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Drone based Sensor Platforms

Dr. Gopi Kandaswamy
TCS Research and Innovation

Outline of this Talk

- What are drones?
- How do they fly?
- Components of a drone
- Applications of drones
- TCS drone platform
- Wildlife conservation
- Forestry
- Agriculture

What are Drones?

- Unmanned Aerial Vehicle (UAV)
  - Any aerial vehicle without a human on-board
  - Remotely controlled by a human operator OR
  - Controlled by onboard computers
- UGV/AGV
  - Unmanned/Autonomous Ground Vehicle
- UUV/AUV
  - Unmanned/Autonomous Underwater Vehicle

Types of Drones: Multirotor

- Vertical take-off and landing
- Fly slowly and hover
- Lower speed & endurance

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Types of Drones: Fixed Wing

- Higher speed & endurance
- Cannot fly slowly or hover
- Cannot take-off & land vertically

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Types of Drones: Hybrid

- Vertical take-off & landing
- Higher speed & endurance
- More complex & expensive

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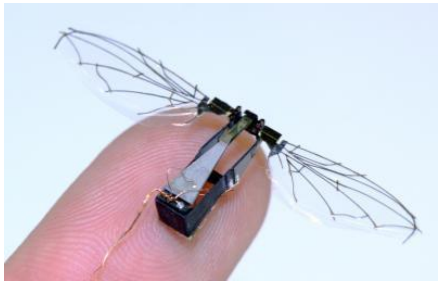
Types of Drones: Nano to Mega









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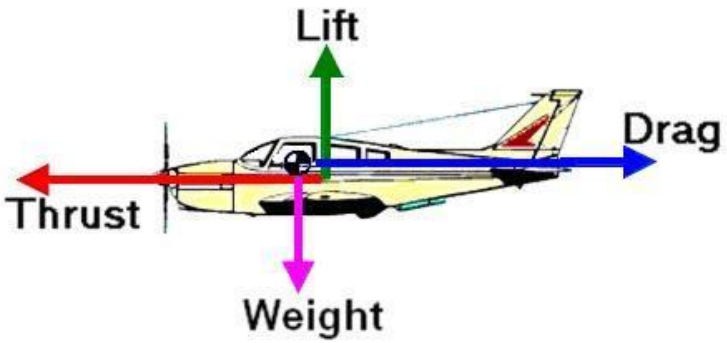
Four Forces of Flight



- Thrust: A force that moves aircraft forward
  - Needs to overcome drag (frictional force)
  - Produced by the engine
- Lift: A force that “lifts” the aircraft up
  - Needs to overcome weight
  - Created by airflow over wings

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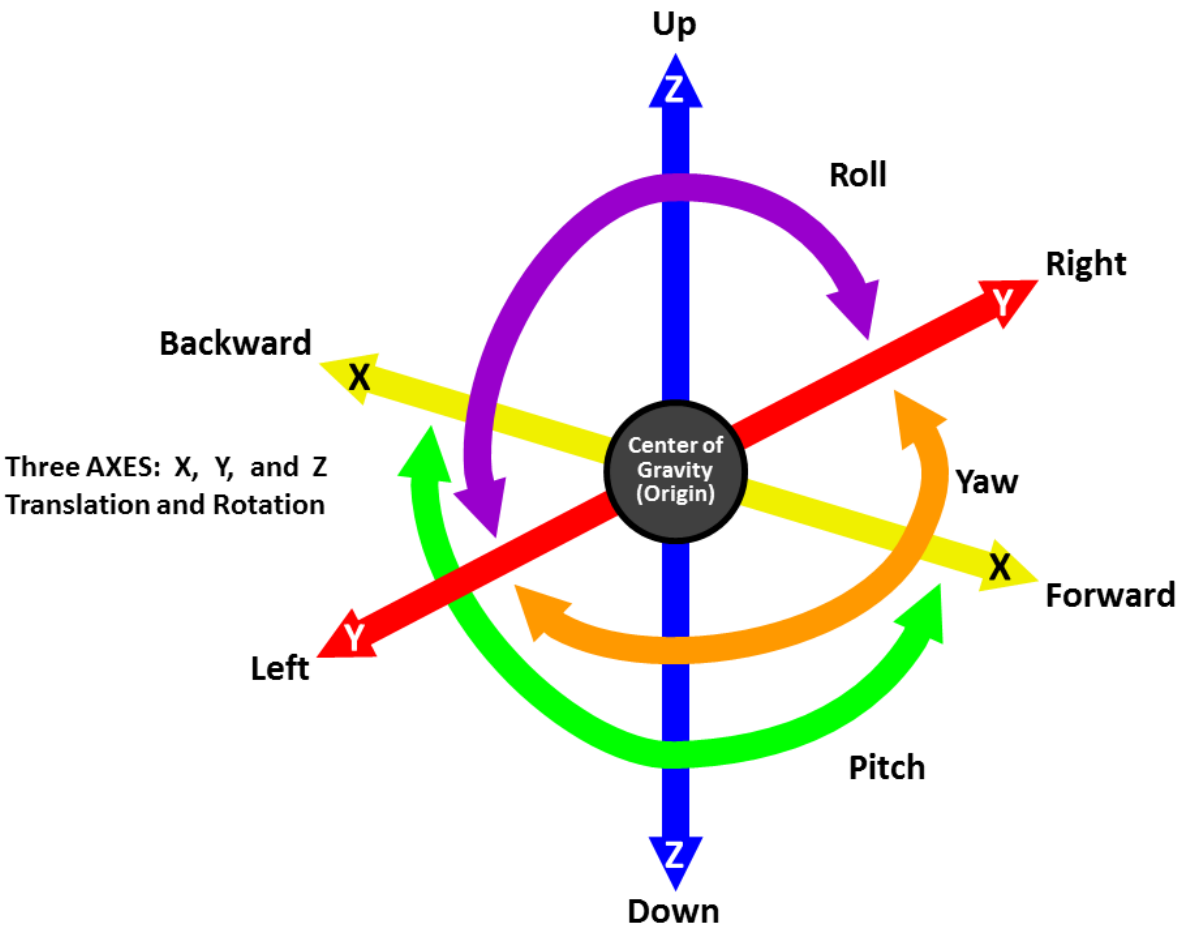
Six Degrees of Freedom



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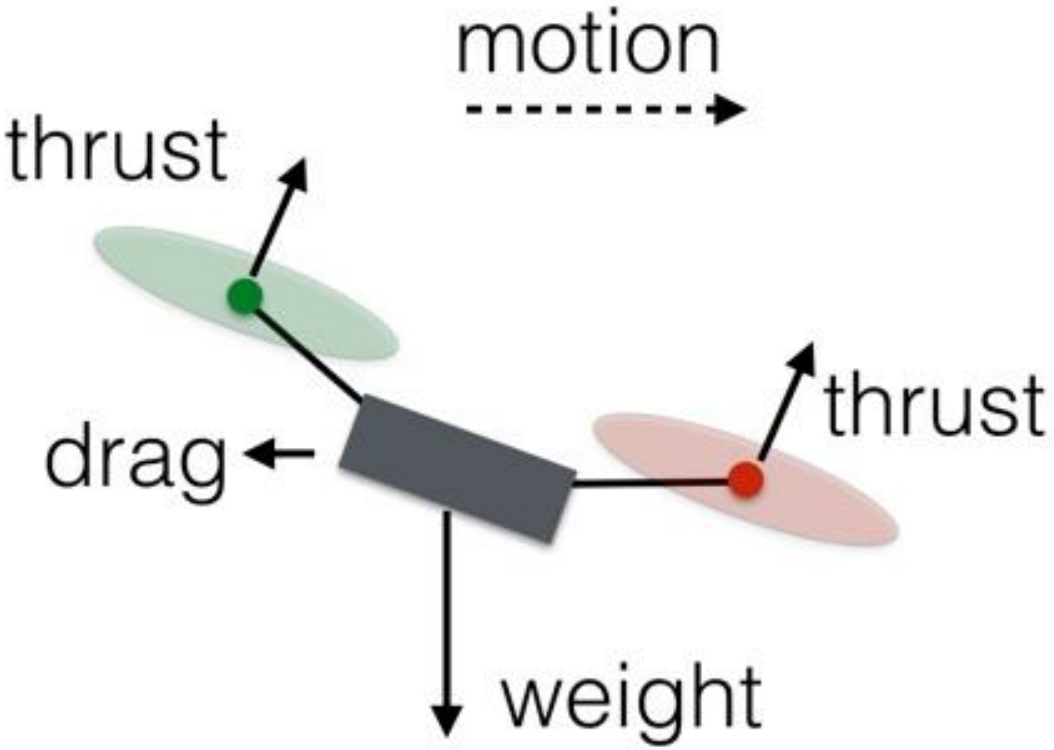
How does a Drone Fly?



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Components of a Drone - 1

Frame

Motor

Speed Controller

Propeller

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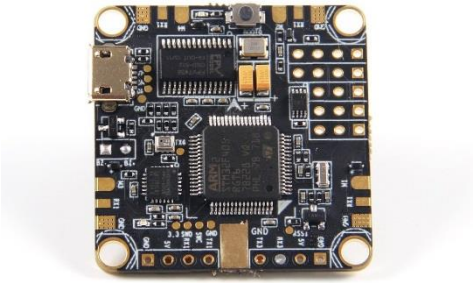
Components of a Drone - 2



Flight Controller

Radio Transmitter

Radio Receiver

Battery

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Components of a Drone - 3

Telemetry Module

Camera

Video Transmitter

Video Receiver

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Components of a Drone - 4

Ground Control Station

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Components of a Drone - 5

OSD

- Monitor vital stats of drone
- Battery voltage
- Current draw
- ESC temperature
- Pitch & roll values
- Radio signal strength
- GPS signal strength
- Altitude, speed, heading
- Distance to next waypoint
- Distance to home

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Sensors in a Drone - 1

- Accelerometer
  - Measures acceleration in all 3 axis
- Gyroscope
  - Measure angular rate in all 3 axis
- Compass
  - Determines heading
- GPS
  - Determines position based on GPS/GLONASS satellites
- Power module
  - Power supply to flight controller

Sensors in a Drone - 2

- Optical flow
  - More accurate landing
- Obstacle avoidance
  - Sense & avoid
- ADS-B
  - Broadcasts your position

Flight Control Algorithms

- PID (Propotional Integral Derivative) control
  - Closed loop control to stabilize the drone
- Inertial navigation
- Extended Kalman Filtering
  - Fuses all available measurements
  - Better error rejection
  - Non-linear state prediction
- SLAM
  - Autonomous navigation in GPS denied environment

Flight Modes

- Four controllable DoFs
  - Forward/backward, left/right, up/down, yaw
- Acro mode
  - Used by racing professionals
  - Gives more control over the drone
  - Uses least number of sensors for control
  - Less stable but high performance
- Stabilize
  - Flight controller (FC) just stabilizes drone
  - User controls all 4 DoFs
- Altitude hold
  - FC controls up/down
  - User controls 3 DoFss

Flight Modes

- Loiter (position hold or hover)
  - FC controls all 4 DoF
- Autonomous
  - FC controlls all 4 DoFs
  - Drone takes-off, reaches a preset altitude
  - Drone navigates through a set of GPS waypoints at set speed
  - Drone returns to the launch point, lands

Safety Features

- Redundant sensors
  - Accelerometers, gyros, compass and power supply
- Pre-flight and in-flight checks
  - Check all sensors and isolate faulty sensors and continue flight
  - Return to home or land in case of sensor failures
- Battery failsafe
  - Return to home in case of low battery voltage
- Radio failsafe
  - Return to home in case of radio signal loss
- GPS failsafe
  - Land in case of GPS signal loss
- Geo-fence
  - Return home if fence is breached

Typical Drone Specs

- Small drones (like DJI Phantom)
  - Weight: 1.5 kg
  - Range: 2-3 km
  - Speed: 40 to 80 kmph
  - Endurance: 20 min
  - Payload capacity: 300 gms
- Racing drones
  - Weight: 750 gm
  - Range: 2-3 km
  - Speed: 150 to 200 kmph
  - Endurance: 5 to 15 min
  - Payload capacity: 100 gms

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Applications of Drones

Hobby Drones

- Fun & recreation
- Photography
- Racing

Commercial

- Surveillance
- Disaster response
- Agriculture
- Inspection
- Media
- Entertainment

Military

- Reconnaissance
- Attack

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Agriculture

- Crop health analysis
  - Estimation of nutition & water levels
  - Detection of pests & diseases
  - Estimation of height, count, acreage & yield
- Spraying fertilizers & pesticides
- Soil analysis

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Infrastructure Inspection

- Pipeline inspection
  - Cracks, leaks, corrosion
- Railway track inspection
  - Rails, sleepers, fishplates
  - Ballast, vegetation
- Wind turbine inspection
- Powerline inspection
- Rooftop inspection

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Other Uses

- Disaster response
- Assess damage
- Search & rescue

- Medical supplies delivery
- Blood, organs, first aid kits

- Package delivery

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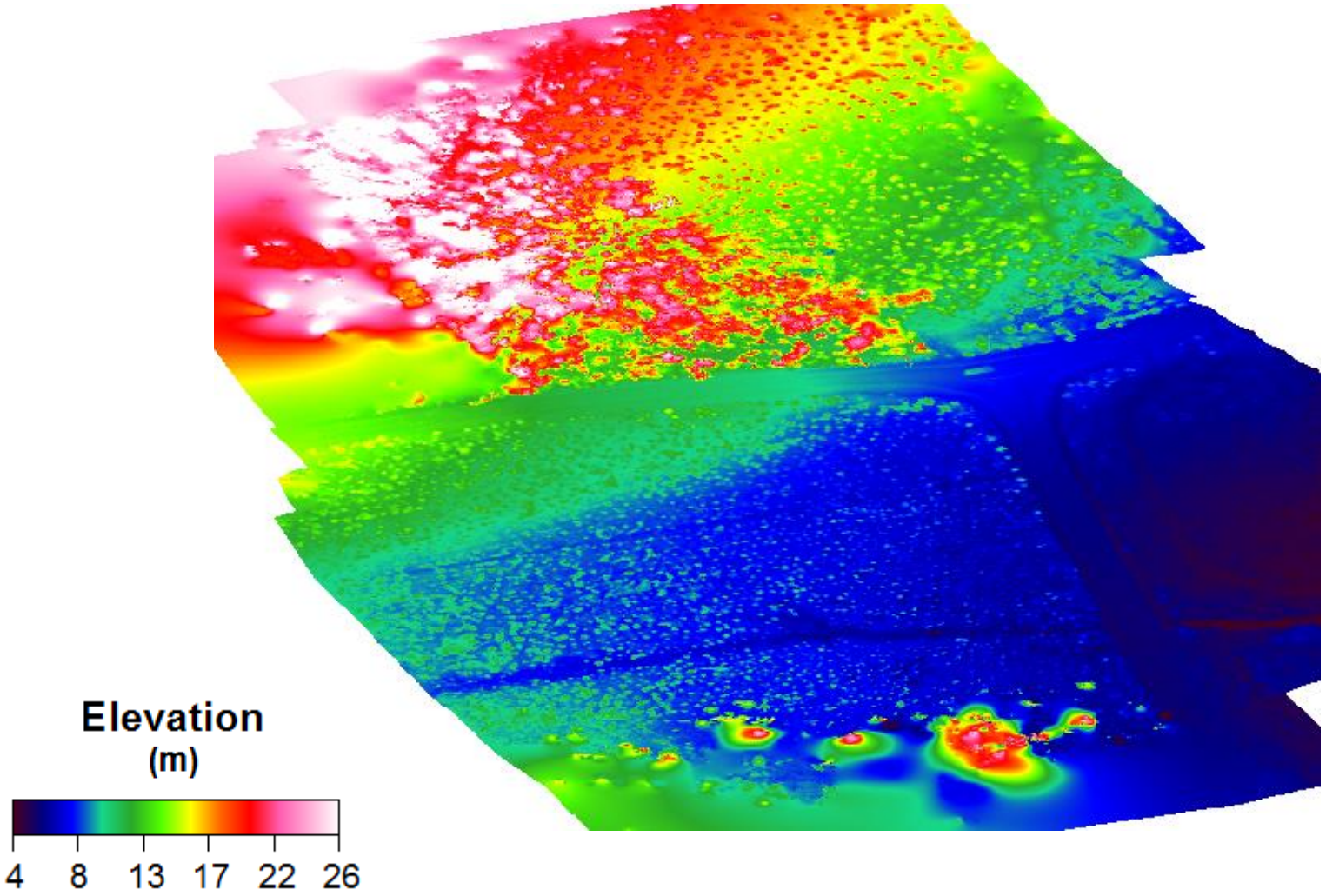
TCS Research UAV

- Fully autonomous multi-rotor drone, designed and built in TCS
- Innovative electronics and structural health monitoring with multiple fail-safes
- Long range, high endurance and high payload capacity
- Configurable multi-payloads; multi-spectral, visual and thermal cameras
- Customizable range, payload and radio frequencies
- Suitable for multiple applications; wildlife conservation, forestry, agriculture, infrastructure inspection


Wildlife conservation
Kaziranga National Park

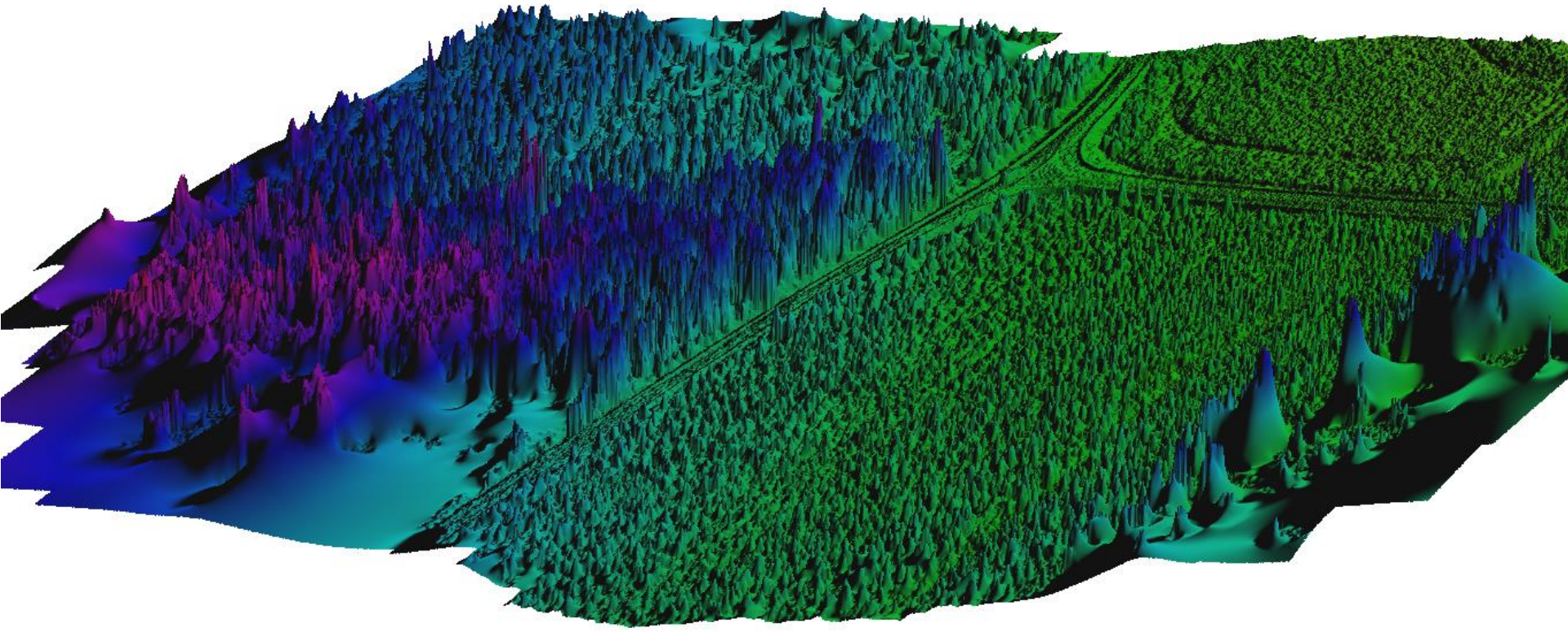
Drones in Forest Plantations

High Resolution Elevation Maps



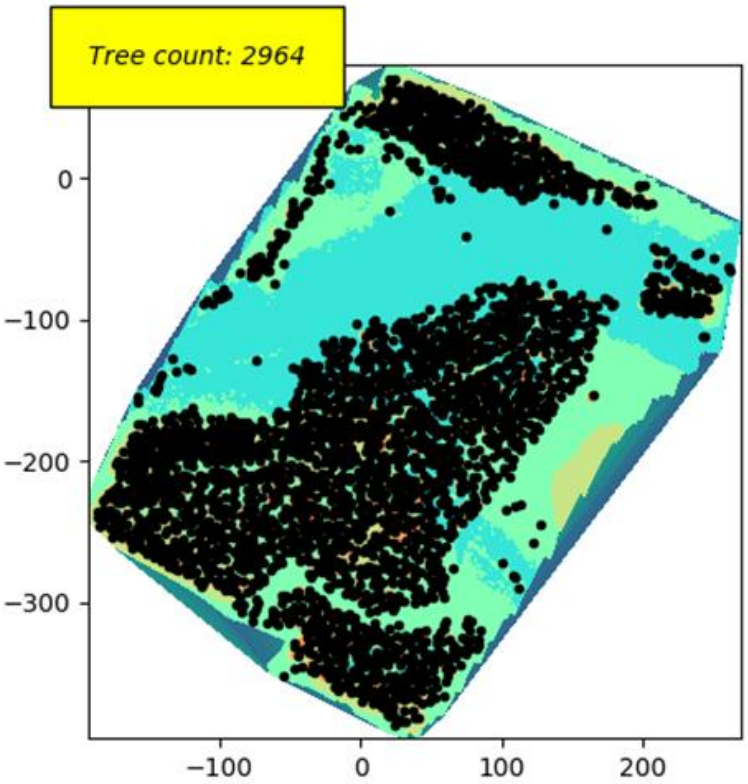
3D Point Clouds and DSMs

- Key forest figures
  - Tree count and height
  - Area and volume estimation

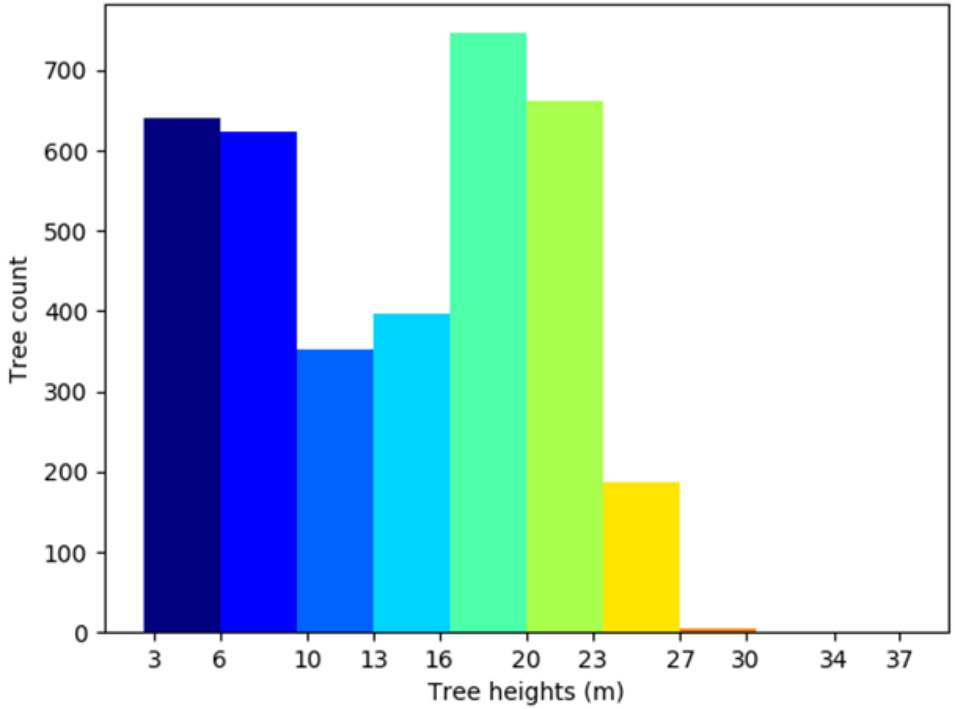


Tree Count and Tree Height Spread

Tree Count Snapshot



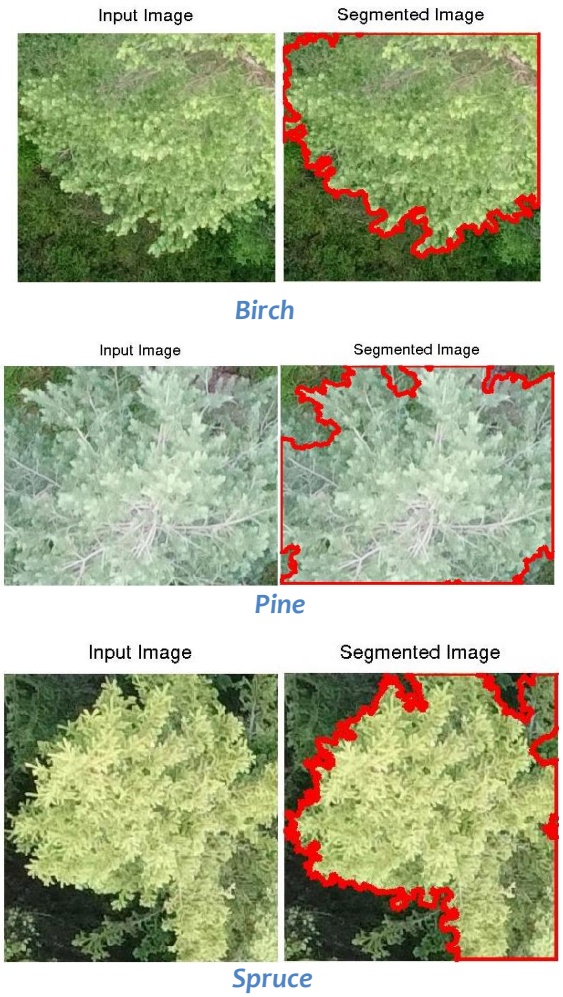
Frequency Histogram – Tree Height



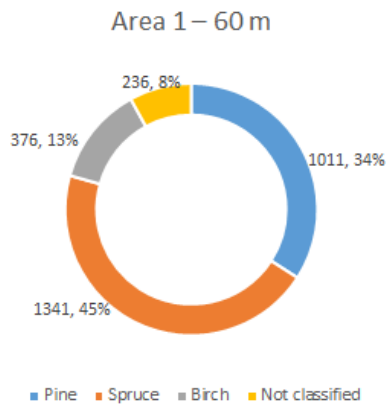
Estimating Crown Diameter

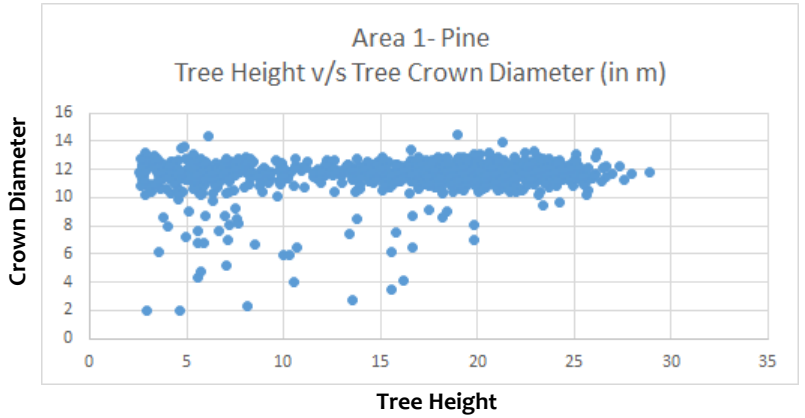
TCS Algorithm approach overview:

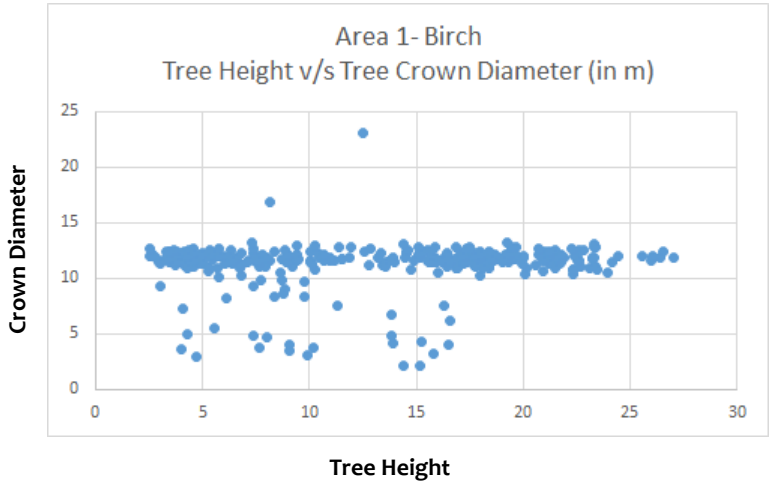
- The crown diameter estimation was performed through a process of continuous iterations of “fitting an ellipse” across the visible canopy of the target tree (*threshold of 1200 iterations were employed for the purpose*)
- The major axis of the ellipse for each tree was considered the diameter of associated crown.

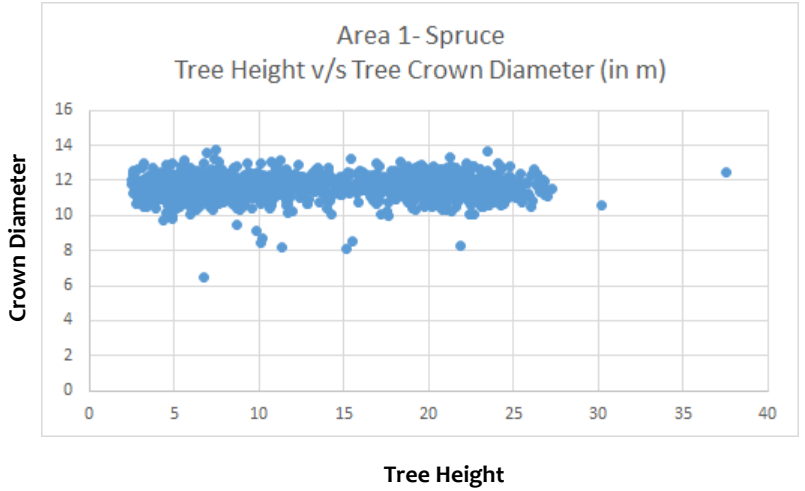


Tree Species, Crown Diameter Results





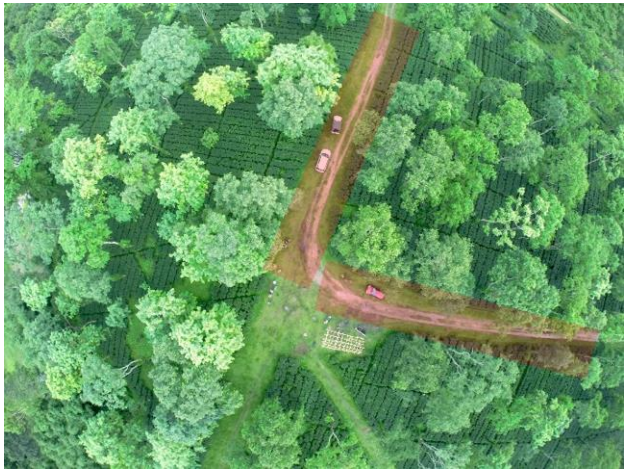




Species Recognition & Proximity Assessment

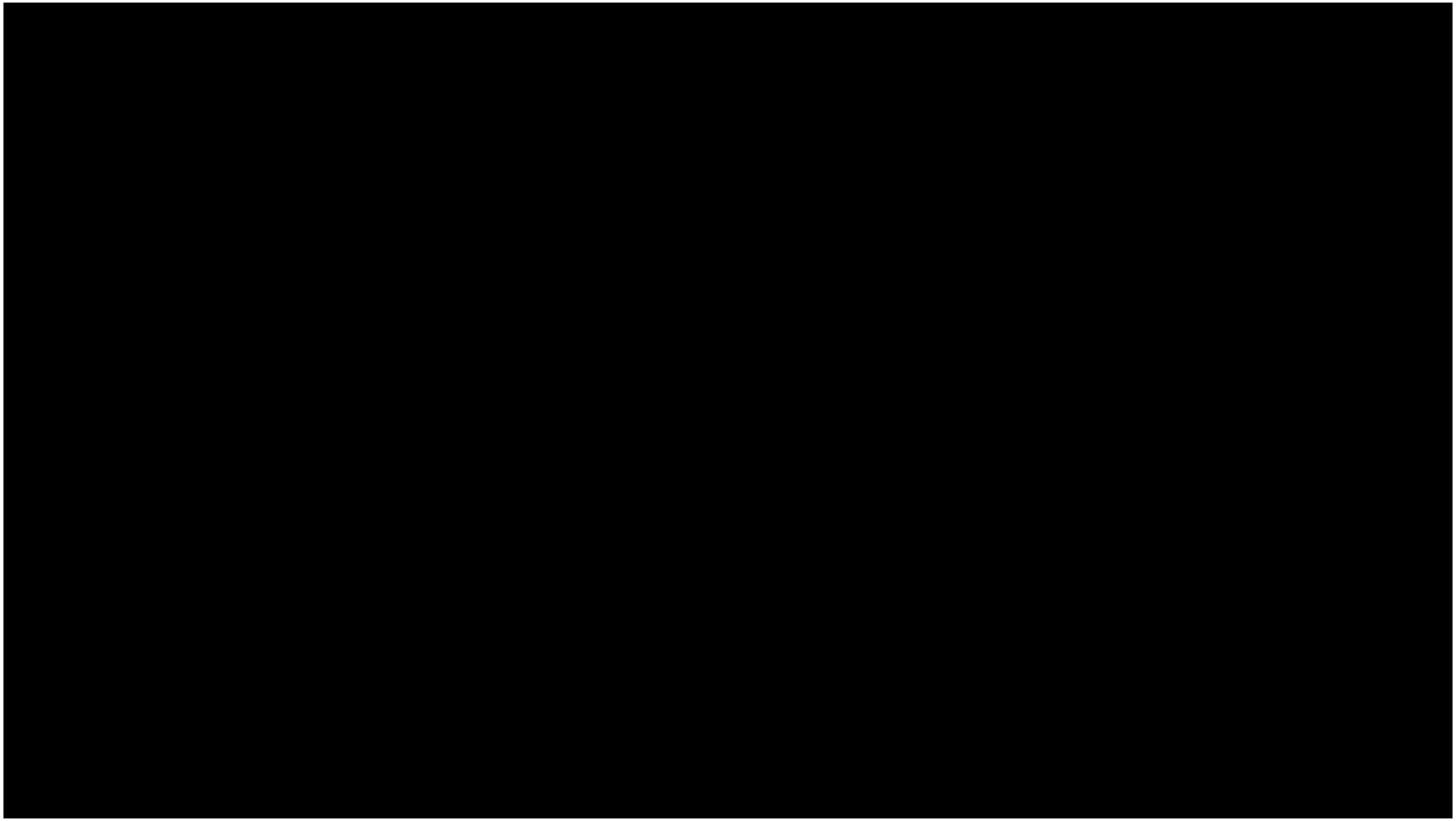
Species identification: Coconut

Road detection



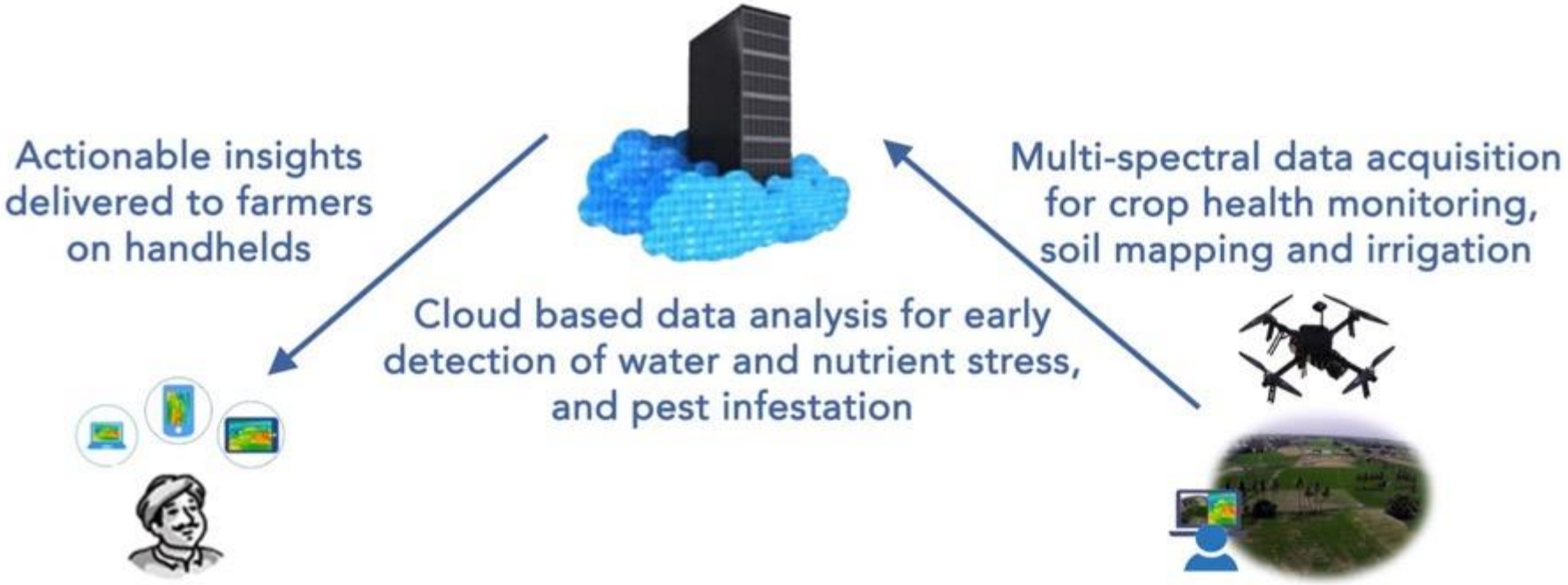
Water area detection

- Deep learning algorithm for tree species identification and common infrastructure detection
- Proximity assessment



Precision Agriculture

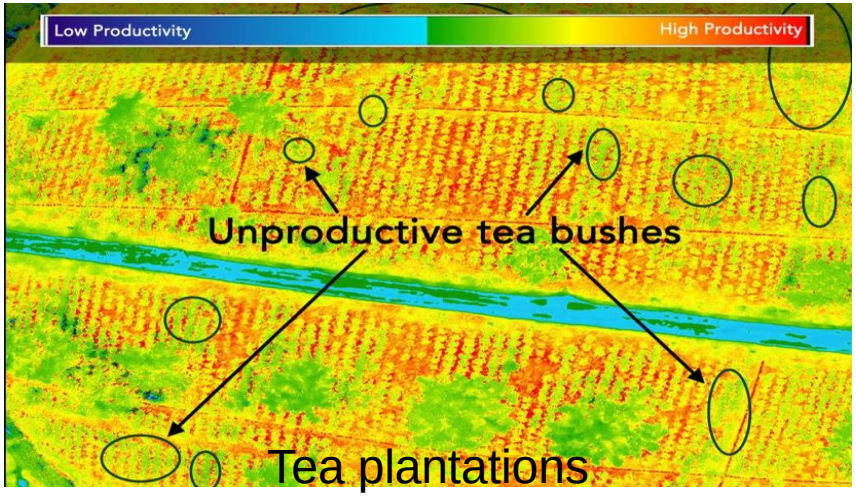
Drones for Precision Agriculture

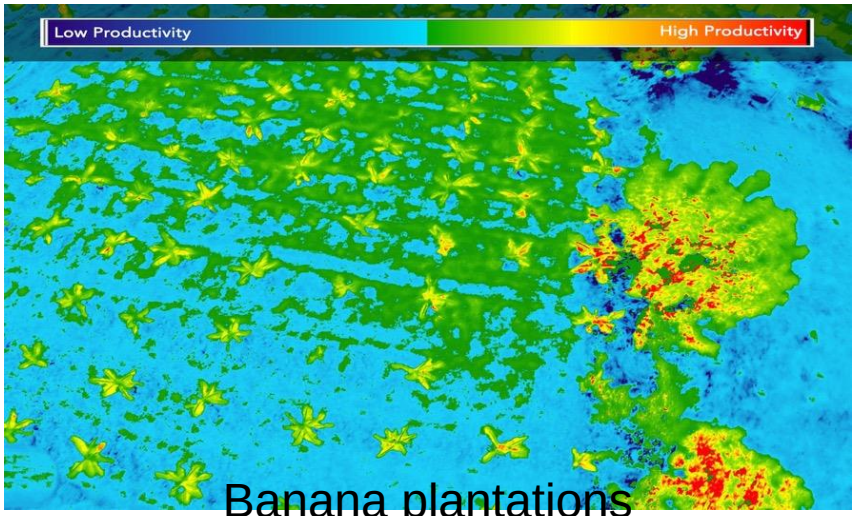


- Reduces water and fertilizer usage
- Reduces pollution
- Increases farmer income

Precision Agriculture Pilot Studies

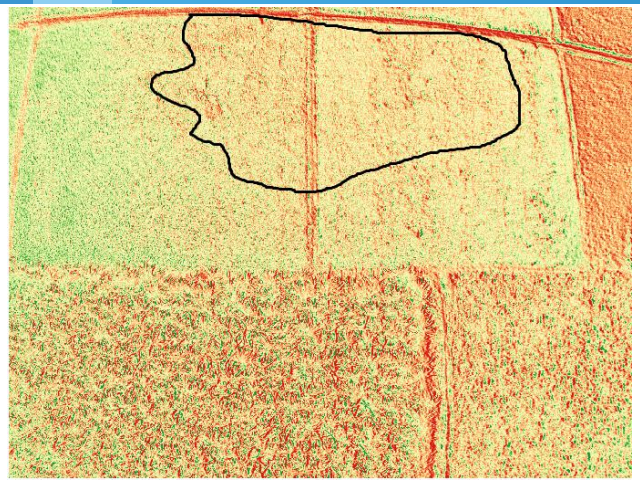
Crop Health Analysis



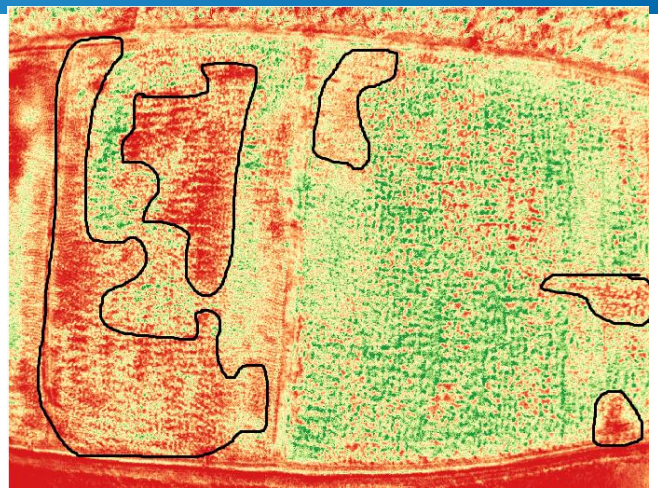


- Multi-spectral and visual imagery acquisition using TCS drones
- Accurate crop health analysis using various crop health indices
- Early detection of nutrient deficiencies and other problems
- Advanced algorithms for species identification, population estimation and localization

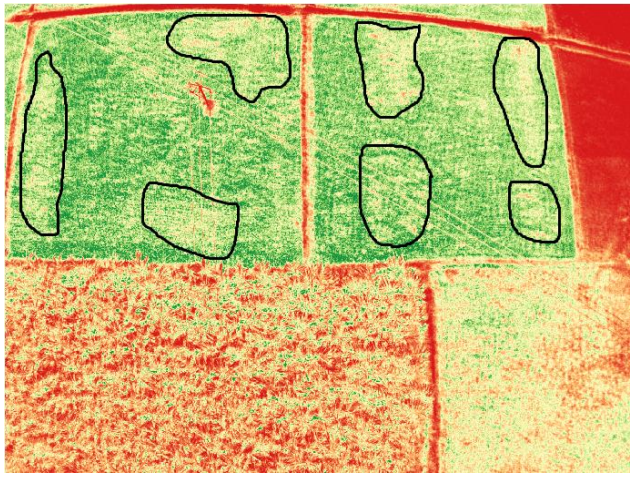
Early Detection of Crop Health Problems



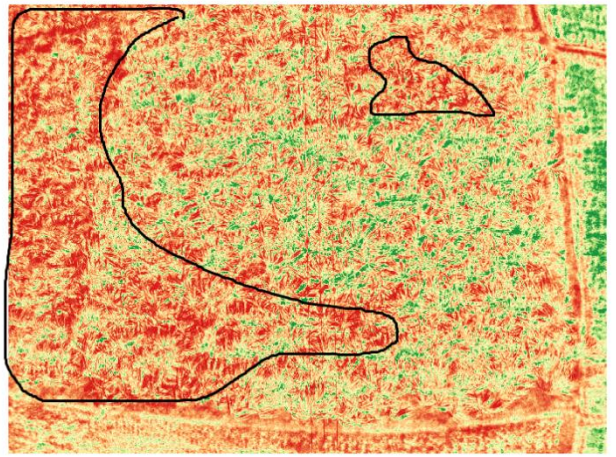
Nitrogen deficiency in paddy



Productivity variations in paddy

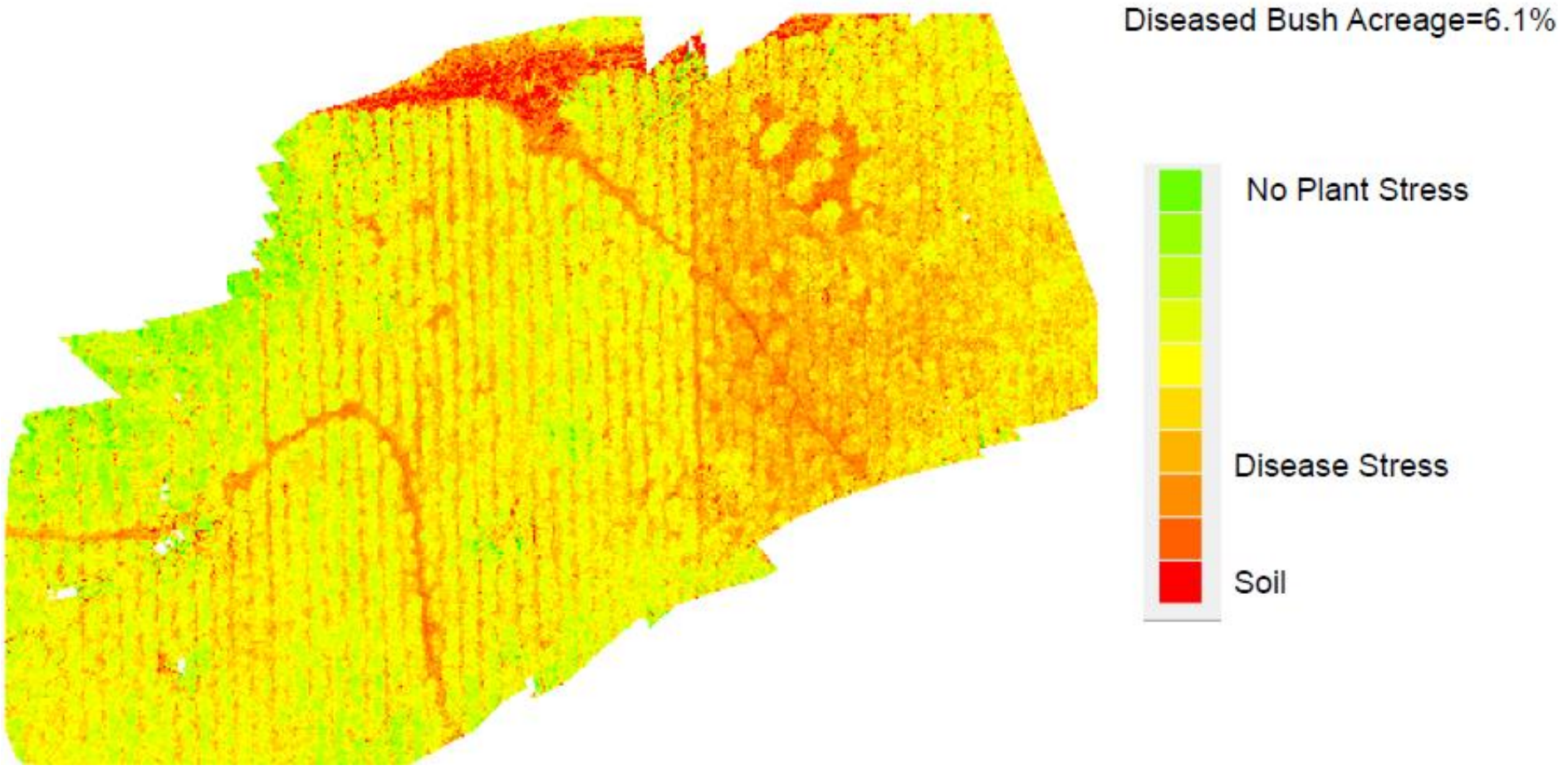


Poor tillering in paddy

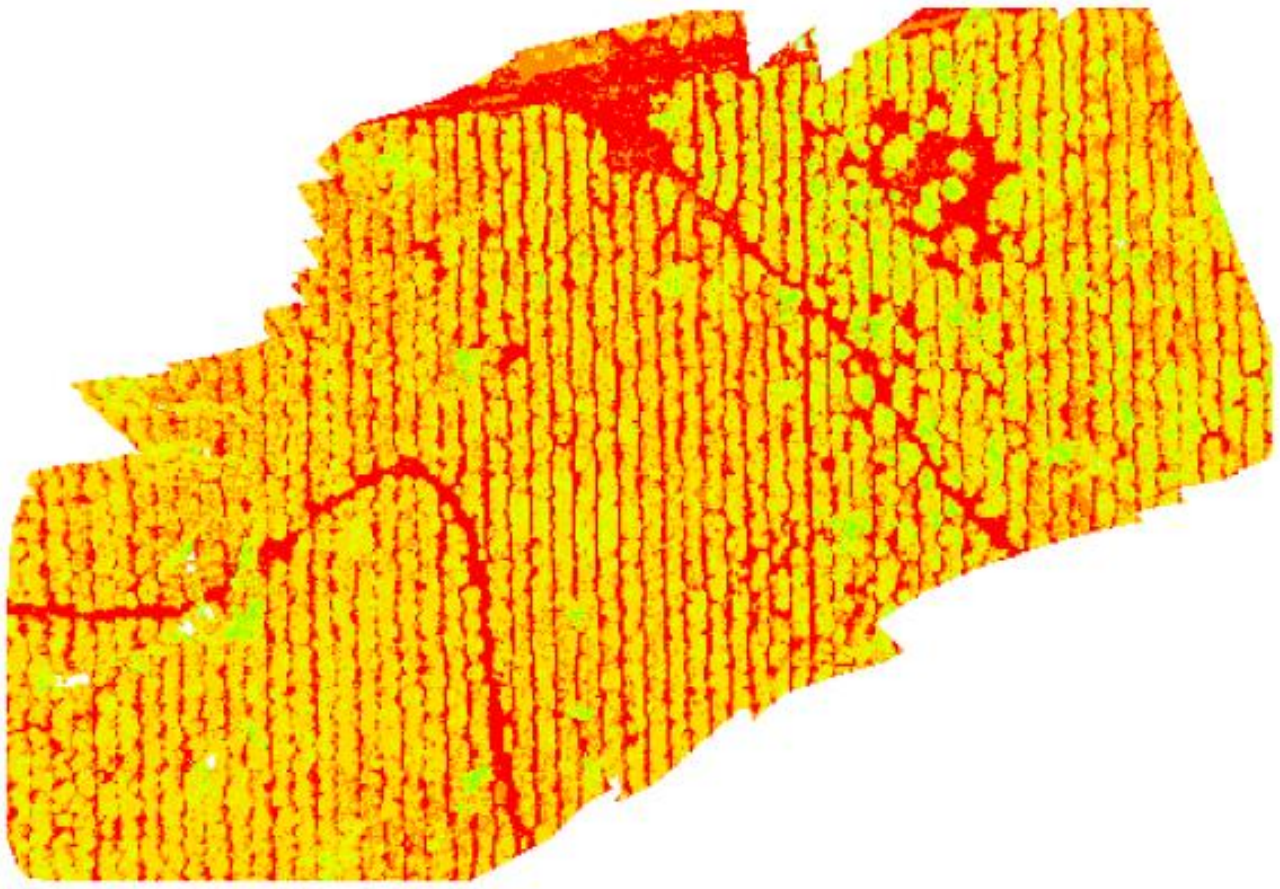


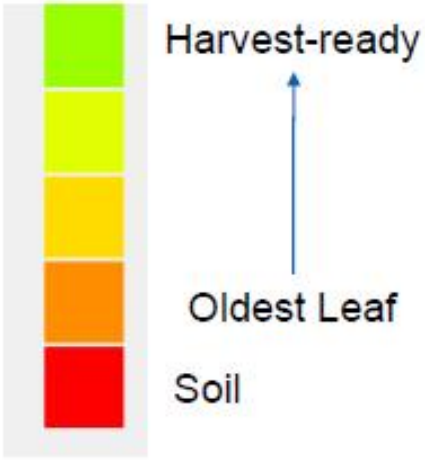
Productivity variations in sugarcane

Disease and Pest Incidence in Tea

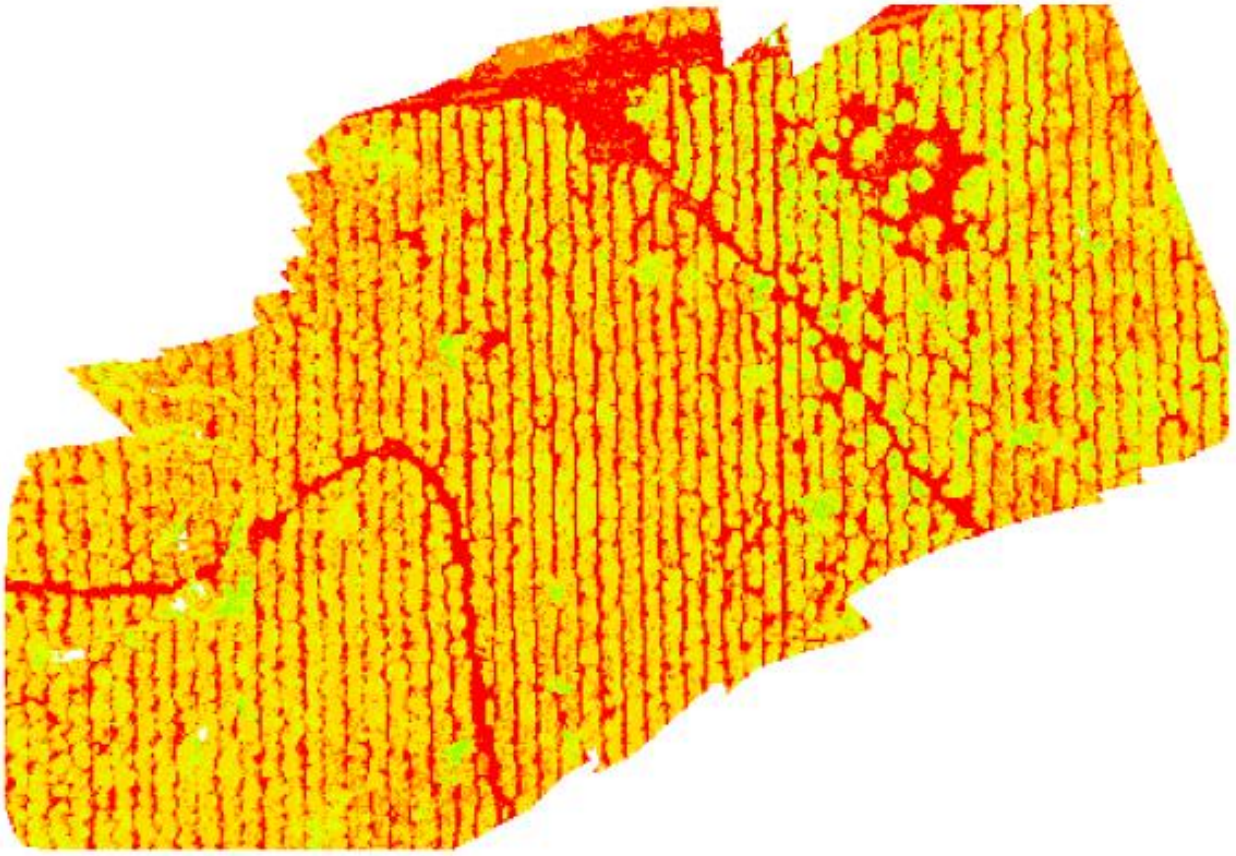


Estimate of Tea Bush Acreage 1/2





Estimate of Tea Bush Acreage 2/2



Bush Acreage =79.18%

Newer Leaf Mass ~3%

Older Bushes ~17%