INVASIVE SPECIES FORECASTING

Analysis of Regional Climate Change Predictions and the Potential Implications for the Sustainability of Forest Resources at Goddard Space Flight Center

Abstract:

In response to an Executive Order issued by the President, NASA has formed the Climate Adaptation Science Investigator Working Group. The purpose of this group is to assess the effect that future climate variability and change will have on each NASA center. The DEVELOP team partnered with the Goddard CASI principle investigator, to assist with climate research.

A large portion of Goddard Space Flight Center is forested. These forests provide critical ecosystem services to the Center. Global and regional climate variability and change may threaten the long term sustainability of these valuable forests resources. In response to increasing temperatures, Goddard forests will likely experience a shift in species distribution, with increases in invasive plants, animals, insects, and diseases. In order for environmental managers at the center to effectively mitigate potential invasions, it is critical that they have an understanding of the invasive species that may onto their lands in response to future climate variability and change.

One method of assessing the risk of invasive species is to perform predictive habitat suitability modeling The team compiled in-situ species presence points, remotely sensed environmental data layers, and present day temperature and precipitation data. Using the Maximum Entropy habitat suitability model, 3 climate change scenarios were run producing map time series showing the influence of climate change on invasive species ranges. This method may prove useful in determine the threat of invasive species to the areas surrounding the Center. Enabling environmental managers to anticipate and mitigate possible future invasions.

Transcript

Slide 1: Welcome

Hi, my name is Rachel Moore, and I am pleased to be representing the DEVELOP Climate Adaptation Science Investigator Team from Goddard Spaceflight Center. I am speaking with you today on behalf of my team members, Christine Suss and Ammar Zaidi.

Slide 2: The Climate Adaptation Science Investigator (CASI) Working Group

I would like to take a moment to acknowledge the NASA science advisors who assisted us throughout the research process, Dr. Molly Brown, Dr. Lahouri Bouonoua, and Dr. John Schnase. I would also like to thank the NASA Center for Climate Simulation, which provided the team with valuable resources throughout the completion of this project.

On October 5, 2009, the President issued an Executive order titled, “Federal Leadership in Environmental, Energy, and Economic Performance.” This order mandates that, “all agencies evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency’s operations and mission in both the short and long term.”

In response to this order, NASA has formed the Climate Adaptation Science Investigator (CASI) working group, led by Dr. Cynthia Rosenzweig of the NASA Goddard Institute for Space Studies (GISS). The goal of this group is to increase the collaboration of NASA Earth science researchers, to investigate the risks that climate change may pose for each NASA center, and to develop center-specific adaptation strategies to prepare for these risks. (Goodman, 2009)

The DEVELOP team was invited by the Goddard CASI Principle Investigator, Dr. Molly Brown, to assist in her research.

Slide 3: Goddard Space Flight Center

As you can see from this image, a large portion of Goddard Space Flight Center is forested. These forests provide critical ecosystem services to the center. Global and regional climate variability and change may threaten the long term sustainability of these valuable forests resources. In response to climate change, Goddard forests will likely experience a shift in species distribution, with increases in invasive plants, animals, insects, and diseases.

Slide 4: Community Concern: Invasive Species

Invasive species are “non-native to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm.” Invasive species out-compete native species, decreasing biodiversity throughout effected ecosystems. They are estimated to have an economic impact of $100 to $200 billion dollars per year in the United States. Early detection and eradication of these species by environmental managers is necessary to mitigate their detrimental effects.

Invasive species habitat suitability is largely influenced by the climate of a given region. It is therefore important that environmental managers have an understanding of predicted climate change, and the effects that these changes could have on the distribution of invasive species across their lands. The ability to anticipate the invasion of detrimental species would allow for effective monitoring, early detection, and eradication.

Slide 5: Project Objective and Goals

The objective of this project was to use the Maximum Entropy (MaxEnt) habitat suitability model to map the potential shift in invasive species ranges in response to climate change

To complete this objective, the team set 4 goals: 1) Identify an invasive species of concern in the state of Maryland, and acquire insitu presence data. *2)* Identify remote sensing data layers that can provide environmental information to the model. *3)* Identify temperature and precipitation data that can be used to create a map time series of climate change predictions for 2010 – 2100 *4)* Determine the response of the Maximum Entropy model to the inclusion of time dependent climate data.

Slide 6: Study Area and Species

The study area for this project was the state of Maryland. The species of interest analyzed was the Wavyleaf basketgrass. This species was first detected in Maryland in 1996. The image on this page shows the aggressive spread of this species at the initial site. If steps are not taken to eradicate this species, it could destroy up to 10% of forests along the Atlantic coast in the next 100 years. The effect of climate change on the habitat suitability of Wavyleaf basketgrass in Maryland was modeled for the time period between 2010 to 2100.

Slide 7: Methodology: Data Acquisition

In-situ species presence data was provided by the Maryland Department of Natural Resources. North American Regional Reanalysis climate data was provided by the University of Maryland Earth System Science Interdisciplinary Center. Environmental data layers were acquired from several NASA sensors, including MODIS Terra and Aqua, Landsat, and SRTM

Slide 8: Methodology: Creation of Climate Raster Datasets

Temperature and precipitation data for 2009 was gathered from the North American Regional Reanalysis (NARR) dataset. This point data was imported into ESRI's ArcMap GIS software. Temperature and precipitation data points were plotted based on latitude and longitude. The resulting map can be seen on the left side of this slide. The point layers were then interpolated using the Krige Spatial Analyst tool, to create raster datasets for the study area. The resulting 2009 temperature and precipitation raster layers are shown on the right of this slide.

Slide 9: Methodology: Creation of Climate Map Time Series

To determine the expected change in temperature and precipitation associated with climate variability and change, the team referred to the predictions of the Intergovernmental Panel on Climate Change (IPCC). The A1B scenario of the IPCC Fourth Assessment Report was analyzed. Predicated temperature and precipitation change curves, were interpreted, to estimate the linear change in temperature and precipitation per year, from 2009 to 2100. The IPCC change curves used, and the linear change curves derived by the team, are shown on this slide.

Temperature was predicted to change 0.027 C per year, resulting in a 2.4 C increase over the 90 year period. Precipitation as predicted to change 0.04 % per year, resulting in a 3.6 % change over the 90 year period. The calculated change for each climate variable was then applied to the corresponding raster data set. This process resulted in temperature and precipitation map time series, providing predicted climate raster data for 2010, 2020, 2030, 2040, 2050, and 2100. The temperature time series produced is shown on the bottom of this slide.

Slide 10: Methodology: The Maximum Entropy Model

Once all of the environmental and climate data layers were prepared, they were processed using a Python command line procedure, and loaded into the Maximum Entropy habitat suitability model. The team chose to test three different climate modeling scenarios. For each scenario, all environmental data layers were included, plus the climate variable of interest: temperature, precipitation, or temperature and precipitation, respectively.

The images on this slide show the influence of the temperature and precipitation variables on the predicted habitat suitability of the species during present conditions. The image in the upper left-hand corner of the slide is the control image, showing the predicted habitat suitability without the influence of temperature or precipitation. The other three images show the predicted habitat suitability with the indicated climate variable added to the modeling conditions.

Predicted habitat suitability is classified using a continuous color gradient, from blue to red, with blue indicating low probability and red indicating high probability. You can see that each combination of climate variables exhibit different influence on the predicted habitat suitability.

Slide 11: Results & Analysis

For each of the three climate scenarios, 6 model runs were completed. In each successive run, the climate layer for the next decade was used in the modeling conditions. Through this process, 3 map time series were produced, showing the predicted habitat suitability under the influence of temperature, precipitation, or temperature and precipitation respectively. Predicted habitat suitability is classified using a continuous color gradient, from blue to red, with blue indicating low probability and red indicating high probability. Also show on this page is a table indicating the top contributing predictor layers for each scenario.

It is clear the climate scenario used has a strong impact on the model predictions. For the temperature scenario and the temperature/precipitation scenario, it appears that the study area becomes unsuitable for the growth of Wavyleaf basketgrass. Conversely, it appears that under the precipitation scenario, the percentage of the study area suitable for Wavyleaf basketgrass increases, but only in a tight band across the study area.

There are several statements that can be made regarding the Maximum Entropy model results. First, the model did respond to the time dependant climate data. Second, these map time series seem to suggest that climate variability and change will NOT result in widespread Wavyleaf invasion. In fact, they suggest that Wavyleaf basketgrass presence may decrease by 2100.

These results should be interpreted carefully. On the bottom left side of the slide, there is map showing the in situ presence points used to train the model. These points are clustered in one section of the study area, which may skew model results. It is suggested that additional ground surveys be performed, to provide a more even distribution of samples across the study area. Also, while it appears that habitat in Maryland is not suitable for Wavyleaf basketgrass by 2100, this does not mean the species will cease to exist. It is suggested that the study area by broadened, so that possible shifts of the species into other states can be analyzed.

Slide 12: Conclusions

- The application of the IPCC change curves to the NARR climate raster data successfully produced climate map time series of temperature and precipitation from 2010-2100.
- The Maximum Entropy model responded to the influence of the climate raster data sets and has the potential for use in the of invasive species range shifts in response to future climate change prediction.

- The relationship between temperature, precipitation, and species range shifts will be dependent on the species of interest. These ecological relationships must be understood prior to any habitat suitability modeling effort.

- Higher resolution data is necessary to model the habitat suitability of GSFC, but coarser resolution data can be used to determine the threat of invasive species to the areas surrounding the Center. This information can help environmental managers anticipate and mitigate possible future invasions.

Slide 13: Thank You

On behalf of the whole team here at DEVELOP, I would like to thank you for taking the time to learn how NASA is using its data and technology to map the spread of invasive species. Have a great day.