Virginia Tillage/Residue Survey - Using an Alternative Approach for Verification

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Version 2

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Introduction and Purpose

Virginia's previous tillage survey was completed in 2015 which prompted the need for an updated survey in the Chesapeake Bay Watershed for reporting purposes. Planning began for a survey during the Fall of 2020 for an anticipated 2021 survey. The 2021 survey was postponed due to COVID concerns over the requirement to have multiple staff in the vehicles performing the observations. Planning resumed during the Fall of 2021 for a rescheduled 2022 tillage survey as the concerns with COVID exposures began to ease.

For the 2022 survey, DCR followed the guidance of the roadside transect survey method as described in the CBP report *Recommendation Report for the Establishment of Uniform Evaluation Standards for Application of Roadside Transect Surveys to Identify and Inventory Agricultural Conservation Practices for the Chesapeake Bay Program Partnership's Watershed Model* (16 March 2017) with one exception. Due to budget and time constraints, an alternative approach for the verification process was established to prevent the need for in-person visits to the minimum requirement of 10% of the survey observations which would be spread across the entire Chesapeake Bay Watershed. The alternative approach involved the use of photographs being captured during the original surveying process that could then be evaluated to determine

residue levels without the need of revisiting those observed points in the field. As described in more detail in subsequent sections of this document, surveyors were instructed in the methods to use to attempt to obtain the highest quality photograph possible to allow for accurate residue interpretation.

Background

Determinations of tillage practices is based on transect residue surveys conducted by survey teams consisting of professionals in the agricultural community - typically SWCD employees and retired USDA employees. The SWCD employees and retired USDA employees have experience in evaluating the level of residue on the fields, and additional training sessions were given by DCR on the methodology that should be used to determine the residue levels. Recordings of the training sessions are made available to all surveyors along with the training materials (PowerPoints, etc). Additional technology training was given for the 2022 survey which utilized a mobile data collection application which will be described in further detail below.

Surveys were conducted in the spring of 2015 and again in the spring of 2022. An expected 5-year survey cycle was interrupted by the Covid pandemic, Surveyors are trained by DCR staff regarding where, when, and how to conduct the survey. The tillage data is not currently verified during the intervening 5 years between cycles. For the 2022 survey DCR followed the guidance of the roadside transect survey method as described in the CBP report *Recommendation Report for the Establishment of Uniform Evaluation Standards for Application of Roadside Transect Surveys to Identify and Inventory Agricultural Conservation Practices for the Chesapeake Bay Program Partnership's Watershed Model* (16 March 2017). The 2015 survey followed CTIC guidance which is very similar. Virginia DCR is proposing that the 2022

survey data replace the data reported from the 2015 survey. The 2022 survey will be the sole source for tillage data, if the methodology used is approved, so there will not be duplications from any other sources.

Survey Methodology

As per the CBP transect survey report, DCR calculates how many data collection points are required per survey unit in both surveys using the multinomial distribution (Tortora) since there were three residue levels in the 2015 survey and four in the 2022 survey.

The 2015 survey collected tillage data for the following categories:

- Less than 30%
- 30% - 60%
- Greater than 60%

The 2022 survey collected tillage data for the following categories:

- Less than 15% (Conventional Tillage)
- 15% - 30% (Reduced Tillage)
- 30% - 60% (Conservation Tillage)
- Greater than 60% (High Residue Tillage Management)

The *a priori* estimate for the 2015 survey was the latest CTIC survey results whereas the 2015 results were the *a priori* estimates for the 2022 sample size calculations.

With few exceptions the survey units in both surveys were the same. They consisted of single jurisdictions with significant crop land or a conglomerate of adjoining jurisdictions where necessary and acceptable. Jurisdictions with little crop land were joined to adjacent jurisdictions with similar past survey results. The *a priori* estimate for these joined units would always be the closest to 0.5.

Survey Preparation

Survey teams for both the 2015 and 2022 surveys were composed primarily of Soil and Water Conservation District staff. Many of these staff have previous experience estimating crop residue, and they are also familiar with the areas they are surveying. DCR provided training for all survey team members to ensure that all teams followed the same procedures. Examples of the materials used for training sessions are provided in the appendix at the end of this document. Each survey team consisted of a minimum of 2 members with one member being responsible for navigating the route and the second member being responsible for data collection.

DCR worked with survey teams during the 2015 survey to help determine the most efficient routes through crop land areas in each survey unit, but the primary responsibility for route determination was on the survey team as they were familiar with the area they would be surveying. For the 2022 survey, teams were allowed to determine their own route if they felt comfortable doing so, but DCR also provided routes that were created using ESRI's Network Analyst in ArcGIS Pro. These routes were setup to navigate through all crop land areas in each survey unit in the most efficient way possible. The routes could then be loaded into ESRI's ArcGIS Navigator mobile application that could be used to navigate through the route with turn-by-turn directions even when a data connection is not available.

Data Collection

Surveyors work in designated survey units to minimally obtain that specific number of crop land survey points. The survey teams submitted hardcopies of completed survey forms in the 2015 survey. An example of a completed form is shown below:

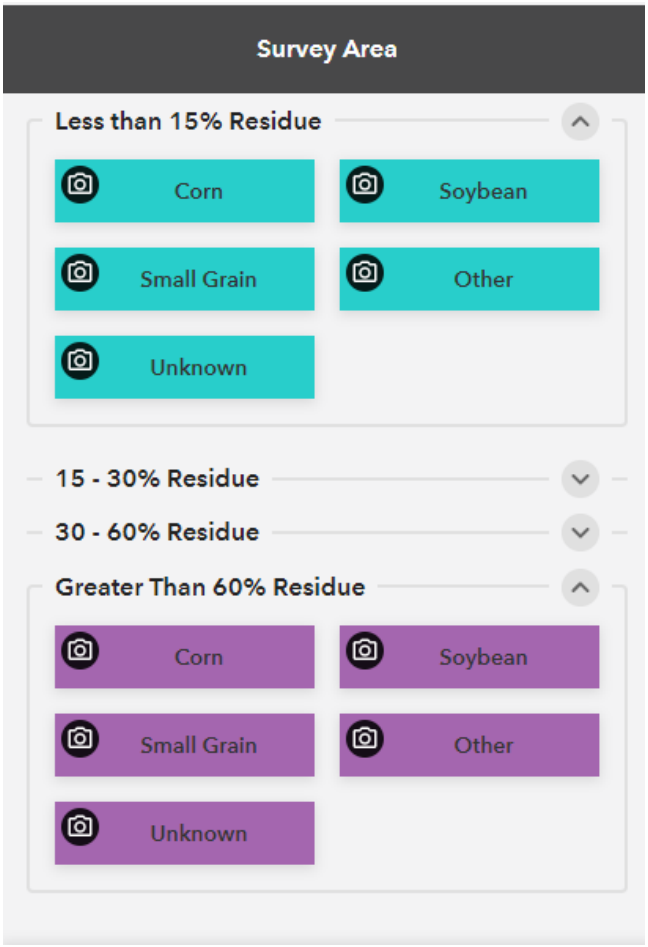
Survey Unit: JR – Lower Survey Team: Jim Askew, Mort Lambeer Date: 5/2/15

CROP RESIDUE	< 30 %	30 – 60 %	> 60 %
CORN	𝍸 𝍸 ||||	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||
SOYBEAN	𝍸 𝍸 𝍸 ||	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||
SMALL GRAIN	||	𝍸 𝍸 𝍸 𝍸 |	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||
COTTON			
OTHER	||	𝍸	𝍸 |||
UNKNOWN	|	|||	|||

A mobile data collection application was used to collect data for the 2022 survey. ESRI's Quick Capture application allows for easy capture of point locations using a very straightforward interface and can collect photos that are associated with each point. This application runs on any Android or iOS (Apple) device including cell phones and tablets. Survey teams utilized a variety of devices for the data capture process, but the application is designed to provide the same experience regardless of the device that is being used.

Photos were captured and used for the verification process as described in a later section of this document. Surveyors were instructed to take a photo for every 5th point that was observed which would lead to approximately 20% of the survey points having photos available for review. The Quick Capture application integrates with ArcGIS Online and can work offline when connectivity is not available for synching the data that's being collected. The interface that was

used to collect the data points is shown in the graphic below. The categories can be collapsed and expanded, and each button has an option to add a picture.

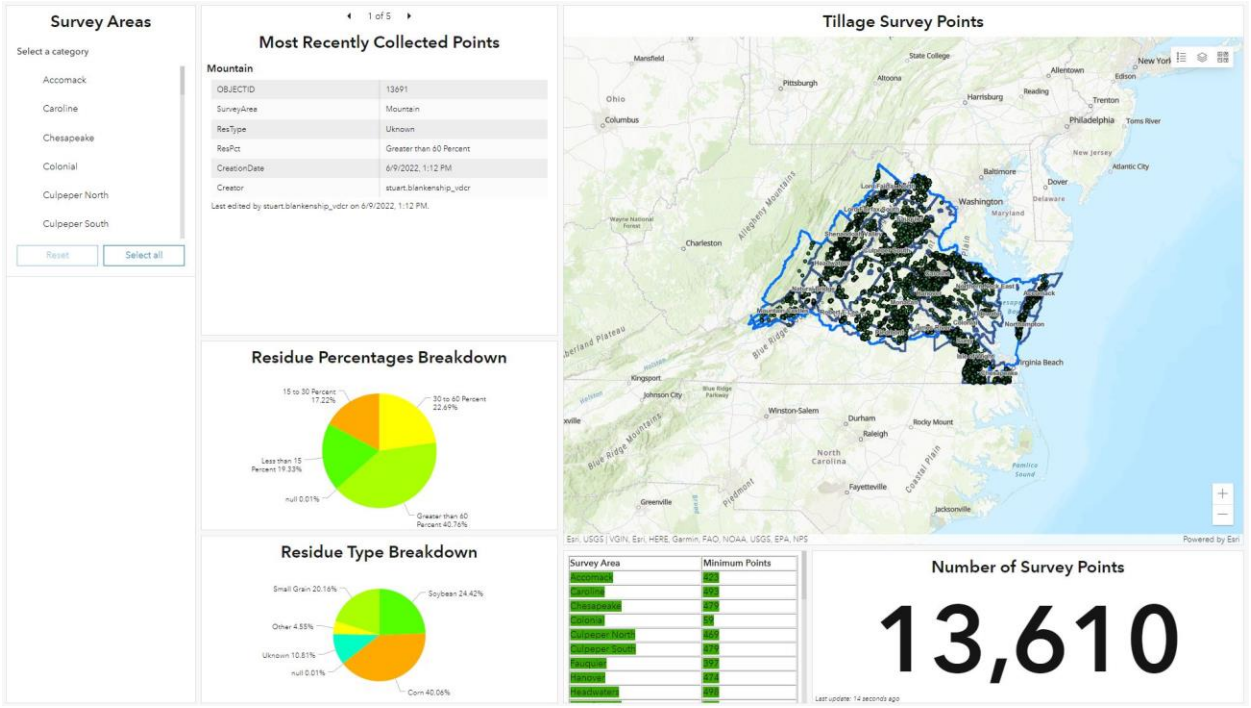


The data collected through this application is automatically synched with a feature class in ArcGIS Online which allowed for near real-time monitoring of the progress of the surveyors. DCR's Data Services Manager for the Division of Soil and Water Conservation monitored an ESRI Dashboard application regularly for the following purposes:

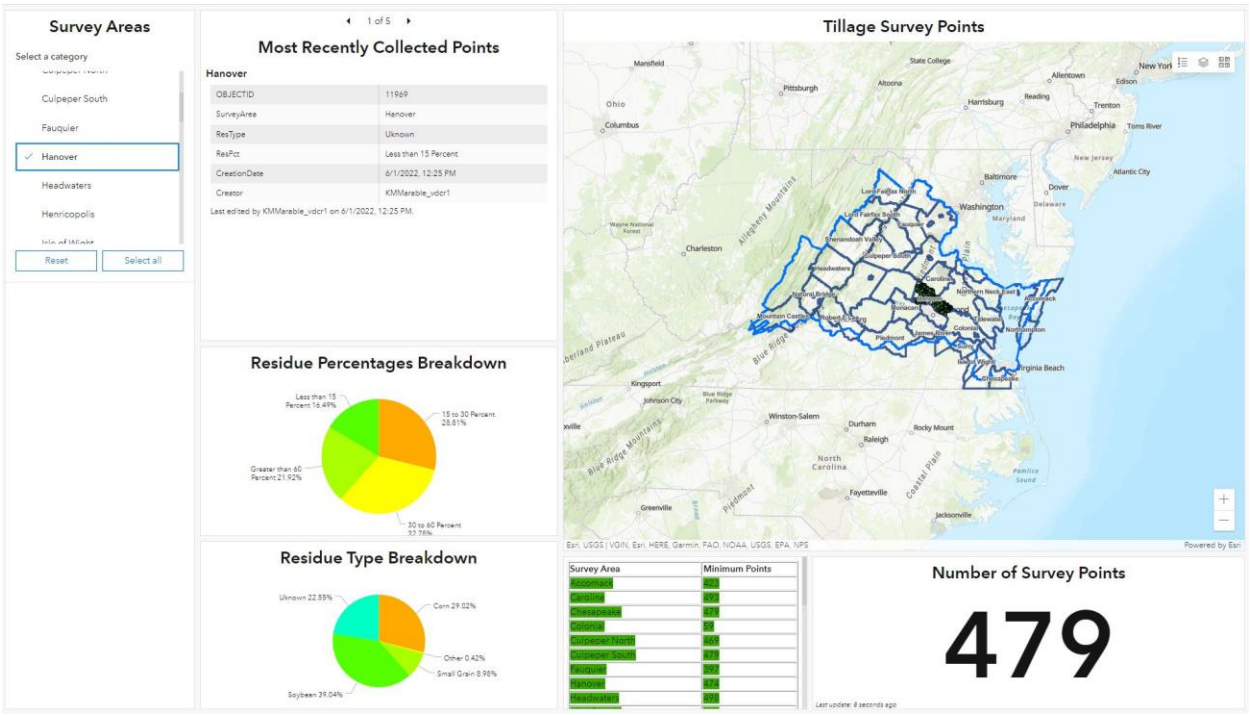
- Photographs could be viewed to ensure that teams were taking them following instructions giving during training sessions.
- General routes could be observed to determine if survey teams were covering the majority of crop land areas in the survey unit.

- When a team reported that a survey unit was complete, the Dashboard could be used to determine if the minimum number of points was obtained.

The ESRI Dashboard that was created to allow for tracking of the progress of the survey is shown below:



The dashboard also has the ability to filter to show progress on a specific survey area as shown below for the Hanover survey area:



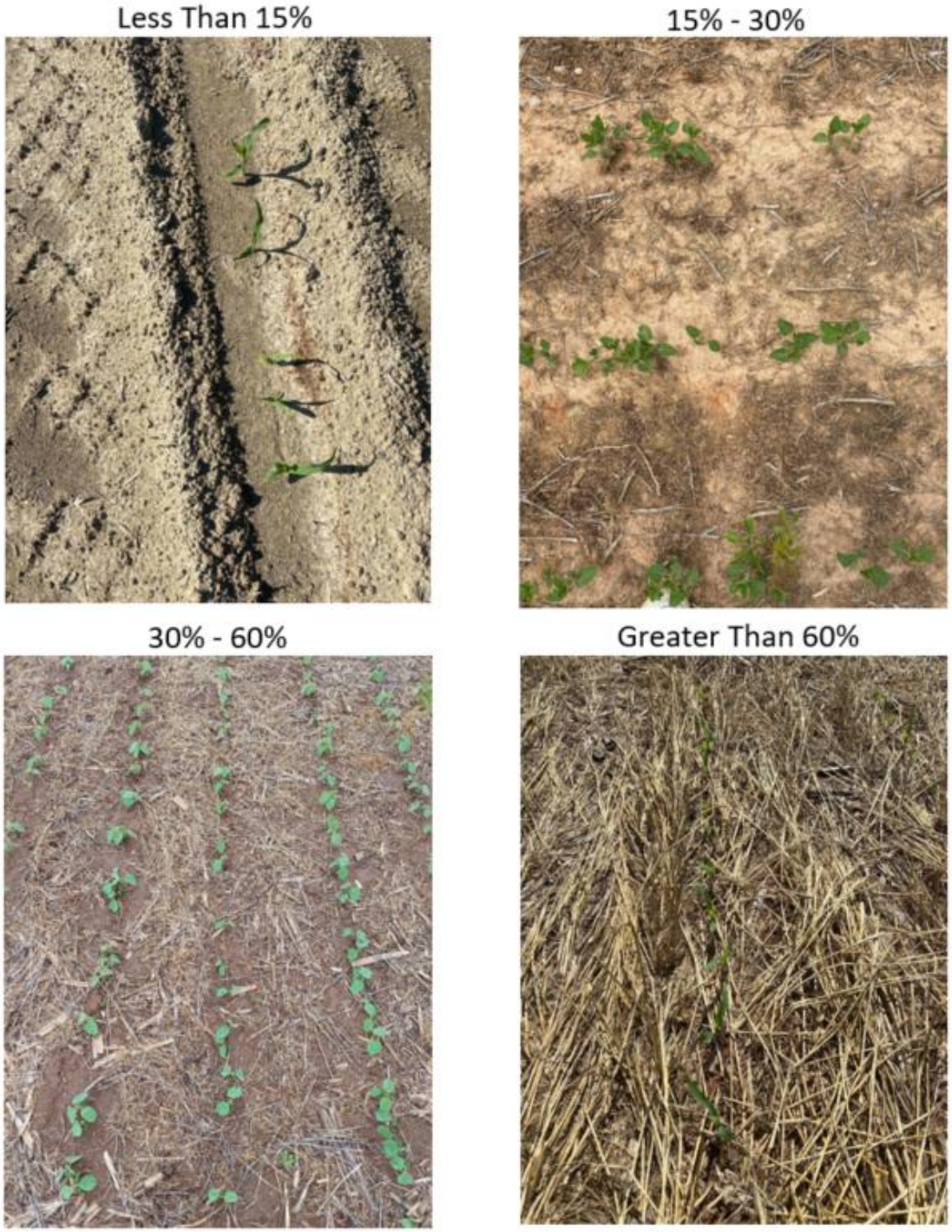
Tillage Survey Verification and Validation

The verification process for the 2015 survey was simply to contact the surveyors for explanations of any results that looked out-of-range of what was expected. This did result in some recapture or additional capture of survey point data. The 2022 survey however is guided by the roadside transect accuracy metrics of the Dressing report. The sample error matrix as constructed from the 2022 survey results can be found in a later portion of the section of the document.

Surveyors were instructed to take a picture of the residue cover indicative of their recording of residue occurrence at a set interval. Surveyors were also instructed to take photos while standing on the field, if possible, and to take the photo in a way that would allow the photo interpreter to clearly see the residue. Since these photos were tied to the survey site and noted condition it was possible to independently compare the residue occurrence in the photo to the

recorded residue occurrence. Approximately 13,600 points were surveyed and over 4,000 pictures were taken and available for review. A random sampling of approximately half of the 4,000 photos was selected for review with the goal of reviewing at least 1,360 photos to reach the goal of 10% for verification purposes. The additional photos over 1,360 were selected as it was expected that there would be photos that would not be of sufficient quality to accurately estimate residue coverage.

Representative photos for the four residue categories used for the 2022 survey can be found in the graphic below:



With 2000 photos needing to be reviewed, it was originally decided that multiple photo reviewers would need to be selected to split the workload. Several DCR employees with experience classifying residue volunteered to help in the effort. A meeting was held to give

guidelines on the photo classification process including instructions on the quality of photo that would be needed to accurately classify residue.

This process was completed with 1,760 photos being classified by the multiple reviewers. The sample count error matrix and area proportion error matrix for the photo verification can be found below.

This is a comparison of the survey classification to the photo (ground) truth classification.

Sample Count Error Matrix			Photo Truthing			Row Totals	Marginal Proportions	
Class		1	2	3	4			
	1	179	53	18	5	255	0.16	
Classified	2	36	88	61	32	217	0.15	
Data	3	13	92	167	86	358	0.21	
	4	3	33	187	707	930	0.48	
Column Totals		231	266	433	830	1760		

Area Proportion Error Matrix			Photo Truthing			Row Totals		
Class		1	2	3	4			
	1	0.111	0.033	0.011	0.003	0.16		0.102
Classified	2	0.025	0.061	0.043	0.022	0.15		0.020
Data	3	0.008	0.053	0.097	0.050	0.21		0.007
	4	0.002	0.017	0.097	0.367	0.48		0.002
Column Totals		0.146	0.165	0.247	0.442			
Adjusted 90% CI	+/-	0.010	0.014	0.016	0.015			
Producer's Accuracy		0.765	0.373	0.390	0.830			
User's Accuracy		0.702	0.406	0.466	0.760			
Overall Accuracy						0.636		
Var(Producer's Acc.)		0.00052	0.00054	0.00035	0.00013			
Var(User's Acc.)		0.00012	0.00014	0.00014	0.00010			
Var(Overall Acc.)						0.00012		

** 1 = Less than 15%, 2 = 15%-30%, 3 = 30%-60%, 4 = Greater than 60%*

This matrix shows that the overall accuracy is around 64% which raised questions as to the accuracy of using photos for verification. Due to this low level of accuracy, further

investigation needed to occur to determine the cause for the inaccuracies. After investigation, it was found that some of the photo interpreters were determining classifications using photographs that were not of sufficient quality to accurately estimate residue coverage. With this finding, it was decided that the same group of photos would be reviewed by a single photo interpreter to reduce variation and to ensure that only quality photos were being used for estimates.

For the final verification, 1,561 photos were classified by one photo reviewer, DCR's Data Services Manager for the Division of Soil and Water Conservation, to ensure consistency as earlier attempts with multiple reviewers resulted in differences in interpretation and classification using photos of insufficient quality.

The final sample error matrix as constructed from the 2022 survey resulted in roughly an 85% match between the original residue observations and 1,561 photographs. This result supports the conclusion that the larger group of photo interpreters classified a large number of photos that were not of sufficient quality to accurately estimate residue coverage. The final sample error matrix can be found below:

This is a comparison of the survey classification to the photo (ground) truth classification.

Sample Count Error Matrix			Photo Truthing				Row Totals	Marginal Proportions
Class		1	2	3	4			
	1	197	28	1	1		227	0.15
Classified	2	18	132	25	5		180	0.12
Data	3	4	44	213	25		286	0.18
	4	2	1	77	788		868	0.56
Column Totals		221	205	316	819		1561	

Area Proportion Error Matrix			Photo Truthing				Row Totals	
Class		1	2	3	4			
	1	0.126201	0.017937	0.000641	0.000641		0.15	
Classified	2	0.011531	0.084561	0.016015	0.003203		0.12	
Data	3	0.002562	0.028187	0.136451	0.016015		0.18	
	4	0.001281	0.000641	0.049327	0.504805		0.56	
Column Totals		0.141576	0.131326	0.202434	0.524664			
Adjusted 90% CI	+/-	0.007331	0.010454	0.012797	0.010617			
Producer's Accuracy		0.891403	0.643902	0.674051	0.962149			
User's Accuracy		0.867841	0.733333	0.744755	0.907834			
Overall Accuracy							0.852	
Var(Producer's Acc.)		0.00037	0.00073	0.00048	0.00004			
Var(User's Acc.)		0.00007	0.00013	0.00012	0.00005			
Var(Overall Acc.)							7.7247E-05	

** 1 = Less than 15%, 2 = 15%-30%, 3 = 30%-60%, 4 = Greater than 60%*

As reviewing photos is not the same as visiting the survey sites, 189 of these sites were revisited to, in essence, provide a third residue occurrence determination. A sample error matrix comparing the call made by the revisiting surveyor to the photo interpreted residue occurrence was constructed to evaluate the effectiveness of the photo as a ground-truthing alternative. Another sample error matrix was also constructed that compared the verification estimate of the 189 revisited sites to the original estimate. This matrix can be found below:

This is a comparison of the original classification of a field to the field checkers classification of that field.

Sample Count Error Matrix			Ground Truth				Row Totals	Marginal Proportions
Class		1	2	3	4			
	1	11	10	2	6		29	0.1534
Original	2	3	7	8	16		34	0.1799
Classification	3	1	3	17	18		39	0.2063
	4	0	0	3	84		87	0.4603
Column Totals		15	20	30	124		189	

Area Proportion Error Matrix			Ground Truth				Row Totals	
Class		1	2	3	4			
	1	0.058201	0.05291	0.010582	0.031746		0.1534	
Classified	2	0.015873	0.037037	0.042328	0.084656		0.1799	
Data	3	0.005291	0.015873	0.089947	0.095238		0.2063	
	4	0	0	0.015873	0.444444		0.4603	
Column Totals		0.079365	0.10582	0.15873	0.656085			
Adjusted 90% CI	+/-	0.028722	0.034106	0.039889	0.044833			
Producer's Accuracy		0.733333	0.35	0.566667	0.677419			
User's Accuracy		0.37931	0.205882	0.435897	0.965517			
Overall Accuracy							0.62963	
Var(Producer's Acc.)		0.011024	0.008726	0.005881	0.000704			
Var(User's Acc.)		0.001246	0.000865	0.001301	0.000176			
Var(Overall Acc.)							0.000696	

** 1 = Less than 15%, 2 = 15%-30%, 3 = 30%-60%, 4 = Greater than 60%*

This matrix shows that the match rate of the in-person verification was significantly lower at roughly 63% than the match rate found in the final matrix of the photo verification. This could possibly be attributed to the small sample size or, alternatively, to the specific, smaller area that was verified in person not having as high of an original accuracy compared to the entire area that was surveyed. In addition, this variability could also be attributed to differences in "ocular calibration" between the different surveyors across the survey teams.

DCR recognizes that additional guidance should be given on data collections methods and photos of residue amounts to allow for better calibration across the survey teams.

Lastly, the classification of 95 of the points that were revisited in person were then compared to the classification using photo interpretation. The classification of 95 of the points that were revisited in person were then compared to the classification using photo interpretation. This comparison resulted in roughly an 84% match as shown the matrix below:

This is a comparison of the photo classification of a field to the field checkers classification of that field.

Sample Count Error Matrix			Ground Truth			Row Totals	Marginal Proportions
Class		1	2	3	4		
	1	8	2	0	0	10	0.1053
Photo	2	3	8	4	0	15	0.1579
Classification	3	0	1	15	3	19	0.2000
	4	0	0	2	49	51	0.5368
Column Totals		11	11	21	52	95	

Area Proportion Error Matrix			Ground Truth			Row Totals	
Class		1	2	3	4		
	1	0.084211	0.021053	0	0	0.1053	
Classified	2	0.031579	0.084211	0.042105	0	0.1579	
Data	3	0	0.010526	0.157895	0.031579	0.2000	
	4	0	0	0.021053	0.515789	0.5368	
Column Totals		0.115789	0.115789	0.221053	0.547368		
Adjusted 90% CI	+/-	0.036112	0.04508	0.050294	0.037246		
Producer's Accuracy		0.727273	0.727273	0.714286	0.942308		
User's Accuracy		0.8	0.533333	0.789474	0.960784		
Overall Accuracy						0.8421	
Var(Producer's Acc.)		0.011475	0.01343	0.006201	0.000832		
Var(User's Acc.)		0.001684	0.00262	0.00175	0.000397		
Var(Overall Acc.)						0.0012	

** 1 = Less than 15%, 2 = 15%-30%, 3 = 30%-60%, 4 = Greater than 60%*

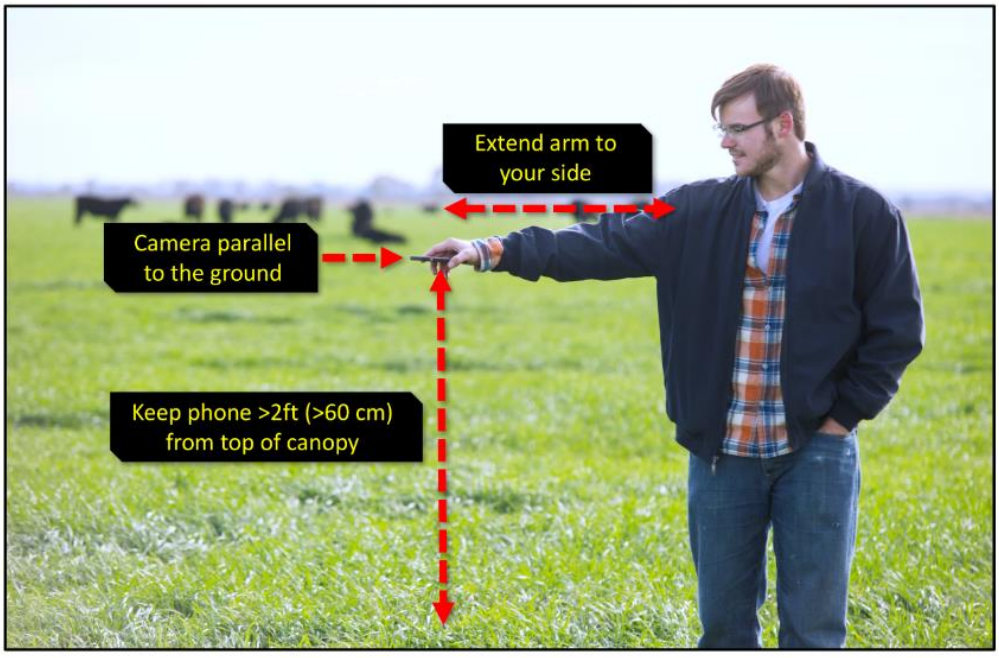
Conclusions and Lessons Learned

Virginia DCR requests that this workgroup review and approve the methodology described in this document. With the final error matrix for verification using photographs being approximately 85%, this process has shown that photos can be used to achieve accurate residue determinations without the need for revisiting points in person. The requirement to revisit in person adds significant time and cost to the survey process that can avoided using photo verification.

Many lessons were also learned during the 2022 survey process that DCR intends to apply to the next survey that is undertaken including:

- The Quick Capture application contained many buttons to click for the various residue types and categories. DCR would strongly recommend that survey teams use tablets whenever possible versus cell phones with smaller screens. The colors of the buttons could also be adjusted to make differences between categories easier to distinguish.
- Quick Capture can collect data without connectivity to the cellular network, but it was found that data duplication issues occurred in areas with poor connectivity. The application attempts to submit data at set intervals by default whenever a connection is available. With poor connectivity, transactions did not always complete, and data was submitted multiple times. These duplicates were easily removed, but turning off the default setting and uploading data manually when a strong connection is present would prevent duplication from occurring.
- To allow for more accurate identification of fields that were surveyed, a left/right designation should be added to points collected using the Quick Capture application.
- General instructions on how to capture photos of the residue on fields was given during training, but it was found that photos were being captured at different heights and

angles by different survey teams. For future surveys, more specific instructions and procedures should be given to ensure that photographs are being taken from consistent heights and angles. See below for an example used by Canopeo (https://canopeoapp.com), an app created to quantify the percent canopy cover of live green vegetation, on how to properly take a photo. A similar example could be created for use in taking pictures of residue on fields.



Another possible option for ensuring consistent heights and angles would be the use of a tripod that is set at the same height for all survey teams. This solution could prove to be challenging due to concerns about accessing private land. An example of a tripod

that could be used for this purpose is shown below:

- While it was possible to determine residue coverage using photographs, an addition of a scale/ruler on the field would improve accuracy. With concerns about accessing private land without the appropriate permission, placing a physical ruler on the field in not always possible. With this in mind, DCR will investigate the possibility of overlaying a "virtual ruler" on photographs that can assist with residue interpretation.

- As noted on Page 14, the variability observed between the in-field verification and the original survey observations could be attributed to differences in "ocular calibration" between the different surveyors across the survey teams. DCR recognizes that additional guidance should be given on data collections methods and photos of residue amounts to allow for better calibration across the survey teams.

Appendix

References

- *Recommendation Report for the Establishment of Uniform Evaluation Standards for Application of Roadside Transect Surveys to Identify and Inventory Agricultural Conservation Practices for the Chesapeake Bay Program Partnership's Watershed Model* (16 March 2017)

- Tortora, R.D. 1978. A note on sample size estimation for multinomial populations. *The American Statistician* 32(3):100-102.

Training Materials

- NRCS Residue Brochure
- Pre-Survey Training PowerPoint
- Survey Technical Training PowerPoint
- Survey Frequently Asked Questions Document
- Survey Process Document

Verification Photo Examples

For examples of photos that were used for classification, use the link below to download a zip file named "Pictures.zip". After unzipping, you will see folders representing the different residue categories that contain representative photos.

Pictures.zip

For examples of photos that were not used due to quality issues, use the link below to download the zip file named "Insufficient_Quality_Picture_Examples.zip".

Insufficient_Quality_Picture_Examples.zip