IITB-Monash Research Academy

Indian Institute of Technology Bombay

MONASH University

An Indian-Australian research partnership

# A Case Study

on

# Leaf Area Index Estimation from drone based top-of-the-canopy digital Images

by

**Rahul Raj**
Research Scholar
CSRE, IIT Bombay
IITB-Monash Research Academy

# Overview of the series of two lectures

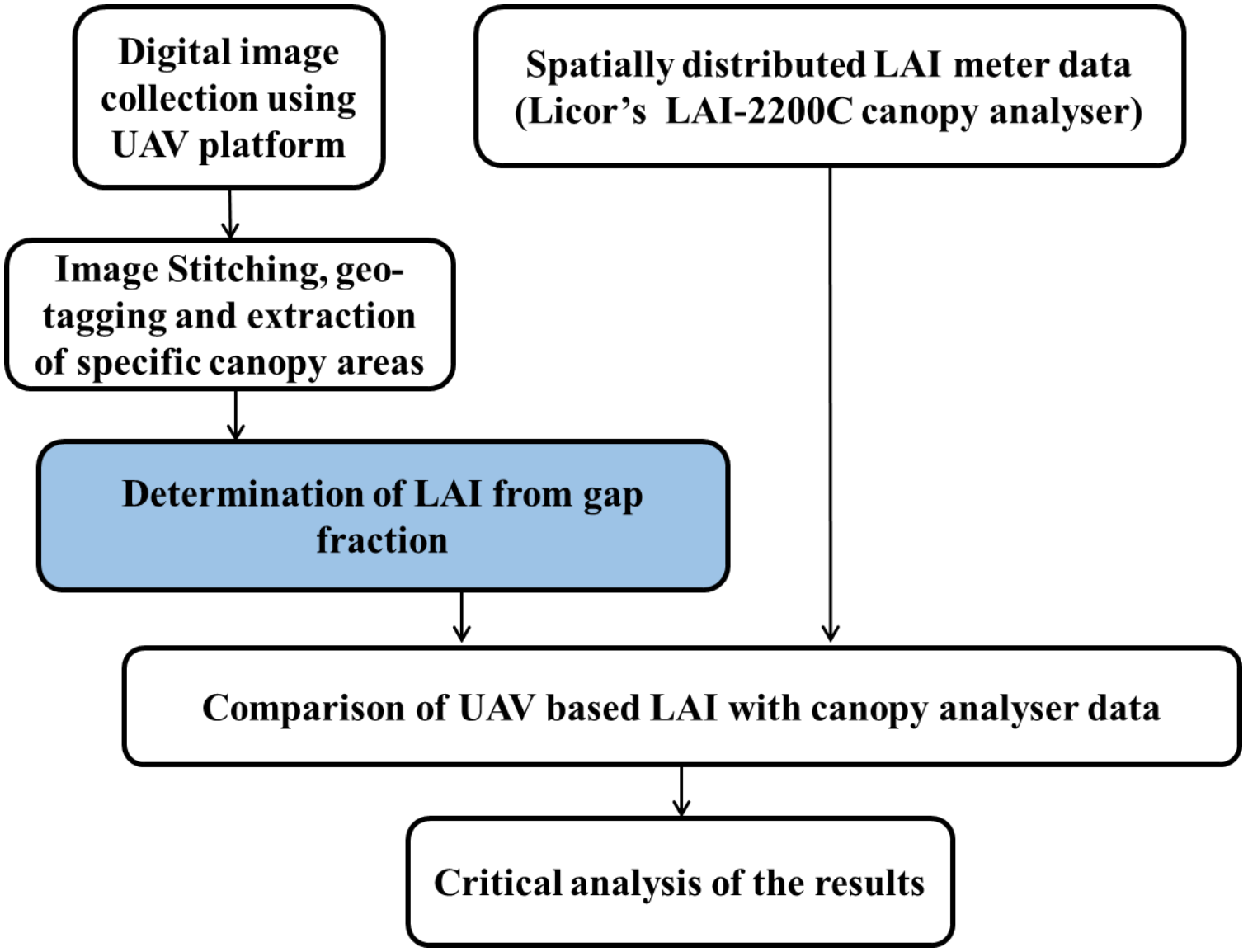
## Understand the method

- How to collect drone-based canopy images and its ground-truth
- How to separate the various classes from an Image
- How to find gap fraction and its relationship with LAI
- How to compare the results with ground-truth LAI data

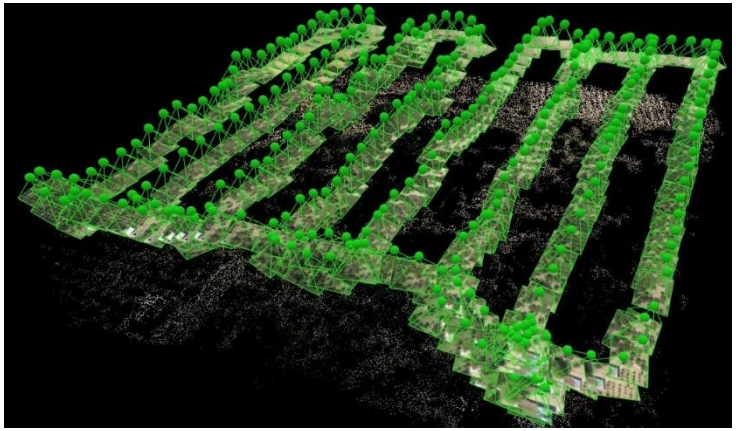
## Apply the technique on Images (Hands-on)

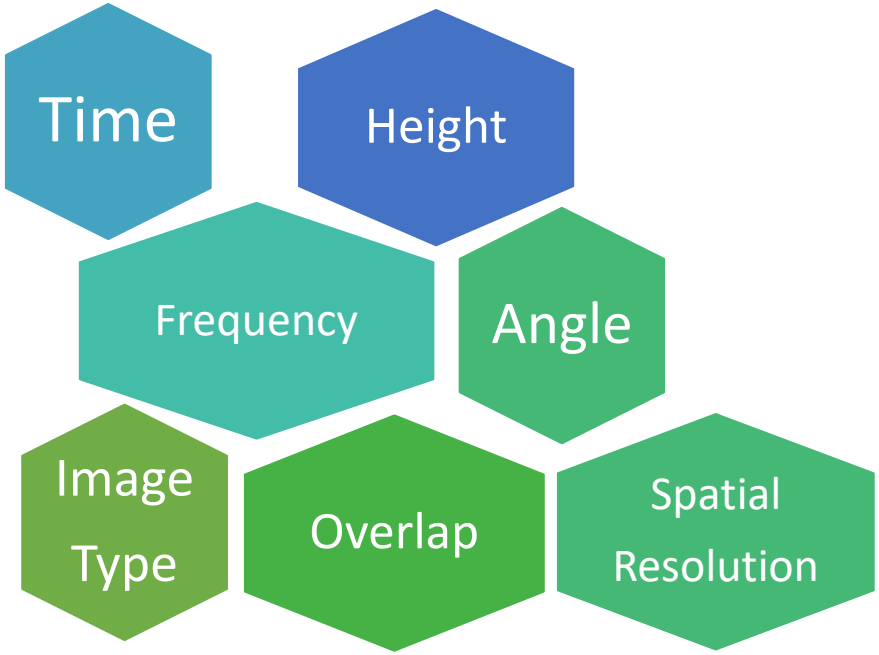
- You will be given few top-of-the-canopy images collected from a drone based digital camera. You will be asked to find gap fraction and LAI value of the area captured in that image.

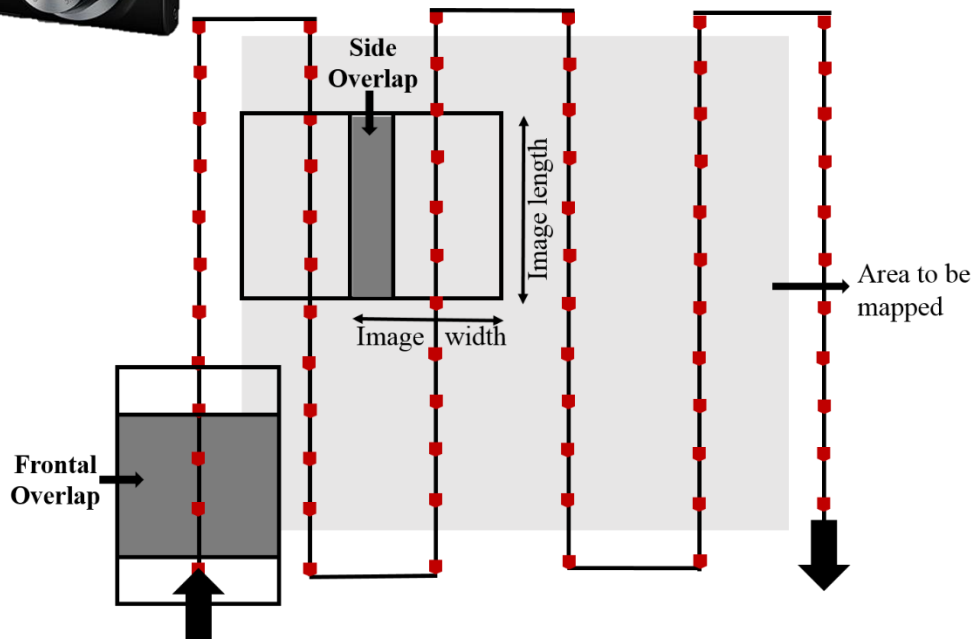
# Flowchart of the study



# Collection of Drone based top-of-the-canopy images



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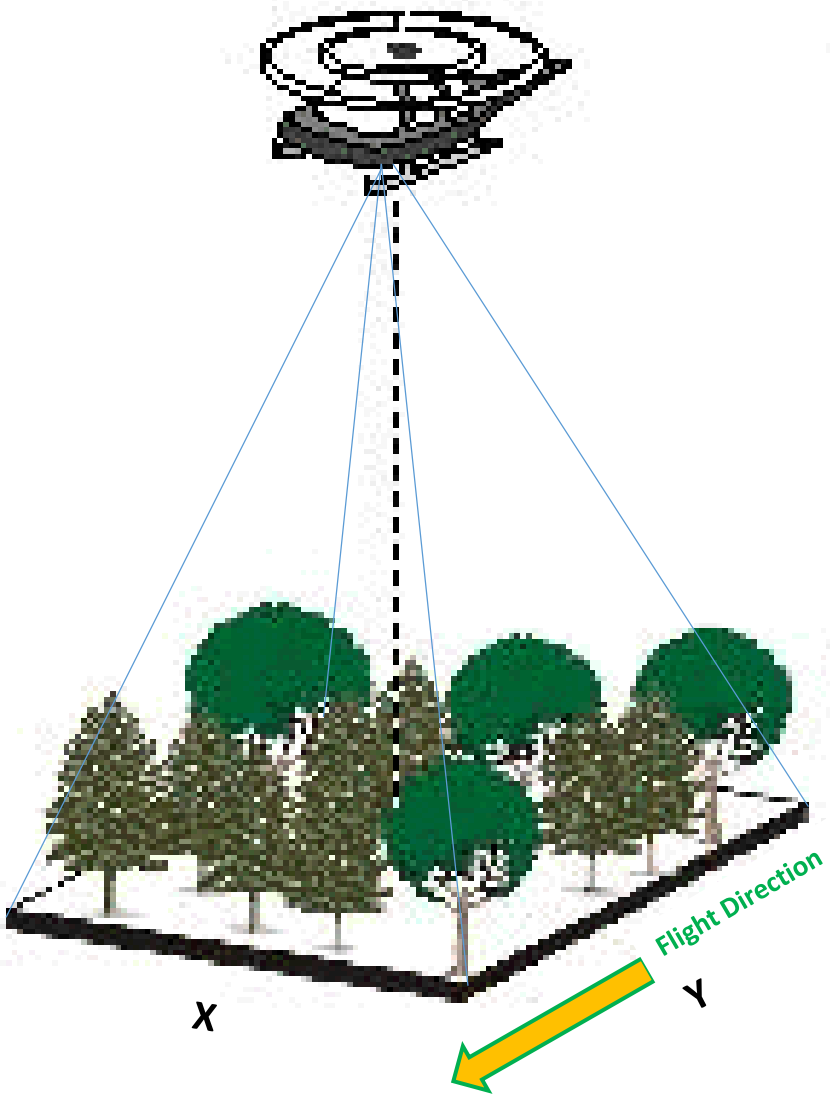


Find the area captured by an image and its spatial resolution if following are known:

- Height of drone: 25 meter
- FOV of camera: 45 x 60 degree
- Pixel count in X direction: 1024
- Pixel count in Y direction: 1280

# Stitched map of a citrus farm (Amravati, Maharashtra)

Ground truth LAI data collection

The **orthomosaic** map of the citrus farm is created by using 265 images collected from a drone based camera, flying at a height of 25 meters from ground

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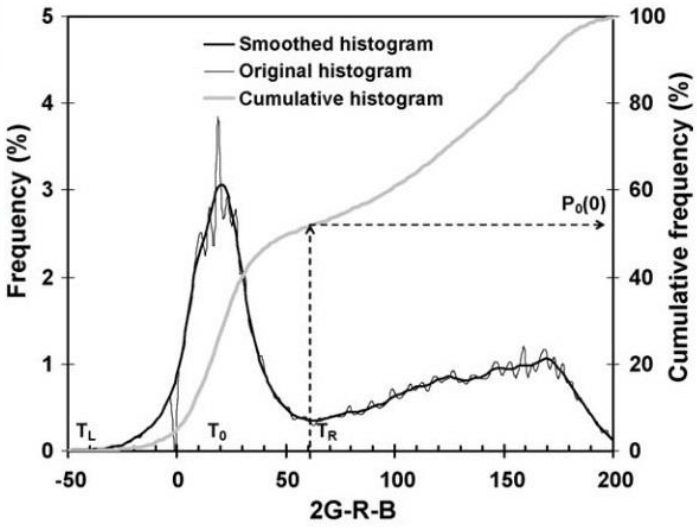
# Estimation of gap-fraction and LAI from canopy images

**Vertical gap Fraction extraction from digital photograph** → **Derive LAI from vertical gap fraction**

1. From digital photograph, calculate greenness and its histogram. (Greenness = 2G - B – R)
2. Use LPF to remove HF noise from histogram.
3. Calculate threshold $T_0$, $T_L$ & $T_R$.
4. Calculate Vertical gap fraction.

1. Relationship between canopy gap fraction and LAI is given by

$$LAI = \frac{-\cos(\theta)\ln P_0(\theta)}{G(\theta)} = \frac{-\ln P_0(\theta)}{k(\theta)}$$



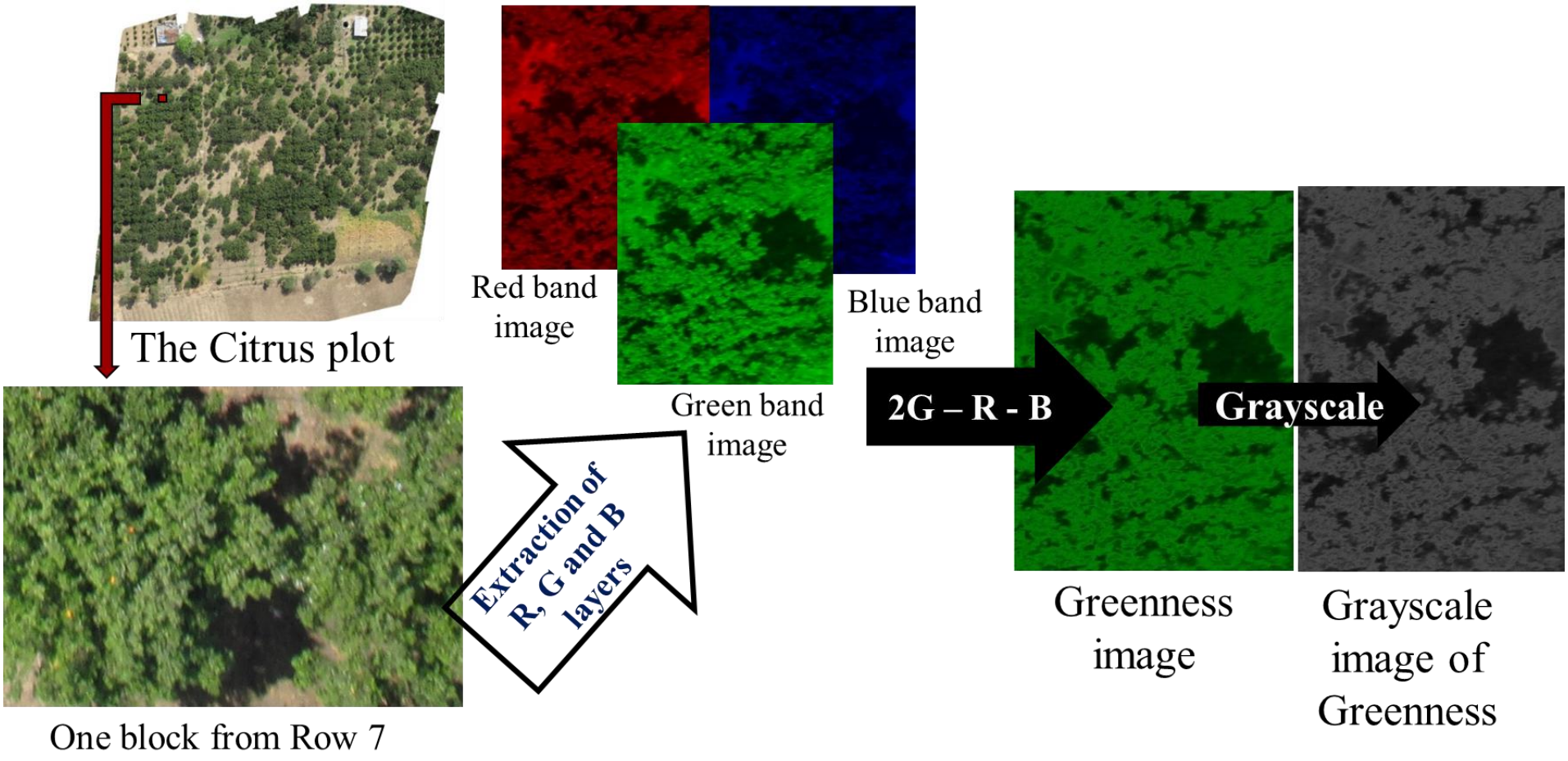

Source: Paper on "Retrieval of leaf area index from top-of-canopy digital photography over agricultural crops' by J. Liu and E. Pattey.

$P_0(\theta)$ : Gap fraction in view or solar zenith angle θ.
G(θ) : Foliage projection coefficient for the plane perpendicular to direction θ
K(θ) : Canopy Extinction Coefficient.

$T_R$ is an important point (first minima of curve) as it separates green and non green pixels. Minima is a point whose left and right side values are greater than its own value

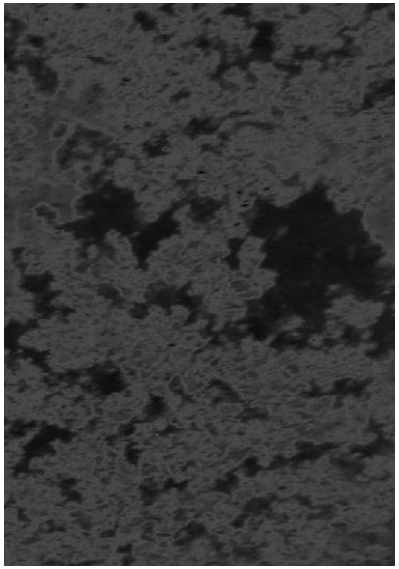
Gap fraction is representation of density of green crop canopy. i.e. how much percentage of ground area is not covered with leaves when seen from above the canopy. Higher the gap fraction, lower the green canopy density.

# Extraction of Area of interest from the image and convert it to grayscale

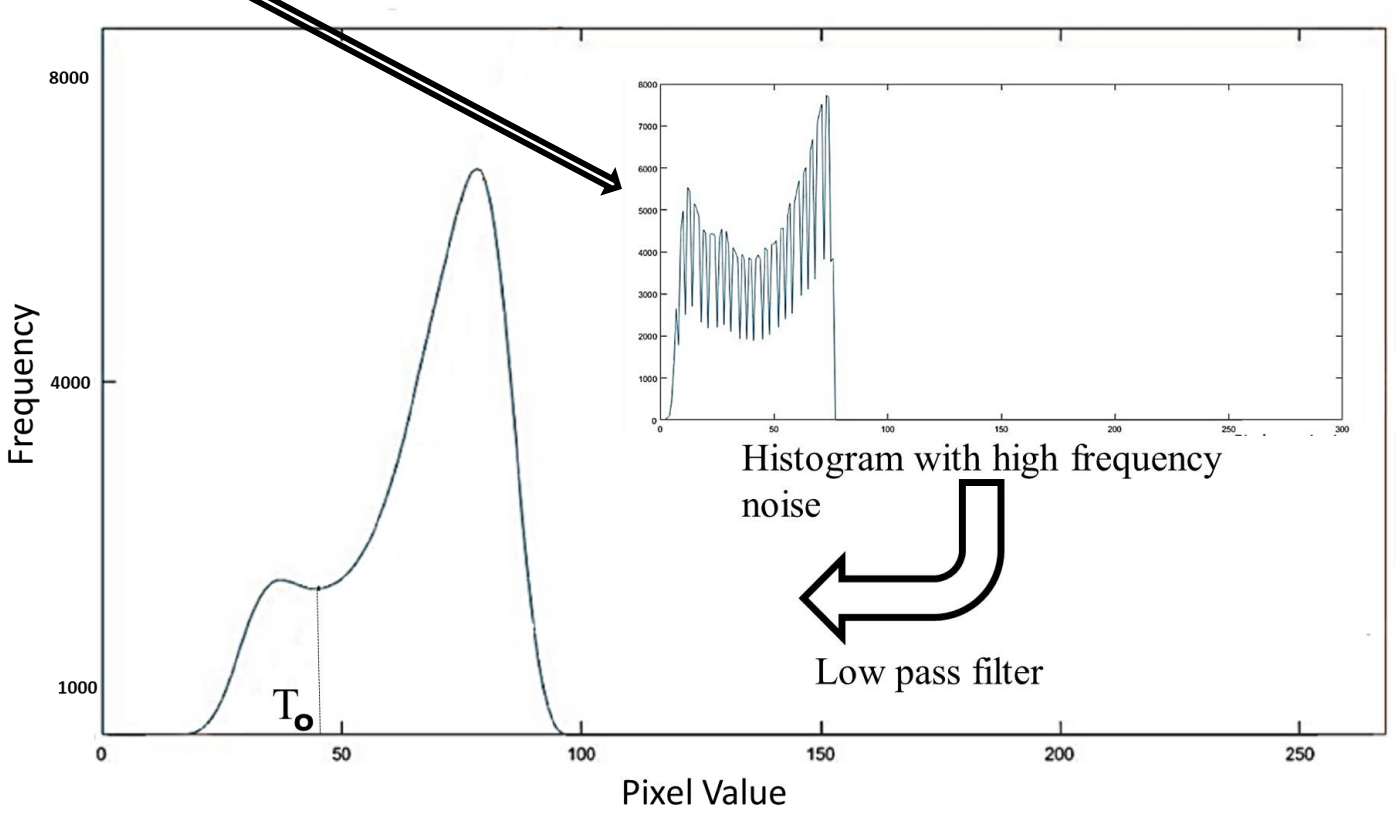



From same place in the citrus plot, the ground truth LAI is also collected

# Histogram of grayscale image

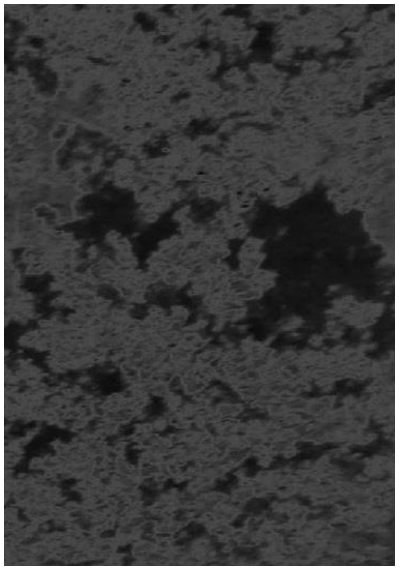


## Where are the two classes ???




**Gap Fraction = ???**

# Histogram of grayscale image



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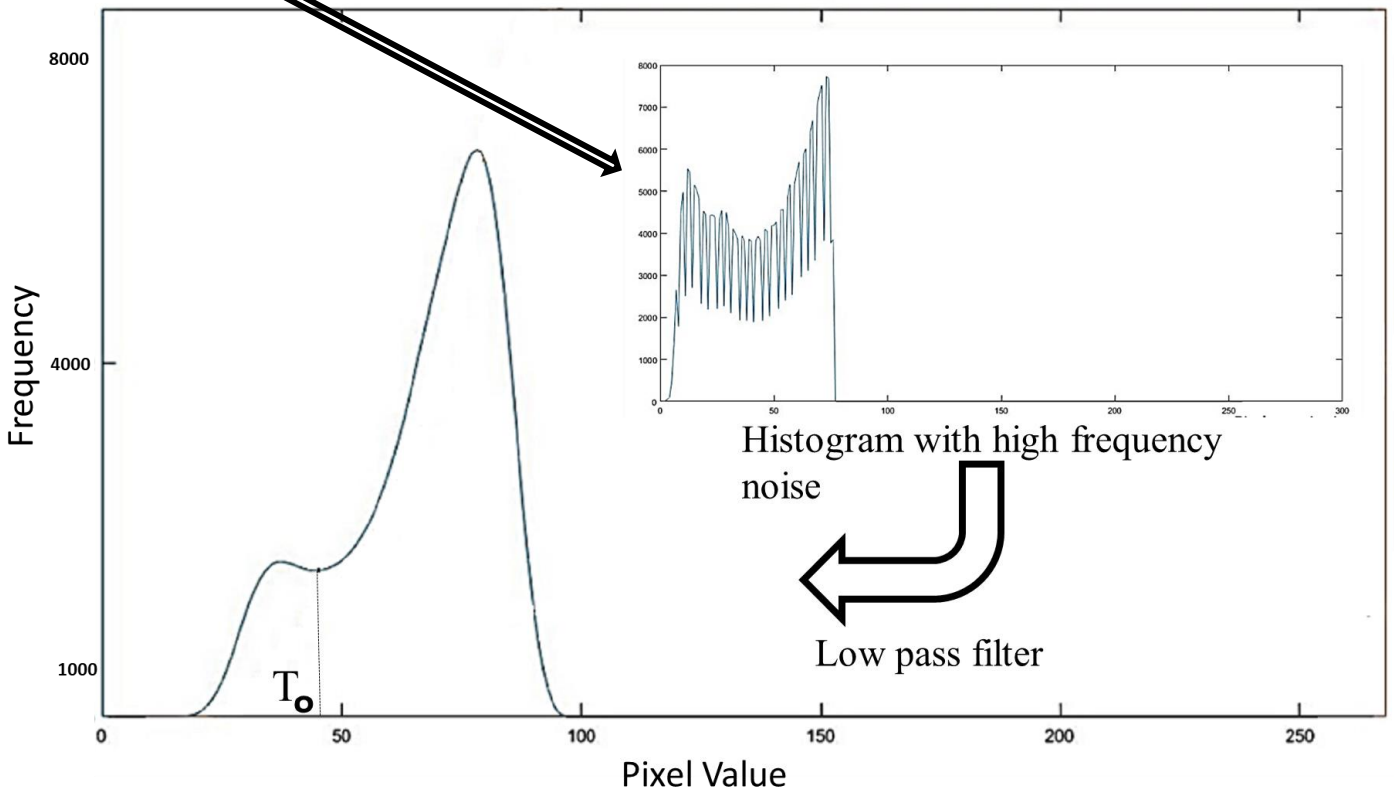
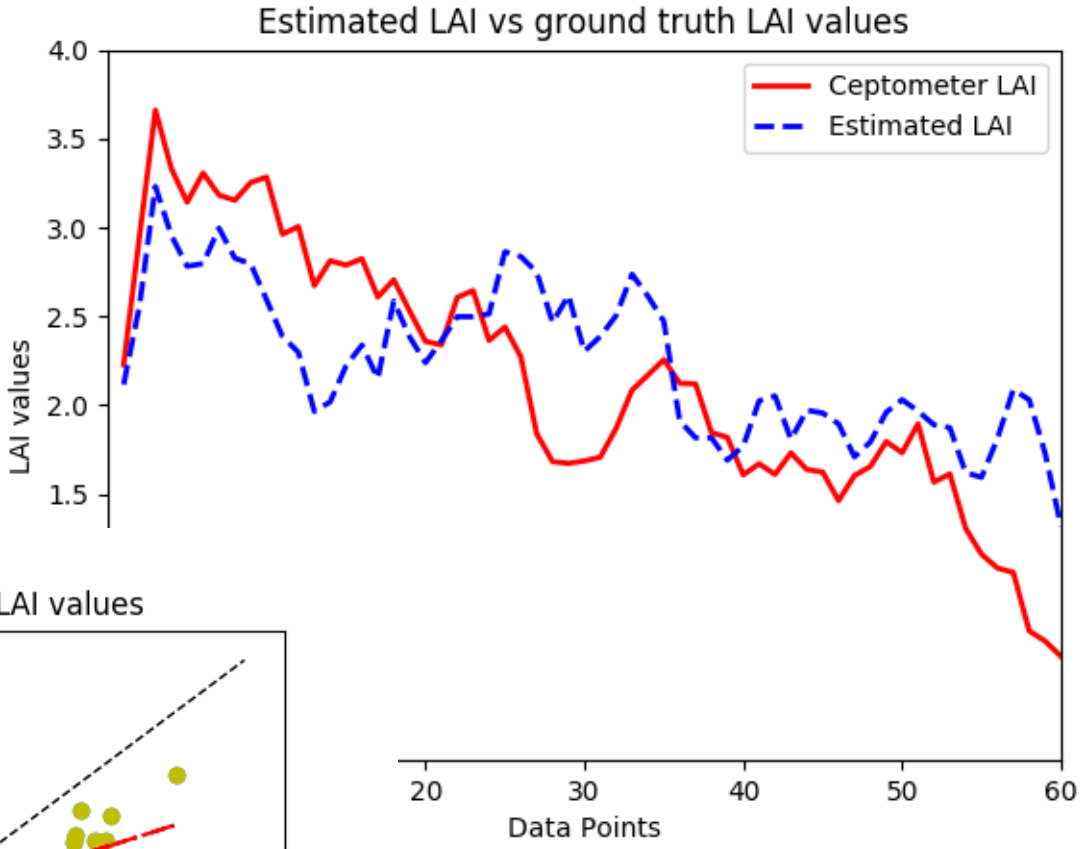
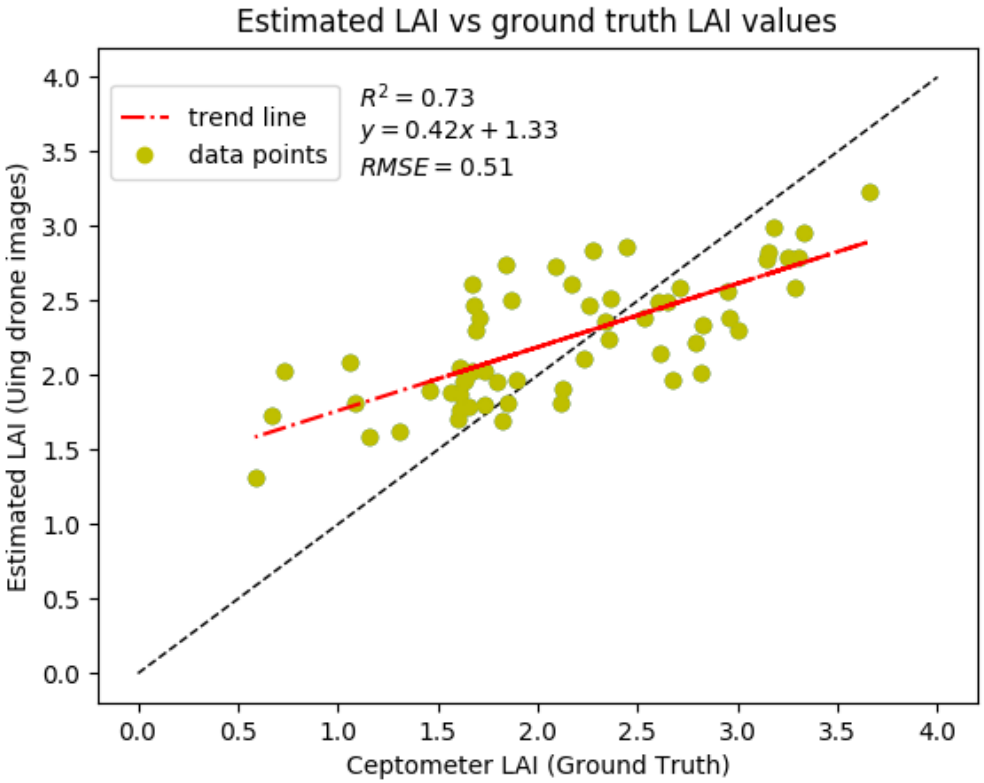


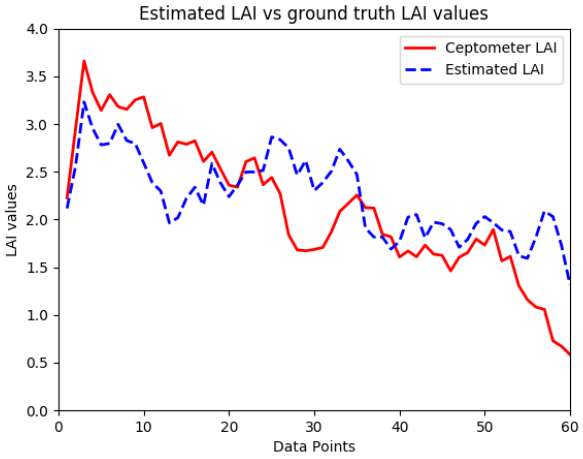

**Gap Fraction = (Number of pixels left to T0) / Total number of pixels in the histogram**

**LAI = -ln(Gap_fraction) / k**

# Analysis of Results






# Analysis of Results

- When GT-LAI > 3, estimated LAI is underestimated but the increase/decrease change trend remains the same
- When the GT-LAI < 1.5, estimated LAI is overestimated, and even the increase/decrease change trend is not maintained.

- The **difference in LAI values** is also because, the area of the **cropped image** (cropped from orthomosaic layer) will always be different from the area that is seen by the **fisheye lens** of the ceptometer; this is because the ceptometer view area is in the shape of a **triangle**, while the cropped images are approximated to a **rectangular** shape

# Limitations

- Effect of background pixel due to its color also contributes to error (for example, weed, green plastic and such others)
- Otsu's method only works when the two classes are having comparable number of pixels. It will not work for very open or high dense canopy
- It is also difficult to fly the drone at a constant height with a constant speed and angle (due to changing wind conditions), which, sometimes, blurs the image pixels. To reduce this blur, the drone should fly at a low wind condition, and different flight paths and directions should be used while collecting the images from multiple flights

## Solve the following:

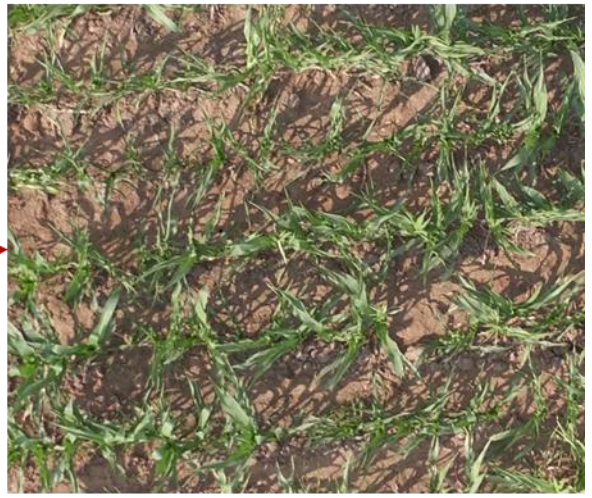
**Find LAI of the below image. Pixel value less or equal to '15' represents background and above '15' represents leaf.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 52 | 45 | 54 | 35 | 89 | 32 | 36 | 1 | 25 |
| 2 | 1 | 3 | 21 | 56 | 1 | 2 | 3 | 35 | 34 | 36 |
| 3 | 3 | 65 | 21 | 21 | 3 | 23 | 25 | 45 | 2 | 1 |
| 15 | 11 | 56 | 2 | 13 | 79 | 13 | 56 | 1 | 2 | 23 |
| 25 | 1 | 2 | 12 | 23 | 54 | 23 | 62 | 33 | 13 | 13 |
| 35 | 75 | 45 | 1 | 2 | 1 | 2 | 42 | 33 | 1 | 1 |
| 40 | 1 | 28 | 78 | 3 | 68 | 21 | 1 | 2 | 56 | 45 |
| 2 | 3 | 54 | 54 | 77 | 5 | 46 | 36 | 12 | 2 | 1 |
| 45 | 2 | 35 | 14 | 25 | 36 | 45 | 35 | 1 | 2 | 3 |
| 2 | 1 | 25 | 1 | 2 | 45 | 1 | 2 | 36 | 56 | 64 |
| 3 | 3 | 65 | 3 | 3 | 65 | 56 | 3 | 36 | 24 | 68 |

# What does LAI actually represent

# Find the LAI of these images

Drone Image



Cropped images