Crunchy Almonds from California
Monitoring with Pléiades Data for Precision Farming

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ENVI CROP SCIENCE

Advanced remote sensing technologies and the increased availability of multispectral data allow the monitoring of plant stress and the estimation of crop yields. We present an automated image analytics workflow from plant counting to health distribution.

The **ENVI CROP SCIENCE PLATFORM** contains remote sensing analytic tools for precision agriculture and agronomy, specifically:

- Get a **TOTAL COUNT OF THE CROPS** in an agricultural field, along with their locations and sizes.
- **IDENTIFY ROWS** within a field, along with the crops that comprise that row. Exclude weeds, grass, and anything else that is not part of the row.
- **IDENTIFY GAPS** within a row, which correspond to missing crops.
- Calculate statistics of **SPECIFIC METRICS FOR EACH CROP**. Examples include height or spectral index values.
- Create a **HOTSPOT IMAGE** that shows clusters of relative **OF VEGETATION HEALTH** in a single field or a larger geographic extent.

PREPARE DATA & ENHANCE CROPS

TEST SITE Almond plantation near Stockton, Central Valley, California, U.S.A.

DATA FILES Multispectral time series of eight images, acquired from May to August 2015 with the Pléiades sensor (data courtesy of Airbus Defence and Space).

PREPARE DATA
- Radiometric calibration & atmospheric correction
- RPC orthorectification
- NN Diffuse Pansharpening to 59 cm GSD
- Image-to-image registration
- Masking

ENHANCE CROPS creates an image to enhance the individual almond trees, using tools as thresholding and/or inversion of the input time series.

For this case study, the **Burn Area Index** (BAI, after Chuvieco et al. 2002) was calculated to clearly distinguish the almond trees from the background soil, providing single-band images.

COUNT CROPS

COUNT CROPS automatically locates and counts the almond trees looking for bright, blob-like shapes. This initial crop count may identify weeds and other non-crop vegetation between the tree rows as valid crops, resulting in false positives.

FIND CROP ROWS AND REMOVE OUTLIERS identifies individual rows in the plantation, and removes the outliers from the initial crop count result. The algorithm uses a FFT method to determine the primary direction of the crops and also estimates the distance between trees in adjacent rows. Using a distance threshold, it determines which trees actually belong to each row.

FIND CROP GAPS finds the locations of missing almond trees within a row.

The final **OUTPUTS** comprise the following layers:
- Output crops raster,
- Removed outliers,
- Location of tree gaps,
- Polyline and polygon indicating the rows and distance thresholds.

CALCULATE CROP METRICS & HOTSPOT ANALYSIS

CALCULATE CROP METRICS calculates statistics for individual trees from a single-band raster such as a spectral index image and a crop file created with the Count Crops tool. The resulting classification image shows the relative pattern of a selected crop metric.

CALCULATE CROP METRICS WITH SPECTRAL INDEX accepts a multispectral image as input and calculates statistics from a specified spectral index.

HOTSPOT ANALYSIS calculates Getis-Ord Gi* local statistics (Getis & Ord, 1992) to group neighboring pixels of similar value into clusters. The algorithm classifies each pixel as "hot" or "cold" (statistically significant clusters of high or low values, respectively) or neutral (not statistically significant).

Crop Metrics allows to describe the health of each single almond tree. Hotspot Analysis can be used to look for subtle variations in tree health throughout an area. Both methods were based on the **Green Normalized Difference Vegetation Index** (GNDVI, after Gitelson & Merzylak 1998), which is more sensitive to chlorophyll concentration than NDVI.
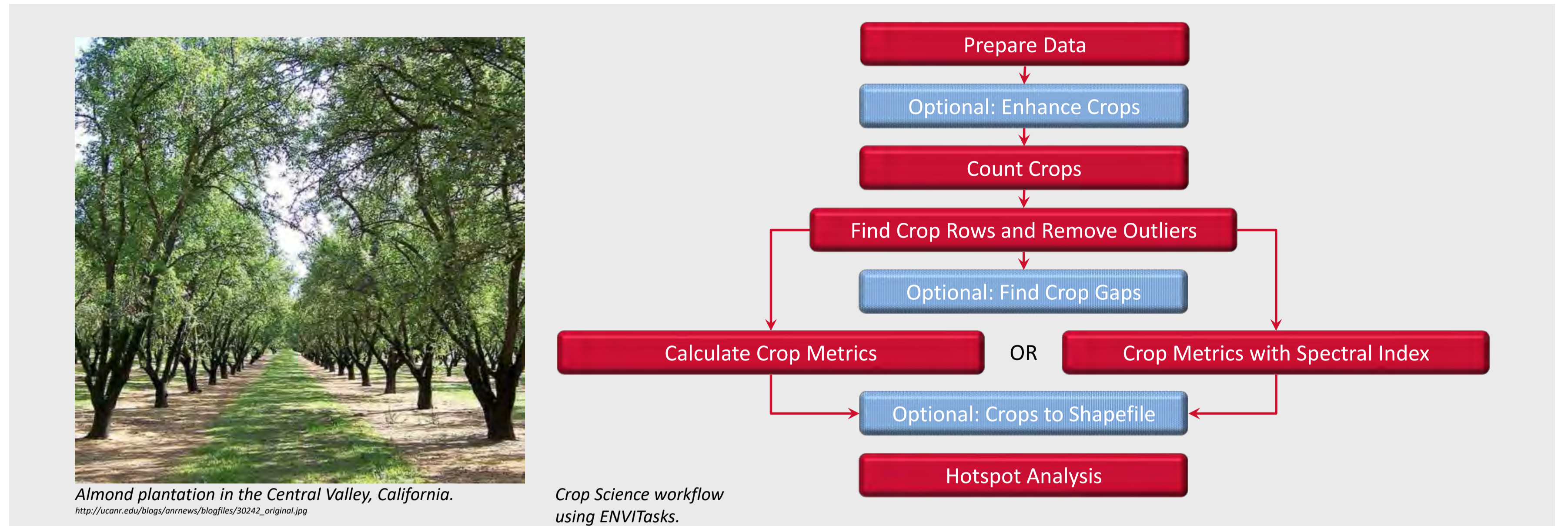
AUTOMATION

The Crop Science workflow is based on the ENVI application programming interface (API). Each processing step is represented by corresponding ENVITasks. Therefore, it can be embedded in virtually any existing geospatial workflow for operational applications.

Tested integration options are:

- Deployment within service-based information systems, notably ArcGIS®. This allows to make the application available to organizations through their Portal for ArcGIS® website.
- Publishing the processing tasks as services via the Geospatial Service Framework (GSF). GSF is a cloud-based image analysis solution to publish and deploy advanced ENVI image and data analytics to existing enterprise infrastructures or cloud solutions.
- General implementation in geospatial workflows using the IDL bi-directional Python bridge.

CONCLUSIONS

- This precision agriculture workflow is suitable for diverse crop species and provides farmers with a fast and accurate solution for tailored crop management to guide activity.
- The extracted metrics of the individual plants in the crop area help to predict yield and allow farmers to efficiently identify crop stress.
- This workflow can be made turnkey for operational use and deployed to enterprise environments. For example, its analytics are implemented in Highland Hub, a web-based farm management system of Highland Precision Ag providing services and analytics for crop monitoring.
- Future research will focus on tracking crop health over time by employing time series analytics on multi-temporal stacks of collected UAV imagery.

Almond plantation in the Central Valley, California.
http://ucanr.edu/blogs/temnews/blogfiles/30242_original.jpg

Crop Science workflow using ENVITasks.

Prepare Data
Optional: Enhance Crops
Count Crops
Find Crop Rows and Remove Outliers
Optional: Find Crop Gaps
Calculate Crop Metrics   OR   Crop Metrics with Spectral Index
Optional: Crops to Shapefile
Hotspot Analysis

True-color reflectance image, acquired 2015 by Pléiades over an almond plantation, Central Valley, California.

ENHANCE CROPS Spectral index image based on the BAI to enhance the individual almond trees.

COUNT CROPS Classification image with circles that represent the almond trees.

HOTSPOT ANALYSIS Variations in tree health (GNDVI) throughout the plantation.

CROP METRICS Almond trees are colored according to relative GNDVI values to describe their vigor.

FIND CROP ROWS & CROP GAPS Removed outliers are displayed in yellow, and missing almond trees in red.

Time series of Crop Metrics (above) and Hotspot Analysis (below) for the almond plantation.