**Chesapeake Bay Agriculture & Food Security II**

*Operational Analysis of Winter Cover Crop Environmental Performance throughout the State of Maryland*

**VPS Title:** No Grain, No Gain: Winter Cover Crop Performance in Maryland

**Project Team**

***Project Team*:**

Logan Kline, (Project Lead), logan.kline1997@gmail.com

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***Advisors & Mentors*:**

Jason Keppler (Maryland Department of Agriculture, Office of Resource Conservation)

Dr. W. Dean Hively (USGS, Eastern Geographic Science Center)

Dr. Greg McCarty (USDA, Agricultural Research Service, Hydrology and Remote Sensing Laboratory)

Dr. Kristofer Lasko (ERDC, Geospatial Research Laboratory)

***Past or Other Contributors*:**

Dr. Sunita Yadav

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**Project Overview**

***Project Synopsis*:** The primary objective of this project was to continue research conducted by the spring 2017 Goddard Space Flight Center DEVELOP team on winter cover crop analysis in the Chesapeake Bay watershed. To fulfill this objective, the current team utilized NASA Earth observation data to analyze vegetation metrics and performance of winter cover crops. Software was developed through Google Earth Engine to provide the Maryland Department of Agriculture (MDA) with a user-friendly graphical user interface (GUI). The functions within this GUI can be used to facilitate cover crop performance analysis, implement effective management strategies, and aid in future decision making.

***Abstract*:**

Winter cover crops increase the sustainability of agricultural lands and the health of surrounding watersheds through erosion control and nutrient retention. The Maryland Department of Agriculture (MDA) incentivizes the planting of winter cover crops in the Chesapeake Bay area via a cost-sharing program that offers subsidies to enrolled farmers. The success of these cover crops is dependent on several factors, such as crop species, planting date, and termination date. Using imagery from Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), and Sentinel-2 MultiSpectral Instrument (MSI), a previous DEVELOP team constructed methods that evaluated the performance of Maryland cover crops on the basis of biomass. However, the MDA required more streamlined methods and user-friendly tools to implement the products in their day-to-day operations. The current DEVELOP project aimed to simplify the methods established by the previous team through the creation of a graphical user interface (GUI) using Google Earth Engine to optimize end user analysis of cover crop data. The graphical analysis produced by this GUI aids the MDA by granting further insight into cover crop effectiveness, promoting more informed decision making and improved conservation efforts for the Chesapeake Bay.

**Keywords:**

Remote sensing, biomass, percent ground cover, Normalized Difference Vegetation Index, graphical user interface, Google Earth Engine

***National Application Area Addressed:*** Agriculture & Food Security

***Study Location:*** Talbot, Washington, Somerset, and Queen Anne’s counties, MD

***Study Period:*** December 2006 – April 2018 (15 December – 31 January; 1 March – 15 April)

***Community Concern:***

* Nitrogen, soil, and other nutrients from agricultural fields can leach or erode into water systems, contributing to eutrophication, fish die-off, and oxygen depletion.
* The Chesapeake Bay is home to over 3,000 species that are threatened by excess agricultural pollution and depend on clean, oxygen-rich water.
* Various recreational and commercial activities, such as boating, fishing, and oyster management, suffer from nutrient runoff affecting water quality.
* Monitoring winter cover crop fields for compliance with MDA requirements is costly and labor-intensive.
* The MDA and Chesapeake Bay Program partnership relies on the effective implementation of the cover crop program but lacks a streamlined tool for data analysis and evaluation of enrolled fields.

***Project Objectives:***

* Implement code and research from prior term into an interactive, user-friendly, Google Earth Engine GUI for streamlined data analysis
* Produce tabular and graphical analyses on the performance of fields in the winter cover crop program
* Provide end user with a program that facilitates regular analysis of cover crops with selective filtering by plant type, planting method, planting data, watershed, and county

***Previous Term:*** Spring 2017 (GSFC) – Chesapeake Bay Agriculture

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Maryland Department of Agriculture, Office of Resource Conservation** | Jason Keppler, Watershed Implementation Program Manager | End User | No |
| **USGS, Eastern Geographic Science Center** | Dr. W. Dean Hively, Research Physical Scientist | Collaborator | No |
| **USDA, Agricultural Research Service, Hydrology and Remote Sensing Laboratory** | Dr. Greg McCarty, Research Soil Scientist | Collaborator | No |
| **US Environmental Protection Agency, Chesapeake Bay Program** | Rich Batiuk, Associate Director of Science | Collaborator | Yes |

***Decision Making Practices & Policies*:**

In order to promote environmentally conscious farming practices, the MDA oversees a cost-sharing program that provides a total of $22.5 million per year to farmers who plant winter cover crops. Payment for farmers is calculated based on the agricultural practices used by each farm; to facilitate these payments, the MDA records the management strategies and location of each enrolled field. Fields determined to be using techniques that yield the most effective cover crops receive larger payments. The MDA verifies that the standards and requirements of the program are being adhered to by spot-checking only 20% of fields. Although the MDA has code for cover crop analysis using Google Earth Engine, un-synthesized components of the code restrict the current use of remote sensing analysis.

***Project Benefit to End User*:**

Remote sensing provides a cost-effective mechanism to monitor plant biomass and percent ground cover analysis that would reduce the need for *in situ* spot-checking and increase the efficiency of the cover crop program. While the previous DEVELOP team created code that was effective in analyzing cover crop variables, components of the code needed to be processed separately in R, Google Earth Engine, and ArcGIS. Synthesizing the work produced by the prior team into one program enables the MDA to more seamlessly integrate remote sensing into its cover crop program and facilitate the production of more detailed performance reports for participating fields. The user-friendly GUI will allow the MDA to analyze the effectiveness of the program on both small and large scales, which will grant insight into best practices for an updated, streamlined incentive structure. The resulting tables and figures will present environmental analysis to encourage sharing of field performance data with conservation districts. Additionally, farmers enrolled in the program will be able to use these results to refine their agricultural practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | Normalized Difference Vegetation Index (NDVI) | Vegetation indices were used to measure biomass and percent green ground cover provided by winter cover crops. |
| **Landsat 8 OLI** | NDVI | Vegetation indices were used to measure biomass and percent green ground cover provided by winter cover crops. |
| **Sentinel-2 MSI** | NDVI | Additional multi-spectral satellite data is desired, as available, to increase temporal frequency. |

***Ancillary Datasets:***

Maryland Department of Agriculture Field Boundary Shapefiles – Annual field boundary shapefiles of statewide cover crop enrollment and agronomic management information on MD farms, used for monitoring progress in achieving conservation targets and for generating remote sensing statistical outputs based on farms enrolled in the cover crop program

USGS/USDA-ARS Calibration Dataset – Calibration dataset (>2000 measurements) of on-farm field sampling of winter cover crop performance (biomass), including photo archive for determining percent ground cover classification

NASA DEVELOP Wintertime and Springtime Imagery Translated to NDVI and Fractional Vegetative Ground cover – GUI input

NASA DEVELOP Performance Data Calculated for Cover Crop Fields – GUI input

NASA DEVELOP Tabular Reports at Watershed and Regional Scale – GUI input

NASA DEVELOP Large-scale NDVI extraction automation scripts – GUI input

NASA DEVELOP Statistical analysis automation scripts – GUI input

***Software & Scripting:***

Google Earth Engine API – Satellite image processing (surface reflectance band extraction, NDVI, calculated percent vegetative ground cover, calculated biomass), data extraction and statistical analysis, and production of tables and graphs summarizing satellite-derived measures. A graphical user interface (GUI) was created to routinely produce these calculations and output in a fashion that communicates information clearly to support adaptive management decision making by the end user.

R 3.4.3 – Code written in R to process data and apply statistical analysis.

ArcGIS Pro – Reproject shapefiles into WGS 1984 (WKID 4326) for compatibility with Google Earth Engine.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **CCROP2: Cover Crop Performance Google Earth Engine GUI** | Landsat 5 TM  Landsat 8 OLI  Sentinel-2 MSI | This product will enable MDA users to easily accomplish the data processing steps required to 1) search, acquire, and composite Landsat and Sentinel springtime and wintertime imagery, 2) overlay field boundaries for MDA cover crop enrollment, 3) create the calibration, calculate performance outcomes, and 4) create tables, graphs, and maps depicting the environmental outcomes associated with various agronomic management strategies for winter cover crops. | IV |
| **CCROP2: Cover Crop Performance Google Earth Engine GUI Tutorial** | N/A | Partners will be able to follow a step-by-step guide to navigate the Google Earth Engine GUI. | N/A |

**Project Handoff Package**

**Transition Plan:**

Upon successful completion of the project, all deliverables were handed off in person to project partners. Joint meetings were held among the USGS, USDA ARS, and MDA partners to discuss deliverables and strategize for the transition to operational usage within the following year. Throughout the project, the team communicated with the MDA so that project deliverables can be well-integrated with the MDA SQL Server database format. The Google Earth Engine GUI cannot be handed off until software release is completed; however, the GUI tutorial was provided alongside all deliverables.

*Software Release Plan*: The Google Earth Engine GUI needs to go through a software release process, initiated as soon as possible, to support hand-off before or during the following term. Because this may not be complete before the end of the term, there is an assigned team point of contact (POC) who will provide continued interaction between the project team and its partners. The software release POC will maintain communication with partners throughout the software release process.

*Project Continuation Plan*: A third term conducted in spring 2019 will conclude this DEVELOP partnership by integrating the previous projects with a spring season time series analysis. This final project would enable the MDA to remotely verify farmers’ adherence to cover crop termination protocol, diminish the need for spot-checking, reduce workload significantly, and increase the effectiveness of cover crop management.

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**Software Release POC:** Julio Peredo, juliop1@umbc.edu

**Partner POC:** Jason Keppler, jason.keppler@maryland.gov

**Handoff Package:**

* CCROP2: Cover Crop Performance Google Earth Engine GUI
* CCROP2: Cover Crop Performance Google Earth Engine GUI Tutorial
* Technical Paper
* Poster
* Presentation
* Project Video

**References:**

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