PA DEP Conservation Tillage BMP Remote Sensing Verification Pilot Project

AGWG Draft Methodology Overview

Thomas Howard

March 20, 2025

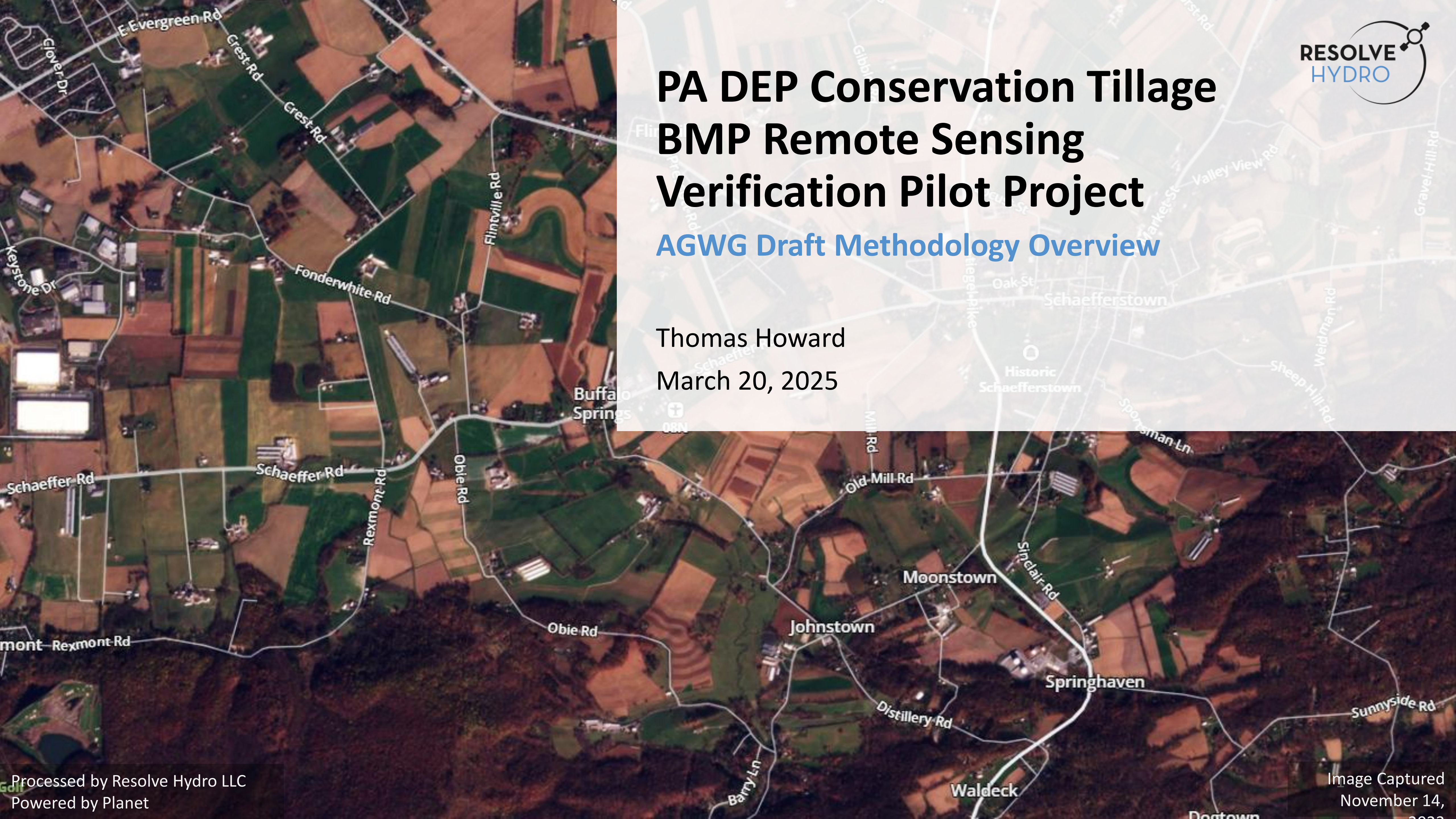

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Image Captured
November 14,

Agenda

- Project background, introduction, and purpose
- Methodology overview
- Discussion and next steps

Please feel free to ask questions throughout!

Accurately monitoring conservation tillage BMPs is critically important to CBP progress and Bay restoration

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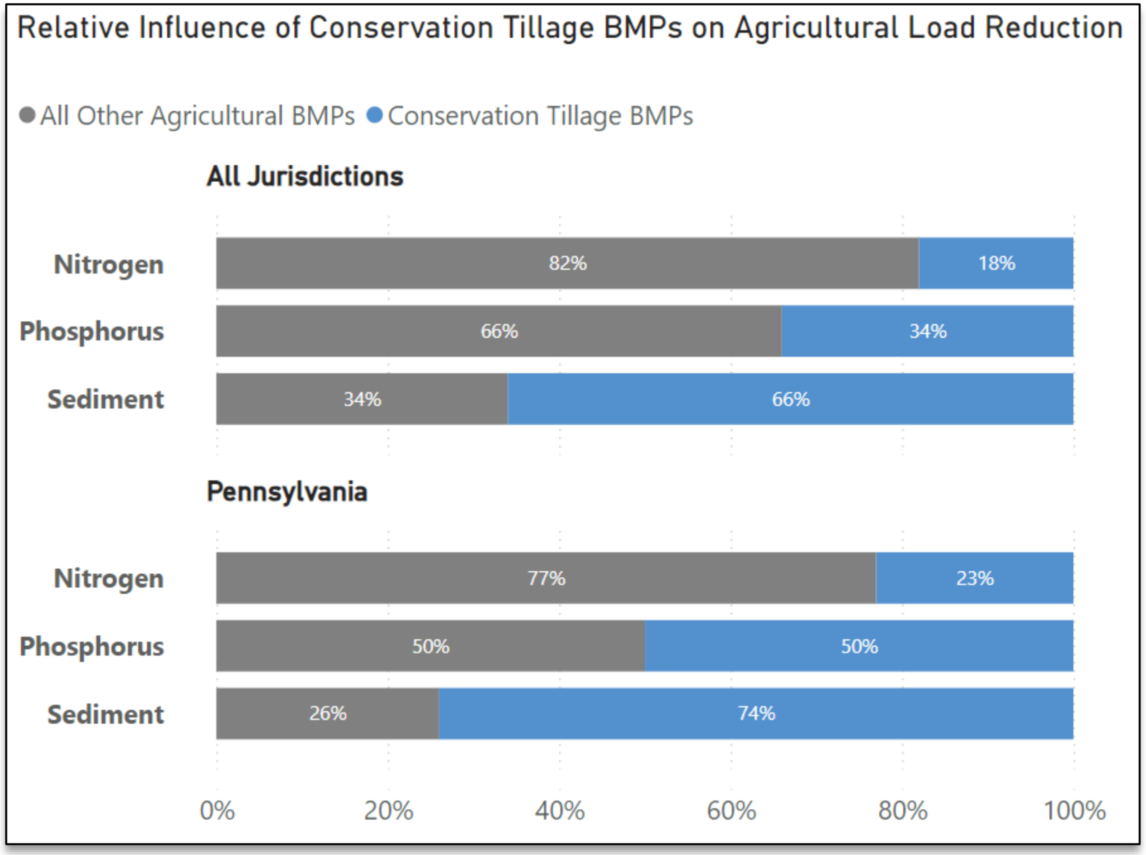

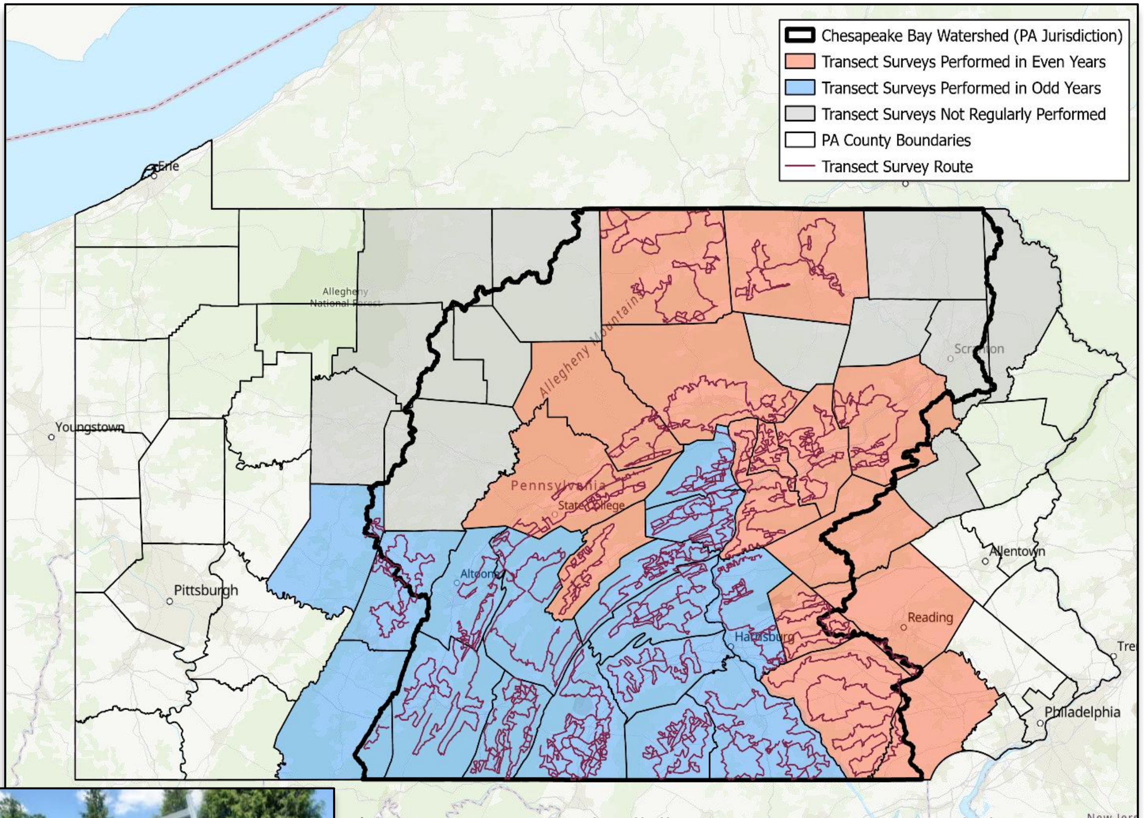

*Transect route in Schuylkill County is not represented above

In Pennsylvania, conservation tillage is responsible for 74% of the agricultural BMP sediment load reduction!

PA DEP drives nearly 4,000 miles/year to estimate conservation tillage BMP implementation!

*Based on 2023 Edge of Tide Progress Scenario

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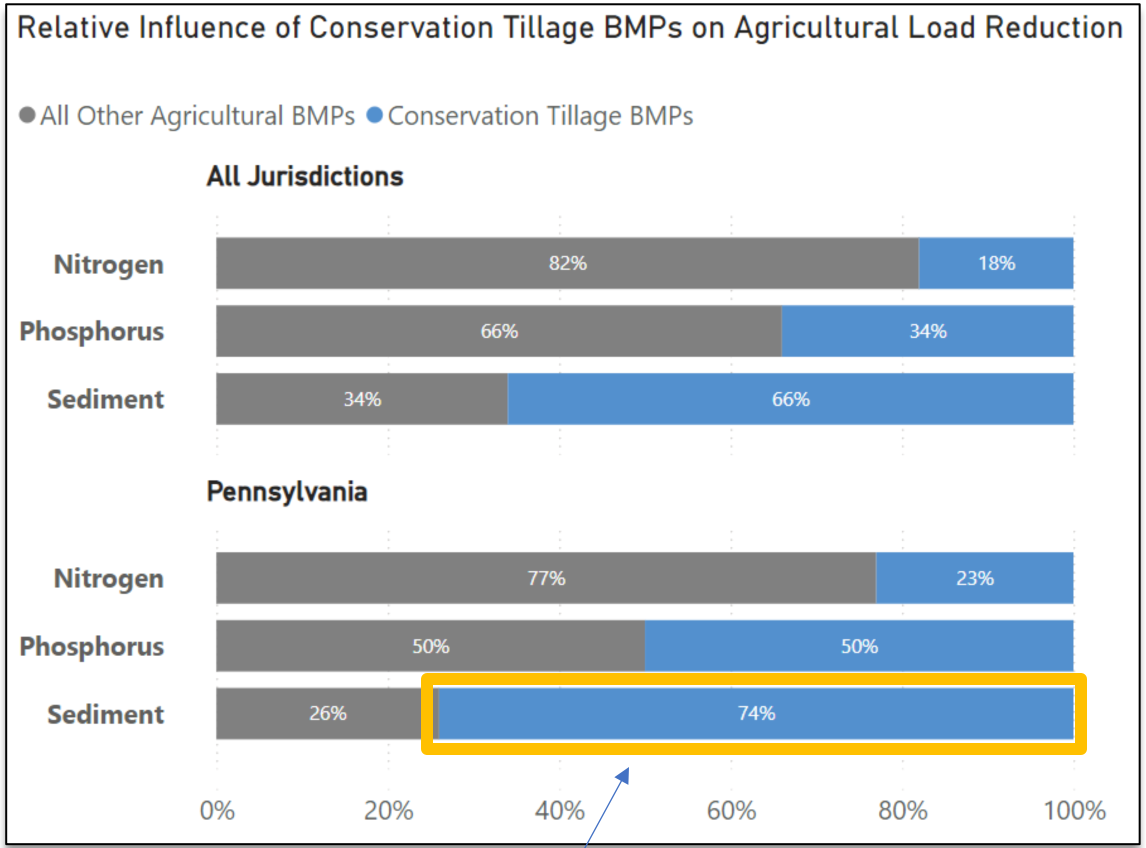

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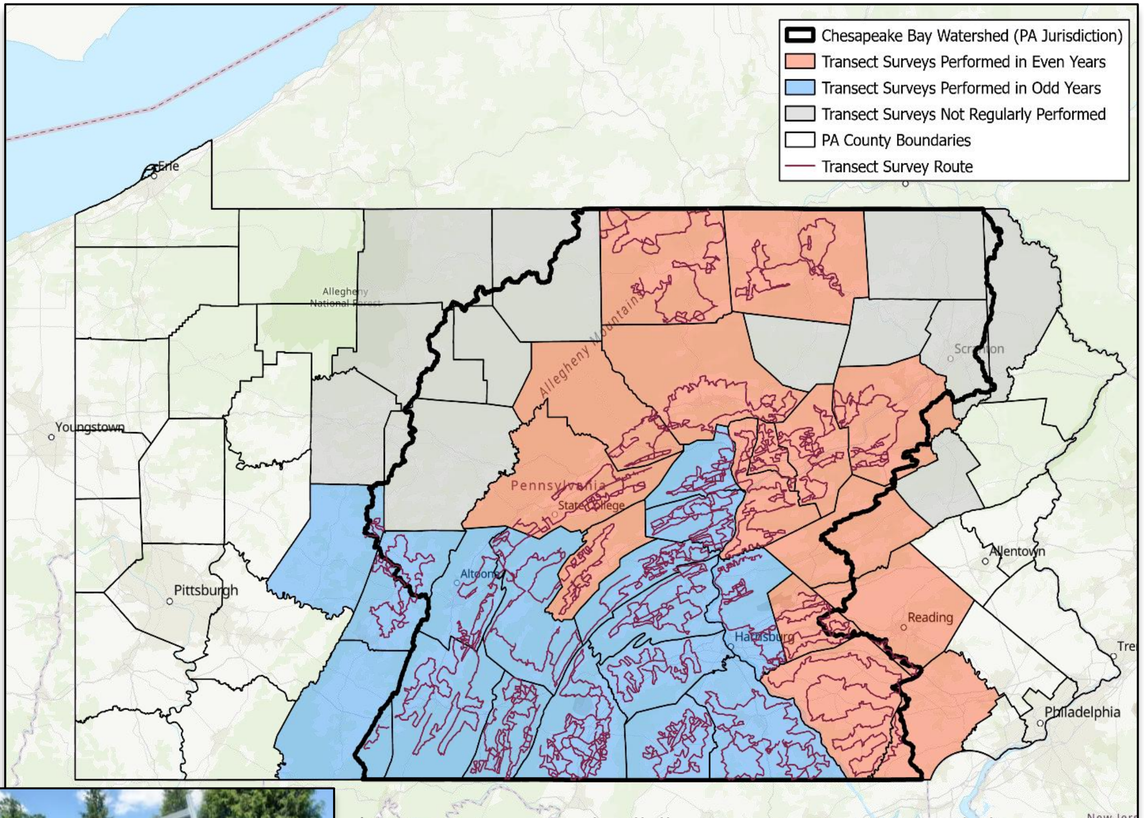

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New satellites provide enhanced capabilities for accurately monitoring conservation tillage BMPs

Using the unique spectral properties of the soil, crops, and crop residue, remote sensing can identify fields implementing conservation tillage practices

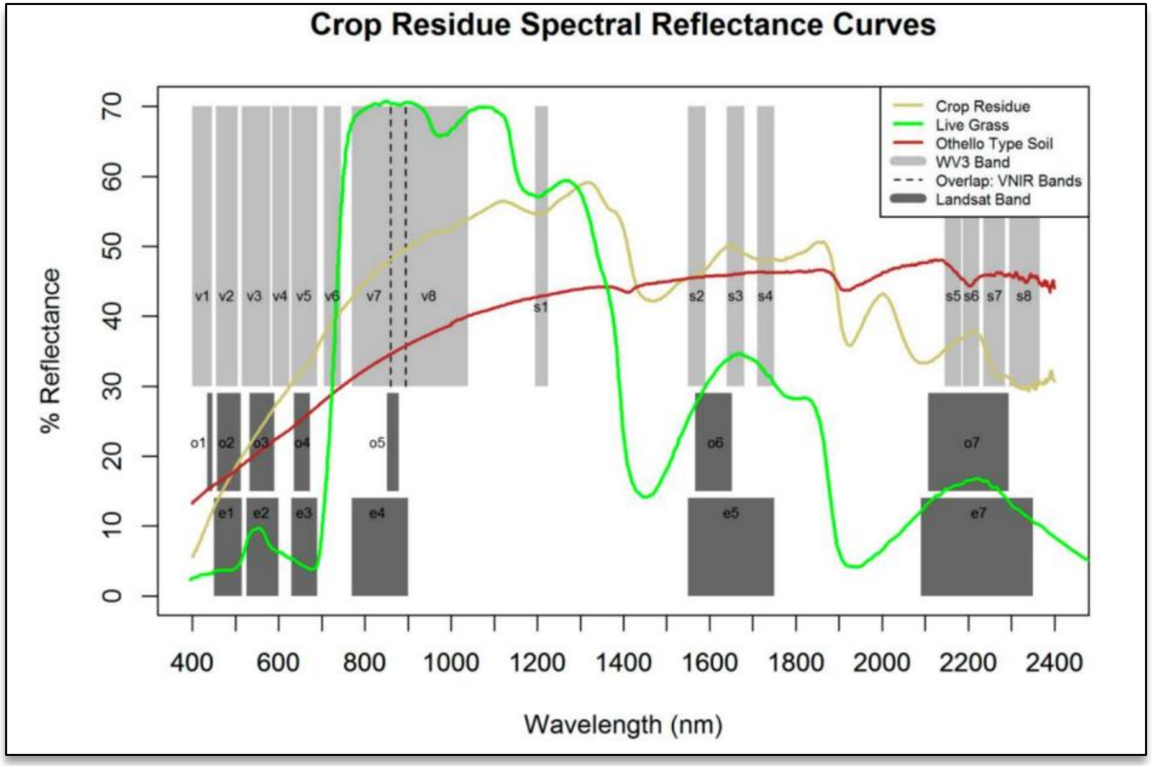
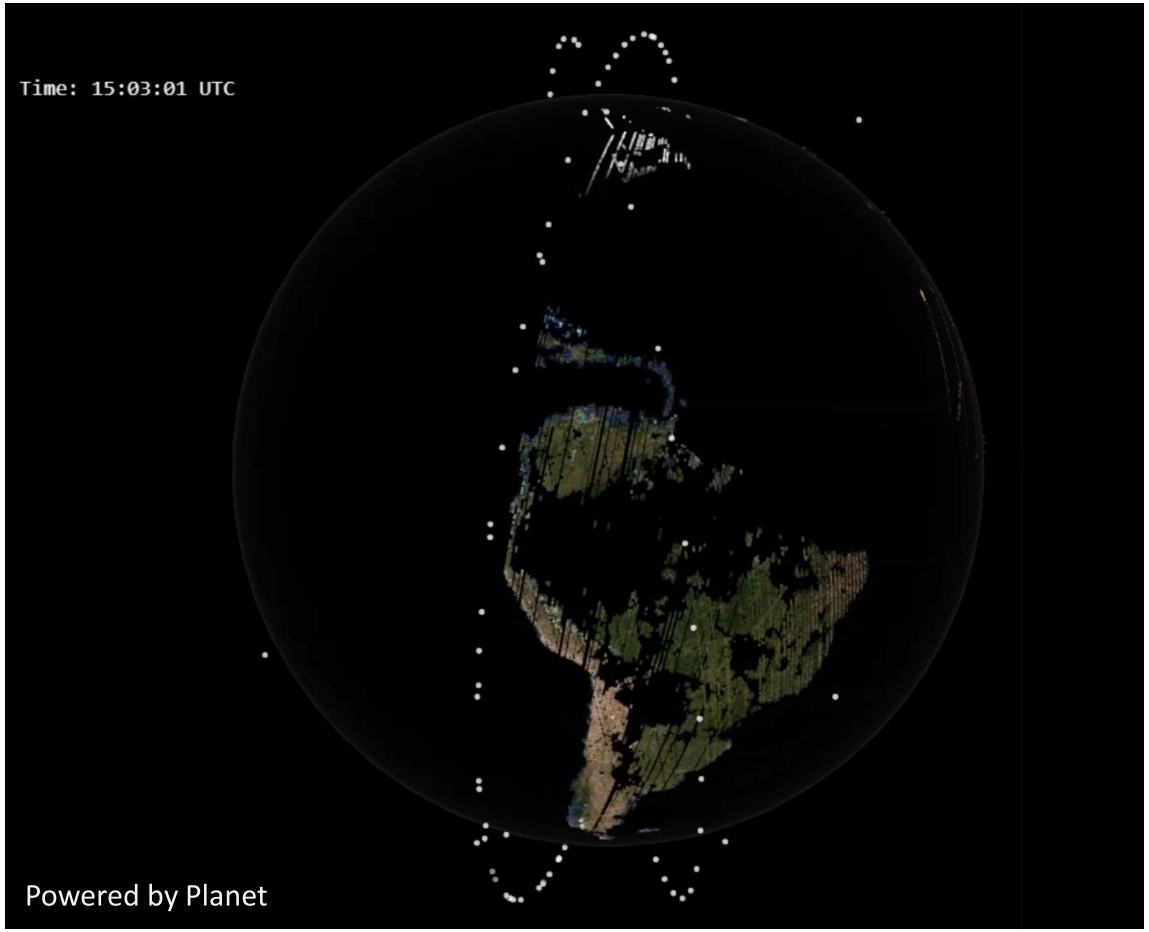


Figure from Hively et al. (2018). Reflectance curves for maize residue (tan line), live grass (green line), and an Othello silt-loam soil (red-line). The grey bars represent the spectral band widths of WorldView-3 and Landsat 7/8



Orbits of PlanetScope satellite constellation

Satellite data promises to provide Bay-wide information on conservation tillage BMP implementation

NDTI Color Scale

High residue

Low residue

HLS image from May 26, 2020 showing normalized difference tillage index (NDTI) over croplands in PA

PA DEP has drafted a forward-looking methodology for monitoring and reporting conservation tillage BMPs using remote sensing

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PA-DEP Remote Sensing-Based Verification of Conservation Tillage BMPs Pilot Project Overview

Phase 1: Methodology Development Plan

March 2024 to June 2024

Presentation to AgWG on Methodology Development Plan

Phase 2: Method Development and Evaluation

July 2024 to Present

Independent Review

Vote for AgWG Approval of Developed Methodology

Phase 3: Implementation

Chesapeake Bay Program
Science. Restoration. Partnership.

We seek to obtain AgWG feedback and official approval on the developed methodology at the April AgWG meeting

PA DEP's Remote Sensing BMP Pilot Project aims to develop a standard operating procedure for remote detection of conservation tillage BMPs

Implementation workflow:

1. Estimate BMP implementation over a large area using remote sensing →
2. Collect ground-truth data using traditional methods →
3. Process ground-truth data and assess suitability →
4. Report results

How do jurisdictions assess whether remote sensing methods and results are "suitable" for reporting conservation tillage BMP implementation?

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Pennsylvania Department of Environmental Protection Remote Sensing Pilot Project

Draft Methodology Guidance for Remote Sensing Verification of Conservation Tillage BMPs

Submitted:
January 13, 2025

Prepared by:
Resolve Hydro LLC

Contents

Goal: Develop a robust methodology to allow jurisdictions to report essential information to NEIN using remote sensing:

- BMP Name (reduced, conservation, or high residue tillage)
- Measurement name (acres)
- Land use (crop)
- Geographic location (e.g., county)
- Date of implementation (year)

Lancaster County will be used as a test case in this presentation to demonstrate how the methodology might be applied

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Go Back

Pennsylvania DEP Conservation Tillage Monitoring Dashboard

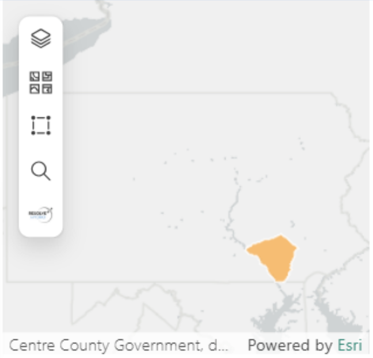
- Home
- Statewide Summary
- Statewide Change
- **County Detail**
- Reduction Calculator
- Glossary

Overview - This page provides county-specific information on conservation tillage implementation in Pennsylvania. The area eligible for conservation tillage is estimated from base conditions defined in the 2023 CAST scenario.

165K

Acres Eligible for Conservation Tillage

County Location Map



Select County Name(s): Lancaster County

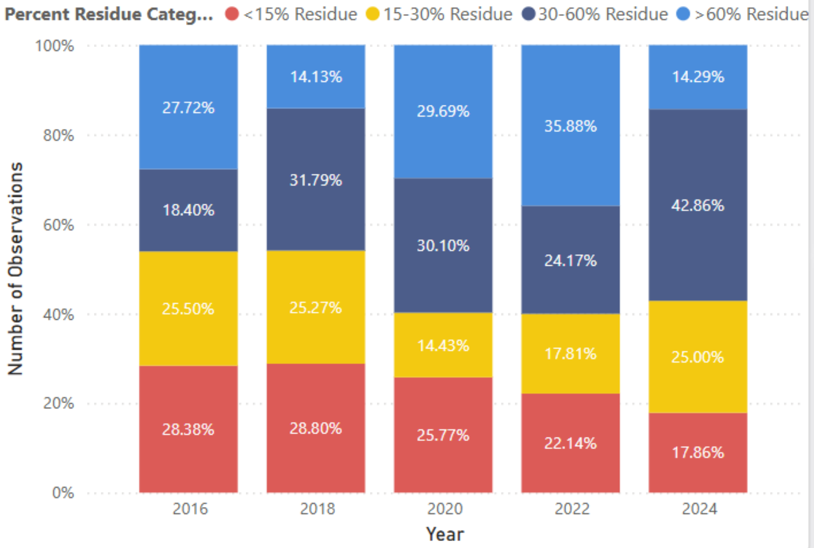
Select Analysis Year(s): All

Select Resiude Category: Multiple selections

Average Nutrient and Sediment Reduction Factors in Selected County

Tillage Management Type	TN Lbs Reduced Per Acre	TP Lbs Reduced Per Acre	TSS Lbs Reduced Per Acre
Low Residue	2.51	0.11	181.85
Conservation	5.01	0.70	414.22
Continuous High Residue	7.02	0.88	798.13

Conservation Tillage BMP Implementation in Lancaster County



Conservation Tillage Survey Results (Number of Observations)

Year	<15% Residue	15-30% Residue	30-60% Residue	>60% Residue	Total
2016	128	115	83	125	**451**
2018	106	93	117	52	**368**
2020	125	70	146	144	**485**
2022	87	70	95	141	**393**
2024	70	98	168	56	**392**
Total	**516**	**446**	**609**	**518**	**2089**

Conservation Tillage Survey Results (Percent of Observations)

Year	<15% Residue	15-30% Residue	30-60% Residue	>60% Residue	Total
2016	28.38%	25.50%	18.40%	27.72%	**100.00%**
2018	28.80%	25.27%	31.79%	14.13%	**100.00%**
2020	25.77%	14.43%	30.10%	29.69%	**100.00%**
2022	22.14%	17.81%	24.17%	35.88%	**100.00%**
2024	17.86%	25.00%	42.86%	14.29%	**100.00%**
Total	**24.70%**	**21.35%**	**29.15%**	**24.80%**	**100.00%**

Step 1: Estimate a minimum sample size using a multinomial distribution

$$n_0 = \frac{q(1-q) * \chi^2_{\left(1,1-\frac{\alpha}{k}\right)}}{d^2}$$

To estimate tillage implementation throughout Lancaster with a 90% confidence interval, $\pm 5\%$ error, uninformed prior,

$$n_0 = \frac{0.5 * (1.0 - 0.5) * \chi^2_{1,1-\frac{1-0.5}{k}}}{0.05^2} = 541$$

Where:

n_0 = the minimum size of the random sample

q = the *a priori* estimate of the proportion for each category (e.g., 0.5 to represent a non-informative prior)

$\chi^2_{\left(1,1-\frac{\alpha}{k}\right)}$ = the Chi-square value for one degree of freedom and the given number of classes and confidence level

k = the number of classes in the population

$\alpha = 1 - p$

p = the selected confidence level (e.g., 0.90 to represent a 90% confidence interval)

d = the allowable error (e.g., 0.10 to represent an allowable error of $\pm 10\%$)

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$$n_0 = \frac{0.5*(1.0-0.5)*\chi^2_{1,1-\frac{1-0.5}{k}}}{0.05^2} = 541$$

$$n = SF * n_0$$

With a 5% safety factor, the size of the sample to be used in the remote sensing survey becomes

$$n = (1 + 0.05) * 541 = 568$$

Where:

n = the size of the sample to be used in the remote sensing survey

SF = the selected safety factor (e.g., 1.05 to oversample by 5%)

n_0 = the minimum size of the multinomial random sample calculated above

Step 2: Select Survey areas

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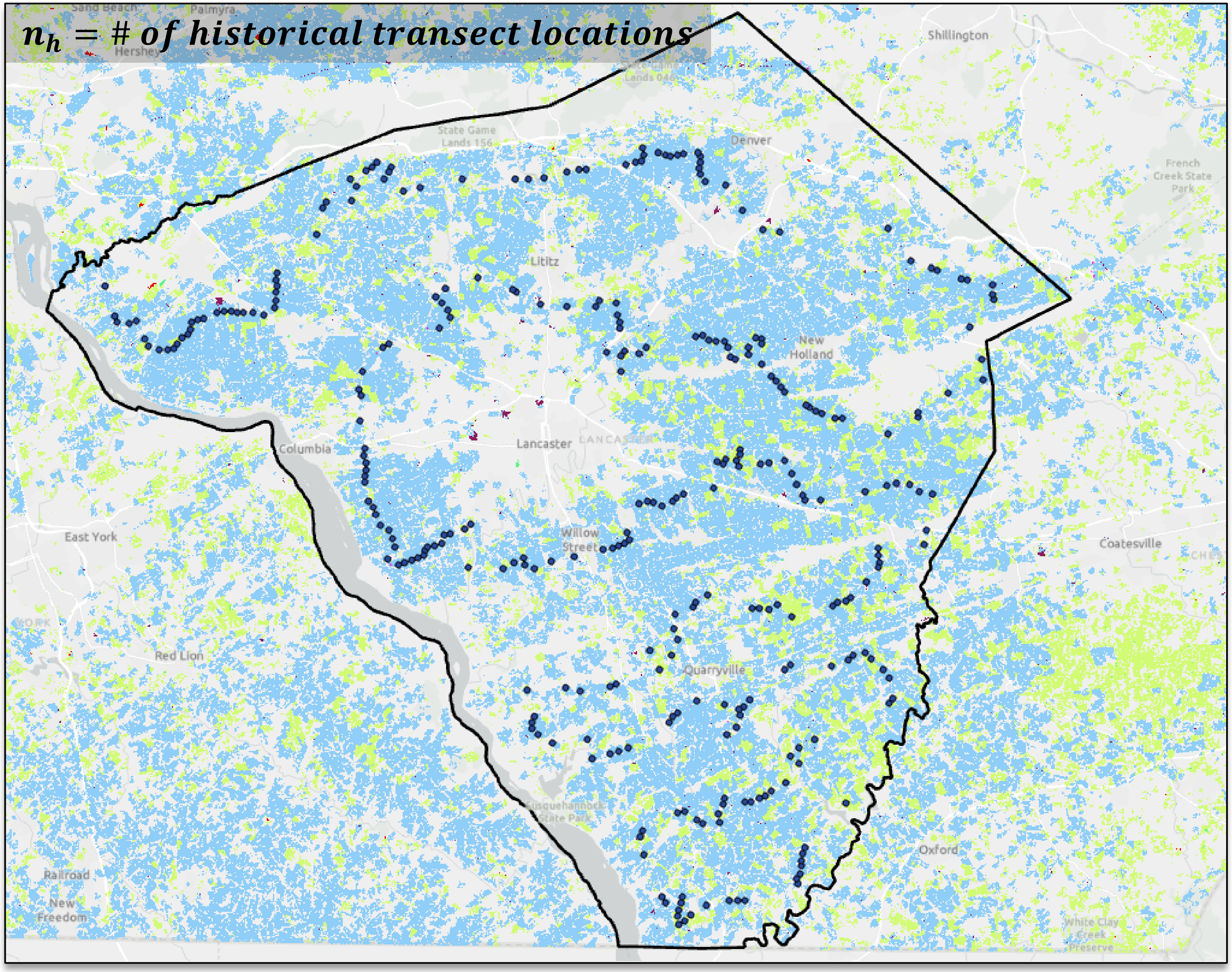


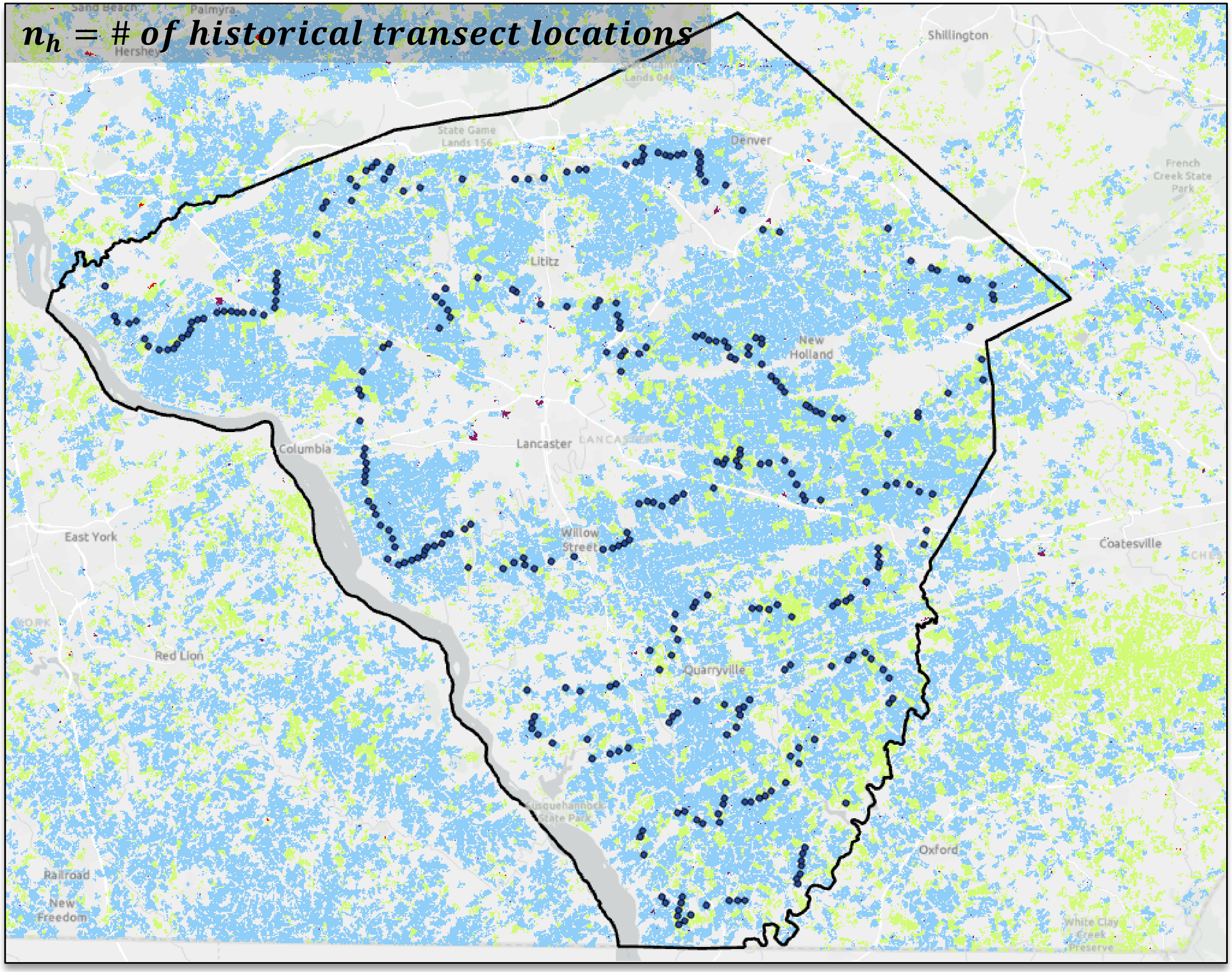
Cropland areas and historical transect points in Lancaster County

With a 5% safety factor, the size of the sample to be used in the remote sensing survey is $n = 568$ so at least 568 acres of land should be sampled in the remote sensing survey

Recommendations:

1. Retain some or all of the historical transect survey locations
2. Each sample location should represent 1-acre of cropland (add more sample locations if the total area of samples is less than n acres)

Step 3: Identify verification data to collect with secondary methodology



Cropland areas and historical transect points in Lancaster County

At least 568 acres of land should be sampled over $n = 568$ distinct locations in the remote sensing survey. This value assumes a 5% SF on $n_0 = 541$

To verify:

1. Collect data at 10% (or more) of the historical transect locations so at least $0.10 * n_0$ acres of land are verified
2. Collect data at randomly selected historical transect locations so that at least 20 ground truth observations of BMP implementation are observed
3. Collect data at $0.10 * n_0$ or more randomly sampled areas within a larger representative area (e.g., HUC or hydrogeomorphic region)

Step 4: Collect the remote sensing and ground truth data

Although **the remote sensing methodology is model agnostic** (e.g., so jurisdictions can calibrate models to their unique environments, so advances in remote sensing can be readily incorporated into state workflows, etc.), the methodology introduces **general guidelines for data collection and model application**:

Recommendations (see Survey Implementation section of report):

1. The **data collection period** should generally be restricted from the start of March to the end of June
2. Links and descriptions of any **ancillary data layers** used in the remote sensing process should be clearly documented
3. The remote sensing modeling of conservation tillage BMPs should ensure that each pixel included in the remote sensing survey is assigned to only (at most) one tillage regime to **avoid "double counting"**
4. Individuals designing the remote sensing surveys and implementing data collection, model application, and verification processes should have **sufficient technical knowledge and training**

Step 4: Collect the remote sensing and ground truth data

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Additional Recommendations (see Model Selection section of report):

1. A model workflow must be capable of **distinguishing between the three types of conservation tillage BMPs** defined by the CBP
2. Models used to generate conservation tillage BMP classifications based on remote sensing data should generate outputs with a **minimum pixel resolution of 60 meters**
3. The methods and data used to develop and calibrate a model should be **well-documented and transparent**
4. The **suitability of a model should be based on performance** and determined on an annual basis
5. Data used to evaluate a model's performance should be **fully separate from the data used to train or calibrate** a model

Step 5: Analyze and report results

Example field accuracy assessment:

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Human observer classifies entire field as “>60% crop residue cover”

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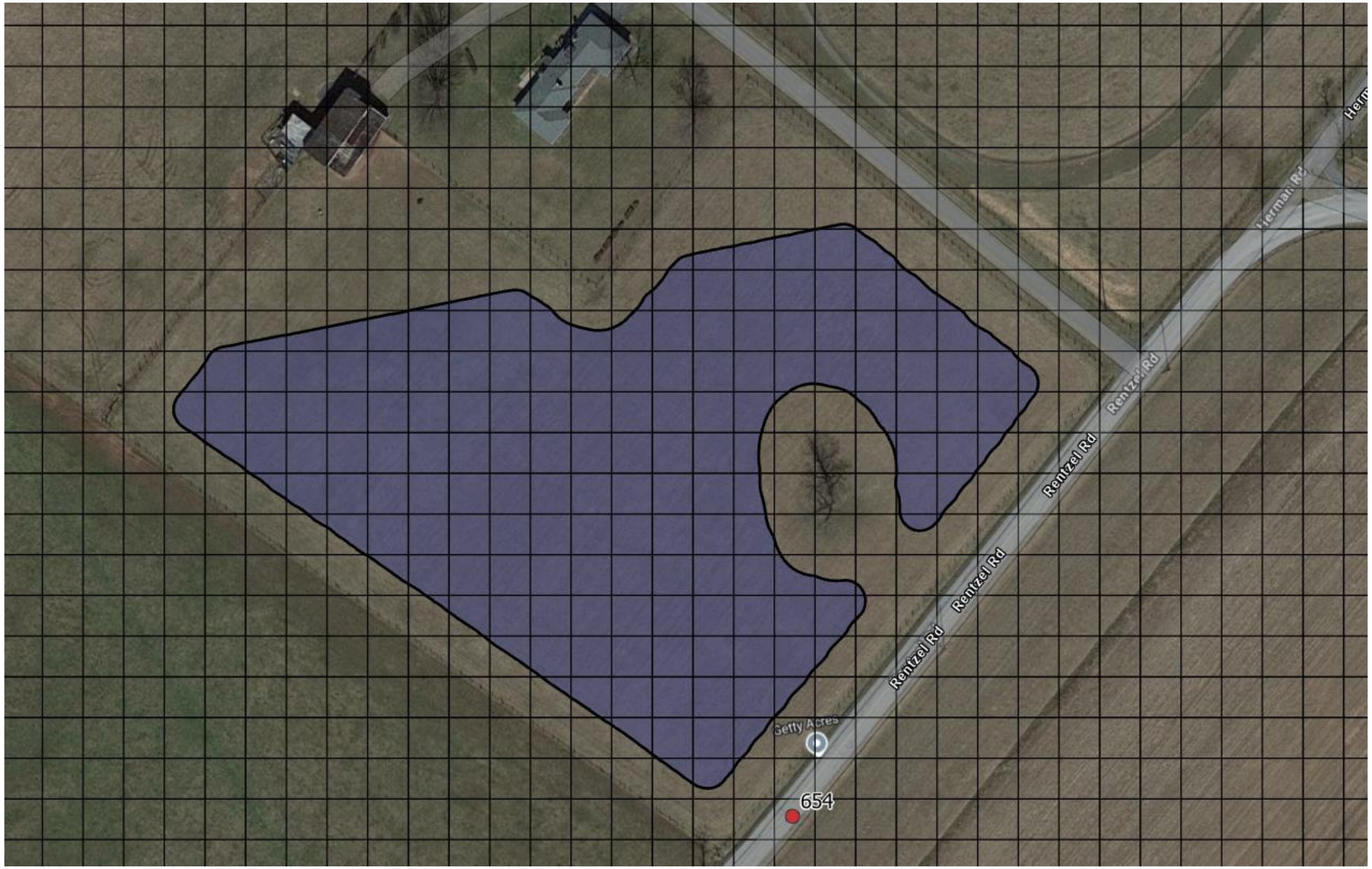

Human observer classifies entire field as ">60% crop residue cover"

Satellite observer classifies field with finer spatial resolution

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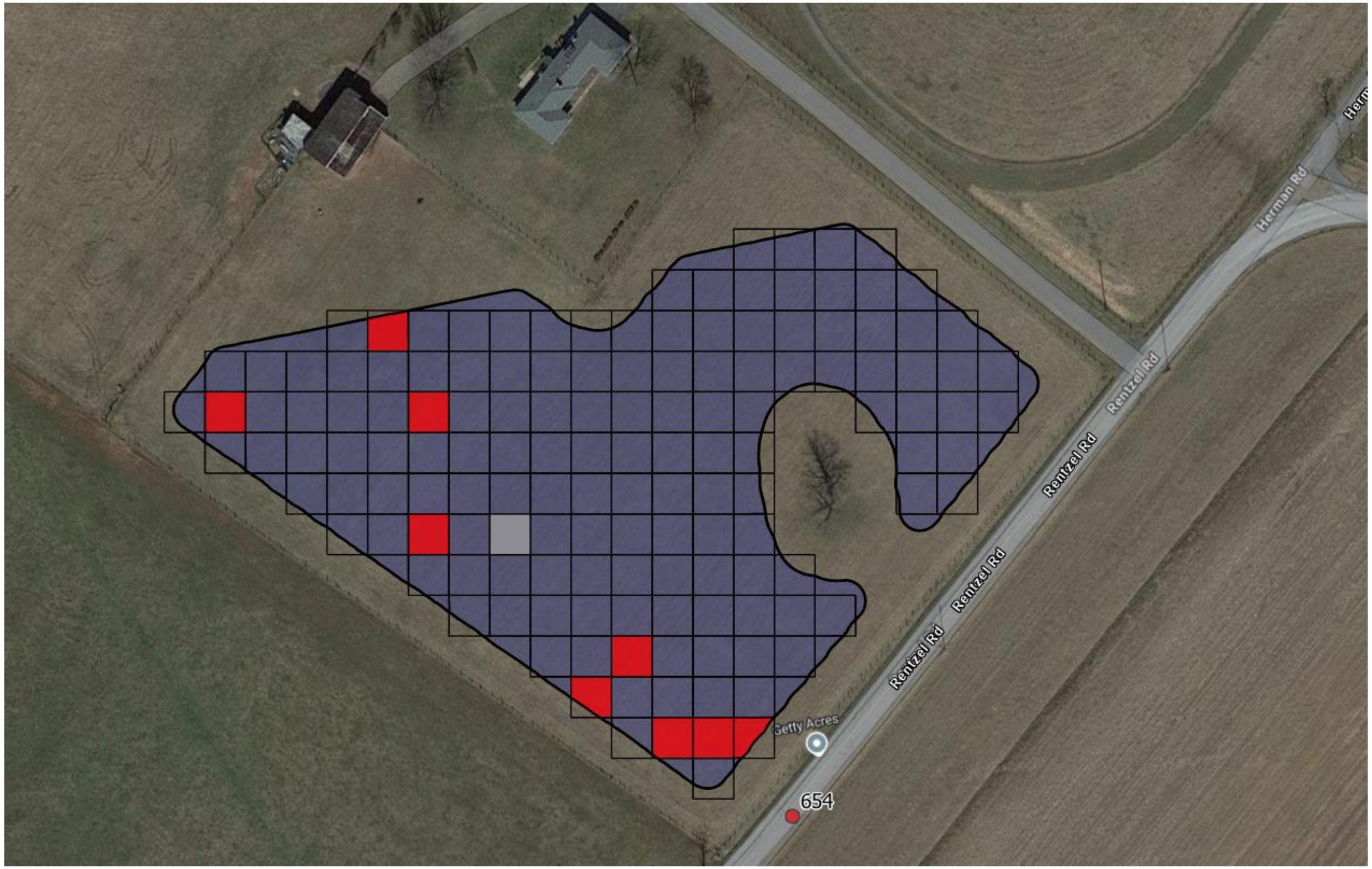

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Residue Class	Area (m²)	Area (ac)
Not eligible for tillage	0	0
<15% crop residue	0	0
15-29% crop residue	100	0.02
30-59% crop residue	831	0.21
>60% crop residue	12,704	3.14
Total	**13,635**	**3.37**

Step 5: Analyze and report results

Imagine ground-truth assessments of remote sensing results were performed at 54+ separate locations with a total area of 1,600 acres

Confusion Matrix for 1600 Acres		**Remote Sensing Observations**				
		Not eligible	<15% residue	15-29% residue	30-59% residue	≥60% residue
Field Observations	Not eligible	0	0	0	0	0
	<15% residue	0	124	16	7	9
	15-29% residue	0	18	135	16	6
	30-59% residue	0	6	15	282	6
	≥60% residue	0	0	25	71	864

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Using the confusion matrix, calculate:

1. Unbiased estimates of the true (adjusted) **marginal proportions of each tillage regime** with bounds from the selected confidence intervals
2. **Producer's accuracy** (also referred to as the hit rate) and variance for each marginal proportion
3. **User's accuracy** (also referred to as the post agreement rate) and variance for each marginal proportion
4. **Overall accuracy** and variance
5. Bias adjustments (as needed)

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Based on these calculations, decide to accept or reject the remote sensing model results

Step 5: Analyze and report results

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From the March 2017: *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*

Because of differences in personnel from county-to-county and year-to-year, the results from the quality assurance are staffing specific. The basic recommendations for acceptability include the following:

- Each quality assurance analysis will report the sample count error matrix; the area proportion error matrix (including confidence intervals of the true or adjusted proportions); the producer's, user's, and overall accuracy estimates; and the confidence interval of the overall accuracy estimate.
- To use the true (adjusted) proportions resulting from the analysis, the lower confidence limit on the overall accuracy must exceed 50 percent. (A value of 50 percent was selected based on the lower range of survey accuracies discussed in the literature review section of this report.)
- A minimum confidence level of 90 percent should be used on all statistics.

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Discussion section

Conclusions reached by Sullivan et al. (2008) indicate that a remote sensing method with an overall accuracy of 71% to 78% is acceptable. Results also indicated that a ground verification sample size of 20-44 is suitable with overall accuracy improving by 7% in this case when n was increased from 20 to 44. Similarly, the error of commission, or FAR, value ranged from 0.15 for $n = 44$ to 0.20 for $n = 20$. It is acknowledged that Sullivan et al.'s objectives for using remote sensing are somewhat different from the present purpose, and these differences should be considered if a minimum sample size for ground verification is selected.

Recommendations section

Based on the available literature (Sullivan et al. 2008) a FAR value of 0.2 or 0.3 and a HR value of 0.7 or 0.8 may be appropriate thresholds for determining whether a remote sensing effort generates suitable BMP data. Single application of the FAR threshold would be appropriate when over-counting of BMPs is the primary concern. It is recommended that the upper confidence level (α=0.10) be used as the threshold value. Single application of the lower confidence level (α=0.10) of HR be used when under-counting of BMPs is the primary concern. Where over-counting and under-counting of BMPs are of equal concern it is recommended that thresholds for both FAR and HR be established.

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THANK YOU

Tom Howard

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