**Nevada & Oregon Ecological Forecasting**

*Employing NASA Earth Observations to Create Enhanced Bare Ground Layers for Invasive Species Habitat Suitability Modeling*

**VPS Title:** Space Invaders: Spatial Detection of Invasive Species

**Project Team**

***Project Team:***

Nicole Pepper (Project Lead)

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***Advisors & Mentors:***

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Terri Hogan (National Parks Service, Exotic Plant Management Team)

**Project Overview**

***Project Synopsis:*** The spread of invasive plant species are putting native plants at risk, impacting local economies, and, in some cases, affecting human health. For this project, our team partnered with the United States Geological Survey (USGS) and the National Park Service (NPS) Exotic Plant Management Team to assist in combating this ecological challenge. We derived bare ground indices using Earth observations to determine the layer most fit to incorporate into the habitat suitability models currently employed by the USGS and NPS. With enhanced models and more detailed maps, the USGS and NPS can direct more targeted management strategies for invasive species.

***Abstract:***

Invasive species threaten the ecological integrity of a region. Such threats have further implications that can affect regional economies and, in some cases, human health. Organizations including the National Parks Service (NPS) and the United States Geological Survey (USGS) are dedicated to the early detection of and rapid response to invasive species of high concern, like medusahead (*Taeniatherum caput-medusae*). To improve these efforts, our team partnered with researchers from the NPS Exotic Plant Management Team and the USGS Fort Collins Science Center. Our partners currently rely on habitat suitability models to discern the geographic range of invasive species. They identified regions with low vegetation and exposed bare ground to be at higher risk of invasion. However, the USGS and NPS are not using the most detailed resolution available for this bare ground variable. Research shows that the incorporation of high-resolution spectral information can improve the precision of habitat suitability models. To test this, our team focused on enhancing our partner’s bare ground data (250-meter resolution) by utilizing Earth observations from NASA’s Landsat 8 Operational Land Imager (30-meter resolution) and the European Space Agency’s Sentinel-1 C-Band Synthetic Aperture Radar (10-meter resolution). We found that overall model performance was not significantly altered by the incorporation of higher resolution soil variables, however, these soil layers did allow for higher resolution spatial outputs. With more precise habitat suitability models, our partners’ management practices can be more time efficient and cost effective, thus allowing them to scale up the methodology geographically and expand it to other invasive species.

**Keywords:**

habitat suitability models, invasive species, risk assessment, ecological forecasting, ensemble modeling

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

***Study Location:*** NV; OR

***Study Period:*** May 2000 to May 2018; Forecasting to 2050

***Community Concerns:***

* Invasive species threaten the ecological integrity of a region. Such threats have further implications, including the destruction of valuable ecosystems and damage to infrastructure, which can affect regional economies and impact human health.
* Organizations like the USGS and NPS are working to prevent the introduction of new invasive species, reduce existing infestations, and restore native plant communities and ecosystem functions. To mitigate associated impacts, there is a need to accurately understand the patterns of habitat distribution over space and time.
* Our partners identified regions with low vegetation and exposed bare ground to be particularly at risk of invasion. However, their approach to invasive species risk management is currently limited by the low-resolution ground cover data included in their models.

***Project Objectives:***

* Derive and compile a collection of high resolution bare ground layers from NASA and European Space Agency Earth observations
* Model habitat suitability by integrating various bare ground layers and evaluate model performance in the Software for Assisted Habitat Modeling (SAHM)
* Create a habitat suitability map for medusahead (*Taeniatherum caput-medusae*) based on updated bare ground data
* Forecast the habitat suitability of medusahead (*Taeniatherum caput-medusae*) for the year 2050 by incorporating NASA climate predictions

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Biological Resource Division, Landscape Restoration and Adaptive Branch, North Rocky Mountain Exotic Plant Management Team** | Terri Hogan, NPS Invasive Plant Program Manager | End User | Yes |
| **United States Geological Survey, Fort Collins Science Center** | Dr. Catherine Jarnevich, USGS Research Ecologist | End User | No |

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

Under Executive Order 13112, invasive species are designated as a significant contributor to ecosystem change. For this reason, all federal land management agencies must address issues related to the introduction and spread of harmful invasive species. Currently, the USGS and NPS employ habitat suitability models to predict the range of invasive species. The current models are derived from climatic and remotely sensed spectral variables. However, many of these variables have low spatial resolutions that vary between 800 and 1000 meters, making it difficult to develop detailed mitigation strategies to target invasive species. Though these coarse maps can help direct general mitigation efforts, the resources allocated for in-field searches of specific species are still costly.

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

The project will support the NPS Exotic Plant Management Team and the USGS Fort Collins Science Center by exploring approaches to develop regional-scale, 30-meter and 10-meter resolution remotely sensed layers that can be used to enhance existing habitat suitability maps. Improved habitat suitability models will provide our partners with a better understanding of areas that are most at risk and lead to more direct, targeted strategies for mitigation and prevention efforts. As a result, these tools will lead to more cost and time efficient invasive species management practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platforms & Sensors** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance, Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index, tasseled cap brightness, greenness, and wetness | This dataset provided the temporal (16 days) and spatial (30 m2) resolution needed for environmental predictive variables employed via a species distribution modeling approach investigating invasive species presence. |
| **Aqua MODIS** | NDVI, Enhanced Vegetation Index (EVI), land cover | Aqua MODIS-derived environmental predictive variables were employed via a species distribution modeling approach investigating invasive species presence. |
| **Sentinel-1 C-SAR** | Synthetic aperture radar  backscatter values and surface roughness | This dataset provided high temporal resolution (6 days) and spatial resolution (10 m2) imagery used to derive a bare ground layer through backscatter and surface roughness. |

***Ancillary Datasets:***

* NPS and USGS aggregated occurrence presence dataset – Generate habitat suitability models
* North American Land Data Assimilation System 2 (NLDAS-2) Mosaic – Environmental predictor variables data, including precipitation, soils, and surface water data
* USGS National Elevation Dataset (NED) – Digital elevation model
* USGS National Land Cover Database (NLCD) – Environmental predictor variables data

***Modeling:***

* Random forest (RF) classification model (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate habitat suitability models
* Boosted regression trees (BRT) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate habitat suitability models
* Multivariate adaptive regression splines (MARS) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate habitat suitability models
* Generalized linear model (GLM) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate habitat suitability models

***Software & Scripting:***

* Esri ArcMap – Image processing and end product generation
* R – Statistical analyses and raster processing
* Google Earth Engine API – Large scale image analysis
* Software for Assisted Habitat Modeling (SAHM) – Habitat suitability mapping

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Bare Ground Layer Comparison** | Landsat 8 OLI  Sentinel-1 C-SAR  Aqua MODIS | These derived environmental layers will be employed in habitat suitability models as training data for predictive risk mapping of focal species. These maps can be used by the NPS Exotic Plant Management Team to carry out mitigation strategies to prevent further spread of invasive species. | II |
| **2018 Medusahead Habitat Suitability Map** | Landsat 8 OLI  Sentinel-1 C-SAR  Aqua MODIS | This map showed the current habitat suitability of medusahead over our study area. This can be used by our partners to better understand which areas are most at risk of invasion by medusahead. | II |
| **2050 Medusahead Forecasted Habitat Suitability Map** | Landsat 8 OLI  Sentinel-1 C-SAR  Aqua MODIS | This map showed the forecasted habitat suitability of medusahead over our study area in the year 2050. It can be used as a tool to help our partners take action on preventative measures for regions that are most at risk of invasion by medusahead based on variations in climate. | II |
| **Calculating Bare Ground Indices and Exporting Images Over a Large Spatial Extent in Google Earth Engine Tutorial** | Landsat 8 OLI  Sentinel-1 C-SAR | This tutorial will demonstrate to our partners how to calculate bare ground indices derived from Landsat 8 (OLI) and Sentinel-1 C-SAR in Google Earth Engine. It also guides users on the process of downloading images over a large spatial extent in Google Earth Engine. | I |

**Project Handoff Package**

*Transition Plan:* The team hosted a seminar on April 5th to disseminate project results and decision support tools to Dr. Catherine Jarnevich of the USGS Fort Collins Science Center and Terri Hogan of the NPS Exotic Plant Management Team. A short training workshop on the use of the methods, data, and tutorial followed the seminar with our partners at the USGS and NPS. Our handoff package was sent to our partners through an email attachment.

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**Handoff Package:**

* Bare Ground Layer Comparison
* 2018 Medusahead Habitat Suitability Map
* 2050 Medusahead Forecasted Habitat Suitability Map
* Calculating Bare Ground Indices and Exporting Images Over a Large Spatial Extent in Google Earth Engine Tutorial
* Technical Paper
* Project Video
* Presentation

**References:**

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