Estimation of Pecan Orchard Area in the Mesilla Valley, from 2008 to 2018, using Remote Sensing Classification Techniques

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Summer 2019

Introduction

The pecan is the most economically valuable crop in New Mexico, accounting for approximately a third of the state's crop-based revenue in 2017 (USDA, 2018). However, pecan cultivation in the region requires large quantities of resources such as water and soil (Sammis et al., 2013). Water usage is particularly relevant for research, since the Mesilla Valley is an arid region that, on average, only receives 200 mm of rain annually (Samani et al., 2009), and water is scarce. Irrigation for all crops in the region comes either directly from the adjacent Rio Grande or from its underlying aquifer. Samani et al. (2009) demonstrate that researchers can use a combination of field-collected and remotely-sensed data to calculate pecan water usage at the field scale. A comprehensive technique of estimating the changes in crop coverage, especially that of pecans, in the Mesilla Valley would allow researchers to apply field-scale calculations of water usage to the entire region. However, on-the-ground census and survey techniques for calculating coverage are costly, inefficient, and often inaccurate (Sammis et al., 2013). Remote sensing presents novel, inexpensive, and easily accessible resources for the classification of crop and land cover, and techniques utilizing such resources have been shown to provide accurate and useful results (Sawalhah et al., 2018; Carfagna & Gallego, 2005). We aim to use satellite imagery to estimate the area of pecans, along with other crops, in the Mesilla Valley of NM, USA (**Figure 1)** from 2008 to 2018.

Methods

This study examines three classification techniques: the Cropland Data Layer (CDL), available publicly from the USDA (Boryan et al., 2011); a supervised Maximum Likelihood Classification (MLC); and a Normalized Difference Vegetation Index (NDVI). All satellite imagery for this study were downloaded from the publicly available USGS website Earthexplorer.usgs.gov. Images were selected from the late summer (August) for the MLC, to best capture the differences between pecan canopy and other crops, and images during the peak irrigation month of the season (October) were used for the NDVI classifications. Then, the boundaries of selected images were defined by an outline of the Mesilla Valley, which was based on visible farmland. The study site thus established (**Figure 1**), supervised training data were constructed for years 2011 and 2014 by consulting National Agriculture Imagery Program (NAIP) and Google Earth imagery. The training data were approximately proportional to the heterogeneity of the class, with relatively homogenous classes like open water requiring fewer training data. A maximum likelihood classifier then extrapolated the training data to determine the crop and land cover of the entire Mesilla Valley for the years 2011 and 2014. The CDL classified land cover maps were collected from the National Agriculture Statistics Service at nassgeodata.gmu.edu/CropScape/ for years 2008 to 2018, and Normalized Difference Vegetation Index (NDVI) maps were derived from the original Landsat imagery for years 2005, 2008, 2010, 2011, 2014, and 2017. Area for all three classification approaches (CDL, MLC, and NDVI) was calculated using direct pixel counts. Tangible maps were created for each approach, organized by year (See **Figure 2**). All of the classified maps were finally compared to determine which techniques provide the most reasonable results for predicting pecan coverage.

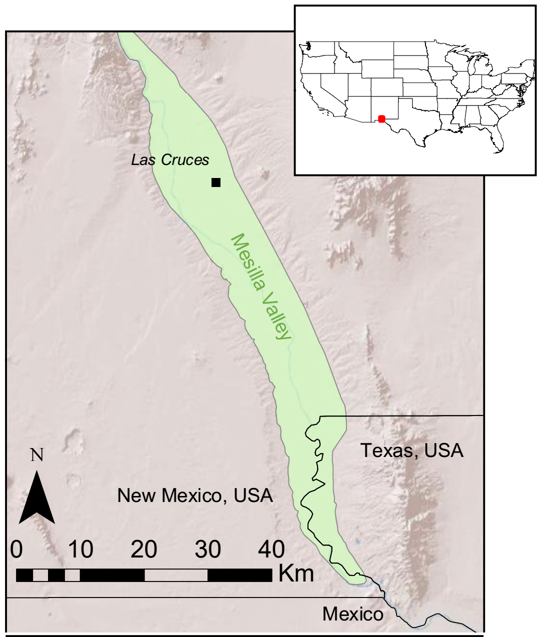

Figure 1. Study site: the Mesilla Valley. Terrain base map from esri.com, and state and country boundaries provided by U.S. Census Bureau.

Results & Discussion

Both the MLC and the CDL provided maps that were reasonably comparable when visually contrasted with the NAIP imagery, but the area calculated for different crops varied significantly between the two approaches. Using the MLC, the calculated pecan area was 72.87 km^2 and 100.58 km^2, for 2011 and 2014, respectively, while the same variables calculated from the CDL were 99.84 km^2 and 108.80 km^2. The NDVI approach, meanwhile, provided valuable information for vegetation cover and "greenness", but was not a reliable metric for determining crop type when compared to the other two classification techniques.

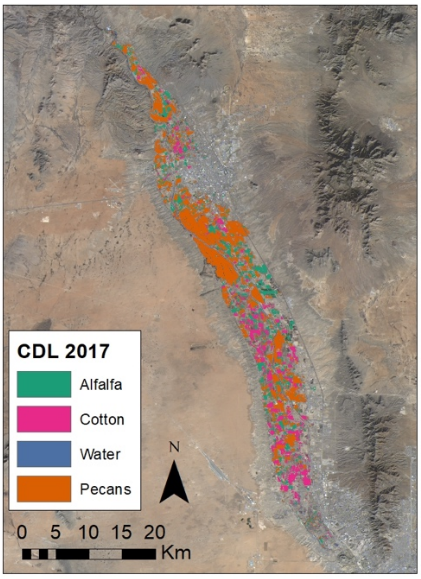

Figure 2. An example of a classified map of the Mesilla Valley major crops, using the CDL approach, for 2017..

The CDL includes accuracy data provided by the NASS; the overall accuracy reported for New Mexico is >70% for each year studied except 2013. The confidence for the MLC, produced by the ArcGIS tool, was relatively low when compared with the CDL. In addition, the direct pixel count approach using the CDL has been shown to demonstrate a downward bias in area estimations (Carfagna & Gallego, 2005). Since the MLC consistently provided lower values for area than the CDL, it is a reasonable assumption that the MLC approach provides a less accurate estimate of total area. Therefore, the CDL approach was used for the final assessment of yearly crop change in the Mesilla Valley (**Figure 3)**.

For the years 2008 to 2018, the CDL approach displays a general trend of expansion of pecan coverage and a shrinkage of other crop acreage (**Figure 3**). The years 2010 and 2012 were particularly low, according to this method, for pecan acreage, and the greatest increase in pecan area was between 2012 and 2014. The greatest total area of pecan orchards was in 2017. The results display similar trends compared with USDA agricultural census data (USDA, 2018) and historical data (Sammis et al., 2013). These changes in crop cover document a shift in the Mesilla Valley towards an agricultural regime dominated by a pecan monoculture.

Conclusion

This study suggests that a direct pixel count using the Cropland Data Layer is an efficient and useful method of quantifying and monitoring yearly crop area changes in the Mesilla Valley. Pecan acreage in the Valley has generally increased from 2008 to 2018.

Recommendation

Further research is needed to quantify the relationship between the crop cover changes we documented and the demand for water. Specifically, developing a locally applicable approach to mitigate pixel count bias (Carfagna & Gallego, 2005) and an approach to correlate water usage with crop type would greatly improve our ability to estimate water demand of the Mesilla Valley agricultural land using remote sensing.

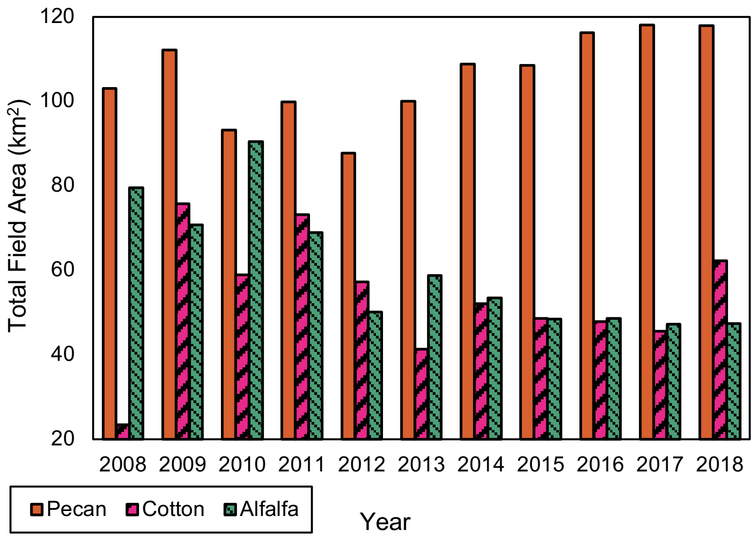

Figure 3. Crop area trends in the Mesilla Valley from 2008 to 2018 using a direct pixel count approach with cropland data layer (CDL) classification. The CDL data are from USDA/NASS.

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