Can Chipped Almond Prunings Provide Carbon Sequestration?

12-STEWCROP4

Background & Purpose

The overall objective of this on-going project is to improve the industry understanding of how pruning management and tree removal techniques impact soil carbon stocks, air quality and greenhouse gas emissions. To serve this purpose, the project included development of various input data sets to incorporate into the DeNitrification-DeComposition (DNDC) model. The DNDC model is a soil biogeochemical model used to estimate greenhouse gas flux from natural systems. The model results were used to quantify how pruning management, tree removal and other factors influence soil C and N cycling, soil C stocks and production of nitrous oxide (N_2O).

This work satisfies many of the Areas of Interest within Environmental Stewardship that the Almond Board has defined for 2011/2012. The main goal of the work described below was to improve the spatial database of almond acreage and biomass determinations across California by incorporating remote sensing techniques.

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The traditional method for estimating biomass is to measure a selected sample of tree trunk diameter at breast height (DBH). This relationship is well-published in biomass studies, especially for the forestry industry. However, equations that describe the correlation between DBH and biomass are specific to region, climate and tree type categorizations. Estimating biomass in almond orchards using a DBH correlation is challenging because of the logistics, time and cost of acquiring data. Also, there would still be a need to evaluate if DBH correlates to biomass successfully as it does for forest stands. Orchard management, irrigation/drainage management, climate, variety, planting density, and soil conditions would likely impact the effectiveness and ability to derive a DBH average value for orchards statewide.

Therefore, there is a need to develop cost-effective and simpler techniques to determine biomass of almond orchards. If this can be done with reasonable accuracy, carbon stocks in almond orchards statewide can be quantified with relatively minimal effort.

Objectives

The main purpose of this effort was to test the hypotheses that almond orchard biomass can be estimated using remote sensing techniques - specifically, correlating the amount of biomass hauled (green chip weight) during orchard removal to canopy coverage in remotely sensed imagery. The following specific objectives were an initial part of this investigation:

1. Identify imagery sources that are the most suited to analyzing almond orchard characteristics
2. Use remotely sensed imagery to determine orchard age
3. Determine if orchard age is correlated to orchard biomass in remote sensing analysis
4. Explore the statistical relationship between various remotely sensed image texture characteristics and almond orchard biomass
5. Begin to establish a statistically valid method to predict carbon stocks in almond orchards
6. Demonstrate the use of LiDAR in determining variability in orchard height

Summary of Conclusions

Biomass in almond orchards can be estimated from vegetative cover determined by remotely-sensed image analysis. The correlation established in 36 orchards (Figure 1) is very strong (**r^2=0.85**), and is potentially a better alternative to estimating biomass using field methods, which is costly, time-consuming, and labor intensive.

Object-based identification analysis can be used to leverage no-cost sources of imagery for improving the type, amount, and level of detail of information in the spatial database of almond acreage in California. Landsat and NAIP are two no-cost sources of imagery that are suitable for determining vegetative cover and orchard age, respectively.

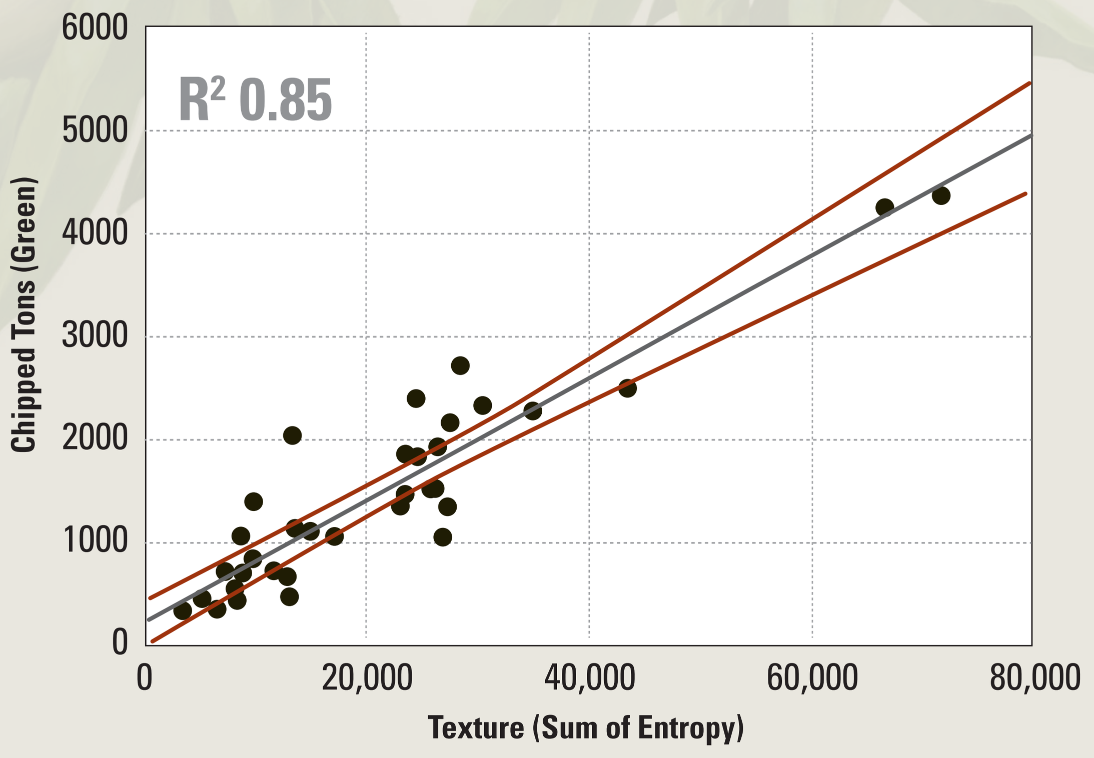

Figure 1 Linear Regression of Chipped Green Weight to Texture (Sum of Entropy)

Methodology

The methodology for this on-going work included field data collection, aerial and satellite imagery analysis, and statistical analysis.

Study Site

The project study site spans five counties in the California central valley which produces approximately 450 million pounds of almonds annually (Figure 2).

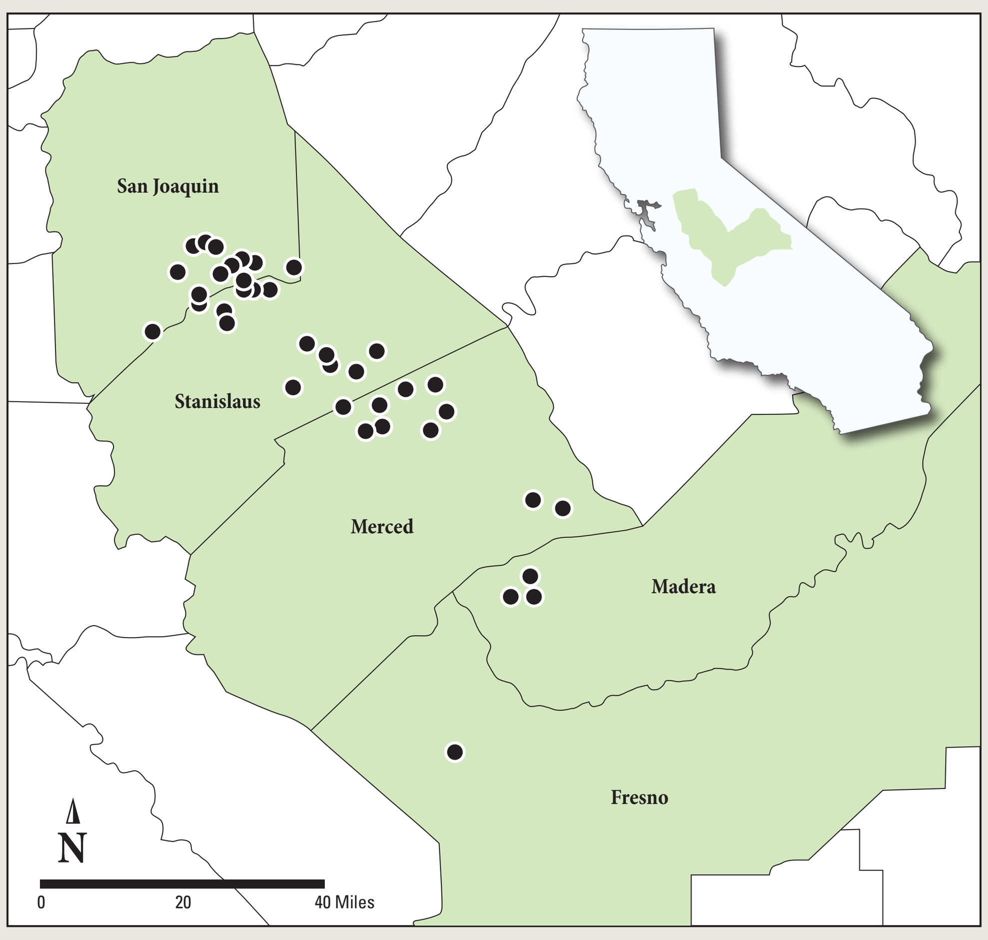

Figure 2 Study Sites in Central California

Field Data

Green chip weights were collected from 36 fields where orchards had been removed, chipped, hauled and weighed offsite in 2010 and early 2011. The weights were converted to estimates of dry biomass. High-resolution imagery of the project fields was used to measure additional variables including tree canopy width by row and width between rows.

Aerial and Satellite Imagery

Landsat5 and imagery from the National Agriculture Imagery Program (NAIP) were both used in the analysis. These two sources of remotely sensed imagery (available to public at no cost) and the remote sensing analytical technique called object-based identification analysis were used to explore the relationship between measured biomass, orchard age, and vegetative (canopy) cover in 36 almond orchards in California (Figures 3 & 4).

Additional Research: Incorporating LiDAR in Almond Orchard Evaluations

For one of the 36 fields evaluated in this study, LiDAR mass point data were used to determine tree height, vegetative canopy, and a rough canopy complexity estimate.

Figure 3 NAIP imagery pixels (left); low homogeneity (higher variance) objects (center); high homogeneity (lower variance) objects (right)

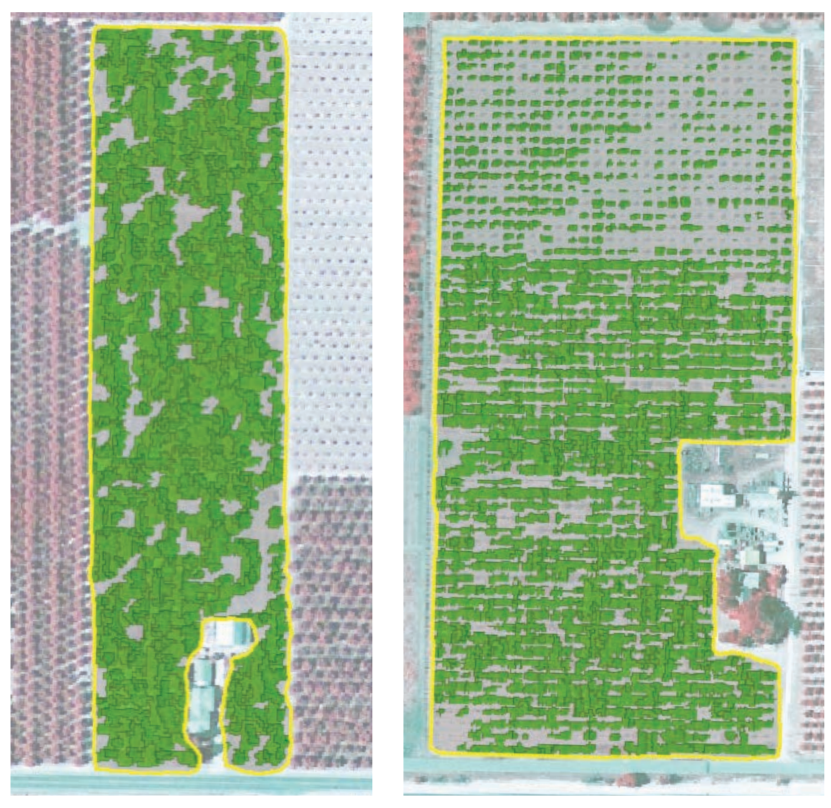

Figure 4 Relatively uniform canopy (left) and a less uniform canopy (right)

Results

1. Green chipped weight measured during orchard removal was correlated to canopy cover as determined using remote sensing analytical techniques.
2. Certain remotely sensed image texture characteristics also correlated well with vegetative cover.
3. Orchard age, determined by remote sensing image analysis, was not a good predictor of orchard biomass.
4. LiDAR has potential to determine tree height in almond orchards and potentially improve the predictive capabilities of remotely sensed methods.

The significance of these findings is that remote sensing imagery and analytical techniques can be used to estimate almond orchard biomass, as well as other almond orchard characteristics, eliminating the need to acquire costly and time-consuming field data to provide this information over a large extent of almond acreage. This information can be used to in the DNDC model to estimate the effects of management practices on carbon flux in orchards soils, and ultimately, to quantify the spatial variability of carbon storage potential in almond orchards. In addition, an accurate method for almond orchard biomass will be used to improve the spatial database of almond acreage statewide.

The following accomplishments resulted from this work:

1. Almond orchard biomass estimates for the DNDC model that are accurate, efficient, and can be updated with minimal effort.
2. A method to evaluate vegetative coverage, using remote sensing analytical techniques, in almond orchards and correlate it to biomass.
3. Demonstration that LiDAR can be used to determine individual tree height determination within almond orchards.
4. Continuing work on identifying orchard age using remote sensing.

Further Research

Biomass Estimation

A larger ground truth dataset and the use of non-parametric classification and regression techniques would further benefit an investigation of remote sensing techniques to analyze various characteristics of almond orchards. These techniques may provide better statistical fit because they can simultaneously take advantage of continuous and categorical data (e.g. soil survey data) in the same model.

LiDAR Applications

The potential value of including LiDAR mass point multi-return data is the ability to determine tree height as well as canopy extent. As multi-return LiDAR, as well as waveform LiDAR, is more widely collected, this data source may be a cost-effective option.

Crop Mapping

Remote sensing is also currently being applied to almond mapping in California. A complete geospatial dataset of almond orchards will not only improve the estimates of biomass for this specific effort, but will also enable the Almond Board of California to track statewide changes in almond acreage, location, and other attributes of almond orchards that are relevant to marketing and regulatory efforts. The current accuracy of mapping almonds utilizing remote sensing is approximately 97%, and the effort to update these data products is expected to be minimal compared to traditional mapping methods.

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