Sensing Light Absorption by Crop Canopy for Estimating Yield in Almonds and Walnuts

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Introduction

- Lightbar system: PAR intercepted through canopy
- LIDAR: Canopy architecture
- UAV: Multispectral image (NIR, red, green)

- Are there any relationship between them?
- What is the minimum amount of information needed to estimate crop yield?
Outline

1. Comparison between sensors
   a. LIDAR versus PAR. Can volume be estimated from PAR intercepted data?
   b. PAR versus UAV. Can PAR intercepted be estimated from reflected radiation?

2. Yield estimation
   b. Net photosynthesis and yield

3. Conclusions
1a. Methodology for LIDAR and PAR data comparison

LIDAR point cloud

PAR intercepted grid (Lightbar)

Beer-Lambert’s law

\[ I = I_0 e^{-kh} \]

\[ V_{PAR} = kV_{LIDAR} = -\ln \left( \frac{I}{I_0} \right) \Delta A \]

I : PAR at the ground.
I₀ : PAR incident upon the uppermost surface
K : Canopy light extinction coefficient.
h : Distance of the light path though canopy

V_{PAR} : Optical volume
V_{LIDAR} : Real Volume
1a. Results for LIDAR and PAR comparison

Row based  →  Block based  →  Tree based

three different scales...

\[ y = 1.0862x + 107.04 \]
\[ R^2 = 0.7677 \]

\[ y = 1.35x + 74.576 \]
\[ R^2 = 0.7506 \]
1b. Methodology for NDVI and PAR intercepted comparison

- The images were georeferenced using 8 targets with known UTM coordinates.
- Radiometric correction was performed using 8 material with known reflectance values.
- Cumulative histogram was used to detect unrealistic pixels.
1b. Results for NDVI and PAR intercepted data

- Even though there were good correlations between NDVI and PAR intercepted for some of the days, the overall value of $r^2$ was low.

- NDVI index seems to be sensitive to shadows. This effect is especially important in images with high spatial resolution.
  - Indices less sensitive to shadows or filters need to be developed.
2a. Estimation of diurnal PAR intercepted

\[ \frac{P_t}{P_n} = \frac{I_t}{I_n} \]

\[ \frac{P_t}{P_n} = \frac{I_t}{I_n} \frac{A_t}{A_n} = \frac{F_t}{F_n} = f(\text{zenith}) \]
2a. Estimation of seasonal PAR intercepted

- PAR at midday on different days need to be estimated to obtain *seasonal growing curve*.

\[
\frac{P_n^s}{P_n^*} = f(\text{growth})
\]

- \(P_n^s\): Noon PAR intercepted on the day to be estimated
- \(P_n^*\): PAR intercepted at noon on the day of the measure
Calibration of PAR intercepted by a block

- Almond: $y = 1.0003x - 3159.5$, $R^2 = 0.8494$
- Walnut: $y = 1.0246x - 9001.7$, $R^2 = 0.811$

- June 28th was used as a reference day to estimate midday PAR intercepted for the rest of the days.
2a. Diurnal and seasonal behavior

Almond example

Walnut example
2b. Net photosynthesis and potential Yield

\[
\frac{dP}{dt} = \left[ \frac{\gamma P_m I_0 \left(1 - e^{-k(LAI)}\right)}{A_0 k + P_m 0} \right] - R_c
\]

PAR intercepted

\[ k = f(\text{zenith}) \]

Light extinction coefficient

\[ \gamma = 0.05 \frac{\mu\text{mol(CO}_2\text{)}}{\mu\text{mol(photon)}} \]

Quantum efficiency

\[ P_m 0 = 23.5 \frac{\mu\text{mol}}{m^2 s} \]

Light saturated photosynthesis
## 2b. Respiration coefficient determination

### Present work

<table>
<thead>
<tr>
<th></th>
<th>Algebraic equation based on a constant respiration value:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( R_c = r_d \times LAI \times A_p )</td>
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</tbody>
</table>

- \( R_c \): Dark respiration of a block of five trees
- \( r_d \): Dark respiration of the leaf
- \( LAI \): Leaf area index
- \( A_p \): Area of a block of five tree

### Future work

<table>
<thead>
<tr>
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<th>Differential equation solve for net photosynthesis using:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>( R_c = \mu \frac{dP}{dt} + b_0 P )</td>
</tr>
</tbody>
</table>

- \( R_c \): Dark respiration of a block of five trees
- \( \mu \): Growth component
- \( b_0 \): Maintenance component
- \( P \): Gross photosynthesis
2b. Potential Yield
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- **Midday PAR intercepted by the canopy on June 28th.**
- Values correspond to the average of all the blocks.

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**Nickels season 2012**

- Almond
- Walnut

- Actual yield
- Potential yield

- *Midday PAR intercepted by the canopy on June 28th.*
- Values correspond to the average of all the blocks.
3. Conclusions

- Canopy volume obtained by LIDAR was found to be proportional to that estimated using PAR intercepted by the canopy. This suggests that there is no need to obtain both LIDAR and lightbar data. Lightbar data, which is easier to obtain, is sufficient.

- It is possible to have a reasonable identification of individual trees using edge detection and segmentation techniques if tree location are provided.

- It is possible to estimated diurnal PAR intercepted based on PAR intercepted at solar noon and zenith angle.

- PAR intercepted at solar noon though the season can be estimated using a seasonal growing curve.

- A reasonable correlation was found between estimated and experimentally measured yield in almond crop.
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Thank you for your attention!

Any comments and questions please?
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