Conservation Innovation Grant Case Study:
Estimating N_2O Reductions from Nutrient Management in the Chesapeake Watershed

Jointly developed by C-AGG and Chesapeake Bay Foundation
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Case Study Objective

This case study has been developed to provide policymakers and future CIG recipients with a better understanding of the challenges faced during the implementation of GHG reduction projects in the agricultural sector, key lessons learned that could be applied to similar projects, and examples of accomplishments that can be expected.

Project Background

The Chesapeake Bay is the largest estuary in the United States, with a 64,000-square-mile watershed that includes parts of six states and the District of Columbia. Home to more than 17 million people and 3,600 species of plants and animals, the Chesapeake Bay watershed is truly an extraordinary natural system marked by its rich history and astounding beauty. Like many estuarine and coastal systems, however, the Chesapeake Bay is degraded. Every summer, the main stem of the Bay and several of its tributaries are plagued by dead zones, where not enough dissolved oxygen exists to sustain many forms of aquatic life. In addition, water clarity in the Chesapeake Bay has declined so that underwater grasses, critically important as fish and crab habitat, have decreased to roughly 20% of historic levels.

In response to these water-quality problems, the Environmental Protection Agency (EPA) promulgated a Total Maximum Daily Load (or TMDL) for the Chesapeake Bay, in December 2010. The Bay TMDL set annual pollution limits for nitrogen, phosphorus, and sediment required to restore healthy levels of dissolved oxygen and water clarity. At the same time, the six Bay states and the District of Columbia developed and have begun to implement clean-up plans to meet those limits by 2025. Agriculture is the second largest land use (second only to forests) in the Bay watershed and all jurisdictions, except for Washington DC, rely heavily on the implementation of agricultural conservation practices to achieve their water quality goals.

The Chesapeake Bay Foundation (CBF) and other conservation partners have been exploring alternate revenue sources, like environmental markets, that can be used to incentivize the implementation of agricultural conservation practices needed to clean up the Bay. In particular, enhanced nutrient management approaches not only can benefit water quality, but also can reduce emissions of nitrous oxide. Reductions of nitrous oxide (N_2O), a very potent greenhouse gas[1], are an accepted approach for generating carbon credits from voluntary carbon markets in the U.S. To better understand the potential to generate carbon credits from nutrient management best practices and encourage greater adoption, CBF and partners[2] were awarded a Conservation Innovation Grant (CIG) by the US Department of

[1] Over a 100-year time horizon, one molecule of nitrous oxide is equivalent to 310 molecules of carbon dioxide (IPCC Second Assessment Report, 1995)

[2] Environmental Defense Fund, Maryland Department of Agriculture, Virginia Tech Extension, DNDC Applications, Research & Training LLC (model development); USDA ARS Beltsville Lab (provided data for model calibration);

Agriculture (USDA) Natural Resources Conservation Service (NRCS) in 2011 to assess the potential for different enhanced nutrient management approaches to reduce N_2O emissions, and to create a tool that would help reduce the technological and financial barriers to certifying carbon offset credits from agricultural best practices.

Project Approach

To achieve GHG reductions and generate carbon credits, three nutrient management approaches on approximately 7,300 acres of cropland were targeted. The approaches included:

- **Soil testing/adaptive management on corn farms in the Upper Chester River Watershed, Maryland[3];**
- **Manure injection in western and central Maryland[4]**; and
- **Variable rate technology (i.e., GreenSeeker (Figure 1)) on grain farms on Virginia's Eastern Shore.**

Figure 1 GreenSeeker technology in use on a VA farm

Project Goals

- Calibrate and validate the DeNitrification-DeComposition (DNDC) model for cropping systems in the Chesapeake Bay watershed to determine the potential to use DNDC to generate carbon offset credits;
- Create a more user-friendly version of the DNDC model by developing regional soil and climate databases and a user-friendly web-based interface;
- Prepare and submit a Greenhouse Gas Project Plan to the American Carbon Registry (ACR);
- Conduct three workshops to educate farmers and technical service providers on the pilot project, carbon markets and potential use of the ACR's Methodology for N_2O Emission Reductions through Changes in Fertilizer Management[5] and DNDC model to calculate GHG emission reductions;
- Complete third party validation and verification of carbon credits; and
- Compare the GHG benefits and implementation costs of three different nutrient management approaches.

EcoFor LLC (consultant in GHG offset verification) as well as Sterling Planet and WGL Energy (formerly Washington Gas Energy Services)

[3] Project location was changed to Pennsylvania to align with Environmental Defense Fund's existing activities.

[4] Technology was removed from the project due to implementation challenges.

[5] http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emissions-reductions-through-changes-in-fertilizer-management/acr-methodology-for-n2o-emission-reductions-through-changes-in-fertilizer-management_v2-0-final.pdf

Outcomes

The project resulted in the implementation of more than 2,000 acres under adaptive nutrient management in Pennsylvania and roughly 14,000 planted acres [6] (over 5 years) under variable rate technology (GreenSeeker) in Virginia.

Using a long-term database provided by scientists at the USDA-Beltsville Lab, the DNDC model is now calibrated for corn, rye, soy and wheat rotations in the Chesapeake Bay region. The project also developed a web-based user–friendly interface for DNDC that contains the following features: an entry portal for farm and crop management data; a crop management summary report generator for export; a Web-GIS interface for easy identification and digitizing of farm fields; and automatic extraction of SSURGO soil data[7] and local weather data to pre-populate necessary fields to run the model. The development of this interface with these features will facilitate credit estimates and certification for future nutrient management projects in this region.

Since five years of historic field-level data is required to calibrate the DNDC model, due to numerous data gaps over this period, the adaptive management acres in PA did not produce reliable emissions reduction estimates that could be translated into carbon credits. The data gaps, which were overcome by using assumptions made by the modeler, resulted in modeling results with a high degree of uncertainty. The other challenge in PA was that participating farmers had for several years been involved in EDF's "farm stewardship" program, which promotes adaptive management and better use of soil and corn stalk testing to determine nutrient application. The team hypothesized that use of this management approach resulted in a gradual but continuous improvement in nutrient use efficiency over time complicating creation of a baseline scenario on these particular farms. This issue, coupled with the high variability and uncertainty in the model output, led to model results with no detectable systematic change in N_2O emissions or nitrate leaching over time. In fact, changes in

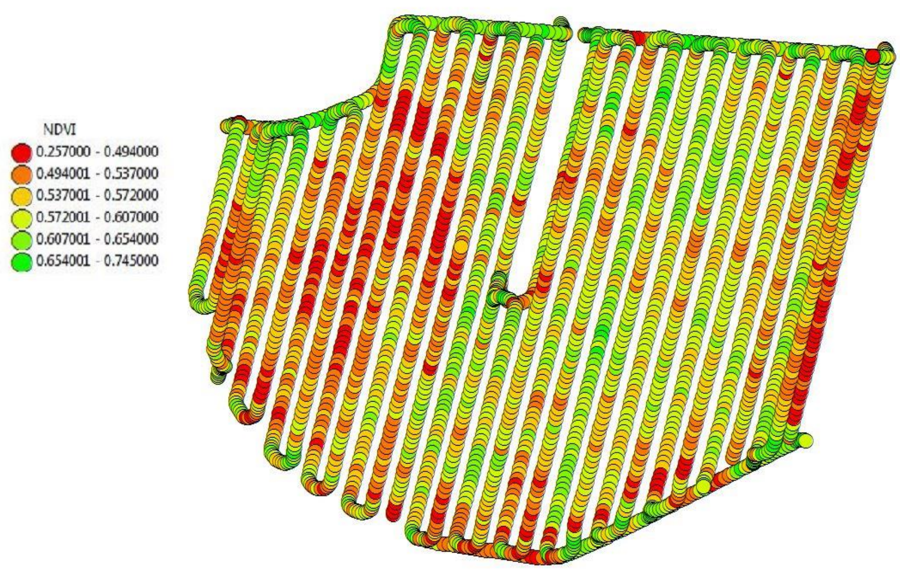

Figure 2 Example of variability in crop growth using the normalized difference vegetation index (NDVI), a predictor of photosynthetic activity, as detected by GreenSeeker across a corn field on the Eastern Shore of Virginia that leads to variable rate fertilizer application.

[6] Note "planted acres" are more than "available acres" since a farmer often plants more than one crop in a season.
[7] SSURGO is an NRCS database that contains information about soil and its properties including water capacity, soil reaction, and electrical conductivity. SSURGO data was collected by the National Cooperative Soil Survey over the course of a century.

nutrient application rates were not apparent for most farms, at least not when averaged across all parcels for each farm.

The project did succeed in producing quantifiable emission reductions from the implementation of the GreenSeeker technology in VA. Figure 2 shows how the GreenSeeker technology captures variability in crop growth to direct the application of variable rate fertilizer application. With the data collected, the project was able to run DNDC model scenarios consistent with the American Carbon Registry (ACR) methodology on the Virginia acres where the GreenSeeker technology was used. Due to data quality concerns with historic farm data, however, and the inability to confidently state that the implementation barriers faced by the project were solely overcome as a result of carbon market incentives – which is a methodology requirement to ensure that emission reductions are beyond "business as usual" -- CBF and partners chose not to pursue the actual verification of carbon credits through the ACR during the project period. Project partners were pleased that GreenSeeker was found to be a viable technology to reduce nitrogen application, GHG emissions, and nitrate leaching, without negatively affecting crop yield and there is interest in exploring the possibility of generating carbon credits in the future.

Lessons Learned

Data requirements for model calibration and baseline establishment can prove to be a major barrier to carbon credit generation: Obtaining the necessary level of historic farm management data (~previous 5 years) to calibrate the DNDC model and to establish a reliable baseline proved to be a major challenge to nutrient management carbon credit generation. Due to data gaps in historic farm data records, the emission reductions resulting from adaptive management on 2,000 acres could not be quantified with enough certainty to generate saleable carbon credits, nor could a distinct change from "business as usual" be detected.

Soil properties should be used as an initial screen: Soil properties can have a significant impact on the potential for N_2O releases after fertilizer application. Therefore, when prioritizing land parcels for implementation of new technologies, such as GreenSeeker or adaptive management, soil properties should be used as an initial screen to target land with soil conditions that result in naturally higher N_2O baselines after fertilizer application and thus a larger possible delta post-implementation.

A definitive practice change is easier to quantify than continuous improvement: A more definitive change in practices during a limited timeframe, as exemplified using GreenSeeker, made the delta between baseline conditions and project conditions more significant and the baseline and delta easier to quantify.

Additionality requirements of carbon offset markets should be more explicit: Determining if the project met the requirements for additionality under the ACR methodology was a challenge. Two basic and straightforward requirements for meeting additionality are: (1) proving the reductions are not required by law, and (2) proving the reductions are the result of activities that are not common practice for the sector. However, a third and less straightforward requirement is proof that the project overcame a financial, technological, or institutional implementation barrier depending on how the baseline was determined and which practices were implemented. CBF had difficulty confidently stating that the financial implementation barriers faced by the project were solely overcome as a result of carbon market incentives. To assist other projects utilizing this methodology, more specific guidance under this section of the methodology is advised to resolve ambiguity.

Using an average N_2O emission factor from agricultural land, a carbon price of $48/ton is needed to drive investment in GreenSeeker for the purpose of generating carbon credits: Assuming an average emission factor for the region (average of PA and VA results) and a 5-year life span for the GreenSeeker technology, CBF calculated that roughly a $48/ton price on carbon would result in a breakeven price for producers who purchase and implement this nutrient management technology.

Major Accomplishments

Use of innovative financing mechanism: Using funds from the Chesapeake Bay Foundation's Carbon Reduction Fund (CRF) for implementation of enhanced nutrient management projects was an innovative financing approach to these agriculture projects. The CRF is supported by funds from the voluntary sale of carbon offsets to WGL Energy natural gas customers. The purpose of this one-of-a-kind fund is to support projects that reduce pollution to the Chesapeake Bay and generate saleable carbon offsets. Although CBF was not able to verify any carbon credits during the project period, the project partners intend to work with the ACR to explore the possibility of verifying GreenSeeker generated credits with additional funding available from the CRF.

Creation of a simplified user-friendly DNDC model: This project resulted in a calibrated and validated DNDC model for corn, rye, soy and wheat cropping systems in the Chesapeake Watershed, which is a significant achievement for future projects in this region, which do not need to invest in this critical step. Additionally, the project developed a more user-friendly online interface for uploading project data, which has been identified by project developers and participants alike as necessary for scaling producer participation in these projects.

Measureable permanent reductions in GHG emissions and N loading: A conservative estimate[8] of reduced GHG emissions by the technologies implemented via this project are 24.4 metric tons CO_2e per year and reduced nitrogen leaching by 3,923 lbs. Use of the DNDC model allowed these reductions to be estimated.

Proof of concept for the viability of GreenSeeker technology: Implementation of the GreenSeeker technology reduced fertilizer use by roughly 6% on corn and wheat fields. These numbers are lower than estimated in other studies, especially for corn, but it is worth noting that most farmers saw a dramatic increase in yield and nutrient use efficiency.

Generation of new and enhanced revenue streams for land owners from efficiency improvements:

Impact	Environmental Benefit	Financial Benefit
GHG Emission Reduction	24.4 MT CO_2e/yr	~$97/yr @ $4/ton[9]
Water Quality Improvement	3,923 lb/yr	$98,075/yr @ $25/lb[10]
Improved Crop Yield	60% increase	$172,612/yr[11]

[8] The estimate only includes the 3,923 acres that used GreenSeeker and provided all required data reducing the uncertainty in the calculations.

[9] Average price on the voluntary market in 2014 (Forest Trends. June 2015. Ahead of the Curve: State of the Voluntary Carbon Markets 2015)

[10] Based on CBF nutrient trading historic prices for nitrogen

[11] Assumes $4/bushel, 11 bushels/acre on 3,923 acres

Next Steps

CBF will work with their local partner, Virginia Tech, to present the results of the GreenSeeker pilot to producers on the Eastern Shore in Maryland and Virginia to show the financial and environmental benefits possible with use of this technology. The desired outcome is to encourage further uptake of the technology by showing proof of concept in the region.

CBF also plans to work with C-AGG and ACR to explore and address some of the challenges with the nutrient management methodology, specifically the process-model requirements and clarification of the requirements for additionality with hopes of bringing future "GreenSeeker credits" to market. Resolving these issues will be an important step towards making these agriculture methodologies more user friendly. Increasing the usability of the methodologies will hopefully result in greater uptake and scaling of agricultural GHG emissions reduction projects and the resulting beneficial impacts.