Regional predictions of potato late blight risk in a GIS incorporating disease resistance profiles, climate change, and risk neighborhoods

A. Sparks[1], R. Raymundo[2], R. Simon[2], G. Forbes[2], K. Garrett[1]

[1]Department of Plant Pathology, Kansas State University, 4024 Throckmorton Hall, Manhattan, KS 66506;

[2]International Potato Center (CIP), Apartado 1558, Lima 12, PERU

Introduction

Potato is an increasingly important staple food crop world-wide for developing countries. Losses to late blight of potato (*Solanum tuberosum*), caused by *Phytophthora infestans* (Mont.) de Bary, can be a major constraint on production. Resistant cultivars can effectively be used to decrease the number of fungicide applications made.

Prioritizing efforts to manage late blight and measuring their impact now and under future climate scenarios demands a national and global perspective. We used a model in a Geographic Information System (GIS) to create late blight severity predictions under current and future climate conditions (Hijmans et al., 2000).

Methods 1: Modification of SimCast

The SimCast model calculates blight units, a measure of late blight disease severity, using hourly weather variables temperature and relative humidity (Fry et al., 1983; Grünwald et al., 2002). We used the blight unit decision table from Grünwald et al. (2002) in a program in R (R Development Core Team, 2008). The program was applied to hourly weather data from the US (Figure 1). Temperature and relative humidity were used to calculate blight units. The hourly output was then summed to produce daily output and then an average blight unit per day for all twelve months was calculated.

We performed this analysis for two categories, susceptible and resistant (moderately resistant, resistant, highly resistant) cultivars (Grünwald et al., 2002).

Methods 3: MonthlyBliteForecastR v. 0.1

The model. A general additive model (GAM) was developed using the first three years of US weather station data and fit against the last three years (Figures 2-7) for validation. Currently the model underpredicts blight unit accumulation for both susceptible and resistant varieties. We are currently evaluating which types of weather patterns result in these underestimates to improve the model.

GAM modeling applied to all six years was used to construct MonthlyBliteForecastR for application to current and 2020 global climate surfaces. The WorldClim climate surface grid files were read into R and MonthlyBliteForecastR v. 0.1 was applied. Grid files of blight units were produced for use in ArcGIS to create maps (Figures 8-11).

We are also evaluating the potential for derived monthly models based on SimCast rules.

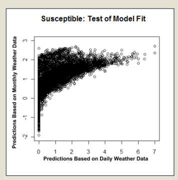

Figure 2: Predicted blight units based on daily weather data vs. monthly weather data for susceptible variety.

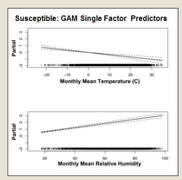

Figure 3: GAM single factor predictors with standard errors and occurrence of observations for susceptible variety.

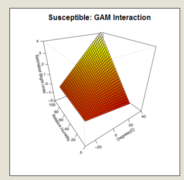

Figure 4: GAM interaction for susceptible variety.

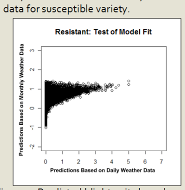

Figure 5: Predicted blight units based on daily weather data vs. monthly weather data for resistant variety.

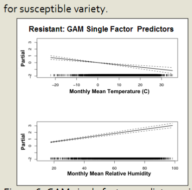

Figure 6: GAM single factor predictors with standard errors and occurrence of observations for resistant variety.

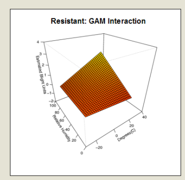

Figure 7: GAM interaction for resistant variety.

Predictions

Global maps of predicted blight units indicate regions where change in severity is likely to occur under future climate scenarios. Here we present current and 2020 results for resistant and susceptible varieties in Peru. Late blight will be a new problem in some high-elevation areas.

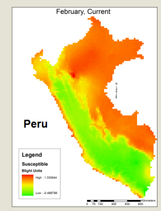

Figure 8: Late blight susceptible variety, average daily blight unit accumulation for February under current climate conditions.

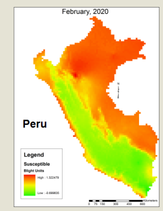

Figure 9: Late blight susceptible variety, average daily blight unit accumulation for February under future, 2020, climate conditions.

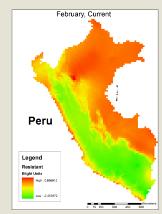

Figure 10: Late blight resistant variety, average daily blight unit accumulation for February under current climate conditions.

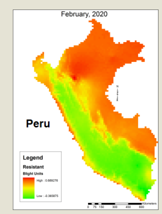

Figure 11: Late blight resistant variety, average daily blight unit accumulation for February under future, 2020, climate conditions.

Methods 2: Datasets

Training Set Data. The training set was constructed using data from the US National Climatic Data Center (NCDC). 233 of the 262 stations in the Hourly United States Weather Observations 1990-1995 (HUSWO) were used (Figure 1). All stations were used except those not collecting hourly precipitation.

Climate Surface Data. WorldClim 10 arc-minute current climate surfaces (1950-2000), and CCCMA a2a for 2020 were downloaded from www.worldclim.org (Hijmans et al. 2005). These data are interpolated to account for elevation making them useful for modeling potato production in montane areas. Since the WorldClim data set does not include relative humidity, in the first stage of our modeling the minimum temperature was assumed to equal dew point and converted to relative humidity.

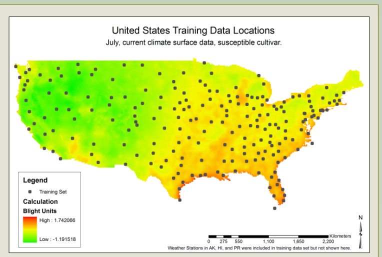

Figure 1: Training data locations and example model output for conterminous US.

Literature

Andrade-Piedra, J.L., Hijmans, R.J., Forbes, G.A., Fry, W.E., and Nelson, R.J. 2005. Simulation of potato late blight in the Andes. I: Modification and parameterization of the LATEBLIGHT model. *Phytopathology* 95:1191-1199.

Fry, W.E., Apple, A.E., and Bruhn, J.A. 1983. Evaluation of potato blight forecasts modified to incorporate host resistance and fungicide weathering. *Phytopathology*. 73:1054-1059.

Grünwald, N.J., Montes, G.R., Saldaña, Covarrubias, O.A.R., and Fry, W.E. 2002. Potato late blight management in the Toluca Valley: Field validation of SimCast modified for cultivars with high field resistance. *Plant Disease* 86:1163-1168.

Hijmans, R.J., Forbes, G.A., and Walker, T.S., 2000. Estimating the global severity of potato late blight with GIS-linked disease forecast models. *Plant Pathology*. 49:697-705.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965-1978.

Margosian, M.L., Garrett, K.A., Hutchinson, J.M.S., and With, K.A. In Revision. Connectivity of the American agricultural landscape: Evaluation national pest and disease risk. *BioScience*.

R Development Core Team (2005). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Neighborhood Risk Analysis

Margosian et al. (in revision) constructed a network analysis of the landscape connectivity of United States agriculture based on host availability.

We are developing a neighborhood risk analysis for potato late blight that incorporates host availability and neighborhoods of environmental conduciveness to disease.

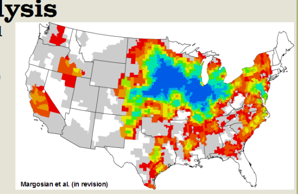

Figure 12: Connectivity of the US for diseases or pests of corn, where blue indicates highest connectivity and gray limited.

Conclusions and Future Work

This model allows evaluation of both the impact of late blight resistance and climate change for research prioritization and policy making. There are several ways in which we are working to improve the model. Using a range of climate change models for a number of future years will provide a more accurate depiction of how late blight severity might change. We also plan to estimate fungicide use as one measure of impact. We would also like to compare SimCast and LATEBLIGHT (Andrade-Piedra et al., 2005) model predictions. Most importantly we will use field data where available to validate predictions.