BMP Verification – Supporting Information

Introduction

The Chesapeake Bay Program's Agriculture Workgroup (AgWG) is exploring options to verify the implementation and operation of agricultural Best Management Practices (BMPs) in the Chesapeake Bay Watershed. The objectives of this effort are to identify approaches or protocols for verifying agricultural BMP implementation, to assess the varying levels of data confidence associated with different protocols, and to reflect the varying confidence levels by potentially adjusting credit values for BMP implementation in the Bay Model. Verification of both cost-shared and non-cost-shared practices is desired. Currently, options identified by the AgWG fall into five categories:

- On-farm assessment by trained personnel;
- Farmer self-assessment, with or without spot check by agency personnel;
- Review of existing agency or on-farm records;
- Statistical sampling; and
- Remote sensing

Two approaches were taken to assemble supporting information for BMP verification. First, a search of scientific literature and published reports was conducted to document past and ongoing BMP verification protocols relevant to the Chesapeake Bay Watershed. Second, brief telephone interviews and email exchanges were conducted with 19 individuals both within and outside of the Chesapeake Bay Watershed who had been identified by the AgWG as having significant experience and/or expertise in BMP verification. The purpose of these interviews was to identify specific verification programs and key principles that should be applied to future verification efforts.

Literature review

Results of the literature review are summarized below, generally organized by the main protocols proposed by the AgWG.

On-farm assessment by trained personnel

Bracmort et al. (2004 and 2006) conducted a retrospective examination of BMPs implemented in the Black Creek Watershed (IN). A representative sample of grassed waterways, grade stabilization structures, field borders, and parallel terraces installed ~20 years previously during the Black Creek Project were inspected and assigned a condition score using evaluation tools developed for that purpose. Evaluation of the current condition of the BMPs found that one-third of the practices no longer existed and that the two-thirds that still existed were in fair condition and partially functional. Efficacy of BMPs in reducing nonpoint-source pollution (evaluated using the SWAT model) varied with their condition. Under good conditions, BMPs alleviated average annual sediment and phosphorus yields at the outlet by 32% and 24%, respectively. As BMPs deteriorate, their ability to reduce sediment and total P diminishes. Modeling results for BMPs in varying conditions revealed that the average annual sediment yield was reduced by only

10%, which is nearly 3 times less than the reduction corresponding to BMPs in good condition. Estimated average annual phosphorus yield at the watershed outlet was reduced by 17% for BMPs in their current condition, providing nearly 70% of the phosphorus reduction estimated for BMPs in good condition.

Farmer self-assessment, with or without spot-check by agency personnel

The Minnesota Department of Agriculture (MDA) conducts statewide monitoring and evaluation of pesticide BMP use (2007). The MDA conducts biennial surveys of pesticide use practices reported by farmers and conducts field audits within select watersheds.

Florida conducts a number of BMP verification programs based on farmer self-assessment. Under Rule 40E-63 permitting, landowners are required to submit BMP plans based on a point system for various BMPs - 25 BMP equivalents or points were set as the minimum target BMP level (South Florida Water Management (SFWMD) 1999). After the BMP permit plans are approved, Rule 40E-63 requires follow-up post-permit verification of the approved BMP plans on two levels: 1) BMP implementation reports and 2) BMP field verification. Annual BMP implementation reports are required to be submitted to the District; they are to summarize not only the initial implementation of BMPs but also ongoing BMP maintenance and documentation. SFWMD Everglades Regulation Section staff conduct BMP site verifications on an eighteen-month rotational basis to allow examination of BMPs implemented in both wet and dry seasons. Field verification procedures begin with generating a database-driven BMP checklist specific to the permit drainage basin. The checklist consists of all BMPs selected by the permittee to be implemented. The checklist is mailed to the permittee prior to the verification to assist the landowner in preparing his documentation for the inspection. The verifications involve a combination of visual field observations and a review of office records. During the office review the SFWMD staff focuses on records that document soil test results, fertilizer recommendations and applications, BMP training of farm personnel, pump logs, and any other material that supports BMP implementation. While in the field, SFWMD staff note any visual evidence that the selected BMPs have been implemented. This evidence may range from spoil on canal banks indicating canal cleaning was performed, fertilizer banding or land leveling equipment operating, and maintenance of vegetation on ditch banks to reduce sedimentation, to any other observable evidence that supports BMP implementation. The verifications are a “spot-check” of the landowner’s implemented BMPs. This spot check is a snapshot in time of how and when BMPs were implemented for that particular field and land use. The SFWMD knows which types of BMP have been chosen by the landowner for each particular land use and location so a verification can be conducted.

In several other regions of the state, the Florida Department of Agriculture and Consumer Services (FDACS) Office of Agricultural Water Policy (OAWP) runs an *Implementation Assurance Program* (FDACS 2008). Producers participate by submitting a Notice of Intent (NOI) to implement a checklist of practices applicable to acres being enrolled. The OAWP developed a Best Management Practices Tracking System (BMPTS) to record the submittal of NOIs and assist in tracking BMP implementation. The OAWP issues detailed reports on results of the program. For example, in the Lake Okeechobee Watershed Implementation Assurance Process, each operation is visited upon completion of cost-share structural BMPs, to ensure these

BMPs have been properly installed, prior to receiving state cost-share funds. Overall Implementation Assurance site inspections are conducted in order of when Conservation Plans are completed and implemented, generally within 6 months of plan implementation. Staff fill out a review/checklist form and assign an overall rating of *Satisfactory*, *Needs Improvement*, or *Unsatisfactory*, based on the observed condition of BMPs relative to the Conservation Plan. For operations that receive a *Satisfactory* rating, no follow-up visit is necessary. However, OAWP staff will conduct "routine" site visits approximately annually, depending on the inspection workload. At this time, maintenance of structural BMPs will be reviewed and rated. For a rating of *Unsatisfactory* or *Needs Improvement*, there will be a scheduled follow-up inspection, usually within 120 days to check on progress. Additional follow-up site visits will be scheduled as circumstances warrant. BMPs commonly reviewed during site inspections include both structural (e.g., culverts, culvert risers, fences, water troughs, well capping) and management (e.g., nutrient management, maintenance of structural practices, and record keeping) BMPs.

OAWP reports include extensive presentation of findings, survey/review forms, and flow charts of the verification process. No assessment of accuracy or confidence is provided.

Review of existing agency or on-farm records

The USDA-ARS Little River Experimental Watershed (LREW) in GA has been the site of several BMP verification efforts. Sullivan and Batten (2007) used historical paper files and maps (circa 1980-2006) to develop a digital geographic database of conservation practices supported by the USDA NRCS. Watershed boundary, USDA tract boundaries, and field boundaries were digitized from USGS quadrangles. An associated database file was created containing county names, tract and field numbers, the NRCS program under which the practice was granted, the NRCS practice number and description, the NRCS estimated acreage covered by the practice, the completion date, and whether the practice was of cost or no cost to NRCS. Results showed that nearly 16% of the land area in the LREW had participated in one or more USDA-NRCS recommended conservation programs within the last 30 years. Forty-seven different conservation practices were observed within the LREW, ranging from fish pond management to grassed waterways. The most predominant conservation practices observed were: nutrient management (13.1% of all practices), pest management (12.9%), grassed waterways (9.6%), contour farming (9.5%), seasonal residue management (8.9%), and terraces (8.8%). Some 46% of BMPs were implemented voluntarily with technical assistance provided by NRCS field staff. Cost-share programs predominantly funded the establishment of grassed waterways, terraces, nutrient management, and pest management. Voluntarily implemented practices consisted primarily of contour farming, residue management, and nutrient management.

Settimi et al. (2010) subsequently used the LREW BMP database in a USDA Conservation Effects Assessment Project (CEAP) study to evaluate the effectiveness of federally funded conservation programs. Using a subwatershed database having complete field coverage of four LREW subwatersheds (with and without USDA NRCS assistance), GIS databases were queried to evaluate the adoption and placement of erosion control practices that were visible in a 2005 digital orthoquad. Forty-seven percent of all fields in the subwatershed database had implemented visible erosion control–specific conservation practices. Implementation was linearly related to slope class ($r^2 = 0.64$, $p < 0.10$). Fields identified as having participated in federally funded conservation programs coincided with high resource concern areas 35% of the time.

Reid-Rhoades et al. (2008) and Wilson et al. (2008) endeavored to determine the effectiveness of conservation practices for reducing sediment yield in Topashaw Canal watershed (TCW) in north-central MS. A census of conservation practices installed within the TCW by various governmental agencies (USDA NRCS, USDA Farm Service Agency, and US Army Corps of Engineers) was compiled by collecting land management history for tracts that were currently or had participated in conservation incentive programs such as EQIP, CRP, and special regional erosion control projects. Descriptive data were entered into spreadsheets with the funded conservation program identified by tract number and sensitive information (e.g., landowner identifiers) removed. Spatial coordinates associated with each practice were recorded to prepare data sets for watershed modeling with AGNPS and SWAT. This was done using 1996 aerial photographs from the Farm Service Agency offices with the tract numbers for each funded conservation practice (CP) identified. Satellite imagery for December of 2006 provided current aerial photography of land use. These images were verified by making GPS measurements at about 30 known points within the TCW that were easily identified in the images. The practice data were interpolated into spatial information through the creation of digitized polygons using scanned aerial photos that associate land use management schemes with tract numbers. Land use practices that were not included in government incentive programs were compiled from agency data and satellite imagery.

Jackson-Smith et al. (2010) used intensive field surveys and interviews with program participants to assess the accuracy of using official records as a measure of short- and long-term BMP use in a northern Utah watershed. The researchers worked in the local USDA NRCS office to review the official contract files for each of the 90 landowners or farmers who participated in the Little Bear River Watershed Project (LBRWP) from 1992 to 2006. They gathered and entered into a database (1) official USDA NRCS practice codes and additional detailed information about each specific conservation practice that participants were contracted to implement during the life of the LBRWP, (2) the USDA Farm Service Agency farm tract and field numbers describing where each practice was located, (3) general information about each operation, and (4) contact information for each program participant. In addition, aerial photographs of each participant’s land were photocopied, and based on the information from the files, markings were placed on the photocopied images to signify where each of the contracted BMPs was located on the physical landscape. Face-to-face interviews were conducted with 55 of the original 90 participants. Following each interview, the original database of LBRWP BMPs was updated to note instances where the participant reported information that conflicted with that obtained from the NRCS files. Subsequently, researchers determined the implementation status for each BMP included in a participant’s original files using several techniques. Initially, they shared a list of BMPs on file and the aerial photographs with respondents and systematically reviewed each practice to discover whether or not the practice was successfully implemented, whether they encountered any problems during the implementation of the practice, and whether or not they were still using the practice. While a seemingly simple exercise, coding the implementation status for BMPs was sometimes complex. During interviews, several instances were encountered where a respondent indicated no recollection of a particular BMP being part of their contract and numerous others where they insisted that the description of the practice (usually drawn from the NRCS practice code definitions) was not a completely accurate characterization of what happened. The net result of post-interview coding was to create a new set of tabular and spatial databases that represent an updated (and presumably more accurate) catalogue of conservation behaviors in the Little Bear River watershed.

Overall, Jackson-Smith et al. (2010) determined that project participants could not verify implementation for 88 (16%) of the contracted BMPs. Most of these were instances where all available evidence pointed to a failure to successfully implement the practice, though a handful of cases involved misclassified BMPs where a different type of practice was actually carried out. In almost every case of non-implemented BMPs, respondents simply did not recognize the practice as being part of their original project. Another group of respondents described what they had done in connection to a contracted management BMP, but it was apparent to the research team that their actions did not meet even a minimal definition of the changes in behavior implied by adoption of this type of BMP. Overall, it was determined that over 20% of implemented BMPs appeared to be no longer maintained or in use. BMPs related to crop production enterprises and irrigation systems had the lowest rate of continued use and maintenance (74% to 75%), followed by pasture and grazing planting and management BMPs (81%). By contrast, nearly every instance of fencing and riparian protection structures in the files were found to have been implemented on the study farms. Generally speaking, structural BMPs and practices for which cost-sharing was available were more likely to be implemented, perhaps because they involved greater investment of public and private funds. However, the implementation gap between cost-shared and non-cost-shared practices was not as significant as anticipated. Although cost-sharing is often believed to be an essential incentive to encourage use of BMPs, in this study, the majority of practices implemented were unfounded. A majority of unfunded practices appear to have been implemented, though the rate of implementation was significantly lower.

The study findings suggested that official watershed program contracts and related records can be a very useful resource for describing patterns of conservation behaviors at the watershed scale but that they may not provide a complete and accurate description of BMP adoption and related behaviors instigated by a conservation program. Management practices are particularly susceptible to non-implementation and maintenance.

Surveys and statistical sampling

Tetra Tech, Inc. developed for USEPA (USEPA 1997) a guidance document intended to assist state, regional, and local environmental professionals in tracking the implementation of BMPs used to control agricultural nonpoint source pollution. Information is provided on methods for selecting sites for evaluation, sample size estimation, sampling, and results evaluation and presentation. The focus of the guidance is on the statistical approaches needed to properly collect and analyze data that are accurate and defensible. Probabilistic sampling designs are discussed – including simple random sampling, stratified random sampling, cluster sampling, and systematic sampling – to meet specific objectives for tracking and evaluating the implementation of BMPs. Measurement and sampling errors are also examined. Sources of information are listed, including the USDA NRI, the USDA Census of Agriculture, the National Agricultural Statistics Service (NASS), local USDA program information, FSA data, and state Cooperative Extension.

The guidance documents methods for estimating sample sizes required to compute point estimates such as proportions and means, as well as detecting changes with a given significance level for a variety of sampling designs. Methods for evaluating data through statistical hypothesis testing are presented. A chapter addresses the process of determining whether agricultural BMPs are being implemented and whether they are being implemented according to approved standards or specifications. Guidance is provided on what should be measured to assess BMP implementation, as well as methods for collecting the information, including physical farm or field evaluations, mail- and/or telephone-based surveys, personal interviews, and aerial reconnaissance and photography. Designing survey instruments to avoid error and rating BMP implementation are also discussed. Self-evaluations, while often not a reliable source of BMP implementation data, are proposed as a way to augment data collected through expert evaluations or in place of expert evaluations where the latter cannot be conducted. Aerial reconnaissance and photography are also discussed as data collection tools, although newer and better technology is now available.

Lambert et al. (2007) presented information on the CEAP-Agricultural Resource Management Survey (CEAP-ARMS) of 2004. This survey represents an annual source of data on the finances and practices of a nationally representative sample of U.S. farms that also includes information on the characteristics of the farm operators and their households. The CEAP-ARMS questionnaire links ARMS farm household, resource, and economic data directly to CEAP production practice and program participation data, and corresponding field-specific NRI data. The paper is an exercise of integrating different data sources of varying precision to draw conclusions about influences of socio-economic factors on adoption of conservation practices and environmental benefits.

Benham et al. (2005) developed sixteen survey-like assessment tools to address the need for a low-cost, rapid method of quantifying the quality of agricultural BMPs. BMP quality was defined as the adherence to design, site selection, implementation, and maintenance criteria as specified by state and federal conservation practice standards. Quality assessments are made based upon visual observations of BMPs rather than traditional assessment methods such as water quality monitoring. Tools were developed and tested as are part of a proof of concept study. A different assessment tool was designed for each of 16 distinct BMP types (e.g., waste storage, grassed filter strips, cover crops, stream fencing) based on cost-share guidelines, NRCS standards, and other practice criteria. Each tool included a mix of nine types of question/answer sets: interview open-ended, interview multiple-choice, interview binary (yes/no), interview multiple-choice photograph selection, assessor chosen open-ended, assessor chosen binary, assessor chosen multiple-choice, binary post-data collection, and multiple-choice post-data collection. A scale of one to five was used as the scoring system for each assessment question. One hundred and fifty-five cost-shared and 150 non-cost-shared BMPs were assessed on 128 farms in the James River Basin of Virginia. Results indicated no significant statistical difference between the overall quality of cost-share and non-cost-share practices within any indicator BMP category. Overall, the quality of the cost-share and non-cost-share practices assessed were roughly equal. No consistent identifiable trend of cost-share status and BMP quality was readily evident from the data.

Storm et al. (2006) reported on a detailed 2005 survey given to Oklahoma State University Cooperative Extension Service Agents and Specialists to gain an understanding of agricultural practices and land covers that occurred from 1996 to 2001 in the Fort Cobb (OK) basin. This survey went into great detail about the different types of crops in the basin along with different tillage practices, common double crops, fertilization rates, cattle stocking rates, and harvest dates. Results from the survey indicated that over thirty different agricultural land covers/practices occurred in the basin. During the summer of 2005, an additional field survey of all cultivated fields in the basin was conducted, including several pieces of pertinent information to develop a new land cover map. The information collected included current crop, previous double crop, tillage practice, presence of irrigation, cattle grazing, and vegetation height. Each cultivated field was mapped using National Agricultural Imagery Program (NAIP) aerial photos and ArcMap software**.** Survey staff drove the entire basin with a laptop connected to a GPS unit with real time tracking. When they encountered a cultivated field, they delineated field boundaries and other information using NAIP photos displayed within ArcMap. To improve accuracy, the GPS unit would plot an icon or marker to represent their location on the aerial photos. The survey was compiled to create a highly detailed crop data layer. The advantage to this approach compared to the previous model was the ability to distinguish crop types.

Veith et al. (2008) compared SWAT modeling of a small northeast watershed under two different resolutions of input data. Management practices of individual fields over an 11-year period (1994-2004) were obtained from annual farmer surveys. The surveys included tillage, fertilizer, plant, and harvest dates and methods for each crop. Results suggested that while detailed input data can enable the model to provide valuable water quality information, research efficiency during exploratory and initial problem-solving efforts might be maximized by using more easily obtained, although more general, data.

In Canada, MacKay et al. (undated) reported that BMP adoption information is collected by a variety of organizations including government, producer groups, and conservation authorities, and is often driven by a specific agri-environmental program. This information is often not synthesized in a way that can provide information on overall BMP adoption across the country, and therefore is challenging for policy makers to make use of it. A BMP Adoption Index has been developed to synthesize this variable information. The BMP Adoption Index calculates a BMP adoption score for farmers based on their responses to the Farm Environmental Management Survey (FEMS). This survey was conducted by Statistics Canada using a representative stratified sample of 20,000 crop and livestock farmers across Canada after the 2006 growing season. The questionnaire asked crop farmers about manure and fertilizer spreading, pesticide application practices, tillage practices, and crop residue management, and asked livestock producers about livestock housing, manure storage and treatment, and grazing management practices. Both crop and livestock farmers were asked about land and water management, hazardous waste management, and environmental farm planning. The survey collected data on all practices being implemented, not just BMPs, in order to gain an understanding of the range of practices being implemented on farms across Canada. In total, 184 practices were included in the calculation from the crop questionnaire and 214 practices were included from the livestock questionnaire. Ninety-six of these practices were common to both questionnaires. The BMP Adoption Index is calculated by combining the management practices being implemented by each survey respondent in 2006 with a ranking that reflects the efficacy of the management practice in improving the environmental performance of a farm. The ranking scale ranges from 1 to 5 where 1 indicates a poor practice that is expected to cause environmental degradation, 3 indicates a neutral practice and 5 indicates the most beneficial practice that is expected to reduce or eliminate risk and provide benefits to the environment. Note that the use of the Index aggregates all BMPs.

The Conservation Technology Information Center (CTIC) conducts an annual tillage/crop residue survey in the Midwest using a detailed roadside transect survey procedure (CTIC 2008). The cropland roadside transect survey method is designed to gather information on tillage and crop residue management systems. Experience has been that counties with a grid road system, those with fields readily visible from the road, where crops are planted in a relatively short period of time, and where conservation tillage is being adopted are the most likely candidates for conducting a transect. Note that the deliberate selection of areas where conservation tillage is being adopted may represent a significant bias to the survey. The purpose of the survey is threefold: (1) to provide information that can be used by individual soil and water conservation districts and others in establishing priorities for educational or other programs, (2) to evaluate progress achieved in reaching county or statewide goals, and (3) to provide accurate data on the adoption of conservation tillage systems by crop for the CTIC National Crop Residue Management Survey. This makes the transect survey an ideal tool for assessment as well as measuring progress for locally led conservation. When conducted properly, this cropland transect survey procedure provides a high degree of confidence in the data summaries. Users can have 90% or more confidence in the accuracy of the results. This level of reliability translates into data summaries that can help guide the local or state decision-making process. Several states have used transect data to allocate cost-share funds, develop new resource management goals, and to provide information to the general public about the positive impact of progress on land use trends. CTIC describes the specific steps involved in conducting the survey, addressing issues such as establishing a driving route, selecting the survey date and team, collecting the survey data, and calculating the crop acreage and percentage of coverage for each tillage system.

Shukla et al. (2006 a and b, 2010) reported on Florida surveys conducted in cooperation with Gulf Citrus Growers Association (GCGA) and FDACS to document and assess adoption of BMPs by FL citrus producers. The survey questionnaire included five major water quality BMP categories: water volume, sediment control, aquatic plant control, pesticide use, and nutrients. The survey captured grove-specific BMP adoption data by asking general questions descriptive of grove management and importance of BMPs with regard to water quality benefits and grove profits. To determine if a particular practice was in use, growers were asked if they implemented it consistently or not. A third choice of "*sometimes"* indicated that this practice was not implemented on a regular basis. To understand whether or not a practice was acceptable to the growers, one of the choices was "*disagree with the practice*." To determine whether a grower would be willing to implement a practice in the future, two additional choices, "*plan to use"* and "*would if cost-shared*," were also included. The latter choice determined the potential for implementation of a specific BMP if federal and/or state cost-share funds were made available to offset a portion of the implementation cost. Sixty groves covering an area of 115,791 acres were surveyed by personally interviewing the farm manager. The surveyed acreage was distributed between large (>1,000 acres), medium (250-1,000 acres), and small groves (<250 acres). From a water quality standpoint, the percentage of grove land area affected by a specific BMP is more important than the percentage of total grove number. Therefore, almost all of the *large* groves in the region (104,170 acres) were included in the survey. In addition, 75% of *medium*-size groves (9,982 acres) in the Gulf Citrus Production Area were included in the survey. The area occupied by the surveyed *small* groves was 1,639 acres. The grove name and location were kept confidential. The results report the percentage of surveyed area using various BMPs, but includes no assessment of error or statistical confidence.

Remote sensing

Daughtry et al. (2004) set out to determine the spectral reflectance of crop residues and soils and to assess the limits of discrimination that can be expected in mixed scenes. Spectral reflectances of dry and wet crop residues plus three diverse soils were measured over the 400–2400 nm wavelength region. Reflectance values for scenes with varying proportions of crop residues and soils were simulated. Additional spectra of scenes with mixtures of crop residues, green vegetation, and soil were also acquired in corn, soybean, and wheat fields with different tillage treatments. The spectra of dry crop residues displayed a broad absorption feature near 2100 nm, associated with cellulose-lignin, that was absent in spectra of soils. Crop residue cover was linearly related ($r^2 = 0.89$) to the Cellulose Absorption Index (CAI), which was defined as the relative depth of this absorption feature. Green vegetation cover in the scene attenuated CAI, but was linearly related to the Normalized Difference Vegetation Index (NDVI, $r^2 = 0.93$). A novel method is proposed to assess soil tillage intensity classes using CAI and NDVI. Regional surveys of soil conservation practices that affect soil carbon dynamics may be feasible using advanced multispectral or hyperspectral imaging systems.

Sullivan et al. (2008) evaluated the usefulness of Landsat TM data as a tool to depict conservation tillage in the LREW in GA. Satellite imagery was used to calculate four commonly used indices: Normalized Difference Vegetation Index, Crop Residue Cover Index, Normalized Difference Tillage Index, and the Simple Tillage Index. Ground truth data consisted of a windshield survey, assigning each site a tillage regime (conventional or conservation tillage) at 138 locations throughout the watershed and surrounding areas. A logistical regression approach was used on two subsets of the data set *(n* = 20 or n = 44) to determine the influence of the number of ground control points on the success of modeling the occurrence of conservation tillage. The most accurate model was re-applied to the satellite image and evaluated using an independent sample of 94 survey sites. Results indicate that the normalized difference tillage and simple tillage indices performed best, with an overall accuracy of 7l% and 78% for models developed using n = 20 and n = 44 sample locations, respectively. Errors were typically in the form of commission, e.g., misclassification based on unusual soil color. Results are encouraging and suggest that currently available satellite imagery can be used for rapid assessment of conservation tillage adoption using minimal a priori information.

Hively et al. (2009) combined cost-share program enrollment data with satellite imagery and on-farm sampling to evaluate cover crop N uptake on 136 fields within the Choptank River watershed, on Maryland's eastern shore. The Normalized Difference Vegetation Index was a successful predictor of aboveground biomass for fields with >210 kg/ha (>187 lb/ac) of vegetation (corresponding to 4.2 kg/ha [3.7 lb/ac] of plant N), below which the background reflectance of soils and crop residues obstructed the cover crop signal. Cover crops planted in the two weeks prior to the regional average first frost date (October 15) exhibited average fall aboveground N uptake rates of 18, 13, and 5 kg/ha (16, 12, 4 lb/ac) for rye, barley, and wheat, respectively, corresponding to 1,260, 725, and 311 kg/ha (1,124, 647, 277 lb/ac) of aboveground biomass, with associated cost-share implementation costs of $5.49, $7.60, and $19.77 /kg N ($2.50, $3.46, and $8.99 /lb N). Cover crops planted after October 15 exhibited significantly reduced biomass and nutrient uptake, with associated program costs of $15.44 to $20.59/ kg N ($7.02 to $9.36 /lb N). Agronomic factors influencing cover crop performance included species, planting date, planting method, and previous crop. Field sampling locations with >1,000 kg/ha (>890 lb/ac) of springtime cover crop biomass exhibited greatly reduced soil nitrate (<3 mg/ kg [<3 ppm]) in comparison to fields with low cover crop biomass (up to 14 mg/kg soil nitrate), indicating a target biomass threshold for maximum water quality impact. Additional sampling years will be necessary to account for cover crop response to climate variability. Combining remote sensing with farm program data can provide important information to scientists and regulators working to improve conservation programs. Results can be used to more effectively utilize scarce conservation resources and increase water quality protection.

Summarizing the methods of Hively et al. (2009):

> ***Cover Crop Implementation Data.*** Cover crop implementation data, including digitized field boundaries, cover crop species, planting date, planting method, and previous crop were obtained from the Maryland Department of Agriculture. These data were transcribed from cover crop cost-share program enrollment documents that were filled out by participating farmers in the fall of 2005. A total of 136 cover-cropped fields located within the study area were included in the evaluation. A digitized boundary polygon delineating each cover-cropped field was provided by the MDA, based on USDA Farm Service Administration Common Land Use boundaries and field-specific Soil Conservation District farm planning documents.
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> ***On-Farm Sampling.*** On-farm sampling was performed on a subset of cover-cropped fields within a week of each satellite image acquisition. The collected data were used to provide calibration of satellite image interpretation (correlation of NDVI to biomass), to estimate cover crop tissue N content for use in calculating nutrient uptake, and to monitor residual soil nitrate.
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> ***Remote Sensing Imagery.*** Multispectral satellite images of the study area (SPOT 5, >90% cloud-free, <20° incidence angle, 10 m [32.8 ft] resolution, four spectral bands, 60 × 60 km [37.3 × 37.3 mi] coverage) were acquired on December 22, 2005, and March 31, 2006. These image acquisition dates were respectively selected to represent total fall and total springtime cover crop nutrient sequestration. Cost-share program data associated with each enrolled field were then used to correlate estimated biomass production and nutrient uptake with agronomic factors (cover crop species, GDD, planting method, and previous crop).
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> **Results.** A multivariate log-linear model of biomass production, ln(Biomass) = $a + b$(NDVI) + c(ImageDate) + d(Species) + ε , (2) where a is the intercept, b, c, and d are linear coefficients, and ε is residual error, revealed significant effects of NDVI (primary

predictor variable, explaining 73% of observed variation), satellite image acquisition date (explaining 3.7% of variability, likely attributable to differences in atmospheric optical conditions at times of satellite overpass), and cover crop species (explaining, in addition to NDVI signal, 4.2% of observed variation, likely attributable to differences in cover crop growth habits and leaf angle in relationship to leaf area index). The remaining 19% of observed variability in measured cover crop biomass was attributed to the unexplained error term. Further research might succeed in reducing model error by attributing components of observed variability to additional predictive factors

Using remotely sensed satellite imagery, cover crop nutrient uptake efficiencies can be derived at the landscape scale, accounting for the effects of spatial variability and providing insight into agronomic factors affecting cover crop productivity. The results of this study, although they must be corroborated over several growing seasons to account for the effects of climate variability, have strong implications for evaluating and improving the success of cover crop programs and promoting effective water quality protection strategies.

Hybrid approaches

Several BMP verification efforts have comprised combinations of two or more of the broad protocols identified by the AgWG.

Tomer et al. (2008) conducted a conservation practice inventory for the South Fork of the Iowa River, 85% in corn and soybean rotations, to describe the extent and placement of key CPs in the watershed and evaluate the results in the context of four years of concurrent, detailed water quality data. Cropping rotations were determined using annual classified satellite data made available by the USDA National Agricultural Statistics Service (NASS) (USDA NASS 2007). The satellite data are subject to a supervised classification (i.e., a classification guided by human judgment) aimed to identify commodity-crop acreages (i.e., corn and soybean in Iowa) with minimal error. Five years of classified data (2000 to 2004) were overlaid to map the dominant crop rotations occurring on agricultural lands within the watershed. Agricultural field boundaries, provided by the USDA Farm Service Agency, were used as a majority filter for each year of crop-cover data to provide a single five-year sequence of cover for each field. The observed crop-cover sequences were then grouped to represent dominant rotations in the water-shed, including two-year (corn-soybean), three-year (corn-corn-soybean), and longer rotations based on number of consecutive years with corn up to five years (ie., continuous corn). Fields with sequences dominated by grass (pasture) were assigned as permanent cover, and perennial rotations were assigned to fields where the crop sequence included a third crop (in addition to corn and soybean) because the third crop was typically classified as alfalfa or hay in the NASS data.

The distribution of manure applications within the watershed was estimated using a GIS model that divided the N load from each CAFO facility by the areas of increasingly sized circles (in 40-m [131-ft] radius increments, without overlap) until the area within the circle accommodated the N load at an application rate of 200 kg N ha–1 (179 lb ac–1) for corn. The application rates assigned to fields within the circles were varied to account for the observed crop rotation by assigning the full rate to fields where three or more consecutive years of corn and half the rate where 2- or 3-year corn-soybean rotations were observed. This essentially assumes manure application occurs prior to corn and not prior to soybean.

An inventory of CPs was conducted during the first half of 2005. The inventory was conducted by USDA NRCS and included four steps. First, a search of records of the agency's progress reporting system with contributions from four local NRCS field offices was conducted. Second, aerial photos were interpreted and digitized to map visible CPs such as terraces and grass waterways. Third, a field-by-field, drive-by survey was conducted during May 2005 to provide a snapshot of tillage practices throughout the watershed and confirm the progress reporting system data and air photo interpretations where possible. The survey was conducted by NRCS personnel with knowledge of local tillage systems and experience in estimating residue cover. Data were digitally collected in the field, using tablet-style, touch-screen computers equipped with global positioning system signal tracking to ensure mapping accuracy. A GIS coverage of the watershed's fields, with field boundaries provided by the USDA Farm Service Agency common land unit system that documents agricultural lands participating in USDA programs, provided the base map for touch-screen linkage to a data-entry interface. Specialized GIS software was developed to expedite the survey process, which included pull-down menus, accessible by field, with tag-lists of common practices and opportunity to annotate the record, correct existing information, and digitize features missing from the office-prepared map coverage that were observed in the field. Four persons, paired in two trucks, completed the field survey in about three weeks. The final step was to combine the survey data entered by crews and build the final inventory product, a completed GIS project detailing practices by field, which excluded all ownership information. Evaluation of CPs in the watershed was conducted by GIS overlay with NRCS Soil Survey Geographic data, particularly highly erodible land (HEL) and hydric soils, stream proximity, and with crop rotations and anticipated manure application areas, determined as described above. All this information was placed onto a single spreadsheet, which was sorted and filtered to determine areas where resource concerns and CPs overlapped.

The survey of CPs showed mulch tillage (>30% residue cover) was the dominant class of residue management, covering 58% including one large field (226 ha [558 ac]) under ridge tillage in the Tipton Creek subbasin. Conventional tillage (herein, conventional tillage refers to tillage systems that result in >70% of crop residue being incorporated beneath the soil surface) occupied about 29% of the agricultural land, with no-tillage more limited in extent (7%). About 20% of the cropland is in fields with grassed waterways and/or terraces. There are also water and sediment control structures in 46 fields, protecting 1,185 ha (2,925 ac). Unfortunately, no assessment of error or statistical confidence was reported.

Grady et al. (undated) demonstrated and evaluated three different methods for obtaining geospatial information for BMPs in a mixed use watershed in central IN. The researchers obtained geospatial information for BMPs through government records, producer interviews, and remote sensing aerial photo interpretation. Aerial photos were also used to validate the government records and producer interviews. This study shows the variation in results obtained from the three sources of information as well as the benefits and drawbacks of each method.

Using only one method for obtaining BMP information can be incomplete, and this study demonstrates how multiple methods can be used for the most accurate picture.

Summarizing the methods of Grady et al. (undated):

Government Records. Records from three agencies were obtained in 2010. USDA agency records required a Memorandum of Understanding (MOU) to follow the requirements of Farm Bill Section 1619.

Producer interview data. Agricultural land owners and operators were interviewed in the winter of 2007/2008. All 54 producers in the watershed were contacted to participate; 32 were interviewed, for a response rate of 59%. Interviews followed a semi-structured interview guide, dealing with a range of topics related to conservation on their land. These topics included reasons for use/non-use of conservation practices, environmental awareness and attitudes, and funding for agricultural practices. In addition to qualitative data collected, producers were asked to provide locations of structural conservation practices and to outline fields with various operational practices on provided maps. These spatial locations were then digitized into a GIS. The interviews collected data on six conservation practices: conservation tillage, cover crops, grassed waterways, filter strips, nutrient management, and pest management.

Aerial Photo Interpretation. Orthophotos of the watershed were available for each year between 2003 and 2010. High resolution imagery from 2005 with a resolution of 1 foot collected as a part of the Indiana Statewide Orthophotography Project served as the basis for analysis and classification of BMPs. These photos were taken before the growing season and therefore show agricultural fields without vegetation and trees without leaves (leaf-off). Photos taken in the summer (leaf-on) with 1 meter resolution from the National Agricultural Imagery Program (NAIP) at the U.S. Department of Agriculture for all other years provided complementary information, such as evidence of the rapid land use changes in this watershed. The 2010 photos helped with identifying BMPs in cases where records indicated past management practices but the land was no longer in agriculture. In addition, seasonality between orthophotos enhanced the ability to interpret these images. The method used for identifying BMPs from aerial photographs utilized a grid system. A grid layer was created using tools in ArcGIS 9.3 and overlaid on the watershed. Each grid cell was 900 m^2 which was the distance and scale at which the 2010 aerial photos can be viewed on the computer screen without compromising clarity, allowing for examination of each section of the watershed at the same scale.

Structural BMPs were analyzed separately from operational BMPs because they could be confirmed through aerial photos. Three structural practices (subsurface drain, stream bank erosion control, and wetland creation), for which information was obtained from NRCS records, could not be identified through aerial photos and therefore they were not included in the analysis of structural practices.

Government records provided information on more practices than the other two sources. However, this source of information would not be adequate on its own, due to at least four difficulties associated with the use of government records. First, obtaining information regarding spatial data for management practices from USDA agencies programs required special permission through an MOU, and then cooperation from the various agencies that provided the records. Although individual staff members were helpful, the process (resulting from the restrictive language in the 2008 Farm Bill) was cumbersome and time-consuming. In addition, important watershed stakeholders such as watershed groups may not be approved for this information release. Second, the data provided lacked some information that would have been helpful. Spatial locations provided by one of the agencies (FSA) did not contain attribute data that would provide descriptive information about the practice such as practice type and date of implementation, while the data provided by NRCS was georeferenced to the centroid point of the land unit where it was implemented, rather than including the precise location and shape of the actual practice. Government records also did not contain information about dates of practice installation. This type of temporal information would be useful for monitoring maintenance/upkeep of practices over time and for more accurate comparison with remote imagery (for which dates are always available). Third, the data provided by NRCS were in a format designed for national record-keeping, consisting in some cases of a separate record for each resource concern addressed by a practice rather than an effort to determine practices in a watershed. This facilitates crediting of practices to the resource concern at a national level, but these records had to be manually combined to represent the true number of practices installed in the watershed. Fourth, government records do not reflect the extent to which practices were fully implemented nor whether they are being adequately maintained (Jackson-Smith et al. 2010). Finally, government records were incomplete and likely under-represent the true total of BMPs in the study area

The producer interviews were the unique source for 29 structural practices and 155 operational practices. Operator interviews were the unique source for a number of practices, because operational BMPs such as nutrient management cannot be identified through photos or other remote sensing. If these practices are implemented without government program incentives (and therefore not present in government records), directly asking producers, either through interviews or surveys, is the only way to gather the spatial and temporal locations of these practices. However, these methods are limited by response rates within a watershed.

Photos were the unique source for 24 structural practices in this study, but if aerial photo digitization had been done without knowledge of other BMP records, this technique would have yielded many more BMPs. Current high-resolution photos provide an unprecedented source of information on agricultural practices that has not often been fully utilized. Photos taken annually can be used to estimate dates of practice implementation.

The Ohio River Basin Trading Project, a new joint venture by the Electric Power Research Institute (EPRI), the American Farmland Trust (AFT), and others, is a project that promotes the achievement of water quality goals for nutrients through a trading program that allows permitted emitters to purchase nutrient reductions from another source (EPRI 2012). In this case, farmers who install BMPs can sell their nutrient reductions to permitted emitters such as power plants and wastewater treatment facilities.

For a nonpoint source to generate a credit, it must reduce its loading of N or P below current conditions. Only non-NRCS cost-shared practices are eligible for crediting. Agricultural nonpoint sources will need to provide three years of farm practice history to document their current conditions, including crop rotations, residue management, tillage, nutrient inputs, location and type of existing conservation practices, livestock inventory, and manure handling. A new BMP will generate credits only after it is installed, and only for so long as it is properly operated and maintained, based on quantitative performance protocols. The status of installation, operation, and maintenance will be periodically inspected by an appropriate verifier, such as the state Department of Natural Resources, soil and water conservation district, or resource management specialist. Verification records will be maintained and the non-confidential portions of those records may be made available to the public upon request.

During the 2012 – 2014 Pilot Program, the State Agency will arrange to periodically monitor, inspect, and verify the implemented BMPs at least annually, based on visual monitoring and inspection, as well as a review of records provided by the landowner and/or SWCD. All states will follow the same verification protocols, and rules. EPRI will ensure consistency and the credit registry will not allow for variation.

A verifier will be assigned to a particular BMP project based on: 1) knowledge of the conservation practices implemented; 2) knowledge of the geography; 3) availability; and 4) absence of significant conflicts of interest. All verifiers will be trained on the Plan, credit calculation tools, processes, and protocols. They will have a working knowledge of farm operations and practices to manage nutrients on farms in the ORB. Verifiers will complete regular continuing education training as required by EPRI. Verifiers will confirm that: 1) the landowner's eligibility information is correct; 2) the BMPs were implemented according to the Standards or approved modifications; 3) credits are quantified using appropriate metrics and methodologies; 4) practices are maintained and performing as designed; and 5) appropriate arrangements are in place to ensure practices are maintained. The type of verification/monitoring will vary depending on whether the practice is structural (e.g., livestock exclusion fencing), vegetative (e.g., buffer strip) or management (e.g., nutrient management). Both structural and vegetative practices can be viewed in the field but verifiers will need to check landowner records to confirm that they are being maintained properly. Management practices will mostly be verified by examining landowner records. The verifier must prepare a report of each monitoring, inspection and verification event, along with its opinion as to whether each BMP is, in fact, verified. This report must be submitted to EPRI within 30 days after each event. Producer personal information will be held confidentially. The public can see the HUC 10 where credits are generated, but not the specific farm or field. Regulators can see the farm records.

Additional considerations

Studies show that BMP function (i.e., efficiency, pollutant reduction) cannot be assumed, even if the presence of a practice is verified by one of the protocols discussed above.

For example, Dosskey et al. (2002) reported that concentrated flow through riparian buffers can be substantial and may greatly limit the actual buffer performance. While sediment removal of up to 99% from field runoff has been reported under ideal circumstances, because of non-uniform distribution of field runoff through a buffer, the authors estimated that only 15 – 43% of sediment would actually be removed.

As noted earlier, Bracmort et al. (2006) reported that one-third of BMPs installed in the Black Creek (IN) watershed no longer exist and the remainder were only partially functional, with efficiencies far lower than those originally attributed.

Sharpley et al. (2009) reported that conservation practices vary substantially in effectiveness within and among watersheds. For example, previously reported total P reduction efficiencies for BMPs, such as cover crops can range from 7 to 63%, contour plowing 30 to 75%, livestock exclusion 32 to 76%, and riparian buffers 40 to 93%. Such variability results from inherent heterogeneity of landscape topography, hydrology, climate, and prior land use, which influences soil test P. This large variability clearly demonstrates the site-specificity of BMP reduction efficiencies and highlights the dangers of having to assign an absolute value, as required by nutrient trading programs

Finally, as noted above, Jackson-Smith et al. (2010) found that 16% of BMPs reported as implemented in a UT watershed project were never actually installed and that 20% of implemented BMPs had been abandoned, principally management practices.

These findings emphasize the need for careful verification of both BMP presence and BMP function and the danger of simply assuming that BMPs reported as implemented are providing their full potential effects on water quality.

Key findings from the literature

- Each of the general protocols for BMP verification identified by the AgWG has been applied elsewhere in the U.S., with varying degrees of effectiveness
- With the exception of some validation data from remote sensing analyses, and a statement of accuracy in the CTIC tillage survey, there have been essentially no assessments of statistical confidence or error reported for any of the approaches to BMP verification described in the literature
- Verification of structural, annual, and management practices will likely require different protocols and provide different information content and accuracy
- Hybrid approaches probably have the best potential to provide complete and accurate information on BMP implementation and performance

- BMP function should not be assumed, even if presence is well-documented
- To meet the objectives of the Chesapeake Bay Program, BMP verification will need to go beyond simple documentation of presence/absence; some assessment of condition, performance, or efficiency will be required.

Summary of Interviews

While interviewers collected detailed notes during interviews and these notes have been edited and accepted by those interviewed, this summary will not attribute specific comments to specific individuals. Rather, summary points, areas of consensus, and areas of distinct opinion will be noted. The summary will address three areas: specific verification programs identified by the interviewees, reported costs of verification programs, and key principles arising from the body of interview responses.

Specific verification programs reported

BMP verification programs reported by interviewees are summarized below and identified by the state in which they take place. These programs are a mix of state government, non-governmental organization, and other efforts. Note that program specifics are those given by the interviewees; no attempt was made to fully document the programs from other sources. Further information is available from other publications, web sites, etc.

Virginia

GreenSeeker, consisting mainly of records of precision agriculture/nutrient management in a six-county pilot program to assess the quality of the BMP record in support of TMDL.

Shenandoah Valley - Data have been collected from 100 – 125 farms using a proprietary protocol (by Watershed Stewardship Inc. (WSI)). In the procedure, WSI staff meet with the farmer, explain the program, and sign a confidentiality agreement stating that they will only use farm information in an aggregate at the sub-watershed or county level; no one has objected to this so far. Farmers sign a release giving electronic access to their NMP, conservation practice, and FSA information (sometimes scanning of paper forms is needed). WSI loads that information into their nutrient load estimator (NLE) software (which describes farms, fields, animals, crops by acreage using CB land use categories). They have a list of practices that have been reported and during the whole farm walk-over they verify implementation of everything reported as implemented (cost-shared and non-cost-shared). They assess and verify implementation and O&M using both CB and NRCS standards. They estimate nutrient losses with and without BMPs, formulate a plan, and work with farmers to make progress on the plan as needed. They believe their protocol is working well if you need this level of detail. They are currently reluctant to turn over a proprietary procedure for governmental use because of concerns regarding maintaining resources to support employment of WSI staff.

Maryland

The state of Maryland is reported to have the most regulated BMP reporting program in the CB region, especially for nutrient management. MD has a procedure for inspection based on technical standards and requirements for compliance with state laws and regulations. Inspectors use pre-printed forms and notify farmers in advance that they are coming. They collect general information from the farm (operator information, operation information-type, size) and then planning information (detailed information written by consultant – e.g., current soil test, date, certified planner name and information, information on field-specific nutrient recommendations, nutrient source, application rate and timing, manure generation, and waste management practices). Also the process checks for record keeping – e.g., is yield goal based on harvested crop in different years? All of these details are reviewed. The final product is a review and evaluation of operation with regard to NM and related management (i.e., animal waste management, fate of excess manure) – this will determine if there are some violations which are grouped into major and minor violations. Warnings are issued for major violations – if not corrected, penalties can result. Minor violations result in recommendations for improvements. A copy of the evaluation is given to the operator and filed in state records. About 8 to 10% of operations are inspected by agency staff annually on a rotating basis. About 70% of inspections are focused on the problem areas; the inspection/verification process applies to all operations, whether cost-shared or not, and all types of operations.

More specifically, the MD program includes a number of components and each includes a rigorous set of QA/QC procedures:

<u>1: Farm Stewardship Certification Program</u>

The program/farm stewardship certification program is run by a third party, sanctioned by MDA and is an incentive program to document practice implementation at the farm scale by inventorying farms and inspecting all practices and nutrient management (NM) records. Trained assessors determine compliance with regulatory requirements, whether BMPs are functioning, any water quality concerns, and whether the farmer can be certified as a good farm steward. Farm stewards are those who are meeting TMDL requirements.

<u>2. Inventory Non-Cost Shared Practices</u>

All types of practices (federal, state, self-implemented) are assessed. They use an established protocol to assess farmer-installed BMPs – take photos, record information in a file, and ascertain whether practices meet standards and specifications. Funding is made possible through a conservation and innovation grant. Data accuracy is high, partly because assessment specialists are trained and certified to collect, record, and verify information.

<u>3: Nutrient Trading</u>

A nutrient trading on-farm assessment tool is used for assessing TMDL Compliance and potential for creating additional nutrient reductions to trade. This is similar to what is done for the farm stewardship certification program and the Inventory of Non-Cost Shared practices. Field-by-field assessments by trained staff (similar to training for farm stewardship certification program) are performed to ascertain whether the farm has met its TMDL obligations. They next explore and discuss with the farmer opportunities for creating offsets for trading. During site visits management records are pulled from the farm record to verify implementation of NM and other practices – this information is utilized in assessing the farm's performance. QA/QC is similar to that for the farm stewardship certification program and Inventory and Non-Cost Shared BMPs. On-farm assessments are performed by two separate teams to confirm offsets for trading and provide certification. A 10% spot check of those farms entering the trading market is also performed. MDE will also do random spot checks (credits are written into an NPDES permit). The person who purchases offsets is required to hire an independent 3rd party to check all farms in trades over the lifetime of trades to confirm the accuracy of trades. MDA's effort (training, staffing) is paid for through a conservation/innovation grant. Because trading involves an NPDES permit, accuracy and confidence have to be very high. If a farm is out of compliance with the permit, there are Clean Water Act fines.

4: Verification of State Cost-Share:

The soil and water conservation districts (Districts) work with the farms on practice installation. MDA and NRCS have standard plans for inspection and verification of practices installed. There is a joint inspection for federal and state c/s funded BMPs. On the front end, once a practice is installed the District certifies implementation and compliance with standards and specifications. MDA and NRCS pull a random list from each District and inspect farms with practices newly installed that year. When on farms, however, they inspect and document all practices installed at any time, including previous years to insure that they are in compliance with standards and specifications. An inspection report is generated, if necessary correction notices are given (60-day and 30-day); if the farmer doesn't fix problems, they are no longer eligible for c/s. State headquarters staff do this work – there is no special grant. Because all programs involve eyes-on-the-ground technical experts to verify everything, data confidence is high.

5: Cover Crop Program

This is the biggest program ($18M/yr). Because of the large investment, verification is much more intense. On the front end, the eligibility of all farmers signing up for the program is reviewed. Participants must certify when the cover crop is planted, the type of cover crop, and areas in the field where it is planted. Staff are sent out to field verify the acreage, type, date, location, stand (80% or greater stand is required), and seed quality to determine planting information. In fall there must be certification that the stand is there; in spring farmers must certify burn-down – staff go out to confirm this prior to final payment. Copies of all records are kept and used in the payment process. MDA is currently converting hard copy maps to GIS files (piloting in a few counties).

Going forward MDA is investigating Remote Sensing of cover crops not involved in c/s programs using satellite imagery and field-scale verification. Imaging is used for analysis and reporting on cover crop implementation. The current cover crop program covers only about ¾ of what is implemented; remote sensing is used to capture the rest (includes farmer-implemented cover crops). The interviewee likes the potential of remote sensing because preliminary pilot studies have shown that it can be used to provide reliable information to communicate with farmers about their cover crop's performance. You can use remote sensing for any field to address presence/absence of cover crop, and N and P benefits that might be derived from the cover crop. This gives a more complete picture of cover crops in the state.

6: Nutrients Management Program

MD regulations require all farms to have a NMP written by certified writer. MDA conducts training and checks on plan writers by pulling random plans and confirming whether they are written correctly. MD has over 6,000 farm operators – check 10% of them (pull plan at site with farmer, pull records, look at equipment, calibration records and verify that farmer is following plan). MDA has a tracking and reporting protocol for this as well. Full-time, state employees are dedicated to this effort. For more information see separate submittal from MD's WIP

MD's protocols all involve direct eyes on the ground to verify BMPs.

7. Conservation Tracker
MD decided 4 years ago that the existing federal tracking/accounting systems being used were not complete (missed state and farmer-installed practices), so MD developed Conservation Tracker, a comprehensive system for tracking all practices on the farm and all farm conservation programs. Tracker is employed at the SWCD level, and the state uses it to report annual implementation progress to the Chesapeake Bay Program. Tracker also has manure transport data, CREP data, cover crop data, etc. MDA has a QA/QC protocol under which they go to state cost-share program records and confirm that data in Tracker is accurate. They do the same thing with federal data and compare this all with Tracker data to ensure that data are correct.

A pilot program in Howard County, MD (and elsewhere in the CBW) has been conducted, consisting of farm interviews and a review of plans; this process addresses both cost-share and non-cost-share "functional equivalent" practices. The program is linked to the MD Nutrient Trading Tool and the MD Conservation Tracker with a direct tie-in to NEIEN. The Howard County process involves an interview and farm walk with the farmer/operator and a farm walk to identify BMPs. Practitioners provide data collected on cropland, animal confinement, pasture and hay land, an updated farm map with BMP location and associated data. The data are verified by a third party (an outside SWCD Employee) and entered into MD Conservation Tracker by the Soil and Water Conservation District and the MD Nutrient Trading Tool by third parties.

Pennsylvania
Warwick Township in Lancaster County has a comprehensive watershed management program that includes stormwater and agriculture. They have worked with local Soil and Water Conservation Districts and have achieved 100% conservation plans on all types of farms in the watershed; the data are used to identify benefits of agricultural BMPs implemented and to identify hot spots and work with landowners toward water quality improvement. They do not pro-actively track implementation of conservation plans but if farmers come in for other permits (e.g., subdivisions or lot development) they try to check on progress with their conservation plan. For farms where their municipal wells are located, the Township has hired an agronomic firm to keep all management records on the farm. They get a lot of good information, the farmer benefits with a high-level NMP, and the Township protects well water quality (e.g., lower nitrate), saving money in water treatment. They do not differentiate between cost-shared vs. farmer-driven practices.

North Carolina
Agricultural information is collected beyond normal NASS data collection in designated nutrient sensitive river basins or watersheds that are regulated by the state of North Carolina, i.e., the Neuse and the Tar-Pamlico. A N Loss Estimation Worksheet (NLEW) that is used to meet the regulatory requirement tracks potential N reduction by county based on implementation of nutrient management. The worksheet requires input data from the NMP (e.g., N inputs, N

uptake) as well as documentation of conservation practices on fields. Data are collected based on the needs of the tools used in the basins (NLEW, and similar tools for P loss and grazing management). Data collection needs are driven by state regulations but regulations are not reported to be an incentive for farmers to provide more data than they would normally provide. Researchers at NC State University have run four additional detailed basin surveys for N-related BMPs; a detailed description of statistical sampling methods is available.

Minnesota

The Livestock Environmental Quality Assurance II (LEQA II) Program is funded by the MN Department of Agriculture. Rather than tracking individual BMPs, the LEQA system uses a “Better Management Systems” index, which is essentially a classification of BMP systems. The process provides some qualitative assessment of BMP system function in order to give a reasonable assurance of performance

Washington

A developing program to manage water quantity and quality for irrigated agriculture and fisheries involves potential transfers of water rights in return for water quality improvements among irrigators and tribes in the Klamath River Basin. Requirements for effective trading provide strong incentives for verification of BMPs installed for water quality protection.

National Agricultural Statistics Service (NASS)

The USDA's National Agricultural Statistics Service provides timely, accurate, and useful statistics in service to U.S. agriculture, although not specifically directed toward verification. They do not ordinarily collect extensive BMP data (although they do routinely collect information on tillage and cover crops); in special programs (e.g., CEAP) they go beyond this. NASS conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. NASS conducts both full censuses and statistical surveys. Information volunteered by farmers and ranchers to trained interviewers (enumerators) is the most important data source for NASS crop and livestock statistics. The four principal types of data collection are mail, telephone, face-to-face, and web-based. Enumerators are carefully trained in survey techniques so that data collected are not biased by the survey process. Statistical measures of survey accuracy are provided for each specific survey effort. NASS does provide their statistical survey services to external agencies and stakeholders (e.g., universities) subject to HQ approval – e.g. CEAP, ERS (ARM survey). Requests for services must meet certain criteria (e.g., cannot do anything proprietary – needs to be made available publicly.)

U.S. Geological Survey

USGS is coordinating conservation data sharing between USDA-NRCS, USDA-FSA and USGS, specifically the transfer of federal cost-share records for all Chesapeake Bay farmland in October of each year to support the NEIEN submission process. Data are obtained from central records. Practices within their lifespan are ‘verified’ by NRCS and FSA protocols, practices outside their lifespan would fall into ‘voluntary verification’ protocols, as yet undefined. USGS gets privacy protected information from this dataset. They work with USDA programs and states, integrating federal and state data to eliminate double counting. Data pertain only to approved federal cost-share conservation practices. Verification is through existing NRCS and FSA procedures. USGS submits a special data request from central records – the whole process will be documented in a report coming out in December. There are about 300,000 practices in the watershed; each practice on each farm has its own data record. If a practice is still within its lifespan it is assumed to be valid and verified. A current proposal under consideration is to follow up this assumption with a field assessment (or other protocol) to verify that the practice is indeed still in place. If a practice is not within its lifespan than a field assessment or other protocol will be needed for verification.

USGS is also involved in remote sensing of winter ground cover for sediment and nutrient conservation, working in most of the state of MD, and areas of VA and PA surrounding the Showcase Watersheds. This could be expanded within a year or so for complete coverage. They are able to look at winter ground cover thresholds to identify green vegetation sufficient for successful cover cropping. Currently they are not able to look at crop residue, although that might be possible within five years depending on satellite technology improvements. Nor are they able to look at nutrient application, although geospatial data can be overlapped with crop type/rotation, specific watershed areas, soil types, drainage classes, etc.

They started this effort with the Choptank River CEAP 6-7 years ago using SPOT and Landsat imagery. The procedure looks at the reflectance of fields and calculates the ratio of near IR to red to estimate vegetation cover in winter fields. This is then linked to performance information for cover crops. They can only look at GREEN vegetation with this procedure, NOT residue, so the procedure cannot be used to estimate such practices as conservation tillage or nutrient management. They employ two strategies: (1) use public data (Landsat and NASS National Cropland Data Layer); select a county, look at crop type in summer and identify e.g. cornland; look at winter vegetation and determine the % of cornland in vegetation as an indicator of erosion and nutrient loss problem areas (this covers both c/s and voluntary practices unlike methods that use only c/s enrollment information), and (2) in Maryland, identify fields enrolled in cover crop c/s program through collaboration with MDA, analyze on-farm effectiveness of various cover cropping practices, and identify areas with poor performance. Then, by using watershed-wide ground cover mapping by crop type and subtracting the areas enrolled in cover crop c/s, voluntary cover cropped areas can be identified. Verification is done via biomass performance thresholds; they can check their remote sensing data against what MD reports on cover crop implementation

The work covers both cost-shared and voluntary practices unlike methods that use only cost-share enrollment information. Verification is done via performance standards – they can check their remote sensing data against what MD reports on cover crop implementation. They know where all cover crop acreage is in MD; the data for VA are not as complete – they are working toward developing better data on cover crop location in VA. When they find green winter cover they cannot tell specifically if it is a cover crop but they can tell it's protected from erosion. Potential exists to also use remote sensing to document stream buffers.

Reported costs of verification

A few interviewees reported estimated costs associated with BMP verification programs they were involved in.

The Howard County, MD BMP inventory is reported to cost approximately $1.50/acre, including verification by trained contractors. More intensive animal operations are more costly. Data entry into the MD Nutrient Trading Tracker is an additional ~$2/acre.

General frameworks for estimating costs were provided for the MD program. If it costs $60,000 per year for an inspector who does an average of 100 inspections per year, the cost is $600 per inspection. This is perhaps for an average farm size of 200 acres, resulting in an average cost of about $3/acre. The estimated cost will be lower if one assumes that the results are more broadly representative of the larger land area. Detailed NM plan implementation verification is the most time consuming and expensive practice to inspect. NM inspections cover NM and animal waste management, but do not address erosion and sediment control which is addressed by the Soil and Water Conservation Districts.

USGS reported costs of ~$50,000 per year to perform their practice tracking work on all federal conservation practices in the Chesapeake Bay watershed (~300,000 practices), but this should get cheaper over time. The $50,000 is in addition to what NRCS does in the field – it is the cost to USGS to get NRCS data, eliminate double counting, work with the states, perform aggregation, and work with the states to get the data into NEIEN.

Watershed Stewardship Inc. (WSI) reports a cost of $3,000 - 4,000 per farm because the work so far has all been related to projects for which they've agreed to do some detailed analysis and testing. This represents a "research phase" that has a higher cost than would an ongoing routine program. The cost should be lower when done on a production scale (perhaps ~$2,000 for up to 1,000 acres, or ~$2.00/acre). They would add $1.00/acre for farms larger than 1,000 acres. The Tidewater has 8,000-acre farms scattered over 50 miles; in these cases WSI is doing just the first 2,000 acres closest to their address for the project. For farms primarily in row crops the cost would be less because they are simpler to do.

NC State University personnel have run 4 basin/watershed surveys using Section 319 money to fund the surveys – two in the Neuse River Basin, and one each in the Tar-Pamlico and Jordan Basins. Each cost around $250,000 or more to collect detailed agricultural information. Costs were projected to be about $9.00-10.00/acre for surveying fields.

The MN LEQA assessment, planning, and assurance (verification) process cost was ~$1,000/farm for the initial baseline assessment and base plan. A verification walk-through was an additional ~$400 and an annual confirmation was ~$200.

Finally, costs were reported for a verification program for forest carbon credits in WA. It takes about 2-4 person-months to obtain and process the data (about $30,000-$50,000). Then a third party spends several weeks on the site. Payment is about 15 cents/metric ton of CO_2 equivalent (1 credit = 1 metric ton CO_2 equivalent). Participants need several hundred thousands of credits to cover the assessment costs and make it a worthy investment. Third party verifiers charge $20,000 - $40,000 per verification event, and the cost of measuring 200,000 acres, for example, is only a little greater than for 400,000 acres because they use statistically-based approaches.

Key principles

The following key principles were derived from comments and issues raised during the interview process. Often, but not always, these points were shared among more than one of the interviewees. In a few cases, interviewees expressed opposing views; these are presented equitably.

- Any proposed verification program, especially as applied to nutrient trading, should be scientifically defensible, and have a high degree of accountability and transparency.
- Verification programs must go beyond simple presence/absence to address actual practice efficiency.
- The Bay Program should seek widest possible verification of implemented BMPs, rather than focusing on intensive verification of a few individual practices, e.g., for trading purposes.
- Verification is so poor at present that use of remote sensing to verify even a limited number of practices observable may be a significant improvement
- There may be some lessons to be learned from other verification programs, e.g., urban stormwater, air pollution emitters, carbon credits from forestry.
- Different types of BMPs – i.e., structural, annual, or management – will require different verification protocols. Remote sensing, for example, may do well at finding structural or land-cover practices, but verification of nutrient management will require strong presence on the ground. Verification – either on the ground or by remote sensing – must be conducted at the right time of year to assess BMPs like cover crops.
- A hybrid approach to BMP verification will generally give better results than a single protocol.
- Some interviewees recommended that different BMP efficiency credits should be given for different (i.e., more or less rigorous) verification protocols.
- While some flexibility in verification programs among states may be desirable, some level of consistency should be assured so that core values/principles of verification cut across all states.
- Design and implement a verification standard that relies upon third party, independent trained professionals. This standard should be scientifically defensible, transparent for the public, and have, as an integral component, a very high degree of program accountability.
- Assessments of accuracy or statistical confidence in verification results have been reported only for statistical survey and census data from NASS and from some validation exercises in remote sensing efforts; otherwise, little reliable information exists on the confidence or accuracy of verification results
- If required, qualitative assessments of verification accuracy should be done by people with statistical and on-the-ground experience, not simply by best professional judgment or by consensus of a committee.

- Assessment of all sources of error in any verification process will provide some measure of transparency and confidence in the process
- Although several programs collect BMP data at the field or other spatially-explicit scales, confidentiality issues generally prevent the release of such information and require the aggregation of data to county level.
- Ability to spatially reference practices to the field level may not be useful at present because the model is driven at the county/watershed level.
- Monitoring of response indicators (e.g., soil test P) may be easier and more productive than trying to verify all the individual management actions that go into a complex practice like nutrient management.
- Specific programs involving water quality and agricultural BMPs can provide strong incentive for verification of installed practices. The Chesapeake Bay TMDL, the Maryland Nutrient Trading Program, the Klamath River Basin irrigation/water quality trading program, the Illinois River/Eucha-Spavinaw (AR) watersheds lawsuits, and the Ohio River Basin Trading Program are examples.
- Staff expertise is important in obtaining information directly from farmers. Staff collecting information must be trusted and agriculturally literate; several programs have had success in training the right people to do the job. Some form of certification and ongoing training may be necessary. It may not be appropriate to have the same individuals that designed or installed the practices conduct the verification.
- Verification reporting by the same technicians who install practices is generally inadequate; insufficient attention is usually paid to operation and maintenance issues and the age of practices. NRCS technicians typically assume a practice is working as designed if it is present.
- Farmer self-surveys can be useful, but require some kind of driver/incentive for farmers to provide reliable information; farmers must have a clear understanding of what the BMP is so that reporting is accurate. Spot checks by professionals/agency staff may be critical.
- Work with NRCS and OMB has shown that a 5 – 10% spot-check level is generally adequate to validate self-reporting.
- Several interviewees recommend having farmers self-report, with a substantial portion of that spot-checked by government employees. A hierarchical system (broad screening followed by more detail) was recommended, where a broad population is assessed in the first level, but not too closely. If things look good, you’re done. If things don’t look good, go back and look in more detail. One interviewee suggests having a penalty for failure to self-report in a cost-share program that is highly certain but not excessively punitive in order to get producers’ attention.
- Farmers may experience survey fatigue. They are surveyed more than anybody and are tired of filling out forms. Some farmers would rather pay a penalty than participate in additional surveys.

- Records review approaches to verification have significant limitations because non-cost-share practices are not included, nor are operation and maintenance or management information. Sparse spot-checks will not be sufficient to overcome this limitation.
- Statistical sampling and/or surveys may be efficient and highly useful, but must be done with rigorous statistical methodology by trained practitioners. Different approaches for different populations of producers (e.g., CAFO, vs. non-CAFO, large vs. small, etc.) may be required.
- Even if it is limited to detecting structural or extensive practices, remote sensing should be used to the maximum extent possible as it is the most cost-effective approach.
- Remote sensing is applicable for some structural and land-cover practices, but not for management or complex practice systems. Despite the non-invasive nature of remote sensing, some negative attitudes concerning privacy may be expressed by farmers.
- Remote sensing of some practices (e.g., cover crops) has some advantages. Using enrollment information for cover crops, for example, has limitations in terms of not catching bad years when the cover isn't sufficient. Remote sensing data have the ability to verify successful cover crop implementation easily and at lower cost than for on-site inspections and can be interpreted with respect to potential function of erosion control or reduction in N leaching.
- High-resolution LiDAR and land use analysis can be used to determine if historically installed structural practices still exist on agricultural land or whether they have been replaced by larger/different structures

Summary

These are the most important principles derived from both the literature review and the interviews:

- Each of the general protocols for BMP verification identified by the AgWG have been applied elsewhere in the U.S., with varying degrees of effectiveness.
- To meet the objectives of the Chesapeake Bay Program, verification programs must go beyond simple presence/absence to address actual practice efficiency. Some assessment of condition, performance, or efficiency will be required.
- BMP function should not be assumed, even if presence is well-documented
- There have been essentially no assessments of statistical confidence or error reported for any of the approaches to BMP verification described in the literature. Such assessments are essential and should be done by people with statistical and on-the-ground experience, not simply by best professional judgment or by consensus.
- Any proposed verification program, especially as applied to nutrient trading, should be scientifically defensible, and have a high degree of accountability and transparency.

- Verification of structural, annual, and management practices will likely require different protocols and provide different information content and accuracy.
- Hybrid approaches probably have the best potential to provide complete and accurate information on BMP implementation and performance.

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