**Wisconsin Agriculture & Food Security**

*Employing NASA Earth Observations to Model Distributions of Wild Crop Relatives, in Support of USDA ARS Genetic Resource Conservation Efforts*

**VPS Title:** Berry Suitable: A Remote Sensing Suitability Analysis of Habitat Distribution for *Vaccinium L.* Populations

**Project Team**

***Project Team*:**

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***Advisors & Mentors*:**

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***Other Contributors*:**

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**Project Overview**

***Project Synopsis*:** The United States Department of Agriculture’s Agricultural Research Service (USDA ARS) National Plant Germplasm System (NPGS) is interested in conservation approaches to ensure that important agro-genetic resources, such as crop wild relatives (CWR), are safeguarded in both gene banks and natural habitats. Currently, the ARS relies primarily on species distribution modeling (SDM) to predict suitable habitats for CWRs. Our research aims to improve the efficiency and accuracy of SDM by introducing a spectral detection component to crop identification via NASA Earth observations. This case study will provide partners at the USDA ARS with novel insights regarding the feasibility of integrating this spectral detection component for two co-occurring species of *Vaccinium L.* within the state of Wisconsin.

***Abstract*:**

Crop wild relatives (CWR) are genetically related to cultivated crops and function as repositories for genetic diversity. These plants have the potential to improve the yield, nutritional value, and resilience of crops, thereby buffering against widespread crop failure and supporting rural economic productivity. As such, our partners at the United States Department of Agriculture’s Agricultural Research Service (USDA ARS) National Plant Germplasm System (NPGS) are tasked with preserving CWRs. This project focused on two species of the *Vaccinium L.* genus: *Vaccinium oxycoccos* (small cranberry) and *Vaccinium macrocarpon* (large cranberry).The species in this genus are critical to preserving both *in situ* and *ex situ,* given their relatively low genetic diversity and scarcity in seed banks*.* Currently, the NPGS relies primarily on species distribution modeling approaches, such as Maximum Entropy (MaxEnt), to predict suitable habitats for CWRs. In order to refine these modeling approaches, the NASA DEVELOP team incorporated Sentinel-1 Synthetic Aperture Radar (SAR), Shuttle Radar Topography Mission (SRTM), and Landsat 8 Operational Land Imager (OLI) data into NPGS’s existing predictive strategies. The team provided a comprehensive tutorial outlining the methodology so that stakeholders can implement these processes in future conservation efforts.

**Keywords:**

*Vaccinium L.*, crop wild relative, species distribution modeling, detection, Landsat, Sentinel, Maximum Entropy, random forest

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

***Study Location:*** WI

***Study Period:*** 2017

***Community Concern:***

* Habitat loss is the largest threat to global plant distribution and biodiversity. It is estimated that 1 in every 5 plant species across the world is at risk of extinction, not only as a response to massive habitat degradation but also as a result of other environmental threats, including the introduction of invasive species.
* CWRs comprise a significant portion of native plant species threatened with extinction across the United States. These plants retain genetic traits that have the potential to increase crop resilience, improve nutritional quality, and improve crop yields. As such, CWRs are essential elements of food security and rural economic productivity on both a national and global scale.
* The NPGS is tasked with collecting, preserving, and making available maintaining an array of these CWR species for research. Conservation methods for CWRs can be supported and improved upon via species distributions models that include the incorporation of Earth observation spectral data.
* It is of particular interest to improve efforts to conserve *Vaccinium L*. species due to their low genetic diversity and scarce representation in gene banks.

***Project Objectives:***

* Utilize NASA Earth observations to *Vaccinium L.* populations
* Employ MaxEnt and random forest distribution models and compare the efficacy of each
* Analyze the feasibility and success of detection methods in conjunction with predictive models in the context of NPGS conservation goals

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, Agricultural Research Service, National Plant Germplasm System** | Dr. Colin Khoury, Research Associate; Dr. Stephanie Greene, Supervisory Plant Physiologist | End User | No |
| **USDA, Agricultural Research Service, National Clonal Germplasm Repository** | Dr. Kim Hummer, Supervisory Research Horticulturist; Karen Williams, Botanist | Collaborator | Yes |
| **USDA Forest Service, Chequamegon-Nicolet National Forest** | Linda Parker, Forest Ecologist | Collaborator | No |
| **University of Wisconsin-Madison** | Lorraine Rodriguez-Bonilla, PhD Candidate | Collaborator | No |

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

The NPGS currently employs MaxEnt modeling in R to create species distribution predictions. These models are the key informants of conservation strategies for the preservation of CWRs. However, the inherent error of these models is that they only allow for a rough prediction that exclusively considers the ecogeographic profile of the species niche, as opposed to also considering spectral variables. This methodology is less accurate for guiding collection and conservation on the ground. Preservation of CWRs complies with Executive Order (E.O.) 13603, National Defense Resources Preparedness. Section 201 of E.O. 13603 (1) falls within the jurisdiction of the USDA to manage or oversee food resources, food resources facilities, and plant health resources (USDA Forest Service, 2014).

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

Incorporating NASA Earth observations into the current NPGS methodology has the potential to improve model accuracy and efficiency. The inherent error of predictive modeling provides only general habitat locality to inform conservation practices; remotely sensed information can be used to detect areas where CWR species overlap and identify locations of rare or endangered CWRs. This can result in improved land management practices and better geographically informed policy.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance, normalized difference vegetation index, normalized difference moisture index, tasseled cap brightness, greenness, and wetness | This dataset provides the temporal (16 days) and spatial (30 m2) resolution needed for environmental predictive variables employed via a species distribution modeling and detection modeling approach investigating crop wild relatives presence. |
| **Sentinel-1 C-SAR** | Synthetic Aperture Radar  backscatter values, surface roughness | This dataset provides high temporal resolution (6 days) imagery used to refine the model of species distribution and detection modeling of crop wild relatives approach in tandem with spectral imagery. |
| **SRTM** | Elevation, slope, aspect,  compound topographic  index | This dataset was used to derive topographic indices to be used as predictors representative of important characteristics of crop wild relative presence. |

***Ancillary Datasets:***

Climate North America Version 5.10, 2000-2010 – Bioclimatic predictor variables used for species distribution models

Consortium of Midwest Herbaria Field Samples – Cranberry presence points used to generate preliminary species distribution models

Global Biodiversity Information Facility (GBIF) Occurrence Data for Crop Wild Relatives – Cranberry presence points used to generate preliminary species distribution models

USDA *Vaccinium L.* Presence Field Samples – Cranberry presence points used to generate preliminary species distribution models

University of Wisconsin-Madison *Vaccinium L.* Field Samples – Cranberry presence points used to generate preliminary species distribution models and to guide Google Earth Engine sample collection

USDA National Agriculture Imagery Program (NAIP) – High resolution (1 meter) aerial imagery used for sampling and image interpretation

USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) Wisconsin – Guide Google Earth Engine sample collection

USGS Biodiversity Information Serving Our Nation (BISON) occurrence data for crop wild relatives – Cranberry presence points used to generate preliminary species distribution models

USGS National Land Cover Database (NLCD) Wisconsin, 2011 – Guide and mask Google Earth Engine sample collection

Wisconsin Department of Natural Resources (DNR) Water Bodies and Land Cover – Guide Google Earth Engine sample collection and mask model outputs

WorldClim Version 1, 1960-1990 – Bioclimatic predictor variables used for species distribution models

***Modeling:***

Maximum Entropy (MaxEnt) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate species habitat distribution models

RandomForest Classification Model (RF) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Generate species habitat distribution and satellite detection models

***Software & Scripting:***

Software for Assisted Habitat Modeling (SAHM) – Suitability mapping

R – Statistical analyses, raster processing, prediction/detection modeling

Esri ArcGIS – Image processing and end product generation

Google Earth Engine API – Large-scale raster image processing and analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Wisconsin *Vaccinium L*. Distribution Maps**  **(Cranberry relatives)** | Landsat 8 OLI Sentinel-1 SAR  SRTM | Prediction and detection maps can be used to evaluate the distribution for *Vaccinium L*. in Wisconsin and guide future modeling and conservation efforts. | N/A |
| **RF and MaxEnt Model Comparison Analysis** | Landsat 8 OLI Sentinel-1 SAR  SRTM | Metrics can be used to determine the most accurate method for modeling *Vaccinium L*.presence. | N/A |
| ***Vaccinium L*. Detection Modeling Tutorial** | Landsat 8 OLI Sentinel-1 SAR  SRTM | The tutorial can be used to incorporate Earth observation data into current modeling practices. | N/A |

**Project Handoff Package**

**Transition Plan:**

Our team met in-person with our primary stakeholder, Dr. Colin Khoury, and virtually with our auxiliary stakeholders to exchange the handoff package and discuss future trajectories. The meeting detailed project results and reviewed the customized modeling tutorial. This tutorial contained step-by-step guides for project processes, such as using SAHM and GEE to run RF and MaxEnt models with ecogeographic and spectral variables. Project results can be used to inform both the NPGS’s future CWR conservation efforts, as well as DEVELOP’s continuation of wild crop assessments in partnership with the USDA.

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**Handoff Package:**

* Poster
* Presentation
* Video
* Technical Paper
* Wisconsin *Vaccinium L.* Distribution Maps
* RF and MaxEntModel Comparison Analysis
* *Vaccinium L*.Distribution Modeling and Mapping Tutorial

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