NASA DEVELOP National Program
2025 Spring Project Proposal

Maryland – Goddard
Southern Indiana Ecological Conservation II
Mapping Foliage Height Diversity and Canopy Closure Trends to Inform Oak and Hickory Restoration and Public Outreach

Project Overview

Project Synopsis: Decades of fire suppression in Indiana is driving an ecological shift towards mesophication in oak and hickory forests. Closed-canopy forests dominated by shade-tolerant, mesophytic species are encroaching upon native shade-intolerant, drought-tolerant, and fire-adapted plant communities. The DEVELOP team will help partners manage this ecological shift by identifying sites undergoing mesophication using canopy height and the Foliage Height Diversity Index calculated from observations of vertical foliage profile normalized by total plant area index. The team will also create public outreach materials demonstrating canopy closure trends in southern Indiana. Building upon work from the first term, this team will model and analyze canopy height and foliage height diversity in priority oak/hickory restoration sites using ISS GEDI, Sentinel-2 MSI, and Landsat 9 OLI-2 Earth observations. The team will also use Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, and Landsat 9 OLI-2 to map changes in tree canopy cover between 1985 and 2024. These analyses will provide insight into canopy structure and mesophication distribution, as well as tools to inform the public about the benefits of management practices.

Study Location: Southern Indiana (IN), Let the Sun Shine In focal areas
Study Period: 1985 – 2024 (March – December)

Advisors: Joseph Spruce (NASA Langley Research Center, AMA) joseph.p.spruce@ama-inc.com, Sean McCartney (NASA Goddard Space Flight Center, SSAI) sean.mccartney@nasa.gov

Partner Overview

Partner Organizations:

Organization	Contact (Name, Position/Title)	Partner Type	Sector
Let the Sun Shine In-Indiana: Central Hardwoods Joint Venture, American Bird Conservancy	Kyle Brazil, Co-Project Lead; Judi Brown, LSSI-Indiana Coordinator, Co-Project Lead; Jeff Powelson, Conservation Delivery Coordinator	End User	Consortium
USDA, US Forest Service, Hoosier National Forest	RD Sample, Forest Ecologist	Collaborator	Federal Government

<u>End User Overview</u>

End User's Current Decision-Making Process & Capacity to use Earth Observations: The partners formed the Let the Sun Shine In-Indiana (LSSI) initiative to collaborate in recovering and maintaining oak/hickory forest ecosystems on a landscape scale basis by utilizing science-based management practices and outreach programming to strengthen public awareness. Some of the forest management practices used include prescribed burns, invasive species control, and mid-story thinning on public lands. Field tours and workshops are used to share management practices with private landowners and demonstrate to the public the positive ecological effects of forest management. LSSI's restoration planning and outreach initiatives can be improved through the application of Earth observations; the collaborators currently do not have maps of forest mesophication and long-term canopy cover trends. Some researchers from the partner organizations are GIS professionals and have created tools for landowners, but LSSI needs support in long term trend assessments using remote sensing and spaceborne lidar data processing.

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
ISS GEDI	Foliage height diversity, Canopy height, Canopy vertical profile, Canopy gap fraction	GEDI L2B trajectory point data will be used alongside Landsat 9 OLI-2 and Sentinel-2 MSI data to model canopy height and foliage height diversity (FHD) for the study area. Lidar data from GEDI may be used to generate other forest structure information on the upper canopy including canopy height, density, and vertical distribution (2019 – 2024).
Landsat 9 OLI-2	Surface Reflectance, Normalized Difference Vegetation Index	Surface reflectance will be used to model tree canopy cover across a portion of the study period (2021 – 2024). Surface reflectance will be used to create true color images and vegetation indices to train a regression model to predict FHD and canopy height.
Landsat 8 OLI	Surface Reflectance, NDVI	Surface reflectance will be used to model tree canopy cover across a portion of the study period (2013 – 2021). Surface reflectance will be used to create true color images and vegetation indices to train a regression model to predict FHD and canopy height.
Landsat 7 ETM+	Surface Reflectance, NDVI	Surface reflectance will be used to model tree canopy cover across a portion of the study period (1999 – 2013). Surface reflectance will be used to create true color images and vegetation indices to train a regression model to predict FHD and canopy height.
Landsat 5 TM	Surface Reflectance, NDVI	Surface reflectance will be used to generate max NDVI composite images and other vegetation indices to model tree canopy cover for a portion of the study period (1985 – 1999).
Sentinel-2 MSI	Surface reflectance, NDVI, Modified Normalized Difference Water Index, Soil Adjusted Vegetation Index	Surface reflectance will be used to create true color images and spectral indices to train a regression model to predict FHD and canopy height across the study area.

Ancillary Datasets:

- Indiana Sentinel Landscape study area shapefile – Identify partners' focal areas

- USGS NLCD All USFS CONUS Tree Canopy Cover (TCC) Products – Use tree canopy cover data from more recent years (2011 – 2021) to derive a linear regression relationship between TCC and Landsat multispectral data for estimating earlier years of TCC
- MRLC Annual NLCD Science Products – Use 39 years (1985 – 2023) of land cover data to estimate historical proportion of canopy cover in the study area
- USGS Land Change Monitoring, Assessment, and Projection (LCMAP) – Provide annual canopy cover identification
- USDA Landscape Change Monitoring Systems (LCMS) – Provide annual maps of land change, land cover, and land use from 1985 to present
- UMD GLAD Global Land Cover and Land Use Change Dataset, 2000 – 2020 – Detect canopy cover change and compare to Landsat-derived change detection
- UMD GLAD Forest Extent and Height Change Dataset, 2000 – 2020 – Detect canopy cover change and compare to Landsat-derived change detection
- UMD GLAD Global Forest Change, 2000 – 2023 – Compare GLAD forest loss/gain observations (2000-2023) to Landsat-derived change detection
- USGS 3D Elevation Program (3DEP) Digital Elevation Model – Predict FHD, canopy height, and other canopy structure parameters

Modeling:

- Random Forest, ArcGIS Pro Image Analyst, Train Random Trees Regression Model and Predict Using Regression Model Tools (POC: Lisa Tanh, ltanh@esri.com – Foliage height diversity and canopy height maps)

Decision Support Tool & End Product Overview

End Products:

End Product	Partner Use	Datasets & Analyses
Fractional Canopy Cover Change Detection Maps	The canopy cover change maps will demonstrate canopy closure trends across LSSI's operational region in Indiana. They will serve as compelling outreach tools to demonstrate the necessity of forest management and convey to the public that management practices, including forest thinning and prescribed burning, do not pose a threat to the forests of Indiana.	NLCD Tree Canopy Cover products will be used alongside Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, and Landsat 9 OLI-2 multispectral imagery to derive a linear regression relationship between TCC and multispectral imagery, including max NDVI image composites. TCC will then be estimated for the years prior to 2011, every third year, using the regression equations and Landsat 5 TM and Landsat 7 ETM+ multispectral imagery. The difference between modelled TCC maps for the study period (1985 – 2024) will highlight changes in canopy cover.
Canopy Height and Foliage Height Diversity Maps	Foliage height diversity and canopy height maps will be used by the partner to evaluate levels of mesophication in highly suitable areas for oak/hickory. Partners will target areas experiencing mild or moderate levels of mesophication for restoration.	Canopy structure parameters, primarily FHD and canopy height, will be modeled using the most recent available data from ISS GEDI, Landsat 9 OLI-2, and Sentinel-2 MSI. GEDI FHD trajectory point data will be used to train a regression model to predict canopy height and

		FHD. The focal areas for canopy height and FHD analysis will be the highly suitable sites identified in the first term.

Project Timeline & Previous Related Work

Project Timeline: 2 Terms: 2024 Summer and 2025 Spring

Multi-Term Objectives:

- **Term 1:** 2024 Summer (GSFC) – Southern Indiana Ecological Conservation
    - o The first term produced oak/hickory restoration suitability maps using landform, slope/aspect, NLCD canopy cover, and SSURGO soil type data. These restoration suitability maps lay the groundwork for a future team to incorporate lidar-derived canopy structure data to increase the utility of the restoration suitability site maps by including a mesophication assessment. Partners identified this mesophication component as central to their selection of restoration sites. The first term also created green vegetation fraction change maps (1984 – 2023), but these maps were generated using a mean NDVI three-year composite approach and assigning pixels with no data values of zero rather than Not a Number (NaN) which led to a miscalculation of the historic baseline NDVI.
- **Term 2 (Proposed Term):** 2025 Spring (GSFC) – Southern Indiana Ecological Conservation II
    - o The second term project will model canopy height and foliage height diversity for improved restoration site selection. Partners identified canopy height, foliage height diversity, and canopy gap fraction as key variables of interest because they reflect the amount of sunlight hitting the forest floor and an expansion in the midstory. Partners reasonably assume that midstory expansion is caused by maple/beech encroachment, therefore, this analysis will be able to inform their efforts to manage mesophication. The team will also improve the canopy cover change maps by amending earlier methods to use linear regression for establishing an empirical relationship between tree canopy cover and multispectral imagery, rather than using the green vegetation fraction approach from Term 1. Furthermore, max NDVI temporal compositing will be used to derive the historic baseline image. The use of max NDVI will reduce the inclusion of poor data due to clouds, aerosols, and shadows, and improve change detection accuracy. The team will handoff an improved canopy cover change detection and foliage height diversity maps for the priority sites identified in Term 1.

Similar Past DEVELOP Projects:

- 2024 Fall (GSFC) – Illinois Ecological Conservation: https://www.devpedia.developexchange.com/dp/index.php?title=Illinois_Ecological_Conservation_GSFC_Fall_2024
- 2024 Summer (GSFC) – Southern Indiana Ecological Conservation: https://www.devpedia.developexchange.com/dp/index.php?title=Southern_Indiana_Ecological_Conservation_GSFC_Summer_2024
- 2023 Spring (CO) – Front Range Wildland Fires: https://www.devpedia.developexchange.com/dp/index.php?title=Front_Range_Wildland_Fires_CO_Spring_2023
- 2016 Summer (CO) – Laramie Mountains Eco Forecasting: https://develop.larc.nasa.gov/2016/spring/LaramieMountainsEco.html

Notes & References:

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Cloud-based aboveground biomass mapping tutorial from Esri

- This tutorial provides a prototype workflow for predicting aboveground biomass using GEDI L4A data. The team will adapt the tutorial to interpolate wall-to-wall canopy height and foliage height diversity maps from GEDI L2B trajectory point data with the help of Lisa Tanh. The team will meet with Lisa on 02/05/25 to walk through the workflow and ask questions.

Modifications to the Esri aboveground biomass prediction methods

- The team will need to create two trajectory datasets in ArcGIS Pro – one for canopy height and one for foliage height diversity using the Create A Trajectory Dataset Tool. After adding data to the trajectory dataset (Add Data to Trajectory Dataset Geoprocessing Tool), the team will need to assemble additional data layers and access the Image Analyst License in order to use the Train Random Trees Regression Model Tool. Once the team assembles the GEDI trajectory point data, cloudmasked Landsat or Sentinel scenes, a DEM, and spectral indices layers (NDVI, Enhanced Vegetation Index, and others determined by the team/science advisors can be calculated using Esri Raster Functions), then they should run the Train Random Trees Regression Model twice – once for the canopy height trajectory point dataset and once for the foliage height diversity dataset. After training the models, the .ecd file ouptput will be used for the Predict Using Regression Model Tool to interpolate foliage height diversity and canopy height across the study area.

ArcGIS Pro Image Analyst License

- The Image Analyst License is a prerequisite to use the Train Random Trees Regression Tool. The Goddard Lead should email Lisa Tanh (ltanh@esri.com) and Cole Walts (cwalts@esri.com) to request access to the Image Analyst License for the team during Week 1 of the spring term.

GEDI L2B Canopy Cover and Vertical Profile Metrics Data Global Footprint Level V002

- GEDI L2B Canopy Cover and Vertical Profile Metrics Data can be accessed at Earthdata.gov. The site allows users to input study area shapefiles and search for granules taken during the leaf-on season.

Approach to Modelling Tree Canopy Cover Using Regression

- In using a regression approach to deriving tree canopy cover (TCC), the team will derive an equation using a NLCD TCC maps clipped to the study area. This TCC map should be randomly sampled to derive training areas for use in comparison to Landsat multispectral data to derive a linear regression relationship. The NLCD TCC maps were derived from photo-interpretation of high resolution NAIP imagery. The USFS defined TCC as the percent of systematically arranged points (109 total) within a 144-foot radius circle centered on an FIA plot that fall over tree canopy for their methods to create TCC reference data. The team may want to explore replicating these methods to collect their own TCC reference data. Once the team derives a linear regression relationship between TCC and Landsat data for later years in the study period (e.g. 2021 when NLCD TCC data is available), the relationship can be applied to Landsat data for any year of interest. Before applying the regression relationship to earlier years of interest, Landsat 5 and Landsat 7 imagery must be transformed to Landsat 8 and Landsat 9 surface reflectance. Roy et al. (2016) provides regression equations to use for converting Landsat 7 to Landsat 8 surface reflectance for spectral bands common to Landsat 7/8, based on data spread across the US. This method may also be used to harmonize Landsat 5 to Landsat 8 spectral reflectance values because Landsat 5 and Landsat 7 produce very similar NDVI imagery and can be used interchangeably with caution for landscape characterization (Vogelmann et al., 2001).

Modifications to NDVI Compositing Methods

- The team will select Landsat scenes from every three years (1984, 1988, 1991, etc.) for March – December within the study period. For each year of imagery, the scenes will be cloud masked and clipped to the study area boundary. NDVI will be calculated for each Landsat scene. The max NDVI values from each scene for a given year will be used to create max NDVI composites for every third year within the study period. The derived NDVI values are used to identify the greenest pixel, or maximum NDVI value, present in the given annual growing season. The team will use raster functions composite bands tool in ArcGIS Pro to generate NDVI composites for the entire study area every three years for the duration of the study period. These NDVI composites can be used to model tree canopy cover.

References:

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