**Northeast US Ecological Forecasting**

*Modeling Invasive Plant Habitat Suitability to Support Management Efforts in the American Northeast*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Disrupting the spread of non-native plant species in the Northeast US demands early detection and rapid response. This project used NASA Earth observations to develop invasive Species Distribution Models for one established (Japanese stiltgrass, *Microstegium vimineum*) and one new (wavyleaf basketgrass, *Oplismenus undulatifolius*) plant species invasive to the Northeast US, combining invaded and native range occurrences with US-specific and global environmental variables. The team evaluated the ability of these models to determine habitat suitability, identified US or global variables that contributed most to model accuracy, and compared how these models functioned for the established versus new invasive species.

***Abstract:***

Invasive plant species threaten environmental and economic interests when they spread into new areas, outcompete native species, and disrupt ecosystem services. If spread is not controlled early, species can become well-established and increasingly difficult to manage. The National Park Service (NPS) Invasive Plant ManagementTeams (IPMTs) thus strive for an “early detection, rapid response” approach to reducing invasive species spread. Management teams can better prioritize their workwith the help of Species Distribution Models (SDMs), which map habitat suitability by combining species occurrences with environmental predictor variables. Scarce invaded range data for newly arrived invasive species presents a particular challenge for producing accurate models. To improve future modeling efforts, this project compared SDM methods using different spatial scales to model two plant species invasive to the Northeast US: the well-established Japanese stiltgrass *(Microstegium vimineum)* and newer invasive species wavyleaf basketgrass (*Oplismenus undulatifolius).* The team used NASA Earth observations and climate datasets to model occurrence data and predictor layers at a US-specific extent (90m2 spatial resolution) and global extent (1 km2 spatial resolution). Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) provided data for US Normalized Difference Moisture Indices (NDMI), while global NDMI and topographic predictor layers derived from Shuttle Radar Topography Mission (SRTM) and Terra Moderate Resolution Imaging Spectroradiometer (MODIS). The resulting models indicated important predictor variables for each species and explored the benefits and tradeoffs of using global data to model habitat suitability for new-arrival invasive species.

***Key Terms:*** Japanese stiltgrass, wavyleaf basketgrass, Species Distribution Model (SDM), Maximum Entropy Modeling (MaxEnt), VisTrails Software for Applied Habitat Modeling (SAHM), invasive plant species

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Northeast, National Capitol Region, and Mid-Atlantic Invasive Plant Management Team regions – CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VA, VT, WV

***Study Period:*** 1980-2020

***Community Concerns:***

* In 2020, the Northeast IPMT region alone faced approximately 1,146 acres of gross infested area experiencing invasive plant species presence.
* Present throughout the majority of our study area, Japanese stiltgrass displaces native species, reduces flora diversity, and disrupts important ecosystem functions. As an annual plant, this species produces and germinates new seeds each year, which can grow after being stored in soil up to 5 years and survive winter temperatures around -23°C.
* Japanese stiltgrass is difficult to control and often needs multiple treatment efforts in order to be removed from an ecosystem. Prevention is the crucial first step in management practice.
* Although only recently introduced to the Northeast US, wavyleaf basketgrass has the potential to damage native ecosystems in ways similar to Japanese stiltgrass.
* Wavyleaf basketgrass, native to Europe and Asia, spreads aggressively through invaded forest understories due in part to its high tolerance for shady conditions, excessive seed production, and clonal replication. Its shallow root system and sticky seeds that adhere to human clothing and animal fur allow it to spread and establish quickly, crowding out native plant species and diminishing native flora diversity. Once a single plant is established in an environment, this perennial species survives year-round, creating monocultures that can endure year after year.

***Project Objectives:***

* Model species distributions for wavyleaf basketgrass and Japanese stiltgrass in the Northeast US
* Compare model performance for *new* versus *established* invasive species and *high* versus *low* spatial resolution predictors
* Evaluate model accuracy in determining suitable habitat for the target species
* Produce habitat suitability maps of target species that indicate patterns in range spread
* Identify predictive variables that contributed most to model accuracy
* Share results that will strengthen future predictive modeling of invasive species

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Biological Resources Division** | Terri Hogan, Invasive Plant Program Manager; Dr. Jennifer Sieracki, Invasive Animals Program Coordinator | End User | No |

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

Since 2000, regional Invasive Plant Management Teams (IPMTs) have worked to control invasive plant species across the United States, collaborating with officials from approximately 290 national parks to protect natural and cultural resources. The Biological Resources Division of the National Park Service currently supports 15 local IPMTs in preventing the arrival and managing the presence of invasive plant species on the ground, with another two funded by specific park bases. The teams use a variety of species management tactics, including monitoring and inventory, prevention, Early Detection Rapid Response (EDRR), treatment and control, and restoration of native plant communities. Prevention, which includes educating staff and citizens as well as developing species watch lists, is the primary strategy to keep invasive plants out of parks. When prevention fails, the secondary strategy is EDRR—when teams are able to identify a species with the potential to spread extensively and damage ecosystem health, but that has not yet established its presence in the habitat, they are able to target management and control of these populations. Along with extensive field efforts, the NPS has a GIS program that adds to decision making and enhances the understanding of issues within the parks. The GIS team at the NPS aids research, analysis, and operational planning at all levels of the system.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | NDMI | The team acquired NDMI median and standard deviation layers for the US study area from 1985-2020, derived from a time series analysis of data from this sensor using LandTrendr (LT) in Google Earth Engine (GEE). |
| **Landsat 7 ETM+** | NDMI | The team acquired NDMI median and standard deviation layers for the US study area from 1985-2020, derived from a time series analysis of data from this sensor using LT in GEE. |
| **Landsat 8 OLI** | NDMI | The team acquired NDMI median and standard deviation layers for the US study area from 1985-2020, derived from a time series analysis of data from this sensor using LT in GEE. |
| **Terra MODIS** | NDMI  | This dataset was used in a time series analysis to create NDMI median and standard deviation layers at 1km resolution for the US study area from 2000-2020 using GEE. |
| **SRTM** | Topography Indices | The team used products from this satellite, including Continuous Heat-Insolation Load Index (CHILI), Multi-Scale Topographic Position Index (mTPI), and Topographic Diversity, to represent the impacts of topography on moisture and evapotranspiration. |

***Ancillary Datasets:***

* Global Biodiversity Information Facility (GBIF), Early Detection & Distribution Mapping System (EDDMapS), and National Invasive Species Information Management System (NISIMS) species occurrence data – Develop suitable habitat models of invasive species
* PRISM Climate Data Bioclimatic Variables – US-specific bioclimatic variables for creation of suitable habitat models of invasive species
* CHELSA Climate Data Bioclimatic Variables Version 2.1 – Global bioclimatic variables for creation of suitable habitat models of invasive species
* NPS IPMT regions shapefile – Delineate study area

***Modeling:***

* Software for Assisted Habitat Modeling (POC: Peder Engelstad, Colorado State University) – Streamline risk model development and easily compare multiple methods and variations
* Maximum Entropy (POC: Nicholas Young, Colorado State University) – Model used to map presence of invasives, as well as areas suitable for future growth

***Software & Scripting:***

* R 4.1.1– Statistical analyses, raster processing, and random forest modeling
* Google Earth Engine JavaScript API – Large-scale image analysis
* Amazon Corretto Open Java Development Kit 11.0.13.8.1 – Java processing in SAHM
* Esri ArcGIS Pro 2.8.2 - Image processing and end product generation
* VisTrails SAHM 2.2.1 - Model workflow

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Invasive Species Habitat Suitability Maps** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Terra MODIS, SRTM | These maps provide the partners with habitat suitability trends at both spatial resolutions in addition to areas with low extrapolation confidence | N/A |
| **Report on Variable Usefulness** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Terra MODIS, SRTM | The report on the methods and outcomes will support the future modeling of invasive species by elucidating what environmental variables are better suited for different invasive species. | N/A |

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

These end products will provide the partners with methods for evaluating the importance of specific predictor variables in identifying suitable habitat for invasive plant species at multiple spatial scales. Similarly, the partners can use the results of this project to better interpret differences in model outcomes based on the resolution of environmental data and distribution of species occurrence points. These products can be used to expand upon and inform species distribution modeling techniques, as well as aid in selection of influential predictor variables for modeling at regional versus global spatial scales. This will be especially pertinent to future habitat suitability modeling of newly arrived invasive species like wavyleaf basketgrass, as our results demonstrate both the benefits and the constraints of extrapolating to new ranges that may be environmentally dissimilar from the native range.

**References**

Drake, Sara J.; Weltzin, Jake F.; Parr, Patricia D. (2003). Assessment of non-native invasive plant species on the United States Department of Energy Oak Ridge National Environmental Research Park.

Fryer, J. L. (2011). *Fire Effects Information System*. Microstegium Vimineum. <https://www.fs.fed.us/database/feis/plants/graminoid/micvim/all.html>

*Japanese stiltgrass*. (2018). Invasive Plant Atlas of the United States.

<https://www.invasiveplantatlas.org/subject.html?sub=3051>

Karger, D.N., et al. (2017). Climatologies at high resolution for the Earth land surface areas. Scientific Data. 4 170122. https://doi.org/10.1038/sdata.2017.122

Karger D.N., et al. Data from: Climatologies at high resolution for the earth’s land surface areas. Dryad Digital Repository. http://dx.doi.org/doi:10.5061/dryad.kd1d4

Kurtz, C. M., & Hansen, M. H. (2017). *An assessment of Japanese stiltgrass in northern US forests*. Res. Note NRS-247. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station. 5 p., 247, 1-5. DOI: 10.2737/NRS-RN-247

National Park Service, Biological Resources Division. (2020). *IPMT Annual Report: FY 2020*.

<https://irma.nps.gov/DataStore/DownloadFile/662804>

U.S. Department of the Interior. (2019). *Northeast*. National Parks Service. <https://www.nps.gov/subjects/invasive/ne.htm>.