**NASA DEVELOP National Program**



NASA Langley Research Center

*Fall 2015*

Peru Climate

Monitoring and Forecasting Shifting Climate and Land Change Impacts in Peru’s Parque de la Papa for Enhanced Agricultural Management

 **Technical Report**

Rough Draft – October 8, 2015

Rebekke Muench (Project Lead)

Kayla McDonald

Ryan Murphy

Michael Sclater

Richard Rose

Dajon Begin

Dr. Kenton Ross, NASA DEVELOP National Program (Science Advisor)

Noel Baker, NASA Post Doc Program (Science Advisor)

# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Insert here 2-8 keywords that relate to your project

Example: Remote Sensing, Biomass Burning, Erosion, Sea Level Rise, etc.

# II. Introduction

Increases in average global temperatures and shifting precipitation patterns are likely to alter agricultural practices (Daccache et al., 2011). While the impact of this change will be complex and variable, it will undoubtedly influence which crops can be sustainably grown and where.

In tropical highland regions like the Andes, the effects of climatic changes may be severe (source). A study based on local meteorological data in this region showed a significant warming trend after 1979 that is expected to continue into the future (Condori, Hijmans, Quiroz, & Ledent, 2014). Changes in temperature and precipitation have altered growing patterns (Daccache et al., 2011) and increased the presence of insect damage (David Ellis, CIP, personal communication, September 22, 2015). Subsequent research has shown that from 1982 to 2012, potato cultivation in the Andes has ascended 150 meters higher in elevation (Shaw & Kristjanson, 2013). As farmers are forced to adapt, the continued use of traditional farming practices and indigenous crop varieties are threatened. Conservation of this genetic and cultural diversity will depend on a clear understanding of the effects of a changing climate on crop suitability.

Generally, locations suitable for potato cultivation are determined by biotic and abiotic factors as well as economic and social conditions. With respect to climate, potato production must occur during a time period that is both “heat free” and “frost free,” (Haverkort, De Ruijter, van Evert, Conjin, & Rutgers, 2013). Risk of frost increases below 3 ℃, and tuber production decreases at mean temperatures above 22 ℃ (Hijmans, Forbes, & Walker, 2000, p. 83). In addition to regulating plant growth, temperature also affects insect growth and development (Jamieson, Trowbridge, Raffa, & Lindroth, 2002). Warming temperatures may also increase vulnerability of plants to insect damage, especially if water availability is reduced (Jamieson et al., 2002).

Potato weevils are one of the most damaging pests of potatoes cultivated in the high Andean mountains (Cisneros, 1999). The rise in temperatures over time in Peru has contributed to an increase in Andean weevil populations (Parsa, 2010). These pests cause irreparable damage to crops as well as surrounding fields. Weevil eggs are laid at the base of potato plants (Parsa, Ccanto, Olivera, Scurrah, Alcazar & Rosenheim, 2012), in the upper twenty centimeters of the soil profile (Rios, 2010) for a period of twelve to fourteen weeks (Cisneros, 1999). Larvae bore tubers for eleven to seventeen weeks, then abandon these tubers and pupate in surrounding soil (Cisneros, 1999). The emergence of overwintering adult weevils lasts eight to fourteen weeks and coincides with the onset of rain (Cisneros, 1999). The weevils then travel to nearby potato fields (Parsa et al., 2012), thereby exacerbating the ubiquitousness of the pest.

Remote sensing and Geographic Information Systems (GIS) have emerged as new tools to assess agricultural suitability (Rahman, 2008) and monitor the distribution of crops over large areas (Panigrahy & Chakraborty, 1998). This project addressed NASA’s Applied Sciences Program National Application Areas of Climate, Agriculture, Ecological Forecasting, and Water Resources. The objective was to develop an increased understanding of changes in climate and their influence on potato cultivation and weevil presence in Peru’s Parque de la Papa using NASA Earth observations. Growing degree days (GDD), chill hours, elevation, soil moisture, and precipitation maps were created using data from 1980 until October 2015 as inputs for a potato suitability analysis within the park.



Parque de la Papa outline

Parque de la Papa

**Area Map Legend**

**Legend**

Peru

Figure 1: Study area map depicting the location of the Parque de la Papa in Peru

Parque de la Papa is located 40 kilometers outside of Cusco, Peru (Argumedo, 2008, p. 45) and is home to over 6,000 individuals (Fowks, 2015). Six indigenous communities reside within the park boundaries, five of which form the Parque de la Papa Legal Association (Argumedo, 2008, p. 45; “Guardians of Diversity,” 2014). The park aims to protect and disseminate traditional knowledge systems (“We are five, but now we are one”), as well as construct a conservation model focused on the sustainable use of plant genetic resources (Argumedo, 2008; “Guardians of Diversity,” 2014). The International Potato Center (CIP) works jointly with indigenous farmers and the Association for Nature and Sustainable Development (ANDES) to promote the objectives of the park. This project provided insight to the CIP regarding the changing locations of potato suitability in order to make recommendations to local farmers.

# III. Methodology

**Data acquisition:**

Daily Aqua and Terra MODIS Land Surface Temperature (LST) level 3, 1kilometer resolution (MODIS tile, h11v10), data were gathered for the study area over the years of 2000 to 2015. Daily Tropical Rainfall Measuring Mission (TRMM) level 3, 0.25 degree resolution, data were gathered for the study area from January 1998 through July 2015 TRMM\_3B42\_daily from NASA’s Mirador. Landsat Surface Reflectance Climate Data Record (CDR) tiles (path 4, row 69) were obtained from United States Geological Survey (USGS) Earth Explorer for 1995, 2001, 2008, and 2014 for the months of November, March, and June in 30 meter horizontal resolution. The digital elevation model (DEM) was acquired from the Shuttle Radar Topography Mission (SRTM), which is a radar based, absolute elevation raster image with a 30 meter horizontal resolution and 16 meter vertical resolution.

**Data Processing and Analysis:**

The Aqua and Terra MODIS land surface temperature (LST) daily datasets from 2000 to 2015 were first corrected to remove pixels that did not register accurate temperature data due to cloud cover. Arrays were constructed using Python dnppy libraries to calculate minimum and maximum temperatures at each pixel for a given day. Growing degree days were estimated from the average temperature minimum and maximum and a base temperature of two degrees Celsius (Hijmans et al., 2000).

The TRMM\_3B42\_daily dataset is part of a larger dataset formerly called the "TRMM and Other Data Precipitation Data Set." This project utilized version 7 of TRMM Multi-Satellite Precipitation Analysis (TMPA) (Huffman & Bolvin, 2014). The TRMM\_3B42\_daily dataset was downloaded and processed using Python to extract all daily data from January 1998 through July 2015. This dataset was then stacked so that a value was given for each pixel every day throughout the timeframe of the TRMM dataset. As the TRMM\_3B42\_daily is in such a coarse resolution (0.25 degree) in comparison to the study area, the final precipitation time-series was converted from raster data to point data over a five by five block of pixels centered on the study area and then interpolated to create a smoother surface.

Landsat scenes were classified as rock, potato crop, water, or other vegetation using the Land Classification tool in TerrSet with reference to Google Earth imagery. Annual potato crop locations were then overlaid to visually reflect the change in cultivation area over the past thirty years. Finally, slope was derived from the DEM using the ArcGIS slope tool.

# IV. Results & Discussion

# V. Conclusions

# VI. Acknowledgments

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# VII. References

Argumedo, A. (2008). The Potato Park, Peru: Conserving agrobiodiversity in an Andean indigenous biocultural heritage area. *Protected Landscapes and Agrobiodiversity Values. Volume 1 in the series, Protected Landscapes and Seascapes, IUCN & GTZ*, 45.

Condori, B., Hijmans, R. J., Quiroz, R., & Ledent, J. F. (2010). Quantifying the expression of potato genetic diversity in the high Andes through growth analysis and modeling. *Field crops research*, *119*(1), 135-144.

Cisneros, F. (1999). Controlling the Andean potato weevil through integrated pest management. *Horizon International Solutions Site*. Retrieved from <http://www.solutions-site.org/node/90>/

Daccache, A., Keay, C., Jones, R. J., Weatherhead, E. K., Stalham, M. A., & Knox, J. W. (2012). Climate change and land suitability for potato production in England and Wales: impacts and adaptation. *The Journal of Agricultural Science*, *150*(02), 161-177.

Haverkort, A. J., De Ruijter, F. J., van Evert, F. K., Conijn, J. G., & Rutgers, B. (2013). Worldwide sustainability hotspots in potato cultivation. 1. Identification and mapping. *Potato research*, *56*(4), 343-353.

Hijmans, R. J., Forbes, G. A., & Walker, T. S. (2000). Estimating the global severity of potato late blight with GIS‐linked disease forecast models. *Plant Pathology*, *49*(6), 697-705.

Huffman, G. J., & Bolvin, D. T. (2013). TRMM and other data precipitation data set documentation. NASA, Greenbelt, USA, 1-40.

Jamieson, M. A., Trowbridge, A. M., Raffa, K. F., & Lindroth, R. L. (2012). Consequences of climate warming and altered precipitation patterns for plant-insect and multitrophic interactions. *Plant physiology*, *160*(4), 1719-1727.

Panigrahy, S., and M. Chakraborty. "An integrated approach for potato crop intensification using temporal remote sensing data." *ISPRS journal of photogrammetry and remote sensing* 53.1 (1998): 54-60.

Parsa, S. (2010). Native herbivore becomes key pest after dismantlement of a traditional farming system. *American Entomologist*, *56*(4), 242.

Parsa, S., Ccanto, R., Olivera, E., Scurrah., Alcazar, J., & Rosenheim, J. A. (2012). Explaining andean potato weevils in relation to local and landscape features: a facilitate ecoinformatics approach. *PLoS One,* 7(5).

Rios, Alfred Arturo. (2010). *Land Use, Spatial Ecology and Control of the Andean Potato Weevil in the Central Andes of Peru* (Doctoral Dissertation). Retrieved from ProQuest Dissertations Publishing. (3447056)

Shaw A, Kristjanson P. 2013. Catalysing learning for development and climate change: an exploration of social learning and social differentiation in CGIAR. CCAFS Working Paper No. 43. Copenhagen, Denmark: *CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)*.

We are five, but now we are one. Retrieved from http://http://www.parquedelapapa.org/eng/02somos\_01.html

# VIII. Content Innovation

# IV. Appendices

Insert here