

Approaches to predicting current and future distributions of *Puccinia psidii* in South America under climate change scenarios

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Background

Puccinia psidii is the cause of Eucalyptus/guava/myrtle rust disease of many host species in the Myrtaceae family, including guava (*Psidium* spp.), eucalypt (*Eucalyptus* spp.), rose apple (*Syzygium jambos*), and ohia (*Metrosideros polymorpha*) (Farr and Rossman 2010). First reported in 1884 on guava in Brazil (Maclachlan 1938), the rust has since been detected in other South American countries (Argentina, Colombia, Paraguay, Uruguay and Venezuela), Central America (Costa Rica and Panama), Mexico, the Caribbean (Cuba, Dominica, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Virgin Islands), USA (Florida, California, and Hawaii), and most recently Japan and Australia (Graça et al. 2010). Of present concern is the recent introduction of the rust pathogen to Hawaii, where it infects an endemic tree species known as ohia, the dominant tree species in Hawaii's remnant native forests. The introduction of additional rust strains could further threaten forests in Hawaii (Loope and La Rosa 2008). *Eucalyptus* rust poses serious threats to several hosts in the Myrtaceae including *Eucalyptus*, a genus native to Australia, which is planted extensively in numerous tropical and subtropical countries (Graça et al. 2010). Despite the potential threats to numerous forest ecosystems worldwide and the expanding geographic range of this disease, little is known about the potential distribution of this pathogen under changing climates.

Bioclimatic modeling methods to predict present and future suitable climate spaces for many tree species have already been developed (Rehfeldt et al. 2006). Similar approaches can be used to predict areas where the pathogen is climatically well-adapted for comparison with areas of host (Myrtaceae) adaptation and mal-adaptation. The objective of this study is to predict current and future distributions of *P. psidii* under climate-change scenarios using bioclimatic modeling. The infor-

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mation generated from this study will be used to evaluate pathways of pathogen spread and conduct risk analysis.

Methods

We used a maximum entropy approach with 169 geo-referenced isolates of *P. psidii* from Brazil, Uruguay, and Paraguay. MaxEnt (Maximum Entropy Species Distribution Modeling) version 3.3.3e (Phillips et al. 2004) was used to predict the current distribution of *P. psidii* using high-resolution climate surfaces of 19 bioclimatic variables (i.e., annual mean temperature, annual precipitation, precipitation coldest quarter, etc.). These data were obtained from WorldClim (worldclim.org) and are based on interpolations of observed data from 1950-2000 (Hijmans et al. 2005). The current prediction model was then projected onto statistically downscaled (delta method) future climate surfaces for the 2050s (years 2040-2069) using the A1B SRES (Special Report on Emission Scenarios) scenario and CCCMA-CGCM 3.1 (Canadian Centre for Climate Modeling and Analysis – third generation coupled global climate model) global climate model (Ramirez and Jarvis 2010).

Results and Discussion

Results from these preliminary models for the year 2050 suggest decreasing suitability of *P. psidii* along the central Brazilian coast and stable to increasing suitability for southern Brazil, and Paraguay (Figs. 1 and 2). Recent analyses on the genetic diversity of *P. psidii* suggest several genetically distinct groups/races of this rust (Graça et al. 2010). This approach can be used to model each of these races to see if they favor disparate environmental conditions. Additional points from areas with known populations of rust (i.e., United States, Caribbean, Mexico, Costa Rica, and Colombia) can also be included to predict worldwide *P. psidii* distribution.

Predictions of the present and future distribution of *P. psidii* can help guide forest managers to implement appropriate forest practices to manage Eucalyptus rust according to current and future climates. This study is of great relevance to about one-half of the forested land area of the tropics and sub-tropics, where the 4,500 species of Myrtaceae grow naturally and/or are actively cultivated. This area includes all countries that have significant investments in Eucalyptus forestry. Thus, information from this study can help identify areas at risk for *P. psidii* establishment, based on climatic envelopes. This information can be used to help prevent introductions of *P. psidii* to global populations of Myrtaceae within regions that are at risk for *P. psidii* establishment.



Figure 1. Predicted current (based on years 1950-2000) suitable climate space for *Puccinia psidii* in South America based on 169 occurrences. The dark-gray shade represents areas with suitable climate for *P. psidii*, and darker gray to black shades represent areas with increased climate suitability. This model prediction used MaxEnt and 19 bioclimatic surfaces from worldclim.org.



Figure 2. Model projection of suitable climate space for *Puccinia psidii* for the 2050s (based on years 2040-2069). The dark-gray shade represents areas with suitable climate for *P. psidii*, and darker gray to black shades represent areas with increased climate suitability. This model prediction used MaxEnt and 19 bioclimatic surfaces from worldclim.org. This prediction is based on the CCCMA-CGCM 3.1 global circulation model and the A1B SRES scenario.

References

- Farr et al. 2010. Fungal Databases, Systematic Mycology and Microbiology Laboratory. Retrieved May 4, 2010, from <http://nt.ars-grin.gov/fungaldatabases/>
- Graça et al. 2010. Proceedings of the 58th Annual Western International forest Disease Work Conference pp 131-134.
- Hijmans et al. 2005. *Journal of Climatology* 25:1965-1978.
- Loope and La Rosa. 2008. Geological Survey Open File Report 2008-1008.
- MacLachlan. 1938. *Phytopathology* 28:157-170.
- Phillips. 2006. *Ecological Modelling* 190: 231-259
- Ramirez. 2010. Decision and Policy Analysis Working Paper No.1 Centro Internacional de Agricultura Tropical International Center for Tropical Agriculture. Cali, Colombia. <http://ccaafs-climate.org/docs/Downscaling-WP-01.pdf>
- Rehfeldt. 2006. *International Journal of Plant Sciences* 167:1123-1150.