**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

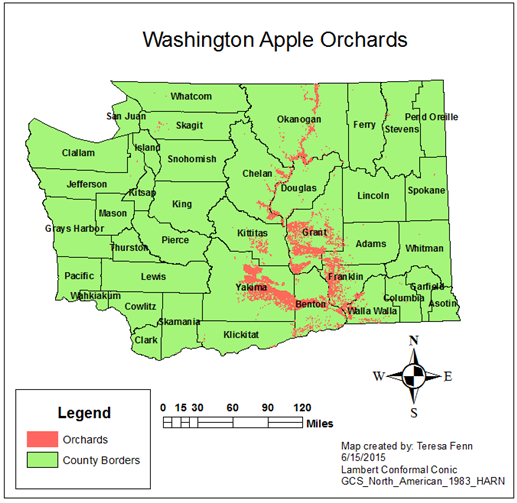
# II. Introduction

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). In 2014, Washington produced a record 7.3 billion pounds of apples, which was a 24% increase from the 2013 yield (NASS 2015).  The record yield was the result of a warm spring and record expansions of high density orchards (NASS 2015). As seen through recently collected data, Washington’s recent 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 (Citation). Regional predictions show that Washington State could see even more severe temperature changes. The RCP 8.5 scenario - which is currently the worst-case scenario- makes regional predictions of up to a 4-5 °C increase in temperature by 2100 (IPCC 2013).

Present methods for identifying areas with ideal apple growing conditions include the USDA’s Plant Hardiness Zone (PHZ) maps. PHZ maps are created by classifying average annual minimum temperatures into 5 °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 producing apples because extreme cold temperatures can cause winter injury that leads to poor production and can even lead to tree death (Quamme 2010). According to Dr. Michael Glenn from the USDA Agricultural Research Service (ARS), apples grow best in PHZs 5 and 6. 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 set time periods through the year 2100. 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.

PHZ maps and orchard suitability maps were created for Washington State. A majority of the apple orchards in Washington are mainly 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. 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).



The study periods for the project are the “present” period of Jan 1, 2002- June 1, 2015, which aligns with the temporal availability of the MODIS LST data. In addition to the present-day time period, there are also three future study periods: 2045, 2065, and 2095.

The project addresses the agriculture application area by using observations from the NASA satellite MODIS to create PHZ maps which will help inform current and future decisions by the USDA and farmers concerning apple production over the 21st century. In addition, 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, specifically with Dr Michael Glenn from the Appalachian Fruit Research Station. Dr Glenn has worked with the project for the previous two terms, and is particularly interested in combining the methodologies and findings from all three terms. 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 CMIP5 based NEX-DCP30 data, and weather station data for Yakima, Grant, and Chelan for 2002- 2015 was downloaded from NOAA’s National Climatic Data Center.

**Data Processing**

The MODIS LST data were processed in python in order to convert the raw MODIS files in HDF format to tiff files. The data were then mosaicked together, projected to the NAD 1983 HARN 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. To convert from land surface temperature to air temperature, a linear transformation was used. This equation was found when weather station data was plotted against MODIS LST data in R to determine a best fit line. 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 be 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 GDD, the data was averaged using a five day rolling average technique. Each pixel was averaged with the data taken two days within 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 plant hardiness zone maps and orchard suitability maps, daily minimum and maximum temperatures were estimated using Land Surface Temperatures (LST). PHZ maps are created by classifying the average minimum yearly temperature for each pixel into 5°F zones. Suitability maps were created by weighing three apple orchard suitability measures 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

Dr. Kenton Ross (NASA DEVELOP National Science Advisor)

Jeffry Ely (NASA DEVELOP Geoinformation Scientist)

Dr. Noelle Baker (NASA Postdoctoral Fellow)

Dr. Michael Glenn (USDA ARS)

Fall 2014 NW US Agriculture Team

Spring 2015 NW US Agriculture Team

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# VII. References

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# IV. Appendices

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