**NASA DEVELOP National Program**



NASA Langley Research Center

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Northwest U.S. Agriculture III

Applying Future Climate Patterns to Apple Orchards in Washington State

**Technical Report** 

Rough Draft – June 25, 2015

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# 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”]

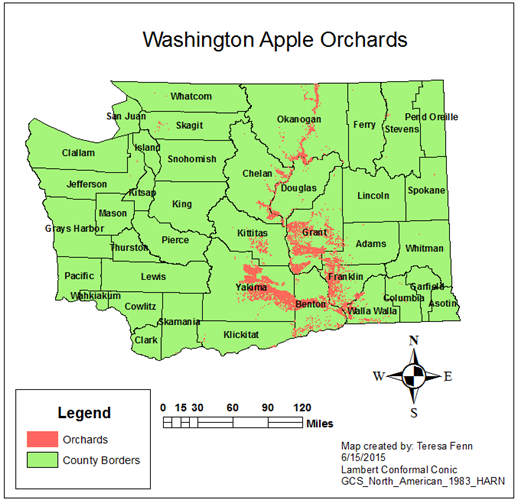
**Keywords**

Remote Sensing, Climate Change, Agriculture, Apples, MODIS, Washington State, Plant Hardiness Zones, Growing Degree Days

# II. Introduction

Washington State’s warm, dry summers and cool, wet winters provide excellent conditions for apple growth. As a result, Washington produces 65% of the nation’s apples, adding 2.2 billion dollars to the nation’s economy (NASS 2015, Washington State Dept. of Agriculture). A majority of the apple orchards in Washington are located in the valleys and basins to the east of the Cascade Mountains (Smith 2001). The primary apple growing counties are Chelan, Yakima and Grant (Figure 1). These counties have a relatively temperate, dry climate coupled with an abundant irrigation source of rivers and streams that are fed by snow melt, creating ideal conditions for producing apples (Smith 2001).

In 2014, Washington produced an unprecedented 7.3 billion pounds of apples, which was a 24% increase from the previous year’s harvest (NASS 2015).  The record yield was the result of a warm spring and expansions of high density orchards (NASS 2015). As seen through recently collected data, Washington’s conditions have been ideal for producing high apple yields, however, there is a strong likelihood that Washington’s suitability for apple farming could be impacted by future climate change. The most recent report from the Intergovernmental Panel on Climate Change (IPCC) projects the global mean surface temperature to increase 1-2 °C by 2065 and 1-3.7 °C by 2100 (2013); while downscaled regional predictions show that Washington State could see even more severe temperature changes. The IPCC climate models use Representative Concentration Pathways (RCPs) to model different possible scenarios in regards to climate change. Their purpose is to provide projections of greenhouse gas concentrations in the atmosphere. The RCP 8.5 scenario - which is currently the worst-case scenario - predicts that Washington could see up to a 4-5 °C increase in temperature by 2100 (IPCC 2013).



***Figure 1: Current Apple Orchard Locations within Washington State***

A good method for identifying areas that are well suited for apple growth include the United States Department of Agriculture’s (USDA) Plant Hardiness Zone (PHZ) maps. PHZ maps are created by classifying average annual minimum temperatures into 10 °F zones, and are used to determine which plants will thrive in a particular location (Daly 2012). Minimum temperature is useful when determining locations for orchards because extreme cold temperatures can cause winter injury, leading to poor production and even tree death (Quamme 2010). According to Dr. Michael Glenn from the USDA Agricultural Research Service (ARS), apples grow best in PHZs 5 and 6, where minimum temperatures are between -28.9 °C and -17.8 °C. The PHZ map is helpful when making present-day decisions, but there are currently no projected PHZ maps that take into account future climate change.

The objective of the project is to create current and forecasted PHZ maps specific to Washington State for 2045, 2065, and 2095 in order to determine which areas will be most suitable for apple orchards. The current PHZ map was created using MODIS LST data from the period of Jan 1, 2002 - June 1, 2015. In addition to the PHZ maps, current and future orchard suitability maps that combine annual minimum temperature, growing degree days, and average temperature for the growing season will also be created for the same time periods.

The project addresses the agriculture application area by using observations from the MODIS sensor on the NASA satellite Aqua to create PHZ maps which will help inform current and future decisions by the USDA and farmers concerning apple production over the 21st century. The climate application area is also addressed because climate models are utilized to demonstrate how climate change will affect the growing conditions for apples through the year 2100.

By creating current and future PHZ maps, growers can better prepare for the predicted effects of climate change. These maps will be shared with the USDA’s Agricultural Research Service. By understanding the effect that climate change will have on suitable growing areas in Washington, growers have more information for their own decision making processes.

# III. Methodology

**Data Acquisition**

Level three Aqua MODIS data (MYD11A1) was acquired from the Land Processes Distributed Active Archive Center (LP DAAC) for January 2002 through June 2015 for the state of Washington, consisting of tiles h9v04 and h10v04.

Future temperature forecasts were obtained using Coupled Model Intercomparison Project Phase 5 (CMIP5) based NASA Earth Exchange - Downscaled Climate Projection 30 (NEX-DCP30) data, and weather station data for Yakima, Grant, and Chelan for 2002- 2015 was downloaded from National Oceanic and Atmospheric Administration’s National Climatic Data Center.

**Data Processing**

The MODIS LST data were processed in python in order to convert the raw MODIS files from Hierarchical Data Format (HDF) to tiff files. The data were then mosaicked together, projected to the North American Datum 1983 High Accuracy Reference Network State Plane Washington South projection, and clipped to the state of Washington. The temperature values were converted from Kelvin to degrees Celsius, and land surface temperatures were converted to estimated air temperatures using a linear transformation obtained by plotting weather station data against MODIS LST data. Using the equation of this line, we derived a transformation equation to be applied to both nighttime and daytime data...(seasonally? Method TBD)

The data were then processed to remove any outliers which may include pixels tainted by cloud cover or other atmospheric conditions. All cloud cover previously detected by the MODIS satellite was given a null value. Other outliers were removed by... (Method TBD)

In order to calculate growing degree days, the data was averaged using a five day rolling average technique. Each pixel was averaged with the data taken within two days of its acquisition date. After completing a five day moving average, the data was averaged from the same day over multiple years.

**Data Analysis**

To create PHZ maps and orchard suitability maps, daily minimum and maximum temperatures were estimated using Land Surface Temperatures (LST). PHZ maps were created by classifying the average minimum yearly temperature for each pixel into 5°F zones. Suitability maps were created by weighing three parameters together: GDD, average growing season temperature, and PHZ. (In future need to explain how each was weighed, what thresholds were for temp and GDD)

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

We would like to thank our science advisors, Dr. Kenton Ross and Dr. Noelle Baker, and

Jeff Ely - the NASA DEVELOP Geoinformation Scientist - for assisting us with the coding for the project. We would also like to thank our project partner, Dr. Michael Glenn; as well as the previous NW US Agriculture Teams from the fall of 2014 and the spring of 2015 for laying a foundation we could build on.

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

# VII. References

Daly, Christopher, et al. "Development of a new USDA plant hardiness zone map for the United States." *Journal of Applied Meteorology and Climatology* 51.2 (2012): 242-264.

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker,T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Quamme, H. A., et al. "The potential impact of climate change on the occurrence of winter freeze events in six fruit crops grown in the Okanagan Valley." *Canadian Journal of Plant Science* 90.1 (2010): 85-93.

Smith, T. J. "Overview of tree fruit production in the Pacific Northwest United States of America and southern British Columbia, Canada." *ACTA Horticulture* (2001): 25-30.

USDA, National Agricultural Statistics Service (NASS). *Washington Apple and Grape Crops Set Record Highs in 2014*, 26 Jan. 2015. *NASS*. Web. 16 June 2015.

Washington State Department of Agriculture. *Agriculture- A Cornerstone of Washington’s Economy*, 2013. *Department of Agriculture.* Web 16 June 2015.

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# IV. Appendices

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