Just the Citrus Trees Please

The California citrus industry is valued at more than $2 billion annually.

Combining UAS data and deep-learning OBIA technology offers new approach to citrus tree management

Researcher makes classifying breakthrough with Trimble technology

Solution

Trimble® eCognition® Software

overview

Valued at more than $2 billion annually, the California citrus industry is a bedrock of the state's agriculture economy. Deeply rooted in that industry is the Lindcove Research and Extension Center (LREC), a part of the University of California Division of Agriculture and Natural Resources, which manages nearly 600 trees, mostly citrus varieties. To continue to support critical citrus research, LREC managers continually look for effective technological management tools. One researcher used that interest to test the feasibility of integrating new deep-learning algorithms into object-based image analysis (OBIA) software to automatically identify multi-age citrus trees from UAS imagery. The successful first-ever test is sowing the seeds for a viable new approach to citrus tree management.

Location
CALIFORNIA

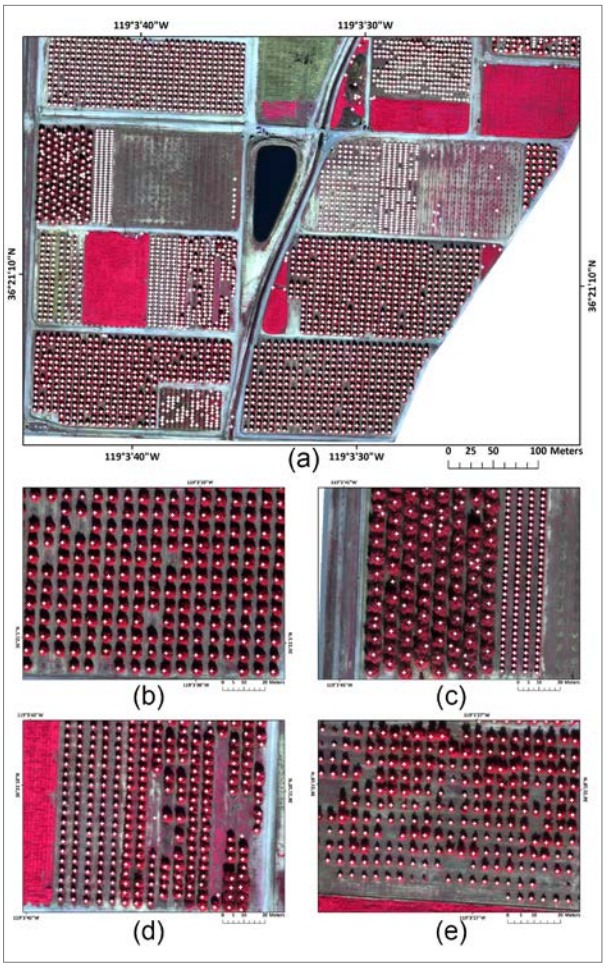
As part of its management improvement tools, the LREC created a reference tree database with the location and attribute data of 2,912 individual trees using 1-meter imagery from the US Department of Agriculture's National Aerial Imagery Program (NAIP). In 2017, they became interested in UAS imagery.

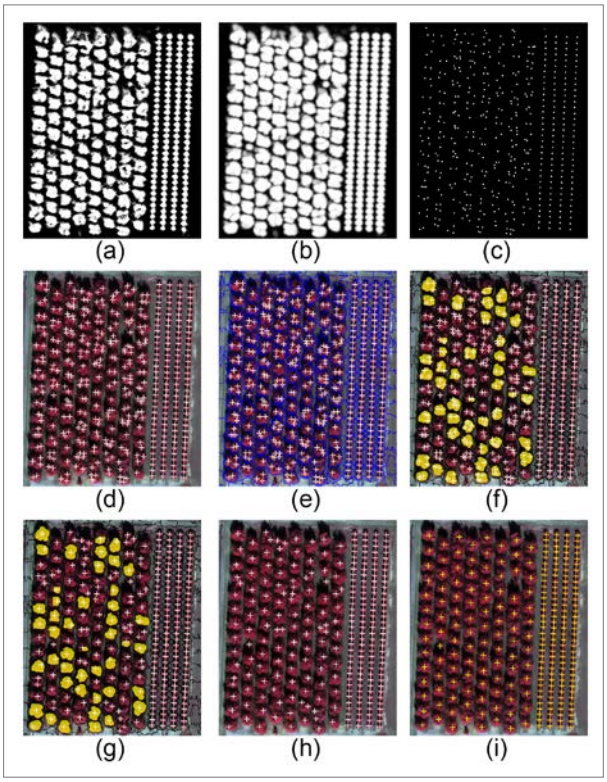
At the same time, Ovidiu Csillik, a visiting research scholar at UC Berkeley's Department of Environmental Science, Policy, and Management, and his research supervisor Dr. Maggi Kelly, were interested in how UAS imagery, a convolutional neural network (CNN) deep-learning algorithm and Trimble's eCognition OBIA technology could be used to accurately map multi-age citrus trees.

"This study would give us the chance to acquire UAS data as a proof-of-concept alternative to NAIP imagery, and to test the feasibility of using a CNN-OBIA method to automatically analyze the UAS imagery and accurately identify and map individual citrus trees," said Csillik.

In January 2017, researchers acquired UAS imagery of the entire 175-acre LREC site. In two flights, the UAS captured 4,574 multispectral images, which were photogrammetrically processed to produce a 4-band orthomosaic with a ground sample distance of 12.8 cm. The red and near infrared bands were also used to create a Normalized Difference Vegetation Index (NDVI) image. Both datasets were used as source data for eCognition.

The first step of the ruleset involved training the CNN model with three classes—trees, bare soil and weeds—with 4,000 training samples per class. To create the samples, eCognition used the orthomosaic and the LREC's tree-location database to break up the mosaic into 40x40 pixel samples around





Left: Tree detection analysis. White crosses indicate automated tree locations and classification using eCogniation.

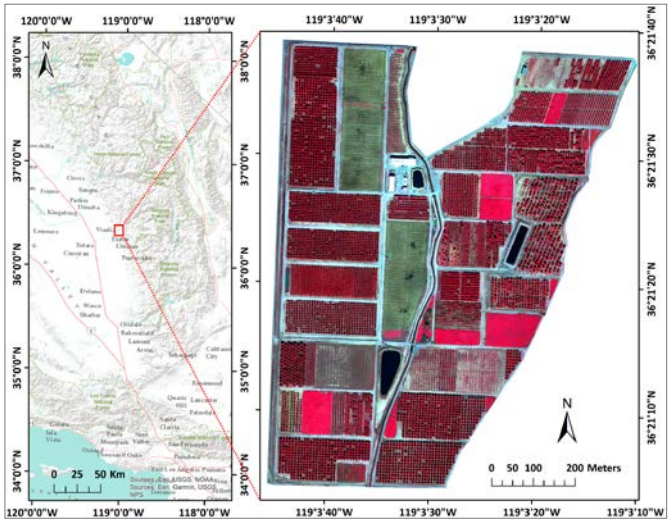
Bottom left: Initial CNN-generated probability heatmap of trees (black to white) and its refined stages to produce results that better matched the ground reference samples (i).

those location points. Csillik used the known sample classes to teach the CNN to differentiate between classes by learning the specific features of each class. A quick study, the CNN completed its training in 13 minutes.

Csillik then tested the newly trained CNN to identify and delineate individual citrus trees. Each 40x40 pixel region was submitted to the network to obtain a likelihood that this image patch contains a citrus tree. Moving the analysis region like a sliding-window across the orthomosaic, it took eCognition's CNN two minutes to produce a probability "heat map", a grayscale image of likely tree locations.

In a final step, the software used another newly integrated feature called superpixel segmentation to further process the heat map to remove multiple crown-detection errors and refine its tree delineation, improving the detection and location of single citrus trees.

In total, eCognition analyzed, identified and delineated 3,105 individual trees in 30 minutes with 96.2 percent accuracy.

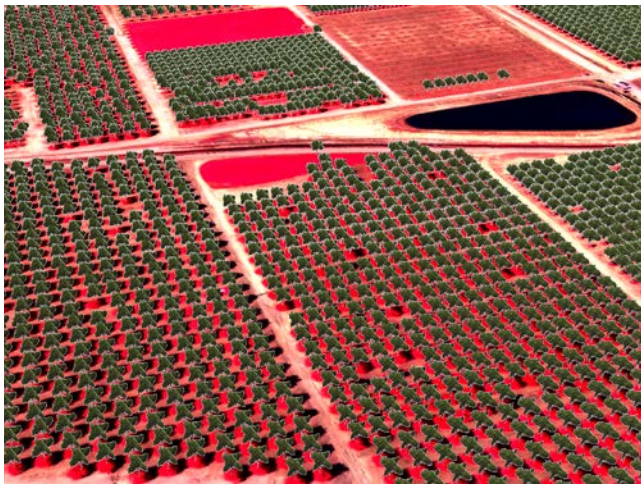


Above: Study area location near Visalia, California (left) and a false color image acquired by the UAS with a spatial resolution of 0.12 m and covering 64.6 ha (right)

Based on Csillik's results, the LREC plans to apply the approach to other study areas, explore how transferable it is, and determine how easily they can update their tree maps over time.

Although more research on pairing UAS imagery with CNN-OBIA technology is needed to fully realize how this approach can better the precision agriculture industry, Csillik is optimistic about the initial result and future ones to come.

LREC's citrus groves from above. In total, the UAS captured 4,574 images which were photogrammetrically processed into a 4-band orthoimagery mosaic and input into eCognition for analysis.



An overview of the identified tree locations using CNN, overlapped on a false color composite of UAV's mosaic.

"Having worked with eCognition for over seven years, I was confident that the integrated CNN would perform well. But it was a nice surprise to see how well it performed. The ability to precisely and automatically identify and delineate individual trees with 96 percent accuracy could offer a much faster, precise and repeatable method for long-term crop management for growers and the LREC."

— Ovidiu Csillik, Postdoctoral Research Associate, Carnegie Institution for Science

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