**New York Ecological Conservation**

*Evaluating Agricultural Conservation Easement Impact Using Earth Observations to Examine Avoided Soil Carbon Loss to Development*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The team partnered with the Finger Lakes Land Trust, Genesee Land Trust, and Saratoga PLAN to determine agricultural conservation easement benefits, justifying partner conservation efforts and serving as a tool for acquiring future easement sites. Our goal was to estimate and examine avoided soil carbon loss of agricultural conservation easements and predict future land conversion and vulnerability to developed land transitions for the years, 2030 and 2050. Remotely sensed observations of agricultural lands and impervious surfaces allowed for characterizations across 37 years by evaluating the conversion rate from farmland to impervious surfaces.

***Abstract:***

Farmland provides ecosystems and communities with services ranging from habitat conservation to food security. As total U.S. farmland continues to decline, agricultural lands near urban areas are especially vulnerable. Our project partners—Finger Lakes Land Trust, Genesee Land Trust, and Saratoga Preserving Land and Nature (PLAN)—can use study results to better profile farmland vulnerability, issuing conservation easements to protect maximum acreage in Saratoga County and the Finger Lakes Region of New York. Multiple existing studies effectively use remote sensing imagery to analyze historical land cover and forecast future change. This study examined soil carbon stocks and land cover change to estimate avoided soil carbon loss. We also predicted farmland vulnerability. We completed these analyses using European Space Agency (ESA) and NASA Earth observations including Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), Landsat 9 OLI-2, and Sentinel-2 Multispectral Instrument (MSI). We additionally used Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) for nighttime lights data that aided in the land change model analysis. We determined that the conversion of agriculture to development from 1990 to 2022 occurred at rates of 0.91% (Finger Lakes) and 7% (Saratoga). Urban development is predicted to increase surrounding urban centers through 2030 and 2050. We also estimate that between 26.5 and 348,101 kilotons (Finger Lakes) and 3.7 and 58,006 kilotons (Saratoga) of soil carbon losses have been avoided through agricultural easements. Findings from this study will support our partners in determining agricultural conservation easement benefits and prioritizing the acquisition of future easement sites.

***Key Terms:***

Agriculture, conversion, soil carbon, Sentinel-2, Landsat, Suomi NPP VIIRS, conservation easements

***National Application Areas Addressed:*** Ecological Conservation, Agriculture

***Study Location:*** Finger Lakes Region and Saratoga County, NY

***Study Period:*** 1985 to 2022 (June to October), 2030, 2050

***Community Concerns:***

* Development pressures in upstate New York are intruding onto agricultural lands, especially in our study areas. Land demand continues to increase as people move to consistently expanding urban areas and the energy sector transitions toward land-intensive forms of renewable power.
* Farmland is invaluable to the cultural identity of New York State, as agricultural lands dominate our study areas. Agricultural land loss also causes a decline in farm-fresh foods for local communities, which provide a host of nutritional benefits.
* Reduction in agricultural lands increases environmental stressors, such as local songbird habitat loss. Farmland conversion also contributes to landscape resiliency, or the ability of habitat to sustain ecological function in a changing environment.
* The development and disturbance of fertile soils can also turn responsibly managed farmland from a carbon sink into an emission source, ultimately contributing to the excessive carbon dioxide levels in our atmosphere.
* Given current public concerns regarding climate change adaptability and atmospheric composition, farmland conservation is paramount for protecting local communities in the northeastern United States.

***Project Objectives:***

* Predictively map historical and future land cover and vulnerability maps for the years 2030 and 2050 using Earth observations including Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI, and Suomi NPP VIIRS nighttime lights data
* Assess avoided soil carbon loss from agricultural conservation easements to validate the land trust organizations that we are partnering with on their conservation efforts and impact

**Partner Overview**

***Partner Organizations:***

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| --- | --- | --- |
| **Organizations** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Finger Lakes Land Trust** | Max Heitner, Director of Conservation | End User |
| **Genesee Land Trust** | Amanda Grisa, Farmland Protection Manager | End User |
| **Saratoga PLAN** | Tori Roberts, Conservation Project Manager | End User |

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

Farmland conservation is of particular interest to many non-profit organizations, as it provides surrounding ecosystems and local communities with various services, ranging from habitat conservation to food security. To reduce future farmland decline and prevent the loss of these services, landowners can opt into legally binding conservation easements with land trusts, preventing the future development of their property. Demand for agricultural conservation easements is on a steady incline within Saratoga County and the Finger Lakes Region of New York State, and obtainment is highly competitive. Each grant cycle, land trust organizations assess their pool of landowner applications based on selection criteria of soil quality and proximity to other easements. From there, each organization selects 2-6 easement projects to fund with their allocated grant money, sometimes supplemented by county funds. When selecting easement locations, partners preference high impact areas that are likely to experience land use change if not protected. The partners currently implement GIS to assess strategic conservation planning, but use little to no remote sensing in their decision making.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 9 OLI-2** | Surface reflectance | Surface reflectance was used to generate impervious surface and vegetation indices for 2022. |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance was used to generate impervious surface and vegetation indices for 2015 and 2020. |
| **Landsat 5 TM** | Surface reflectance | Surface reflectance was used to generate impervious surface and vegetation indices for 1985, 1990, 1995, 2000, 2005, and 2010. |
| **Sentinel-2 MSI** | Surface reflectance | Surface reflectance was used to generate impervious surface and vegetation indices for 2020 and 2022. |
| **Suomi NPP VIIRS** | Nighttime lights | Nighttime lights data were used as a driver variable input into the TerrSet Land Change Modeler. |

***Ancillary Datasets:***

* USGS National Land Cover Database (NLCD) – used to mask cropland for the neighborhood analysis and to create land change prediction maps
* NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas – used in land classification for impervious surface mapping for years before NLCD covers
* ORNL Global Aboveground and Belowground Biomass Carbon Density – input as driver variable into Land Change Modeler
* U.S. Census Bureau Population and Census Tracts (2020) – input as driver variable into Land Change Modeler
* U.S. Department of Homeland Security Transmission Lines (2021) – input as driver variable into Land Change Modeler
* U.S. Geographical Survey 3D Elevation Program (3DEP) – calculate slope and input elevation and slope as driver variables into Land Change Modeler
* International Soil Reference and Information Centre (ISRIC) World Soil Information – used to calculate avoided soil carbon loss

***Modeling:***

* TerrSet Land Change Modeler (LCM) (POC: Caroline Williams, NASA DEVELOP) – modeled future land cover and generated transition suitability maps between agriculture and developed land cover types

***Software & Scripting:***

* Google Earth Engine (GEE) JavaScript API – acquired data and generated historical impervious surface maps
* R Studio 4.2.3 – processed and analyzed data to create figures, maps, and calculate avoided soil carbon loss
* Esri ArcGIS Pro 3.0.0 – processed data and visualized final map products
* QGIS 3.26 – processed data for use in the TerrSet Land Change Modeler

***End Products:***

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| --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Historical Impervious Surface Maps** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI | The team used historical impervious surface  mapping methods from Kaspersen et al. (2015) to create impervious surface maps every 5 years from 1985 to present. These maps act as a historical record for partner organizations and contribute as inputs in the neighborhood analyses. |
| **Conservation Rates** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI | Neighborhood analyses provide information on agricultural conversion rates to impervious surface. This information was used as an input for the avoided soil carbon loss analysis to inform partners of land change trends. |
| **Predicted Land Cover Classification Maps** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI, Suomi NPP VIIRS | These maps can be used to assess the spatial distribution of urban sprawl. Partners can use these maps to predict land classes at high risk of conversion, influencing their conservation easement issuance type and placement. |
| **Predicted Transition Vulnerability Maps** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI, Suomi NPP VIIRS | Partners can use these maps to determine the likelihood that a parcel of agricultural land will be developed. Areas at high risk of development might be strongly considered for a conservation easement. |
| **Avoided Soil Carbon Loss** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI | Avoided soil carbon loss information can be leveraged by partners to validate the climate impact of agricultural conservation easements ex-ante. |
| **Ecosystem Service Analysis** | Landsat 5 TM, Landsat 8 OLI, Landsat 9 OLI-2, Sentinel-2 MSI | Comparison of vegetation and soil health parameters between  agricultural conservation easements and nearby non-protected agricultural lands will help partners demonstrate  the impact of their conservation  efforts. |

***Product Benefit to End User:***

Our partners' conservation easement selection process and success measure will benefit from our findings. Land trust organizations can use agriculture to developed transition potential data as an additional selection criterion when determining easement placement. Conservation rates can also serve as a great baseline to inform easement issuance, as our partner organizations have never previously had access to this form of calculation. Our data on conversion rates, soil carbon, and ecosystem services may be used to communicate with landowners about the value of easements and inform the public, government, and funding sources on the inherent value in creating agricultural conservation easements.

**References**

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