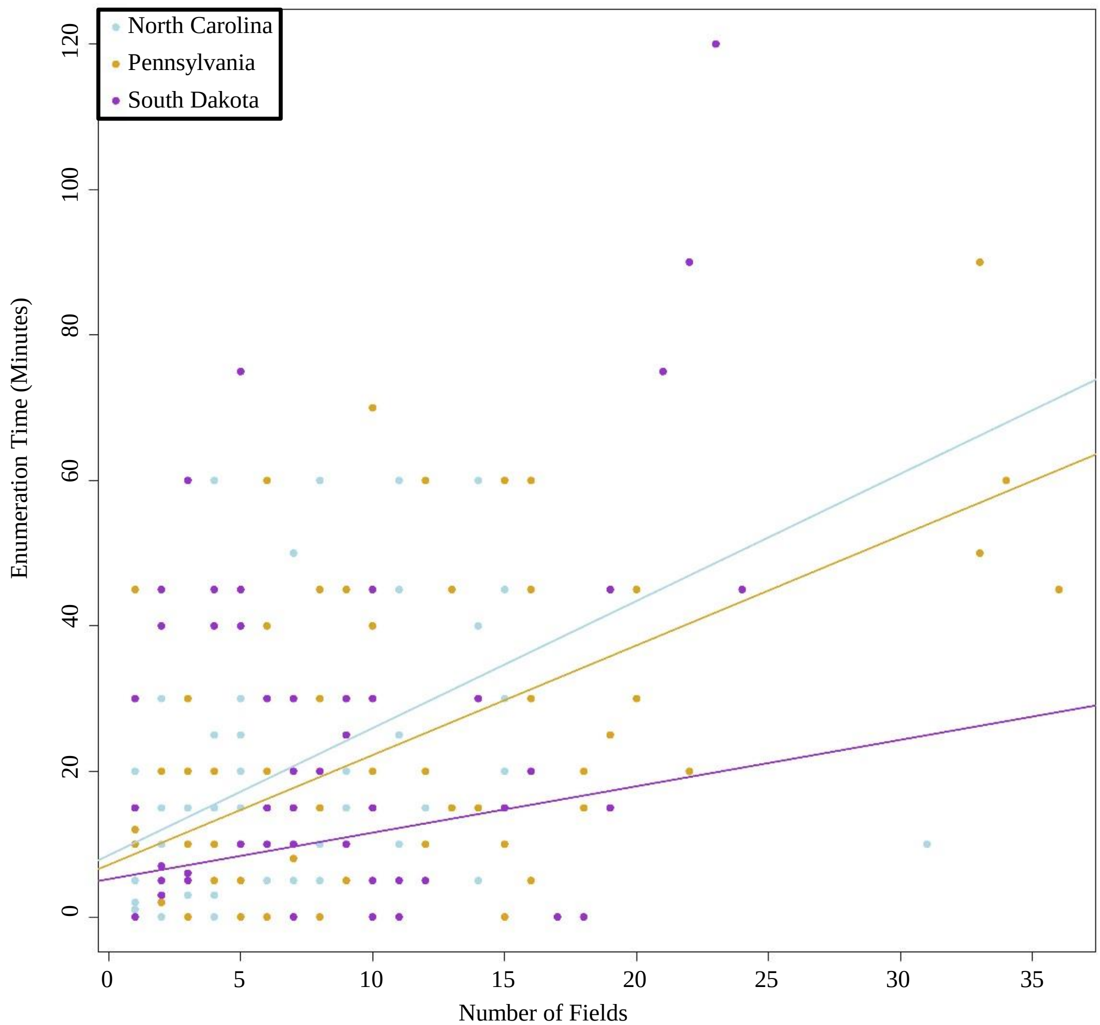

Figure 20: Enumeration time vs the number of fields per tract

5.1 Reported Issues: Aerial Imagery Part of Instrument

Enumerators were asked whether they had any problems using the aerial imagery part of the instrument. Their responses were tabulated for each of the 457 agricultural tracts completed. Table 8 displays the number of times that enumerators experienced difficulty navigating within the aerial imagery portion of the mobile mapping instrument. It was concerning that issues occurred during almost 40% of all agricultural tract interviews. The Pennsylvania enumerators may have responded "yes" more often due to the complexity of their grid cells, which contained numerous small fields.

Table 8: Did You Encounter Any Issues While Using the Aerial Imagery Part of Instrument?

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Yes	11	9.6	42	22.0	10	12.7	63	16.4
Sometimes	36	31.3	41	21.5	11	13.9	88	22.8
No	68	59.1	108	56.5	58	73.4	234	60.8
Total [1/]	115	100.0	191	100.0	79	100.0	385	100.0

1/ There were 72 no—response to this question that are not accounted for in the total. Counts by state: NC-21, PA-48 and SD-3.

All positive responses were investigated, and the vast majority of the issues reported were based upon difficulty splitting fields, a failed merge, or unresponsiveness of the touch screen. Various factors can contribute to an enumerator struggling with splitting fields. The main difficulty reported was accidentally double-tapping on the screen before the polygon was complete. This erased all of the vertices and forced them to start over. It is recommended that the option to double tap to complete a split be removed from the instrument. It is also recommended that the vertices be retained if a split fails.

A merge will fail if all of the selected areas are not adjacent to one another. The enumerators were inadvertently selecting additional fields while using the select tool to move around. A suggestion to address this issue would be to add a pan tool that would allow enumerators the ability to navigate without selecting. In addition, pop-up warning messages should be clarified to indicate the number of fields involved and the reason a merge failed. One important suggestion is to have enumerator training incorporate more role-play practice that mimics live interviews and focus on more specific skills of the various instrument tools and features.

Several enumerators commented that the iPad touch screen was unresponsive at times. They noted that this seemed to mainly occur when they were trying to delineate the field boundaries in the middle of an interview. It was discovered that the touch screen became unresponsive when the user's finger wiggled as it pressed a button. This instability was previously undetected because testing and training were primarily done with the iPad on a flat surface whereas these tests were conducted holding the iPad in one hand while standing outside. For future iterations of the instrument, programmers should specify that slight finger movements be ignored.

5.2 Reported Issues: Electronic Section D Form

Enumerators were asked whether they had any problems completing the electronic Section D form. Their responses were tabulated for each of the 457 agricultural tracts completed. Table 9 displays the number of times that enumerators reported issues while answering the questions within Section D of the mobile mapping instrument.

Table 9: Did You Encounter Any Issues While Completing the Electronic Section D Form?

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Yes	6	5.3	21	11.3	4	5.1	31	8.2
Sometimes	5	4.4	44	23.7	3	3.8	52	13.7
No	103	90.3	121	65.0	72	91.1	296	78.1
Total [1/]	114	100.0	186	100.0	79	100.0	379	100.0

1/ There were 78 no-response to this question that are not accounted for in the total. Counts by state: NC-22, PA-53 and SD-3.

North Carolina and South Dakota enumerators reported no issues completing over 90% of the agricultural tracts. The primary complaint of the Pennsylvania enumerators was having to scroll through a list of 32 “other” crops that were not alphabetized. The survey form designed for Pennsylvania was much more complicated than in the other states due to an extensive listing of other crops. In 2015, the other crop question was eliminated from the instrument due to a policy change eliminating the need to specify the type of other crop.

Enumerators reported that the placement of the calculated GIS acreage was not adequate for the interviews to flow smoothly. If the respondent did not know the number of acres in a field, the enumerator had to close the Section D form to view the calculated GIS acres in the general table and then reopen the form in order to continue. The GIS calculated acres should be displayed at the bottom of the Section D form as shown in Figure 21.

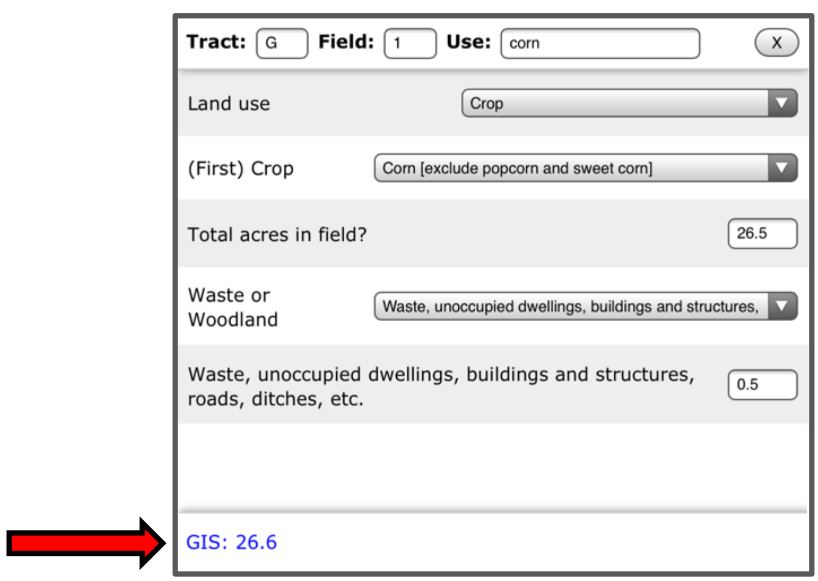

Figure 21: Shows the additional placement of calculated GIS acreage

5.3 Reported Issues: Connectivity

Enumerators were asked to report any issues related to connectivity. Their responses were tabulated for each of the 457 agricultural tracts completed. Table 10 displays the number of times that enumerators reported connectivity problems. Even though the mobile mapping instrument was designed to function without an internet connection, connectivity problems were reported 9.1% of the time in all 3 states.

Table 10: Did You Have Any Connectivity Related Issues?

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Yes	24	20.9	7	3.7	4	5.1	35	9.1
Sometimes	32	27.8	41	21.6	0	0.0	73	19.0
No	59	51.3	142	74.7	75	94.9	276	71.9
Total 1/	115	100.0	190	100.0	79	100.0	384	100.0

1/ There were 73 no-response to this question that are not accounted for in the total. Counts by state: NC-21, PA-49 and SD-3.

In areas of low signal strength, the geo-location feature actually timed out and caused the instrument to malfunction. North Carolina may have experienced more issues due to the mountains and poor cellular coverage. The geo-location feature should be removed from future iterations of the instrument.

Pennsylvania enumerators misunderstood the cache routine. They thought that it automatically cached all zoom levels when in reality it was not designed to capture the higher zoom levels they needed to view the smaller fields. Enumerator training should be modified to help them identify when specific areas are not cached properly. In addition, enumerators should be instructed to switch the iPad to airplane mode after running the cache routine. This will prevent any signal and display a pink tile in place of any imagery that has not been cached. They should then turn airplane mode off and cache any additional imagery needed before heading out to the field.

Some of the connectivity issues were instances when the NAIP imagery was not available. The instrument is dependent on public servers for hosting aerial photography (www.nationalmap.gov). To avoid the NAIP unreliability, it is recommended that all required imagery be stored on the same server as the mobile mapping instrument.

5.4 Reported Issues: Visibility

Up to this point, summary tables refer to all 457 agricultural tracts. To study visibility issues and, in particular, whether farm operators had difficulty viewing the iPad screen, it was necessary to remove any instances of refusals or in-accessible interviews. This allowed the focus to be on the 323 completed interviews. Table 11 displays the results to the screen visibility question.

Table 11: Did You Encounter Any Issues with Screen Visibility?

	North Carolina		Pennsylvania		South Dakota		All 3 States	
	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent	Number of Agricultural Tracts	Percent
Yes	21	26.2	87	57.6	6	9.2	114	38.5
Sometimes	15	18.8	17	11.3	22	33.9	54	18.2
No	44	55.0	47	31.1	37	56.9	128	43.3
Total [1/]	80	100.0	151	100.0	65	100.0	296	100.0

1/ There were 27 no-response to this question that are not accounted for in the total. Counts by state: NC-6, PA-20 and SD-1.

Glare, especially in bright sunlight, hinders the ability to collect data and needs to be significantly reduced to avoid visibility difficulties, which were observed in over half of all interviews. Pennsylvania reported the most issues with screen visibility. This is likely due to difficulty viewing smaller fields since Pennsylvania had almost twice the number of fields per grid cell than in the other two states.

One suggestion to help improve visibility is to adjust the color scheme on the iPad. Currently, the iPad has the invert colors option that could be turned on and off to allow a different view of the sampled segment (Figures 22 and 23). Another suggestion for better segment view is to increase the width of the segment border to distinguish it from roads.

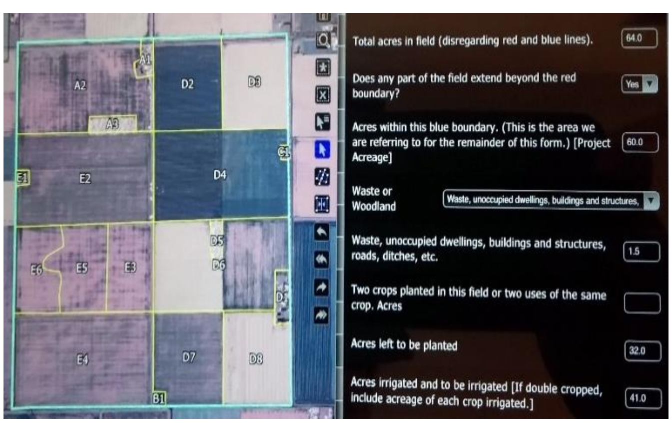

Figure 22: iPad screen with invert colors option turned on

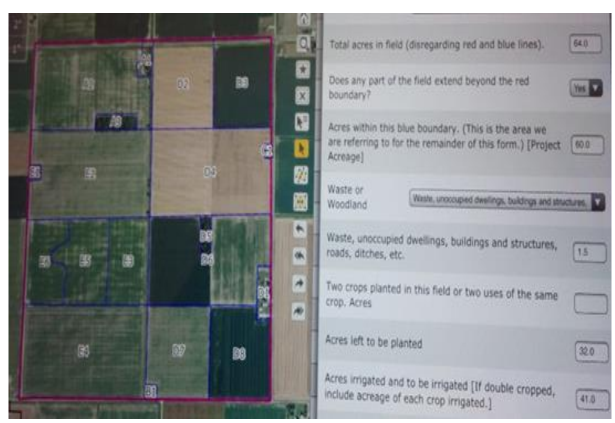

Figure 23: Normal view of iPad screen with invert colors turned off

6. Conclusions

The primary objective of this research was to determine whether grid cells could potentially replace JAS segments. This was evaluated as a cost and resource-saving initiative. The lack of physically identifiable boundaries for the grid cells presented a substantial problem for enumerators to identify where the imaginary grid boundaries fell in order to properly determine the areas to be included in a sampled grid cell. Partial fields also caused an increase in respondent burden since additional operators had to be contacted to complete a survey form based upon relatively small portions of land. Another lesson learned is that the average time it took enumerators to draw off the fields with the mobile mapping instrument was not reasonable for the approach to work operationally. This was especially difficult in Pennsylvania where enumerators had many tracts within the grid cells as well as many small fields within each tract.

One key suggestion to enhance usability of the mobile mapping instrument is to simplify the design. Many enumerators in rural areas do not have high speed WiFi in their homes; therefore, it is important to be mindful of connectivity limitations. Sophisticated GIS features may not be practical due to connectivity requirements. Further, enumerators need to have a higher level of technical expertise than with the current operational procedures. Efforts should continue to obtain feedback from enumerators on instrument enhancements and to test the instrument in all possible environments.

Enumerator training should incorporate more role-play practice that mimics live interviews and focus on more specific skills. In addition, special features such as the use of the iPad’s airplane mode and the invert colors option should be provided to better prepare enumerators for what they will encounter during live interviews. Screen visibility on the iPad continues to be a problem and needs to be significantly reduced. Efforts should continue to identify new devices and screen protectors as they come on the market.

The use of grid cells as an enumeration unit for the JAS is not feasible for NASS. However, the mobile mapping instrument is still a promising tool for modernizing the agency data collection activities. Because the instrument can be used with both grid cells and JAS segments, research should continue with the application being on JAS segments. One way to reduce the time taken to enumerate segments is to provide pre-delineated field boundaries. Currently, information from the Farm Service Agency’s Common Land Units, NAIP imagery and topology maps could be used to create the segment delineations.

7. Recommendations

1. Do not use grid cells as an enumeration unit to collect data for the JAS.

2. Provide enumerators with JAS segments with pre-delineated field boundaries using sources such as Farm Service Agency's Common Land Units, imagery from the National Agricultural Imagery Program (NAIP), and topology maps among other sources.

3. Implement the following instrument and training modifications:

    a. Store all required imagery on the same server as the instrument.

    b. Test the instrument in all possible environments.

    c. Make the following enhancements to the instrument:

        i. Increase the width of the segment border to distinguish it from roads.

        ii. Retain the vertices of the incomplete polygon when a split fails.

        iii. Add a pan tool to allow enumerators to navigate around the imagery without selecting.

        iv. Clarify warning messages to indicate the number of fields involved in a merge and the reason a merge failed.

        v. Ignore slight finger movements when a button is pushed.

        vi. Display the calculated GIS acres for each field at the bottom of the Section D form.

    d. Remove the following features from the instrument:

        i. Option to double tap to complete a split.

        ii. The geo-location feature.

        iii. Menu requiring the selection of the type of other crop.

    e. Incorporate more role-play practice exercises that mimics live interviews during field enumerators training.

    f. Reinforce the use of the iPad's airplane mode and the invert colors options.

4. Investigate new devices and screen protectors as they come on the market to further address the issue of screen visibility on the iPad.

8. References

Abreu Denise, Lawson L., Boryan C., Gerling M., and Hardin R., (2015). "*Using a Mobile Mapping Instrument to Evaluate a Permanent Grid Sampling Frame*" Proc. In the 2015 Federal Committee on Statistical Methodology.

Boryan, Claire, Lawson, L., Abreu, D.A., Weaber, J., Gerling, M., Hyman, M., and Hardin, R. (2017). *"Comparing Geographic Information System (GIS) Calculated Acres to Farmer Reported Acreage Utilizing a Mobile Mapping Instrument"* Research and Development Division. RDD Research Report #RDD-17-XX. Washington, DC: USDA, National Agricultural Statistics Service. Pending internal review.

Boryan, Claire, Yang, Z., Di, L., and Hunt, K., (2014). *"A New Automatic Stratification Method for U.S. Agricultural Area Sampling Frame Construction Based on the Cropland Data Layer"* IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, pp. 1939-1404, May 2014, DOI: 10.1109/JSTARS.2014.2322584.

Boryan, Claire, Yang, Z., Mueller R., and Craig M., (2011). *"Monitoring US Agriculture: the U.S. Department of Agriculture, National Agricultural Statistics Service Cropland Data Layer Program"* Geocarto International, 26, (5): 341-358.

Cotter, Jim, Davies, C., Nealon, J., & Roberts R. (2010). *"Area Frame Design for Agricultural Surveys in Agricultural Survey Methods"* (eds R. Benedetti, M. Bee, G. Espa and F. Piersimoni), John Wiley & Sons, TD, Chichester, UK, doi:10.1002/9780470665480.ch11.

Gerling, Michael, Lawson L., Weaber J., Dotts A., Vardeman A., and Wilson E. (2015). *"Field Data Collection Using Geographic Information Systems Technologies and iPads on the USDA's June Area Frame Survey"* Research and Development Report RDD-15-03, United States Department of Agriculture, National Agricultural Statistics Service.

Lawson, Linda A., Abreu D.A., Boryan, C., Gerling, M., and Hardin, R., (2015). *"A Summary of Issues Associated with the Modernization of Data Collection"* Proceedings of the 2015 Federal Committee on Statistical Methodology.

USGS (2016). The U.S. Map: *The Public Land Survey System.* <http://nationalmap.gov/small_scale/a_plss.html> (last accessed 02/24/16).

USDA FSA (2015). *National Agricultural Imagery Program (NAIP) Imagery,* <http://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/> (last accessed 02/24/2016).

APPENDIX A

SECTION D – CROPS AND LAND USE ON TRACT

How many acres are inside this blue tract boundary drawn on the photo (map)?........................ [.]

Now I would like to ask about each field inside this blue tract boundary and its use during (year).

Field Number		01	02	03	04	05
1. Total acres in field		828 .	828 .	828 .	828 .	828 .
2. Crop or land use. [*Specify*]						
3. Occupied farmstead or dwelling		843 .				
4. Waste, unoccupied dwellings, buildings and structures, roads, ditches, etc.		841 .	841 .	841 .	841 .	841 .
5. Woodland	**NP = Not Pastured**	83_ .	83_ .	83_ .	83_ .	83_ .
	P = Pastured	☐ NP ☐ P	☐ NP ☐ P	☐ NP ☐ P	☐ NP ☐ P	☐ NP ☐ P
6. Pasture	Permanent (not in crop rotation)	842 .	842 .	842 .	842 .	842 .
	Cropland (used only for pasture)	856 .	856 .	856 .	856 .	856 .
8. Idle cropland – idle all during (year)		857 .	857 .	857 .	857 .	857 .
9. Two crops planted in this field or two uses of the same crop.		☐ **Yes** ☐ **No**	☐ **Yes** ☐ **No**	☐ **Yes** ☐ **No**	☐ **Yes** ☐ **No**	☐ **Yes** ☐ **No**
	[*Specify second crop or use.*]					
	Acres	844 .	844 .	844 .	844 .	844 .
10. Acres left to be planted		610 .	610 .	610 .	610 .	610 .
11. Acres irrigated and to be irrigated [*If double cropped, include acreage of each crop irrigated.*]		620 .	620 .	620 .	620 .	620 .
16. **Winter Wheat**	Planted	540 .	540 .	540 .	540 .	540 .
17. (*include cover crop*)	For grain or seed	541 .	541 .	541 .	541 .	541 .
20. **Oats**	Planted and to be planted	533 .	533 .	533 .	533 .	533 .
21. (*include cover crop*)	For grain or seed	534 .	534 .	534 .	534 .	534 .
24. **Corn**[*exclude popcorn and*	Planted and to be planted	530 .	530 .	530 .	530 .	530 .
25. *sweet corn*]	For grain or seed	531 .	531 .	531 .	531 .	531 .
29. **Other uses** of grains planted (*Abandoned, silage, green chop, etc.*)	Use					
	Acres	.	.	.	.	.
30. **Hay**	Alfalfa and Alfalfa Mixtures	653 .	653 .	653 .	653 .	653 .
31. [*Cut and to be cut*	Grain	656 .	656 .	656 .	656 .	656 .
33. *for dry hay.*]	Other Hay	654 .	654 .	654 .	654 .	654 .
34. **Soybeans**	Planted and to be planted	600 .	600 .	600 .	600 .	600 .
35.	Following another harvested crop	602 .	602 .	602 .	602 .	602 .
51. **Other crops**	Acres planted or in use	--- .	--- .	--- .	--- .	--- .

APPENDIX B

ENUMERATOR'S DATA COLLECTION FORM (Front)

Area Frame Modernization Research Team 2014 JAS-CAPI Phase 3Test Enumerator Evaluation Form Project Code: 504	State	Segment	USDA	National Agricultural Statistics Service	U.S. Department of Agriculture Rm 5030, South Building, 1400 Independence Ave., S.W. Washington, DC 2025,0-2000 Phone: 1-800-727-9540, Fax: 202-690-2090 Email: nass@nass.usda.gov
	__ __	000__ __ __ __ __ __			

Item	Description	TRACT																
	TRACT LETTER	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		Enter: 1-Yes, 3-No, 2-Sometimes																
101	Problems with Grid Segments (Partial field problems, etc.)																	
102	Problems with Aerial Imagery Part (Zooming, Splitting, Functionality, NAIP, etc)																	
201	Any Problems with Section D Form Experienced (Navigation, Questions, Drop Downs, etc.)																	
301	Connectivity Problems (3G/4G)																	
302	Screen Visibility Problems (glare, sunlight, etc.)																	
		Enter: Number of Minutes																
406	Time spent <u>with</u> the farmer completing Section D & Photo?																	
407	Time spent <u>without</u> the farmer completing Section D & Photo?																	
		Enter: 1-Morning, 2-Afternoon, 3-Evening																
401	Time of Day that the Interview was Conducted																	
		Enter: 1-Indoors, 2-Outside, 3-Other																
402	Where was the Interview Conducted																	
		Enter: 1-Enthusiastic, 2-Ambivalent, 3-Reluctant																
403	Respondent's Receptiveness to <u>this</u> <u>Technology</u> in data collection																	

APPENDIX B

ENUMERATOR'S DATA COLLECTION FORM (Back)

Please Comment on All Aspects of this Data Collection Process with Comments as Detailed as Possible for this Segment.

Grid Segments: If Item 101 is" Yes" or "Sometimes", please comment and include tract letter where applicable.	099
GIS/Aerial Imagery: If Item 102 is" Yes" or "Sometimes", please comment and include tract letter where applicable.	100
Section D Form Comments: If Item 201 is" Yes" or "Sometimes", please comment and include tract letter where applicable.	200
iPAD Specific Comments: If any of items 301-302 are " Yes" or "Sometimes", please comment and include tract letter where applicable.	300
General Comments: Relating to Items 401-407, Respondent Burden, Training, or Anything else.	400

Enumerator Name:	501 Enumerator ID ______	502 MM DD YY Date: __ __ __