FarmBeats:
AI & IoT for Agriculture

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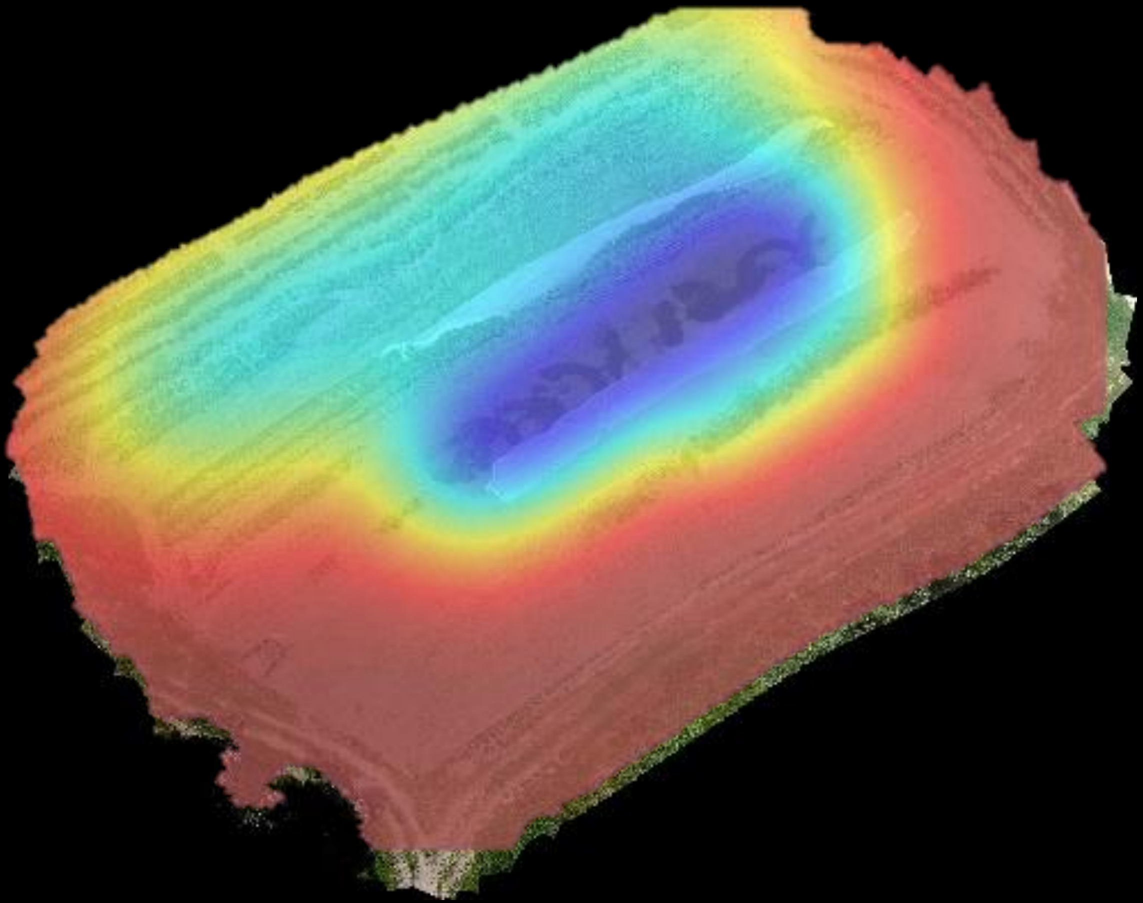
Microsoft

Data-Driven Agriculture

Data-Driven Agriculture



Ag researchers have shown that it:

- Improves yield
- Reduces cost
- Ensures sustainability

But…

According to USDA, high cost of manual data collection prevents farmers from using data-driven agriculture

IoT System for Agriculture

Problem 1: No Internet Connectivity

- Most farms don’t have any Internet coverage

- Even if connectivity exists, weather related outages can disable networks for weeks

Problem 2: No Power on the Farm

- Farms do not have direct power sources

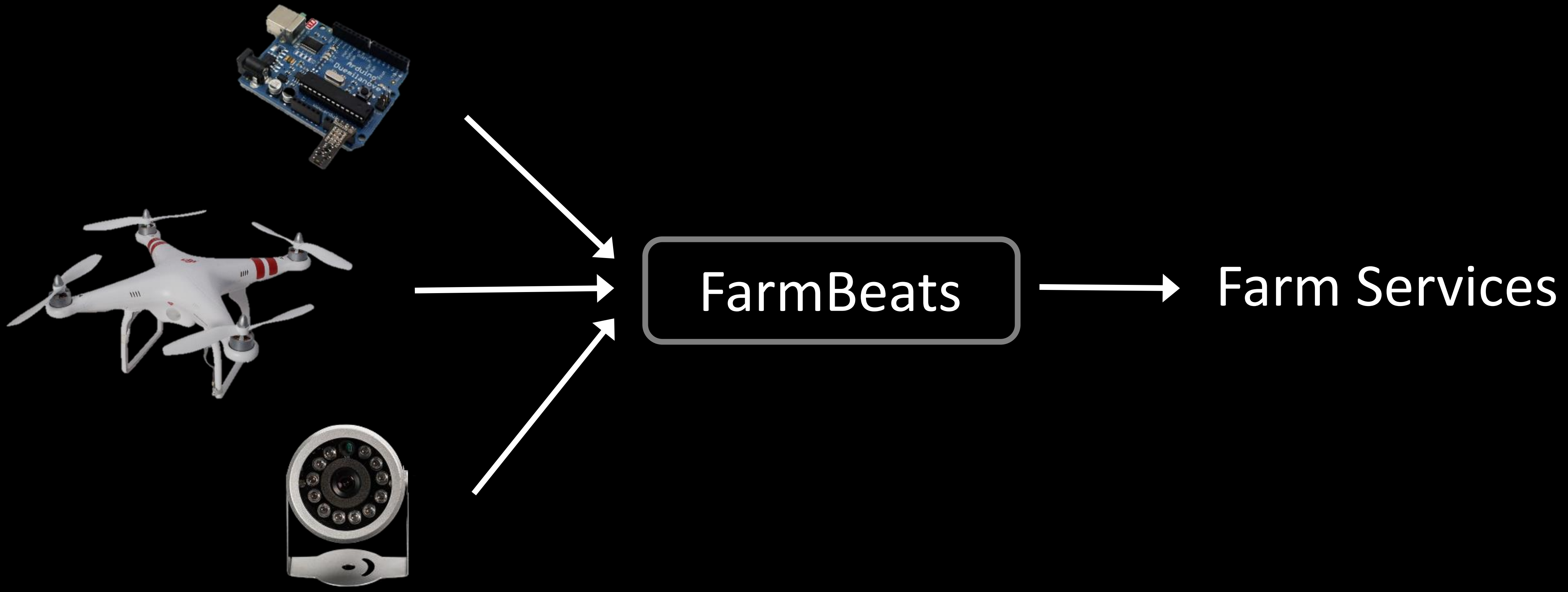
- Solar power is highly prone to weather variability

Problem 3: Limited Resources

- Need to work with sparse sensor deployments
  - Physical constraints due to farming practices
  - Too expensive to deploy, and
  - Cumbersome to maintain

FarmBeats

- End-to-end IoT system for seamless data-driven agriculture



Outline

- End-to-end IoT system for seamless data-driven agriculture
- Challenges:
  - Network Connectivity on the Farm
  - Low-cost aerial mapping and image analysis
  - Limited Sensor Placement
  - Internet Connectivity
  - Power Availability
- Deployment in two farms in NY and WA for six months ()

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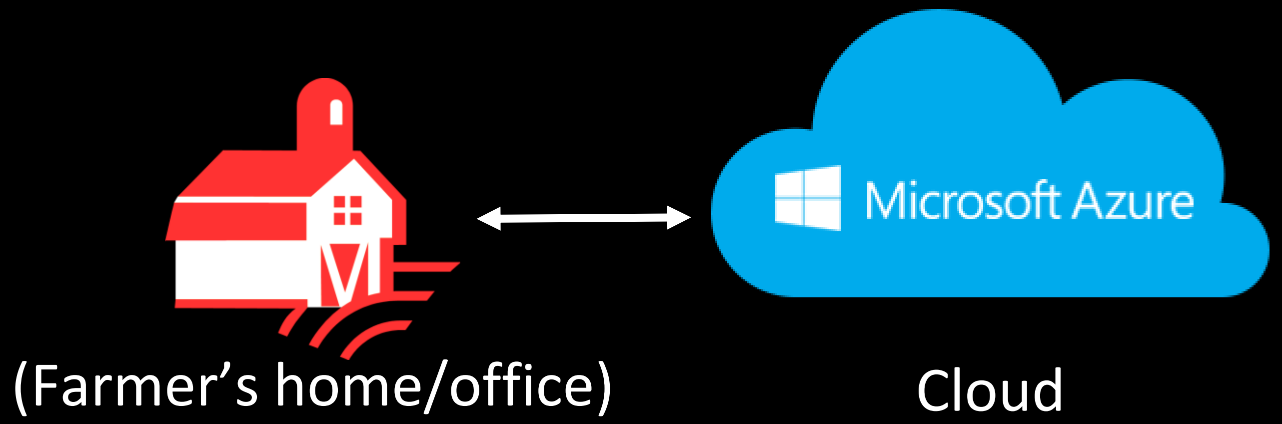
Challenge: Network/Internet Connectivity



Challenge: Internet Connectivity

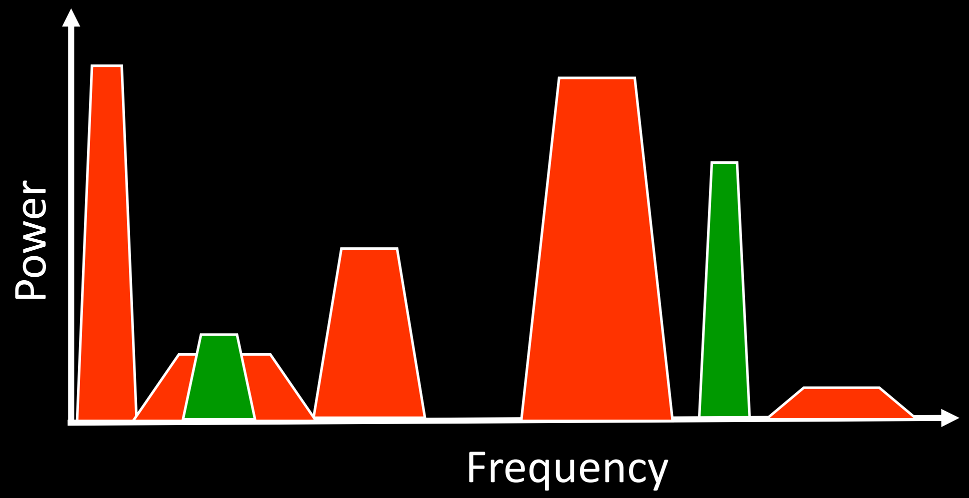
Sensors

(Farmer's home/office)

Cloud

- Few miles away
- Obstructed by vegetation, terrain etc.

TVWS using Dynamic Spectrum Access (DSA)



- **Determine** available spectrum **(white spaces)**
- **Transmit** in "available frequencies"
- **Detect** if primary user appears
- **Move** to new frequencies
- **Adapt** bandwidth and power levels

MSFT Supported Pilot Projects

Commercial Scale is the Next Step

36,000 K-12 Students Being Connected

38,500 University Students Getting MSFT Devices & Services

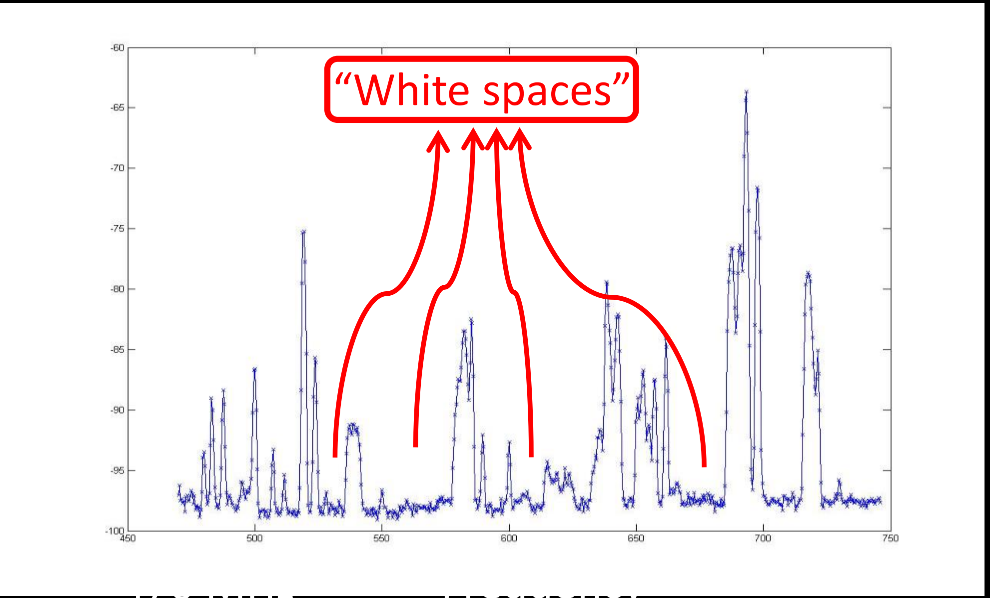
200,000+ Population Under Coverage

Launched 14 pilot projects and the global Dynamic Spectrum Alliance. Objective: Trigger regulatory changes and develop commercially viable ecosystems for TV White Spaces technology.

Regulatory changes achieved in USA & Singapore with drafts in UK and Canada. Critical progress made in ITU-D and ITU-R.

Built working relationships with USAID, OPIC, World Bank, PEPFAR, DFID,/UKAID, Africa/Asia/Inter-America Dev. Banks, non-profits, ITU, ISP and Telco providers.

TV White Spaces in the Farm



- What are the TV White Spaces?
  - Unused TV channels
- Benefits over Wi-Fi, Zigbee, etc
  - High throughput at long range
- Key insight for farms:
  - “lots” of TV spectrum is available, more than 100 MHz
  - Just like Wi-Fi router covers the home, TVWS base station can cover the farm

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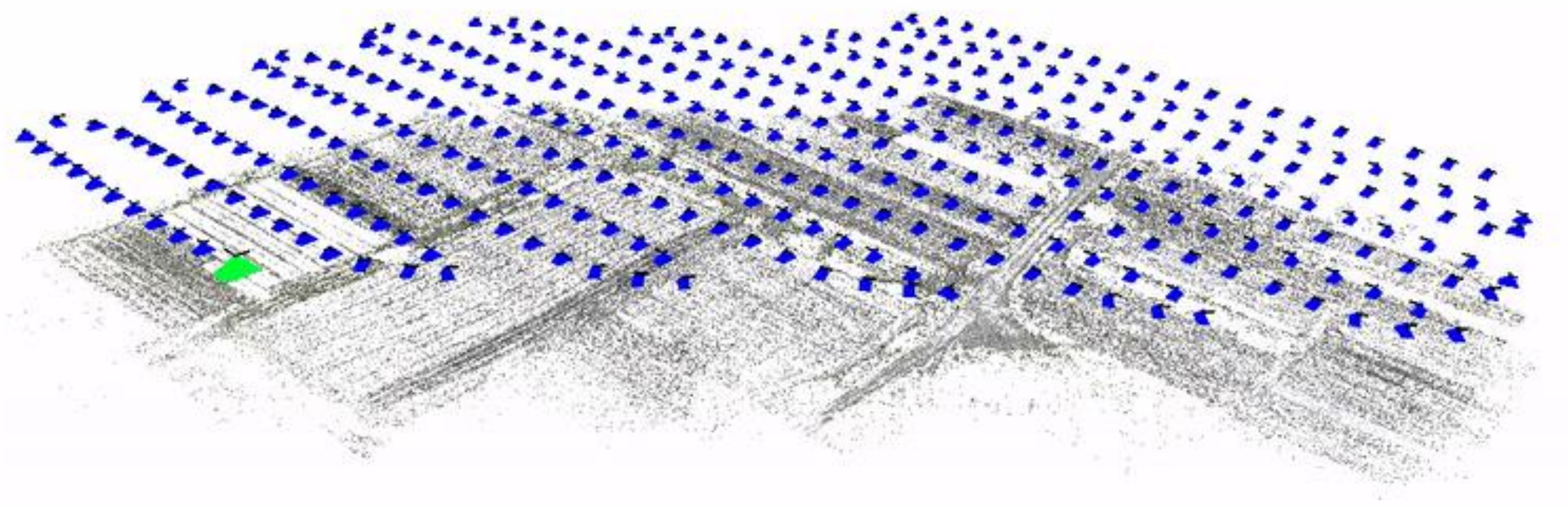
Aerial imagery in precision agriculture

- Aerial imagery from drone, UAV, balloons, …
- Orthomosaics (2D image) or 3D point cloud
- Visual monitoring
- Crop inspection
- Many applications

Aerial imagery in precision agriculture

3D point cloud reconstruction (using aerial 3D photogrammetry)



Cameras corresponding to video keyframes shown in blue

Aerial imagery in precision agriculture

- Video from ~2 minutes flight
- High-resolution RGB orthomosaic
- Resolution: 2—3 cm per pixel

Aerial imagery in precision agriculture

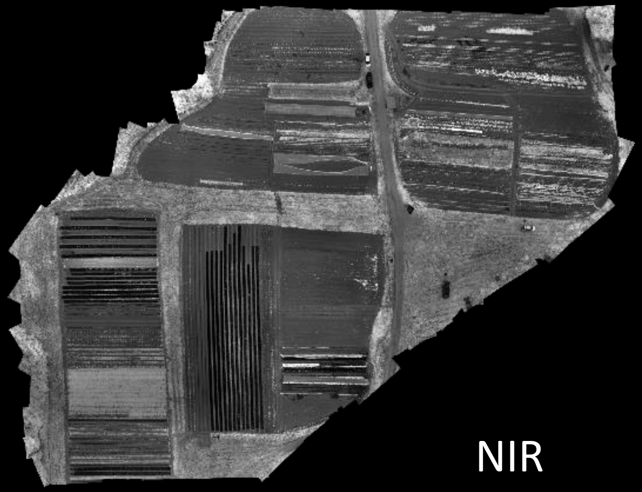
- Several advantages over satellite imagery
  - Off-the-shelf drones
  - Automatic and repeatable capture
  - Unaffected by cloud cover
  - High resolution imagery
  - processing on an ordinary PC

India

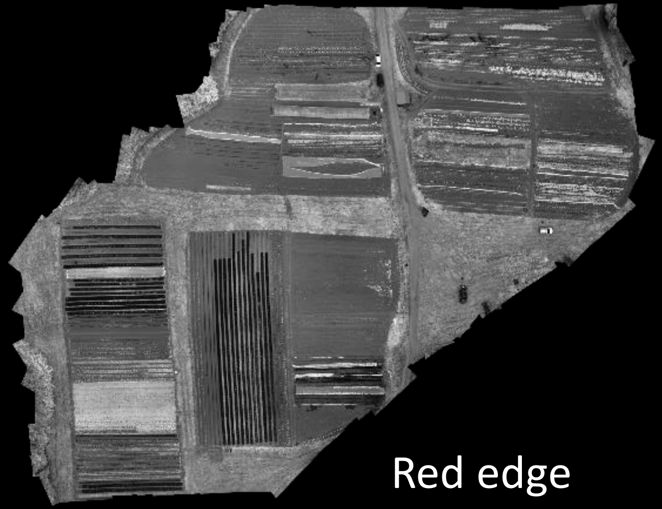
Carnation, WA

Processing multi-spectral imagery

Sequoia
multi-spectral camera

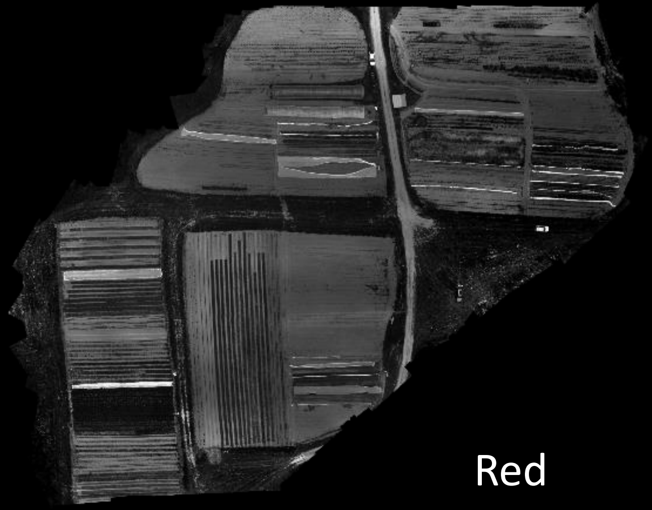


NIR

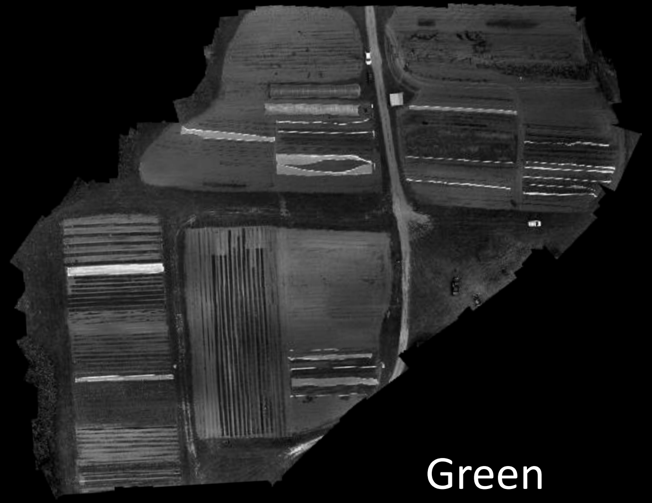


Red edge

RGB



Red



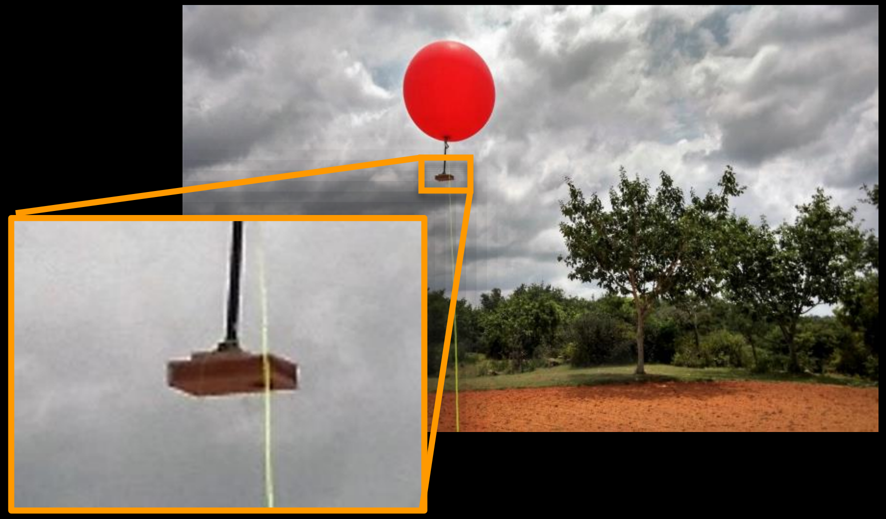
Green

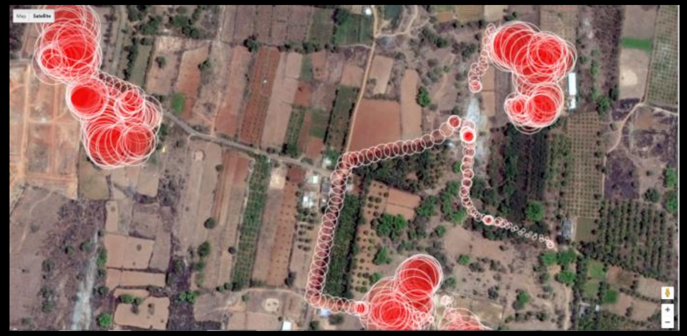
Time-series of aerial maps & orthomosaics

- Repeated drone flights (uses same plan with GPS waypoints)
- Completely automated pipeline using computer vision and image processing technology

Lower cost alternatives

- UAVs are costly, have limited battery life
- Regulatory concerns in some countries
- Alternatives we are exploring
  - Tethered Helium balloons with smartphone payload
  - Balloon manually moved around (person, tractor, …)
  - Automatic video processing (same as described earlier)
- Automatic balloon time-lapse imagery
  - Long-term monitoring and analyzing change
- Ongoing deployments in India





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Challenge: Sparse Ground Sensor Placement

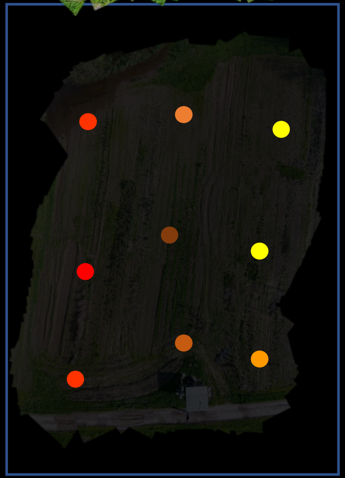
- Ground Sensors deployed sparsely on the farm
- Reasons:
    - Sensors are expensive,
    - Difficult to maintain too many
    - Farming constraints

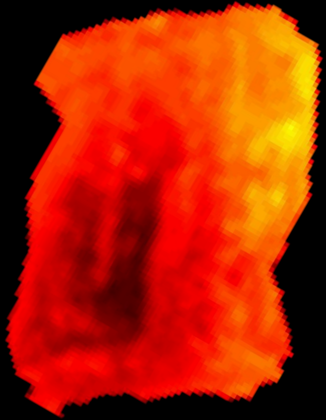
Main idea:

Make predictions with a model that fuses UAV *aerial imagery* and *ground* sensor data

Approach: Supervised Learning

- Dataset
  - Build geo-registered aerial map
  - Store data from geo-registered ground sensors
  - Compile dataset (X: image patches, Y: sensor data)
- Learning stage:
  - Train a Gaussian Process (X → Y)
- Prediction stage:
  - Process aerial map (in sliding window fashion)
  - Extrapolate sensor values to areas with similar
  - visual features





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The Real World

Base Station

- Weak Connectivity
- Prone to outages

TV White Spaces

Few miles

(Farmer’s home/office)

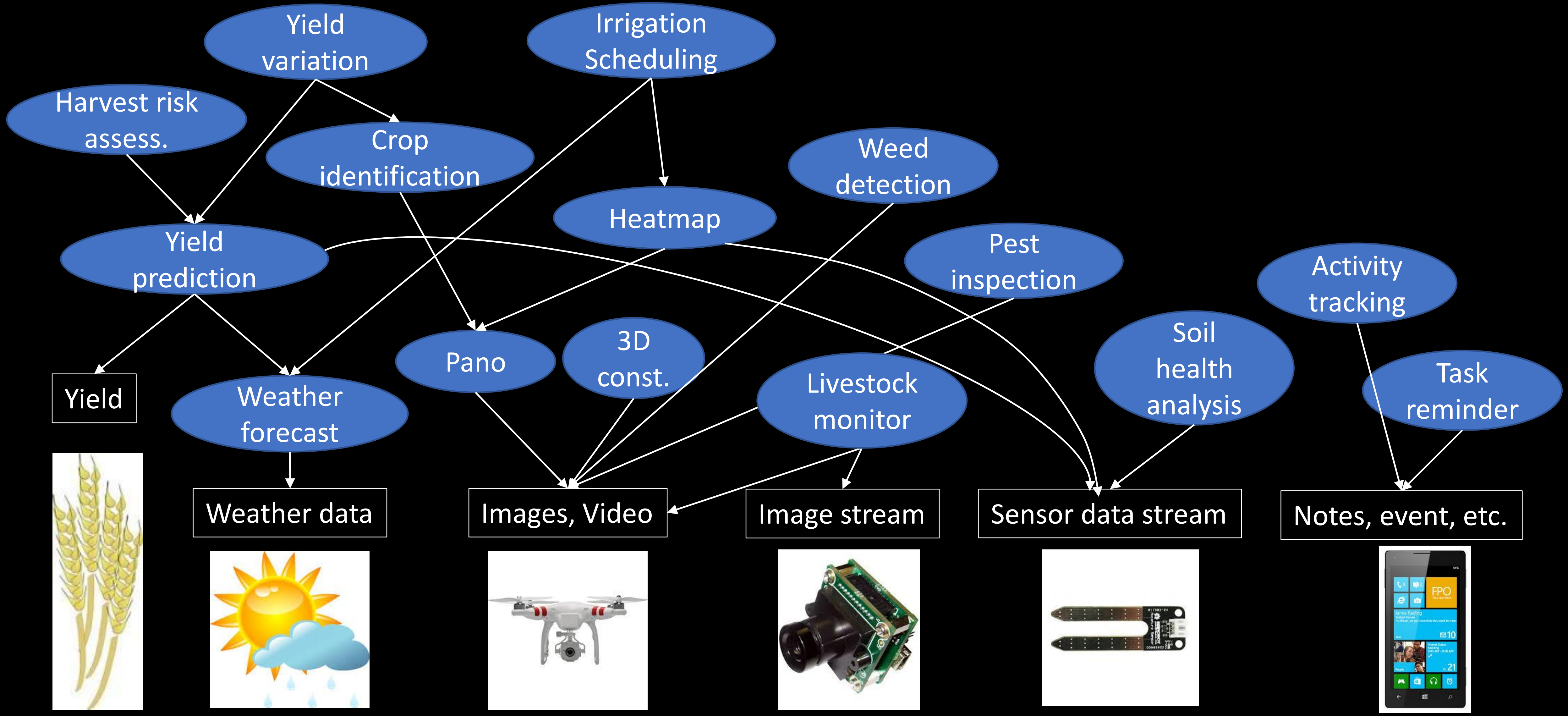
Microsoft Azure

Cloud

Wi-Fi, BLE

Sensors

What Services We Can Provide



Service Characteristics

- Large inputs

Data Source	Daily size
Sensor	70K
Drone video	10G
Drone image	4G
Camera	28M

- Latency constraints

Service	Latency
Query sensor data	seconds
Livestock mon.	seconds
Irrigation sched.	hours
Pest inspection	hours
Variability analysis	Days

The Ideal World

The Real World

Base Station

- Weak Connectivity
- Prone to outages

TV White Spaces

Few miles

(Farmer's home/office)

Microsoft Azure

Cloud

Wi-Fi, BLE

Sensors

FarmBeats Design

Base Station

TV White Spaces

Few miles

(Farmer's home/office)

FarmBeats Gateway
(IOT Edge)

Weather Data
(Rain, Wind, Pollen)

Microsoft Azure

Cloud

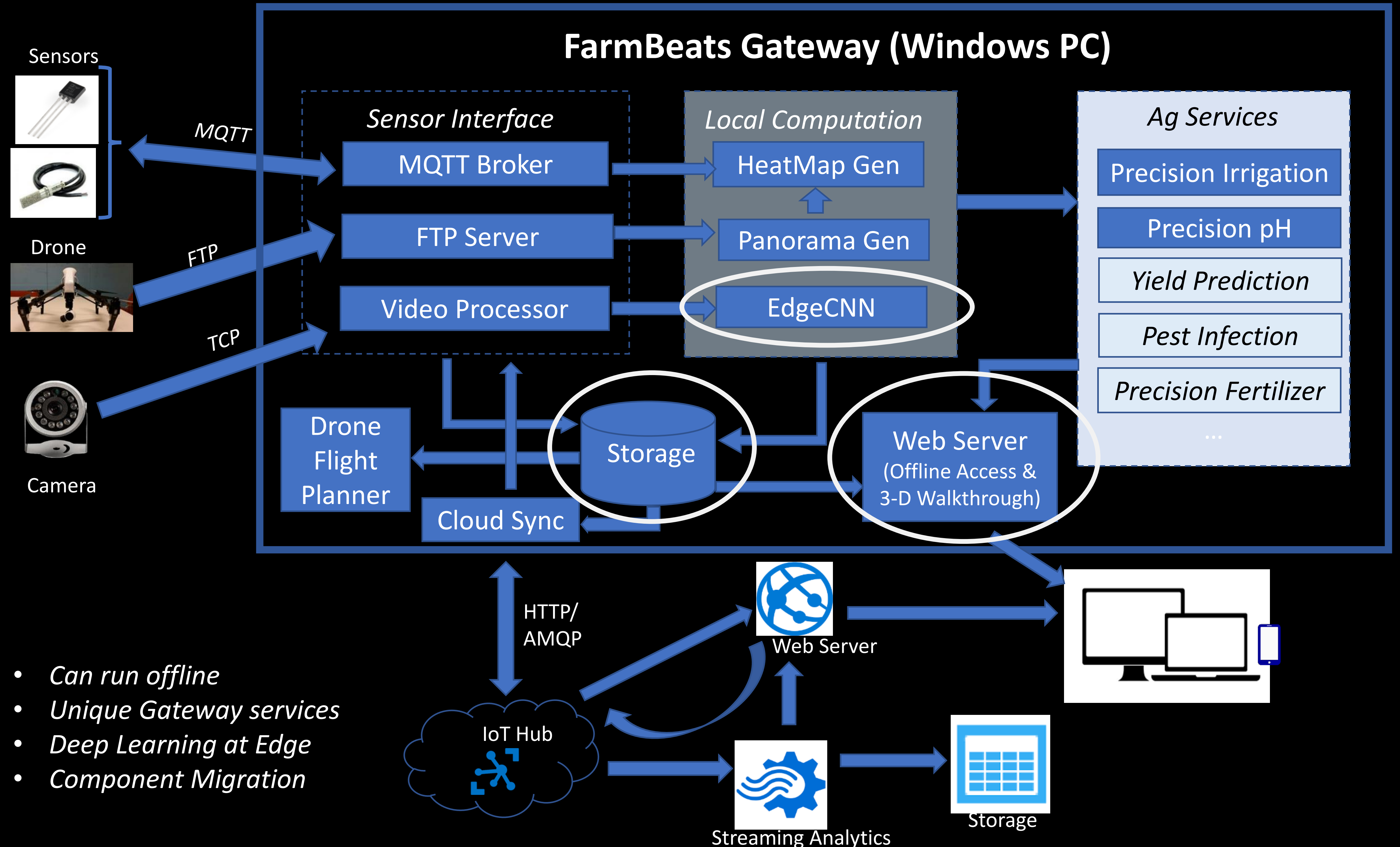
Analytics

Seed vendors
Agronomists
Farmers
…

Recommendations
(daily best practices)

Wi-Fi, BLE

Sensors



- *Can run offline*
- *Unique Gateway services*
- *Deep Learning at Edge*
- *Component Migration*

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  - Power Availability
    - Solar power, RF power, UAV battery life
- Deployment in two farms in NY and WA for six months ()

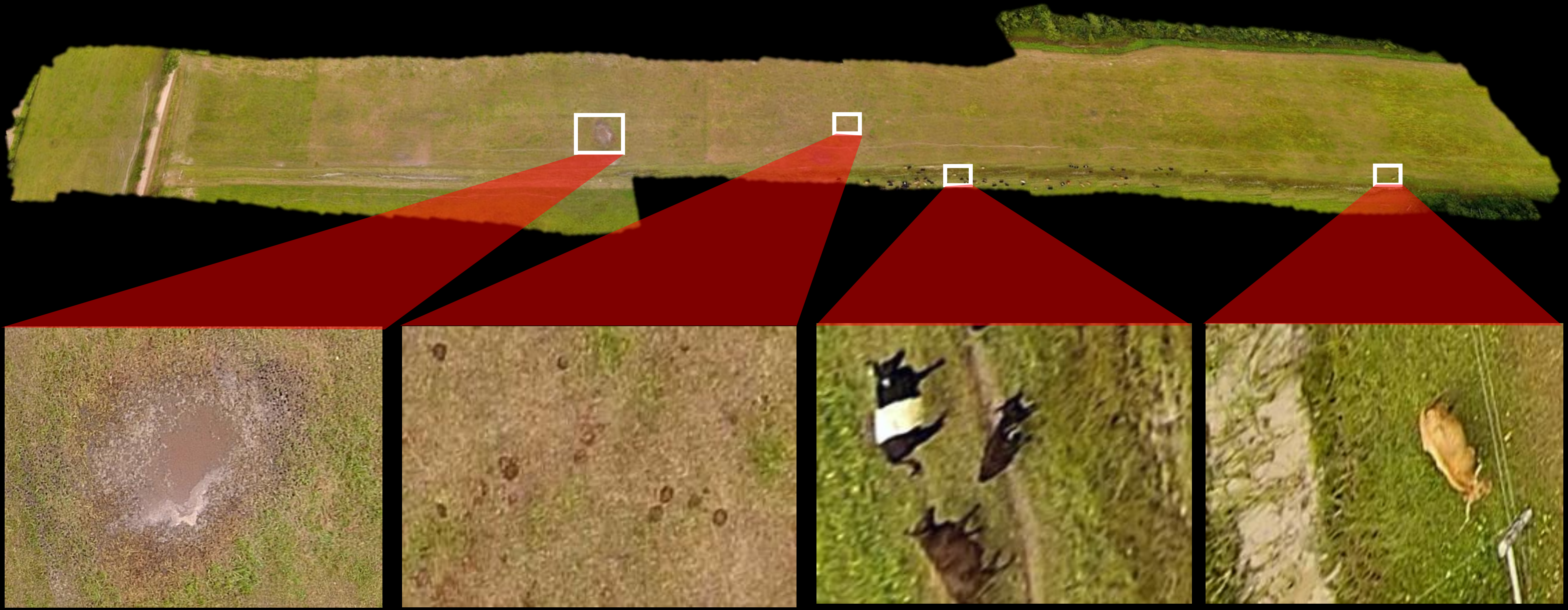
Deployment

- Deployed in two farms
  - Carnation, WA (since April 2016)
  - Essex, NY (six months)
- Farm area was 5 and 2000 acres
- Sensors:
  - Drones: DJI Phantom 2, DJI Inspire1, 3DR Solo
  - Particle Photons with Moisture, Temperature, pH Sensors
  - IP Cameras to capture RGB/IR imagery
- Cloud Components: Azure Storage and IoT Suite

Deployment Statistics

- Used 10 sensor types, 3 camera types and 3 drone versions
- Deployed >100 sensors and ~10 cameras
- Collected >10 million sensor measurements, >0.5 million images, 100 drone surveys
- Resilient to week long outage from a thunderstorm

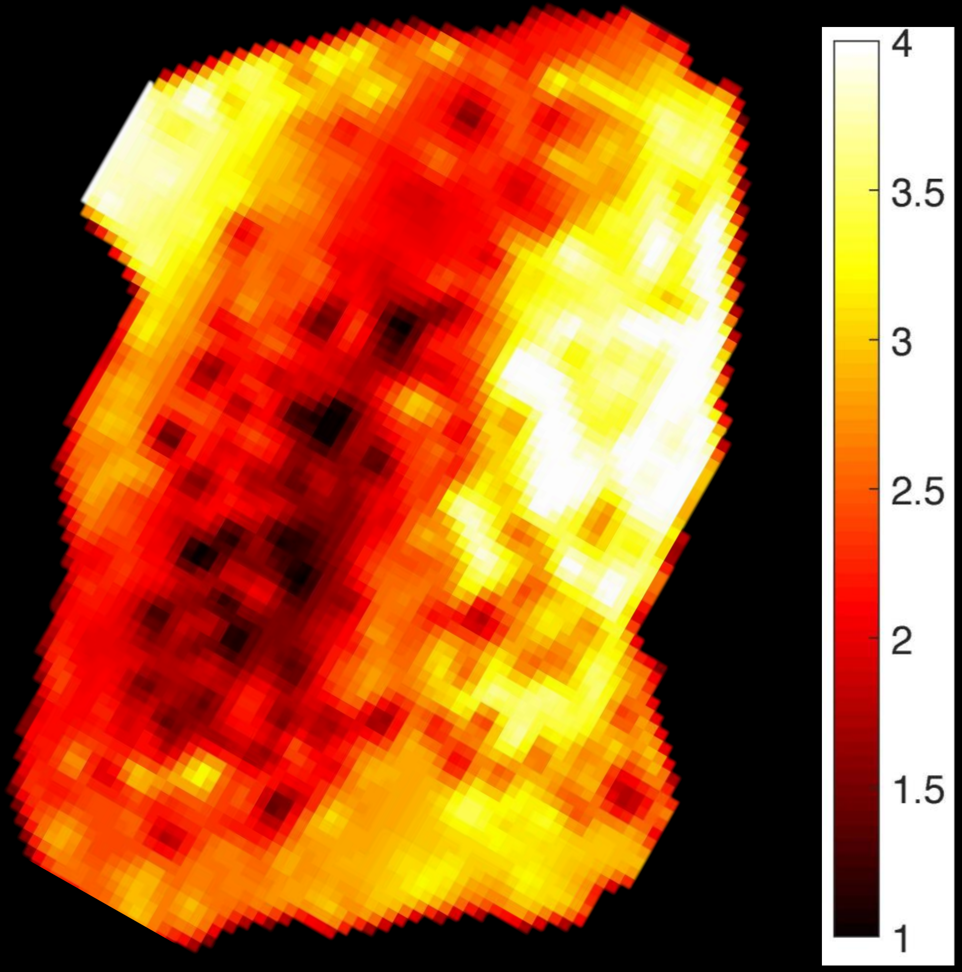
High-resolution Orthomosaic from Essex, NY



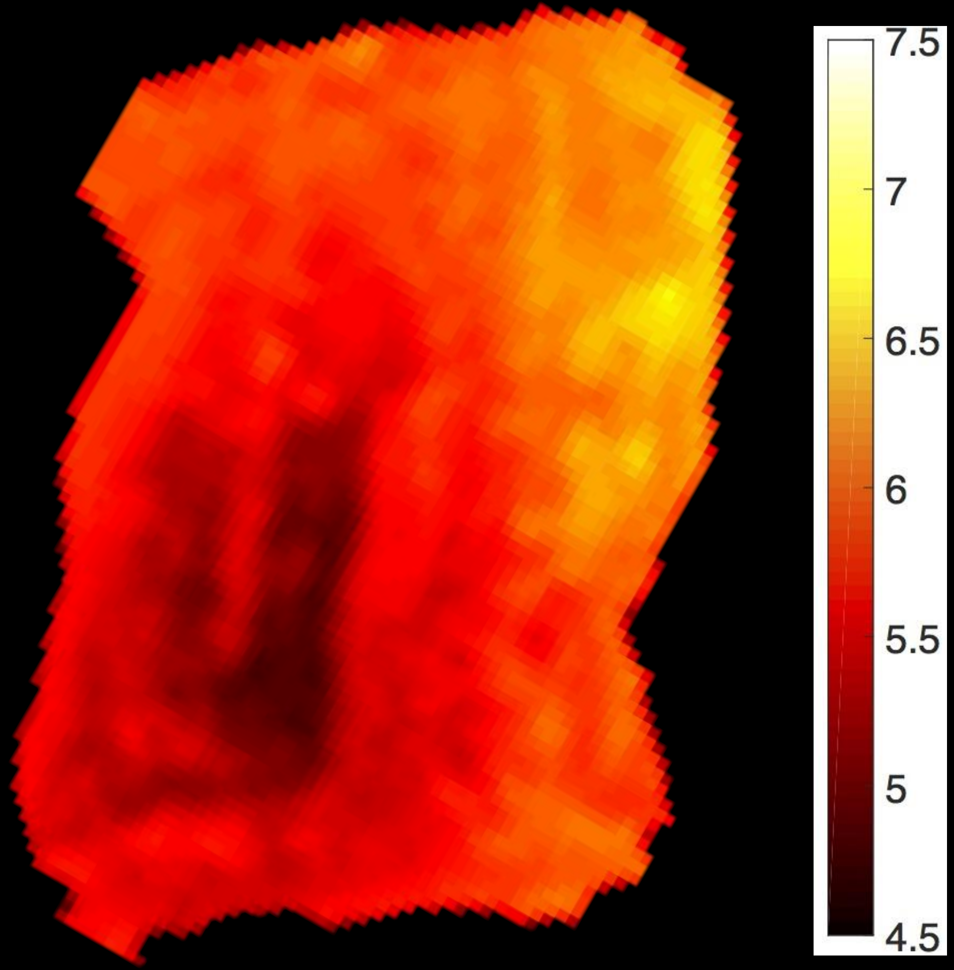
Water puddle Cow excreta Cow Herd Stray cow

Precision Map: Orthomosaic

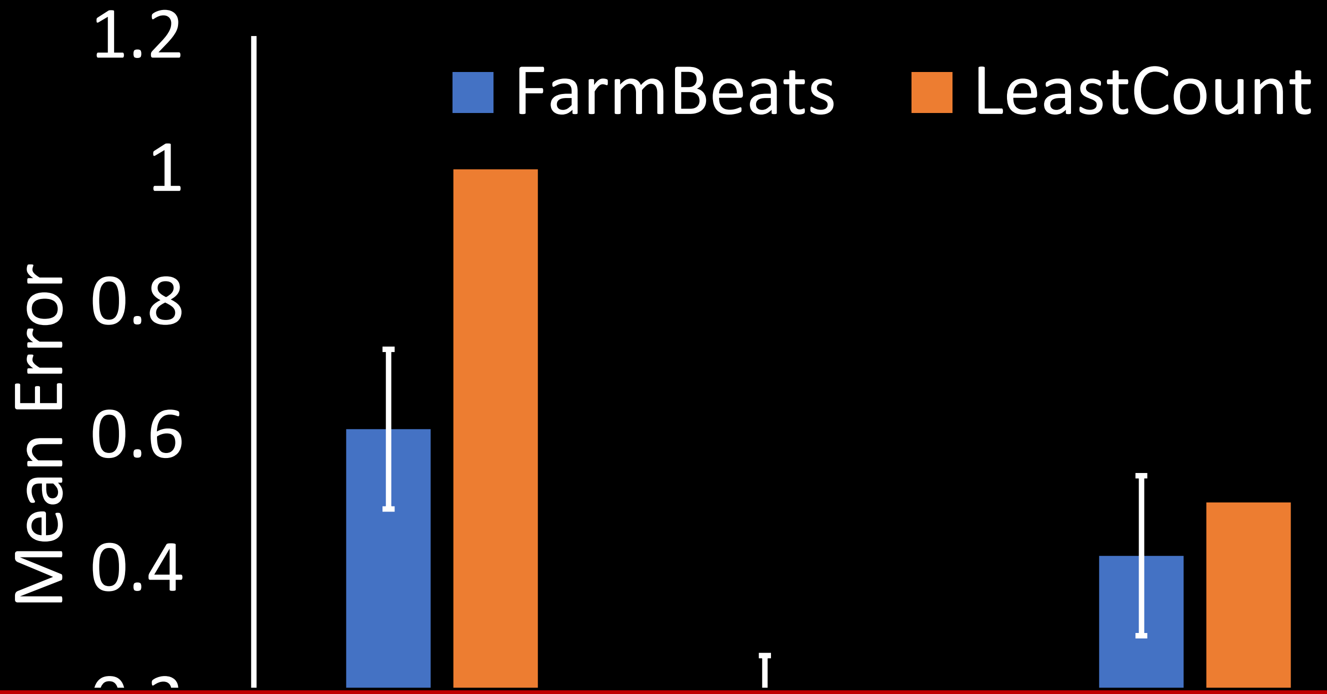
Precision Map : Moisture



Precision Map : pH



Precision Map: Accuracy



FarmBeats can accurately expand coverage by orders of magnitude using a sparse sensor deployment