

MOISTURE

MODERATE

# FarmBeats: Empowering Farmers with Affordable Digital Agriculture Solutions

Ranveer Chandra





# The Agricultural Challenge



## Global Access

**1 in 9** people are undernourished (UN)

**65%** Reduce poverty for 65% of the world's poor who live in rural areas and work in farming

**70%** more food is needed by 2050



## Sustainable Production

**70%** of global water resources are needed for Agriculture

**24%** of global greenhouse emission comes from Agriculture

**251T** liters of water to be saved in 2030 from implementing Smart Agriculture



## Need for Economic Growth

**30%** of global workers are employed by Agriculture

**10-30%** Agriculture contributes 10% of global GDP and up to 30% in low income countries

**\$4.8T** Global Agriculture revenue



# Data-driven agriculture

Precision agriculture has shown to:



Improves yield



Reduces cost



Ensures sustainability

NITROGEN  
19ppm

Recommendation:  
25ppm



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



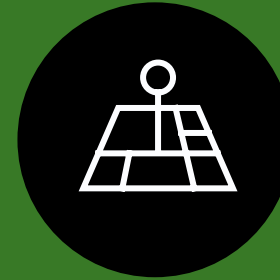
# There are 4 problem areas hindering adoption...



No connectivity in  
fields



No power  
in fields



Precision  
mapping with  
few sensors



Slow connectivity  
at farm office



## Problem 1:

### No farm connectivity

Most farms do not have any Internet coverage

Weather and crops cause signal blockage





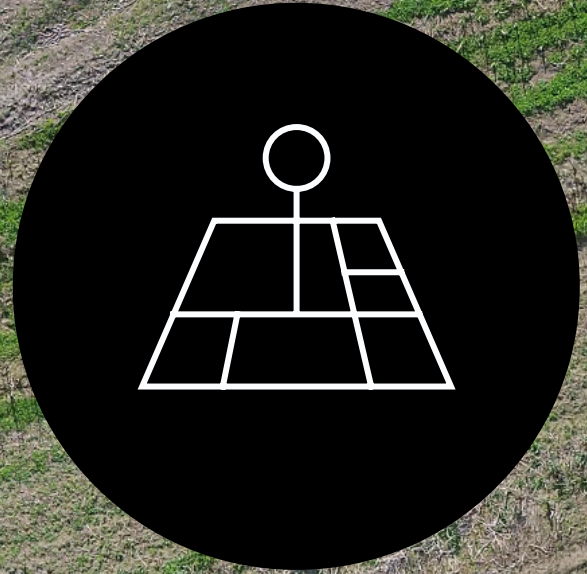
## Problem 2:

# Precision mapping with limited sensors

Obstructs farming activity

Too expensive

Cumbersome to maintain



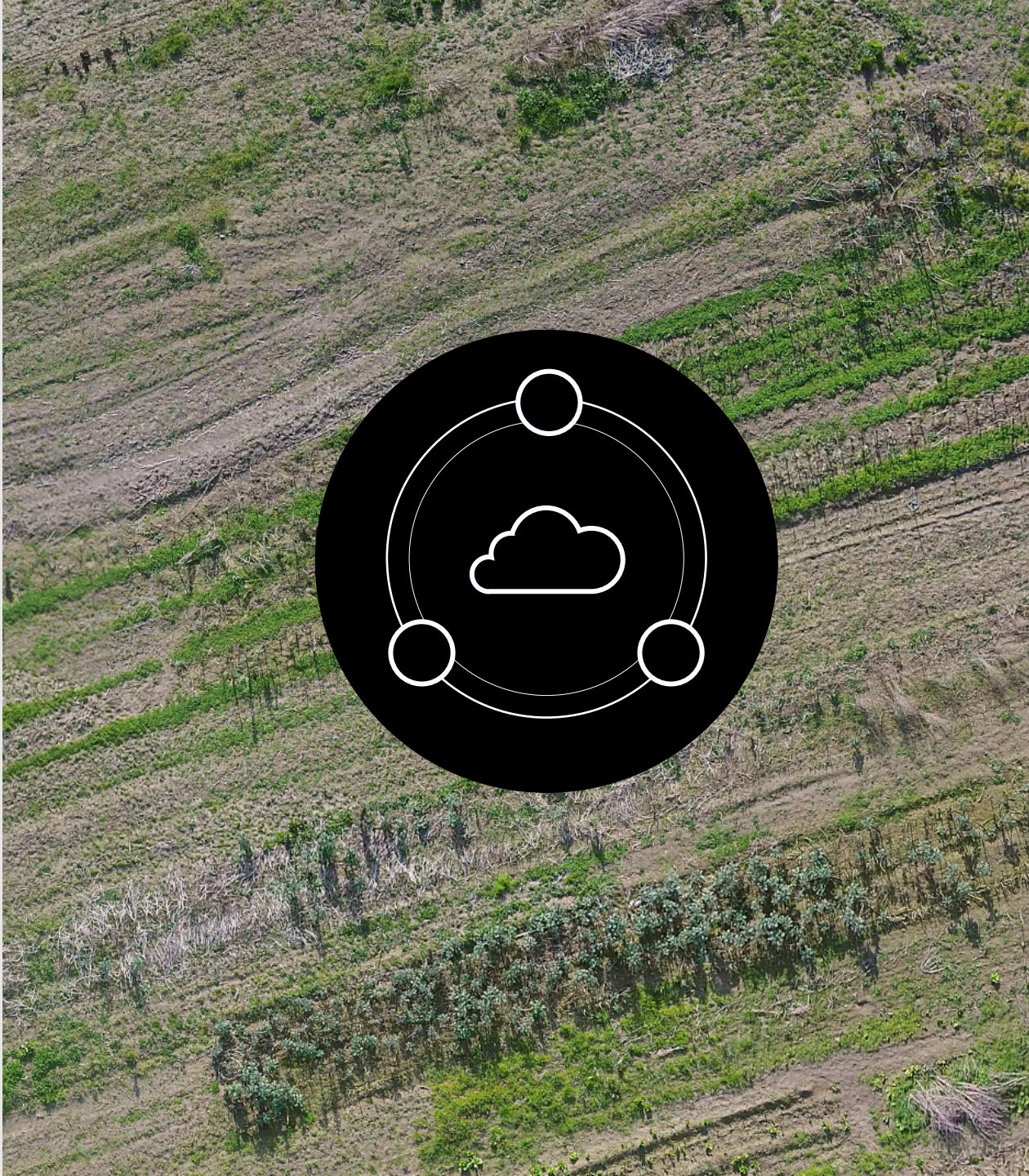


## Problem 3:

# Slow rural connectivity to the cloud

No broadband

Intermittent connectivity





## Problem 4:

No power on the farm

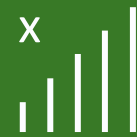
No power in the field

Solar power is unpredictable





An end-to-end system that enables seamless data collection and insights for agriculture



FarmBeats





# In this talk

FarmBeats: An end-to-end system that enables seamless data collection and insights for agriculture

Solves key challenges:

No farm  
connectivity

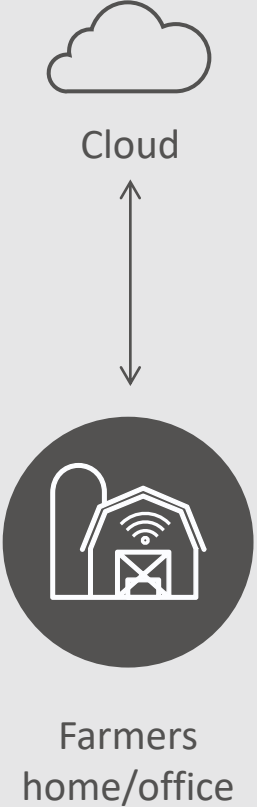
Precision  
Mapping

Slow cloud connectivity

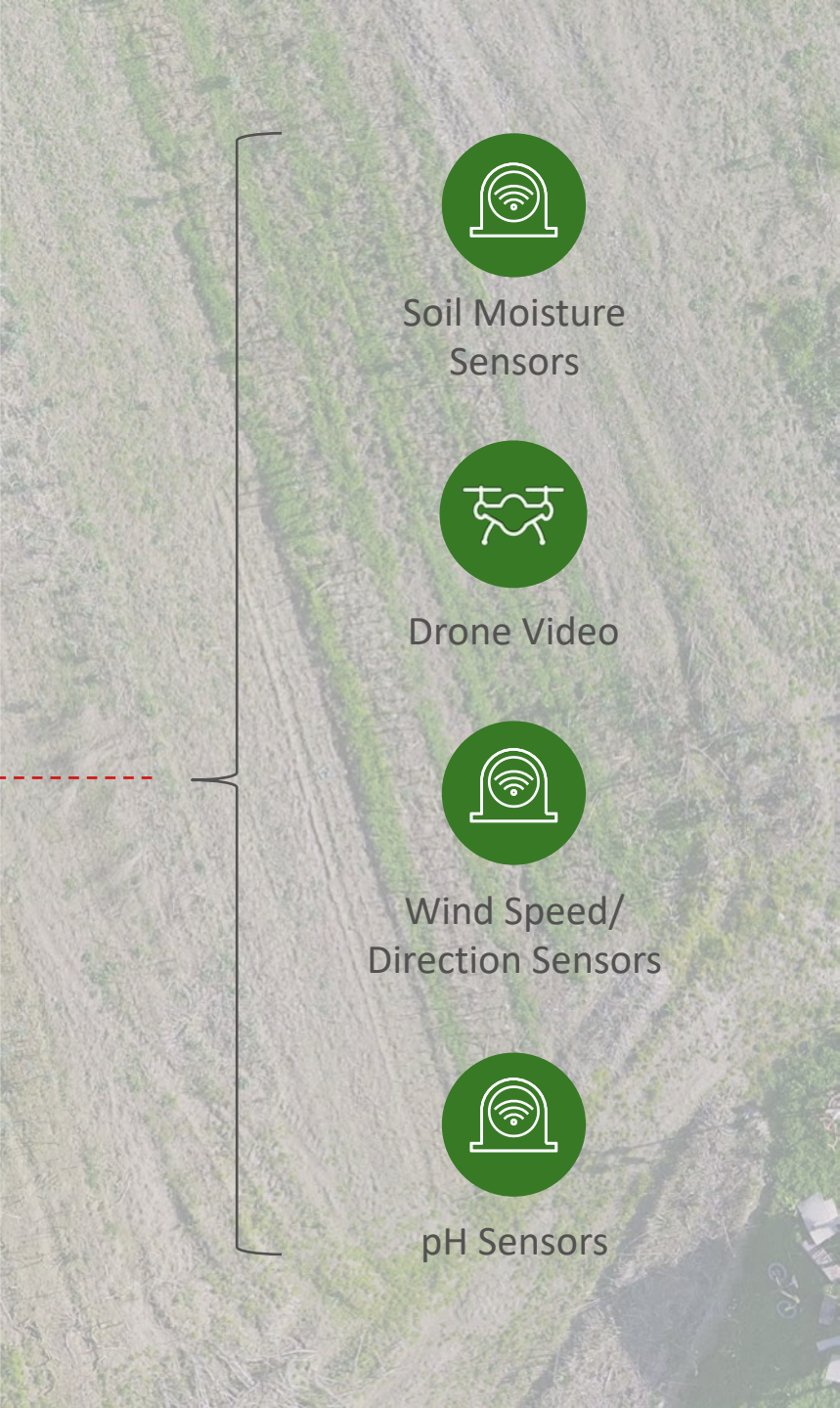
Power on  
the Farm



# Challenge: Farm connectivity

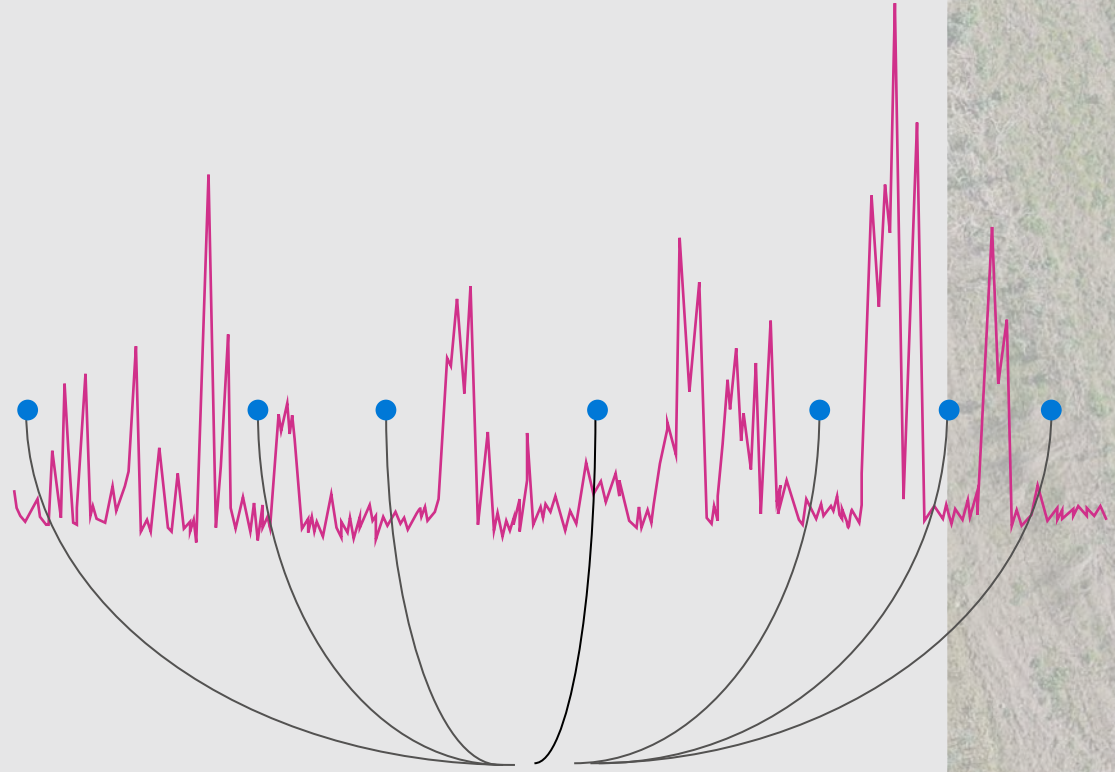
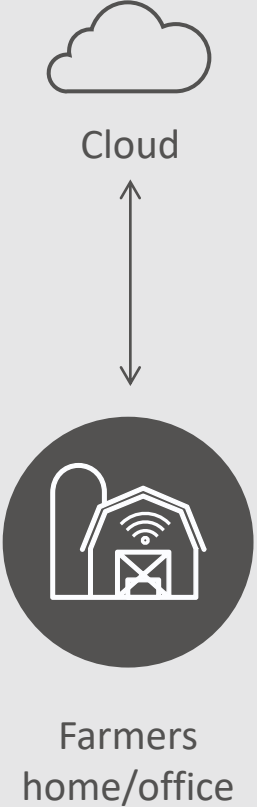


Few miles away and obstructed by crops, canopies, etc.

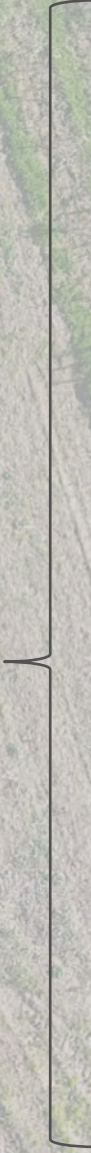
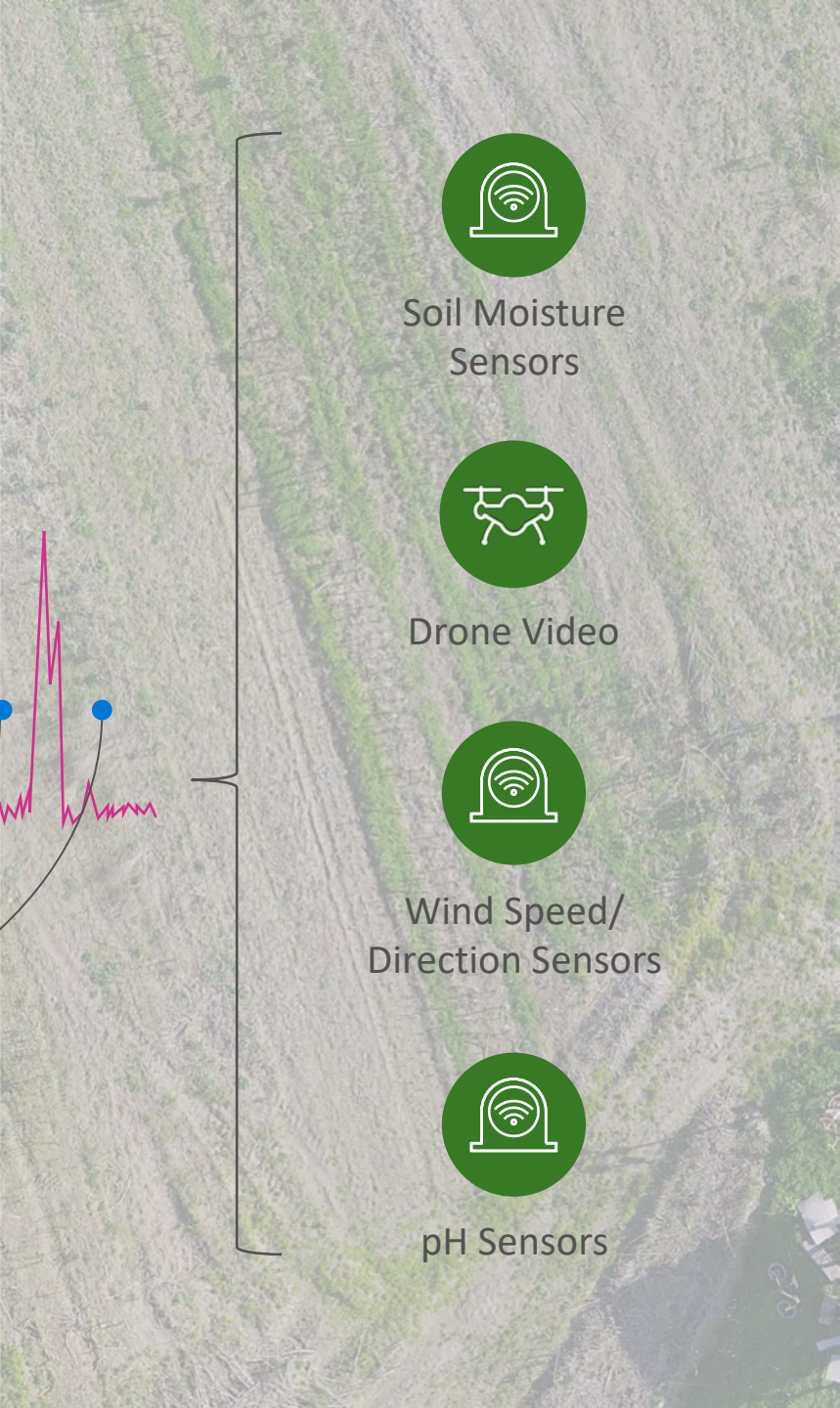




# Challenge: Farm connectivity



TV White Space frequencies used to carry data signals



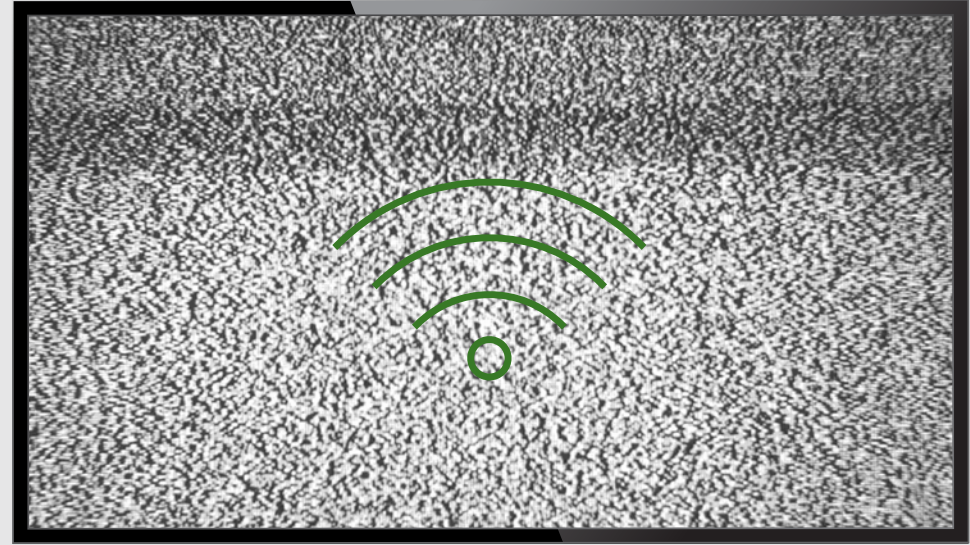


Microsoft Research has been studying this for over a decade...

Networking Over White Spaces (KNOWS)



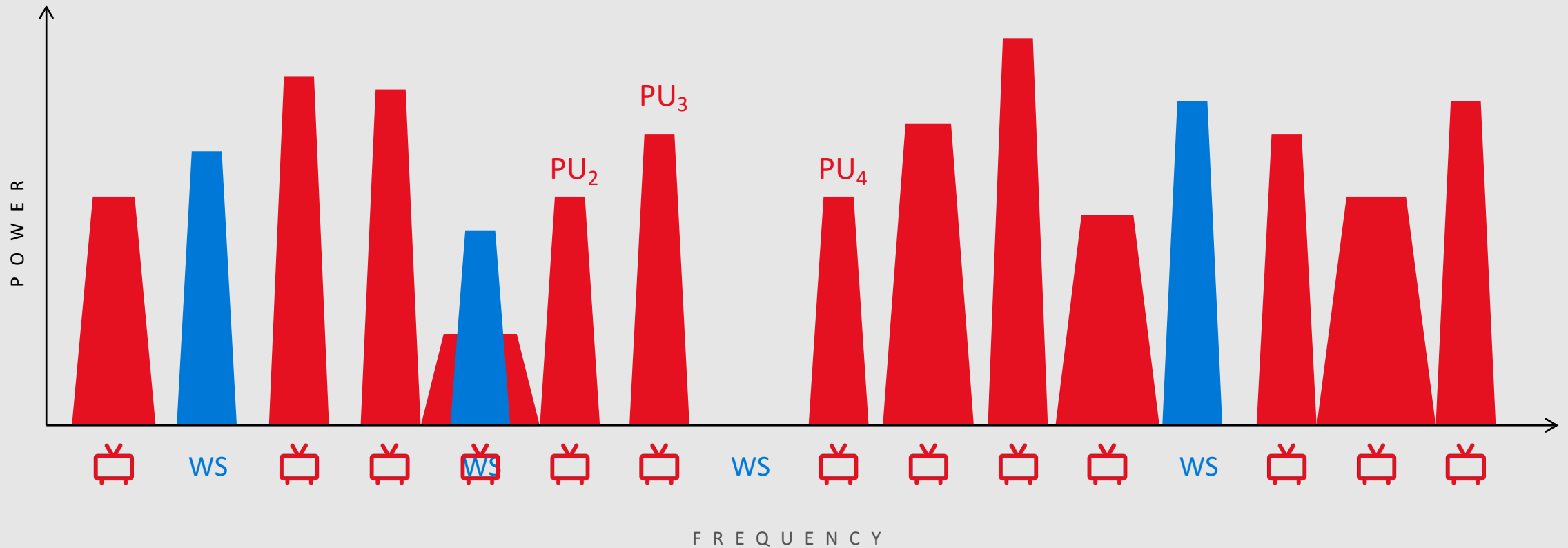
TV channel on network



Unused TV channel



# TVWS using Dynamic Spectrum Access (DSA)



**Determine** available spectrum (**white spaces**)

**Transmit** in “available frequencies”

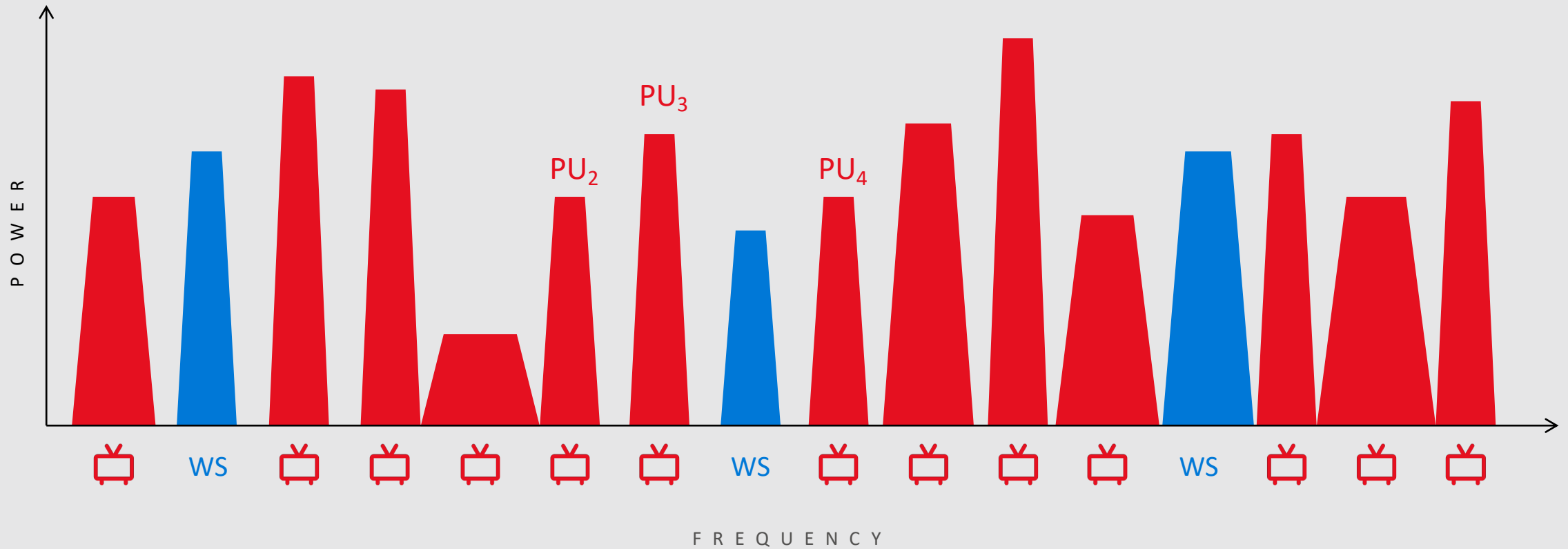
**Detect** if primary user appears

**Move** to new frequencies

**Adapt** bandwidth and power levels



# 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



# Key technical contributions

Microsoft Research was amongst the first to:



Build TVWS  
radios



Design WhiteFi,  
a Wi-Fi like protocol  
for TVWS



Demo world's first  
WhiteFi network in 2009



# Airband

## Internet Access

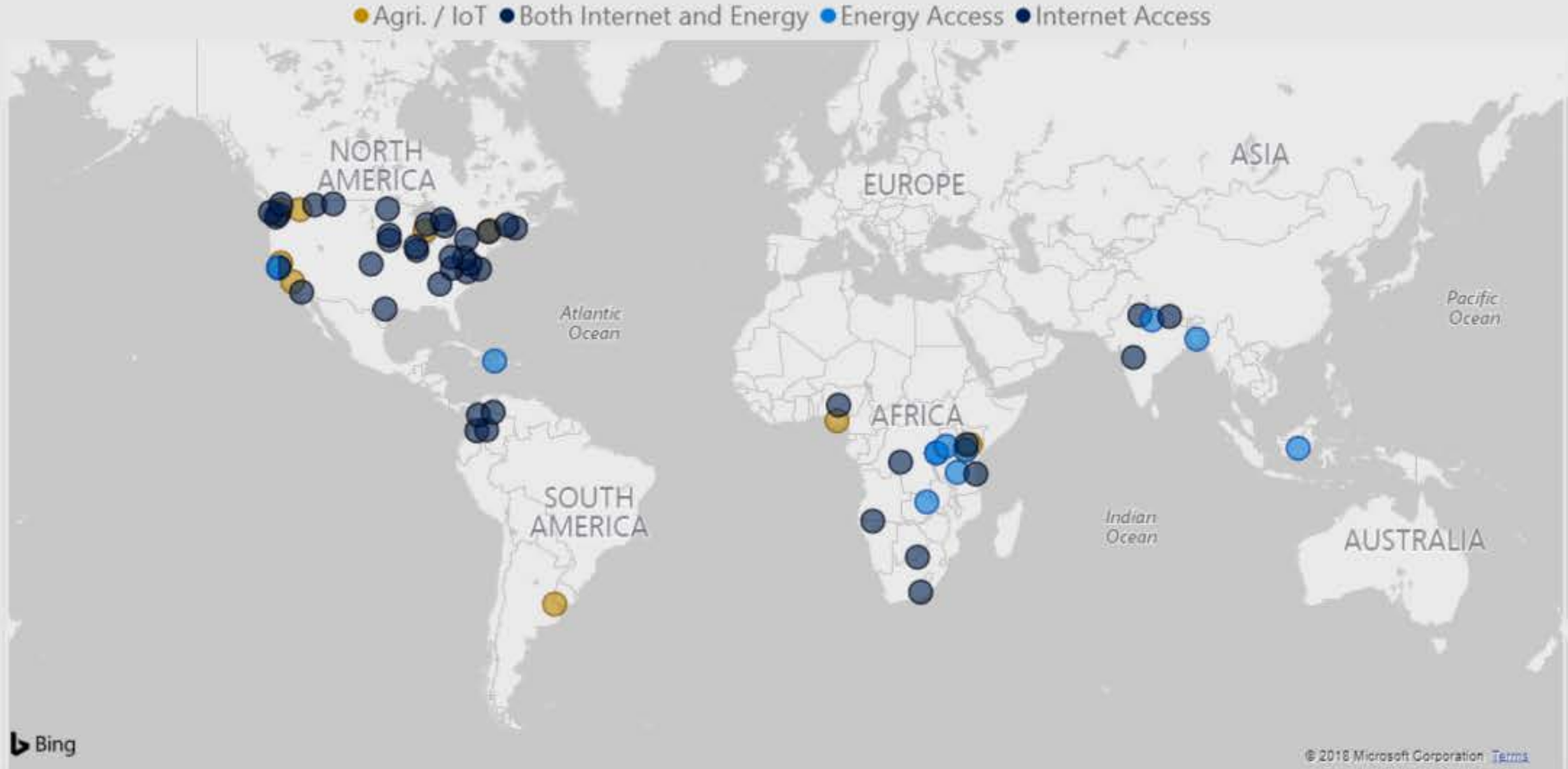
Active Projects  
**69**

Population Covered  
**11,778,136**

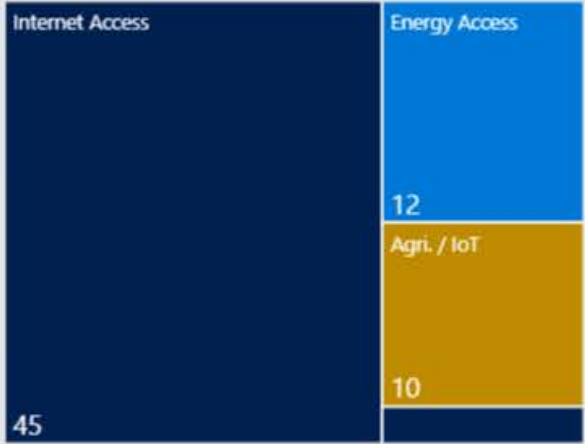
Population Connected  
**594,918**

Energy Access  
**705,360**

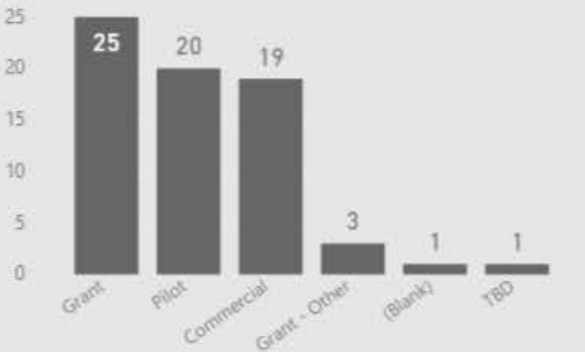
Project Locations



Project Count by Project Type



Project Count by Funding Type





# TV White Spaces in the Farm

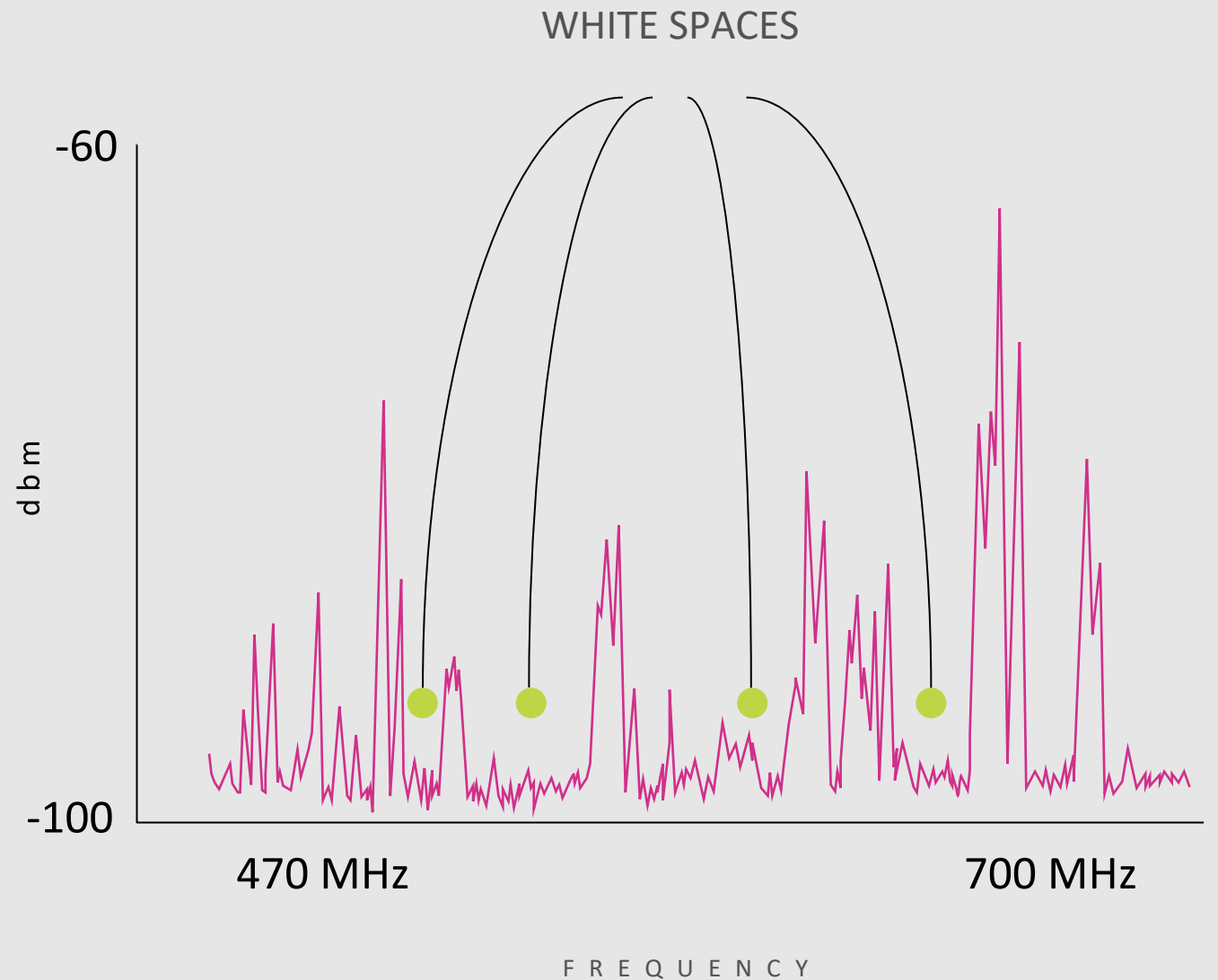
## What are the TV White Spaces?

Unused TV channels

## 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





# In this talk

FarmBeats: An end-to-end system that enables seamless data collection and insights for agriculture

Solves key challenges:



Connectivity on  
the Farm

Precision  
Mapping

Slow cloud connectivity

Power on  
the Farm

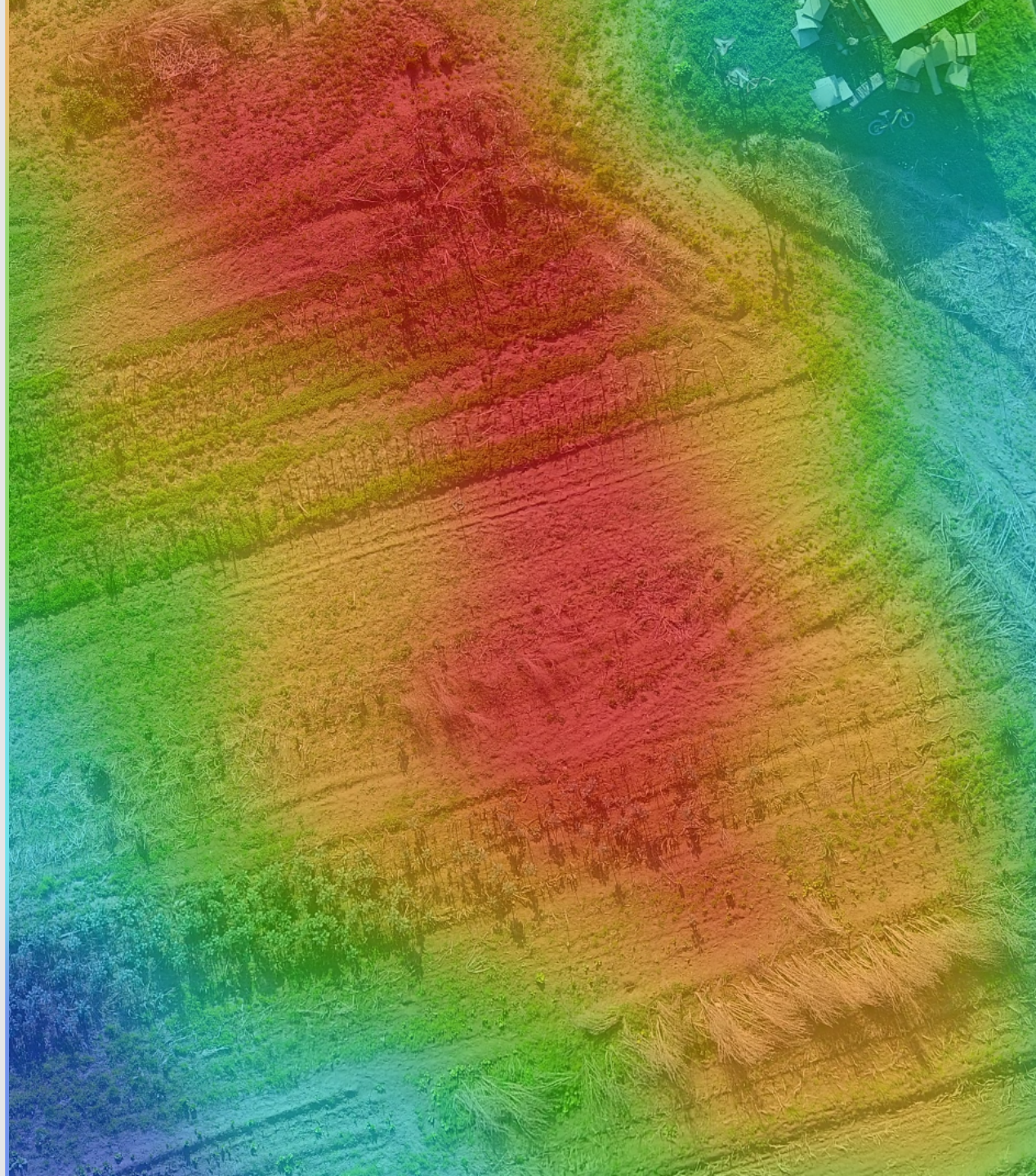


# Challenge: Limited resources

Need to work with sparse  
sensor deployments

- Physical constraints due to farming practices
- Too expensive to deploy and maintain

How do we get coverage with a sparse  
sensor deployment?

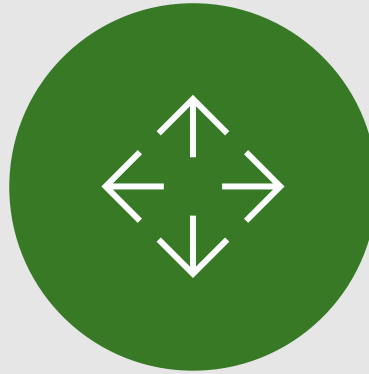




# Idea: Use UAVs to enhance spatial coverage



Drones are ~1000 dollars  
and automatic



Can cover large  
areas quickly



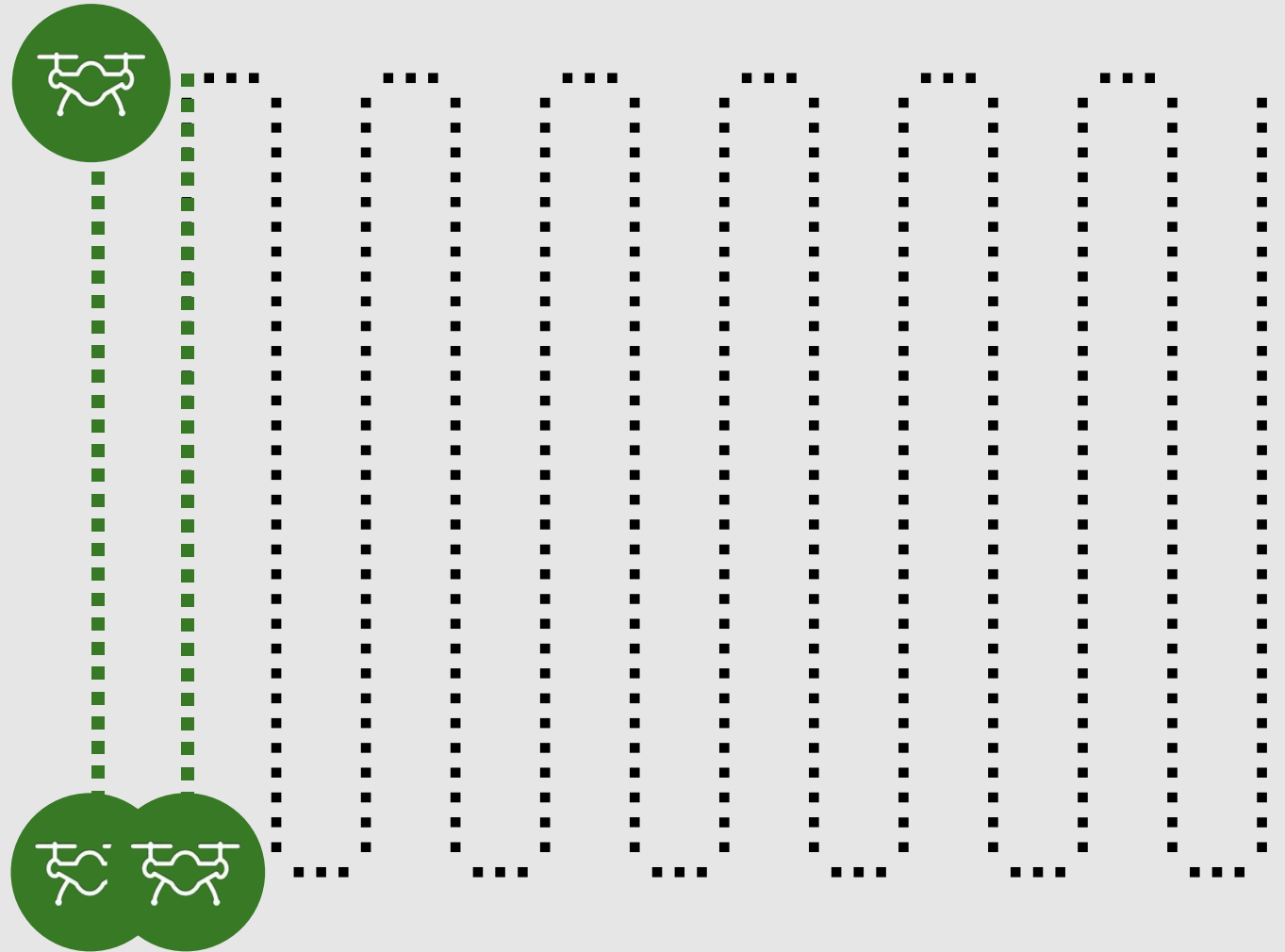
Can collect visual  
data

Combine visual data from the UAVs with the sensor data from the farm

# Aerial imagery in precision agriculture



Drone Video

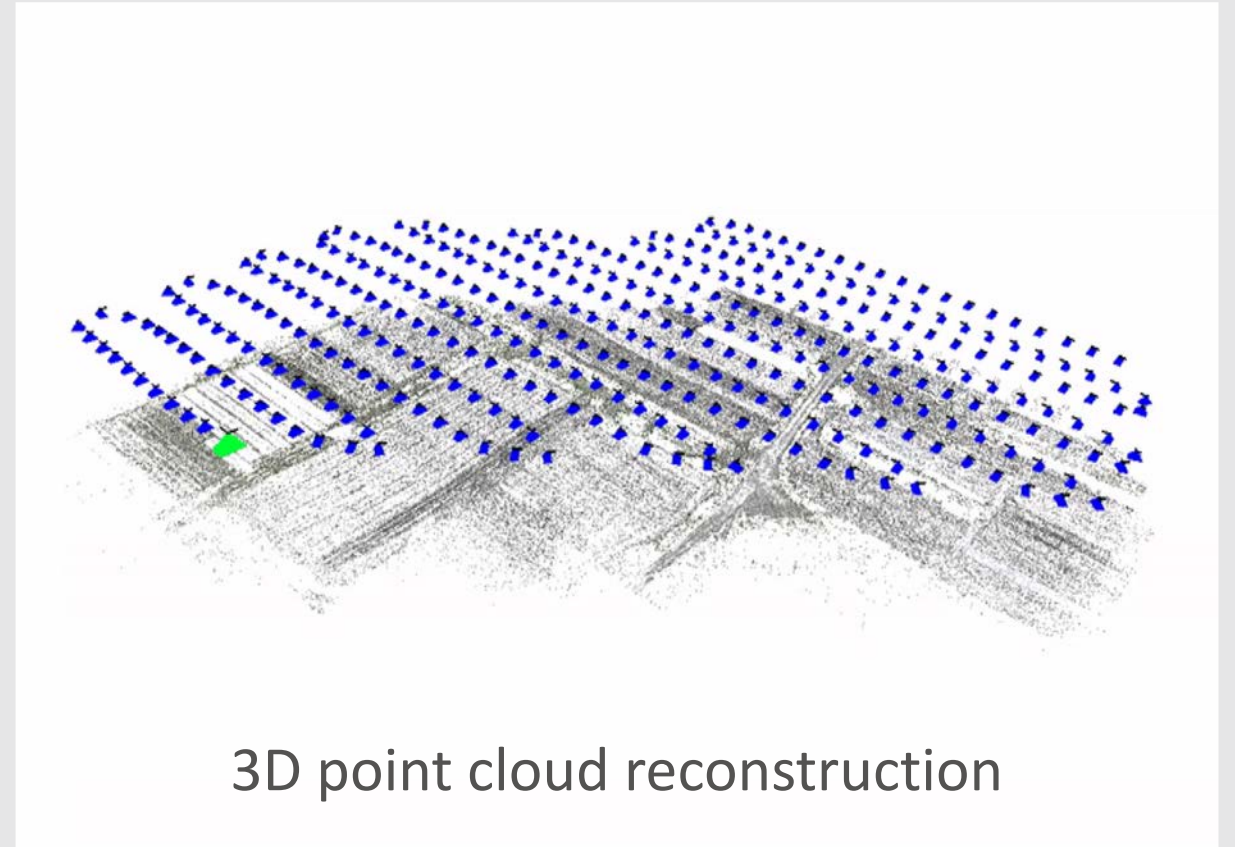




# Processing RGB & multi-spectral imagery



Aerial footage

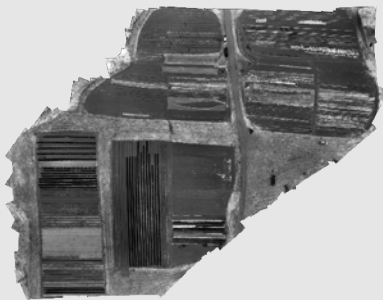


3D point cloud reconstruction

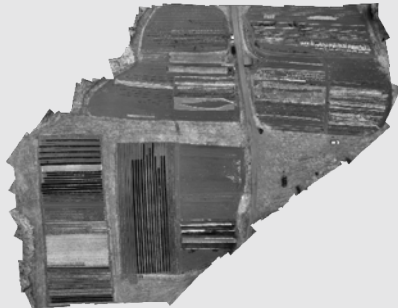
# Processing RGB & multi-spectral imagery



Sequoia  
multi-spectral  
camera



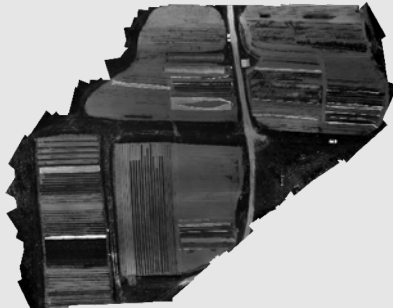
NIR



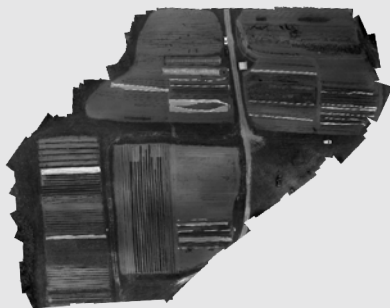
Red edge



RGB



Red



Green



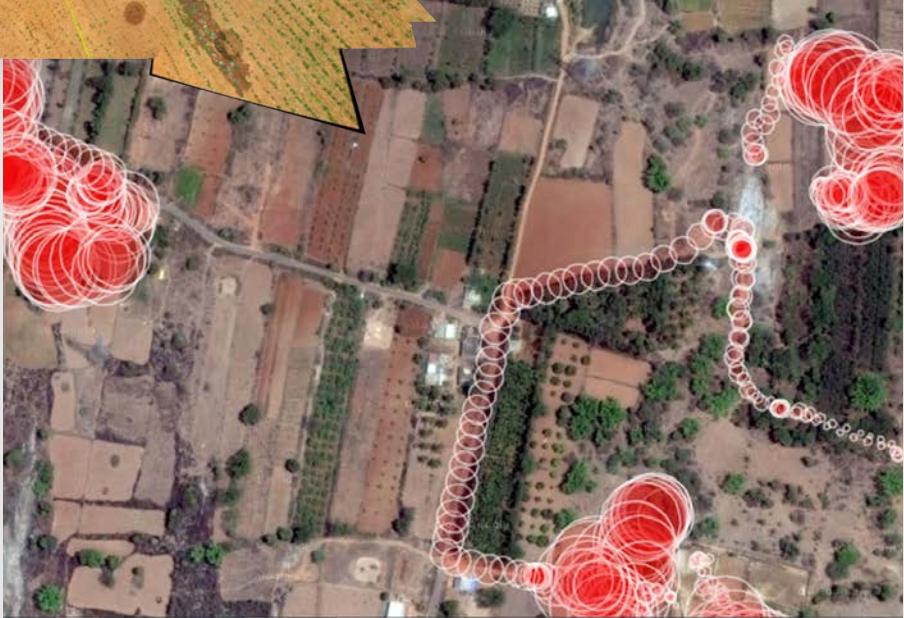
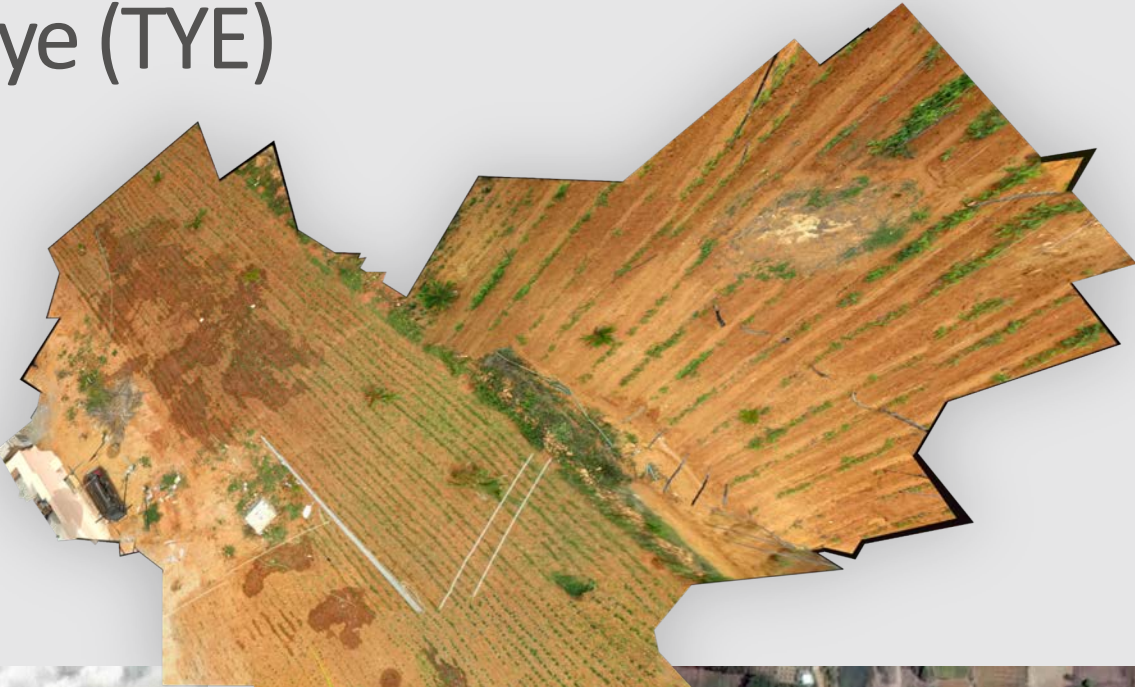
# Low-cost aerial imagery: Tethered Eye (TYE)

UAVs have a few limitations:

limited battery life

Regulatory concerns

Cost



# Idea: Use Drones to Enhance Spatial Coverage



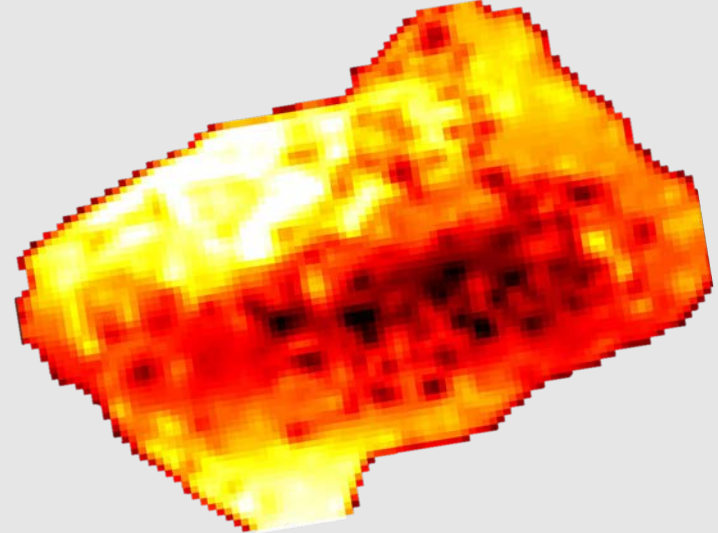
Drone Video



Panoramic Overview



Sparse  
Sensor Data



Precision Map



Idea: use drones/balloons to enhance spatial coverage

FarmBeats can use drones to expand the sparse sensor data and create summaries for the farm



Orthomosaic Map



# Idea: use drones/balloons to enhance spatial coverage

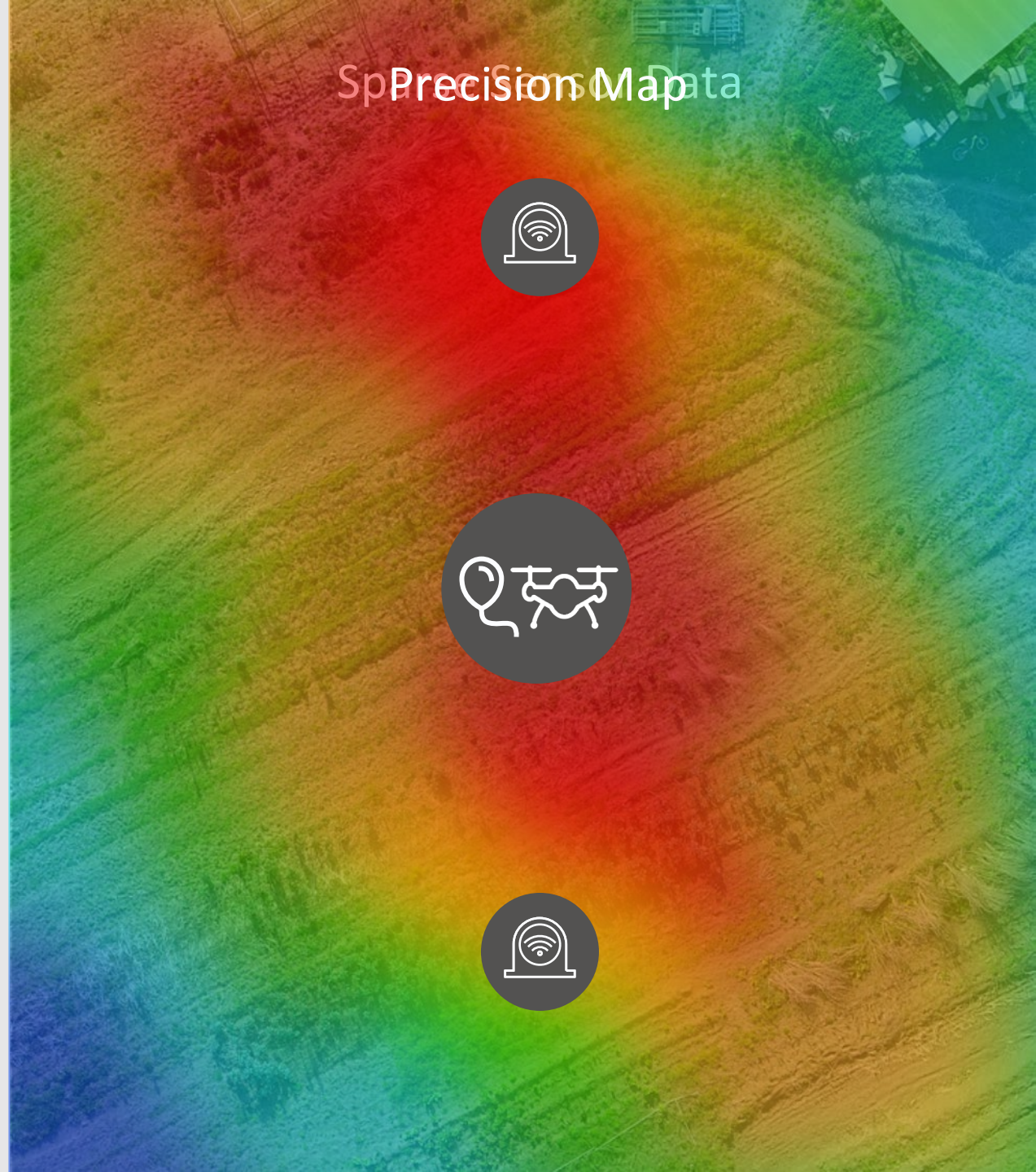
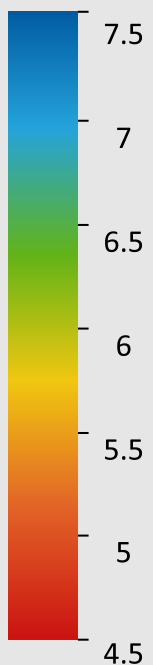
FarmBeats can use drones to expand the sparse sensor data and create summaries for the farm



Precision Map:  
**Moisture**



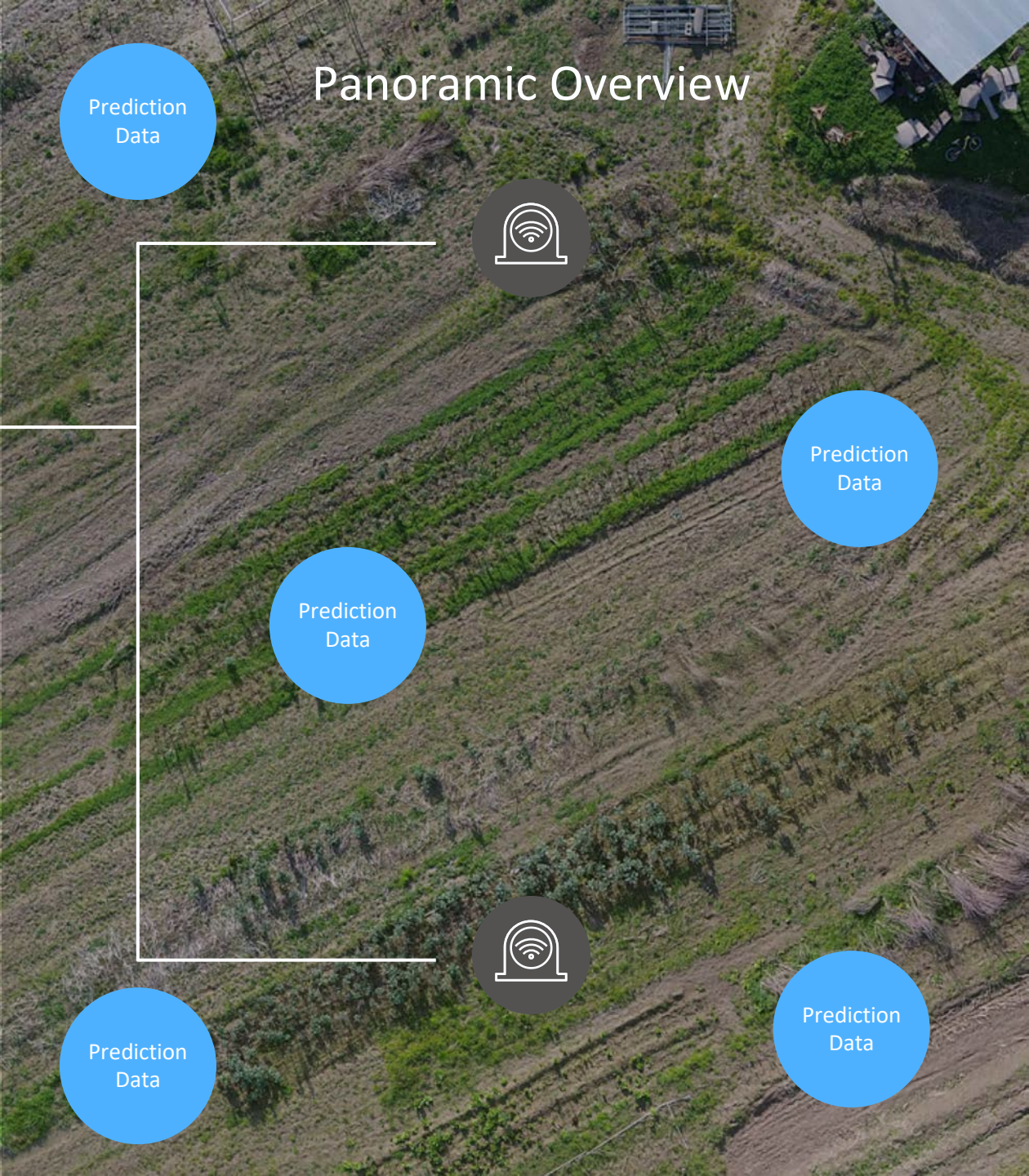
Precision Map:  
**pH**





# Formulate as a learning problem

Training Data



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Connectivity on  
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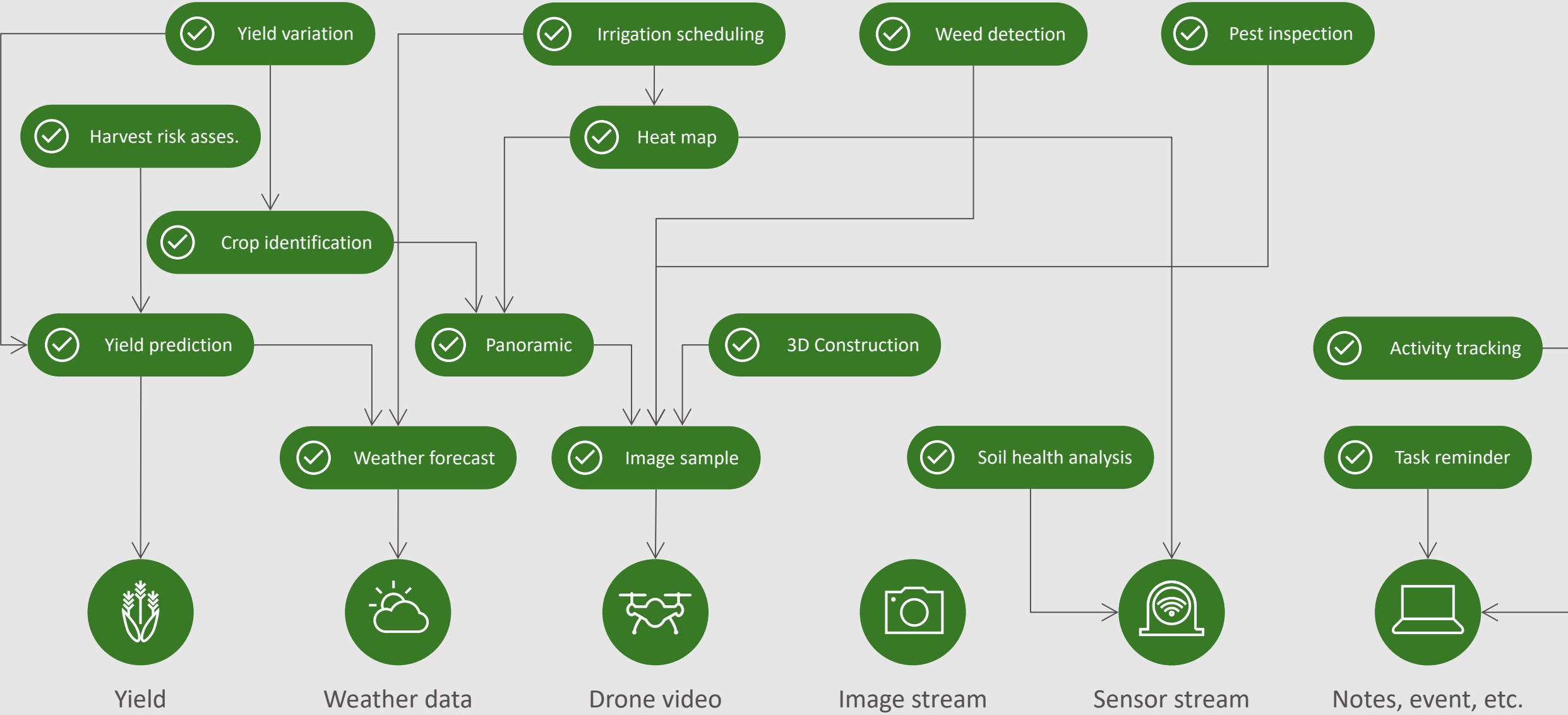
Precision  
Mapping

Slow cloud connectivity

Power on  
the Farm



# 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

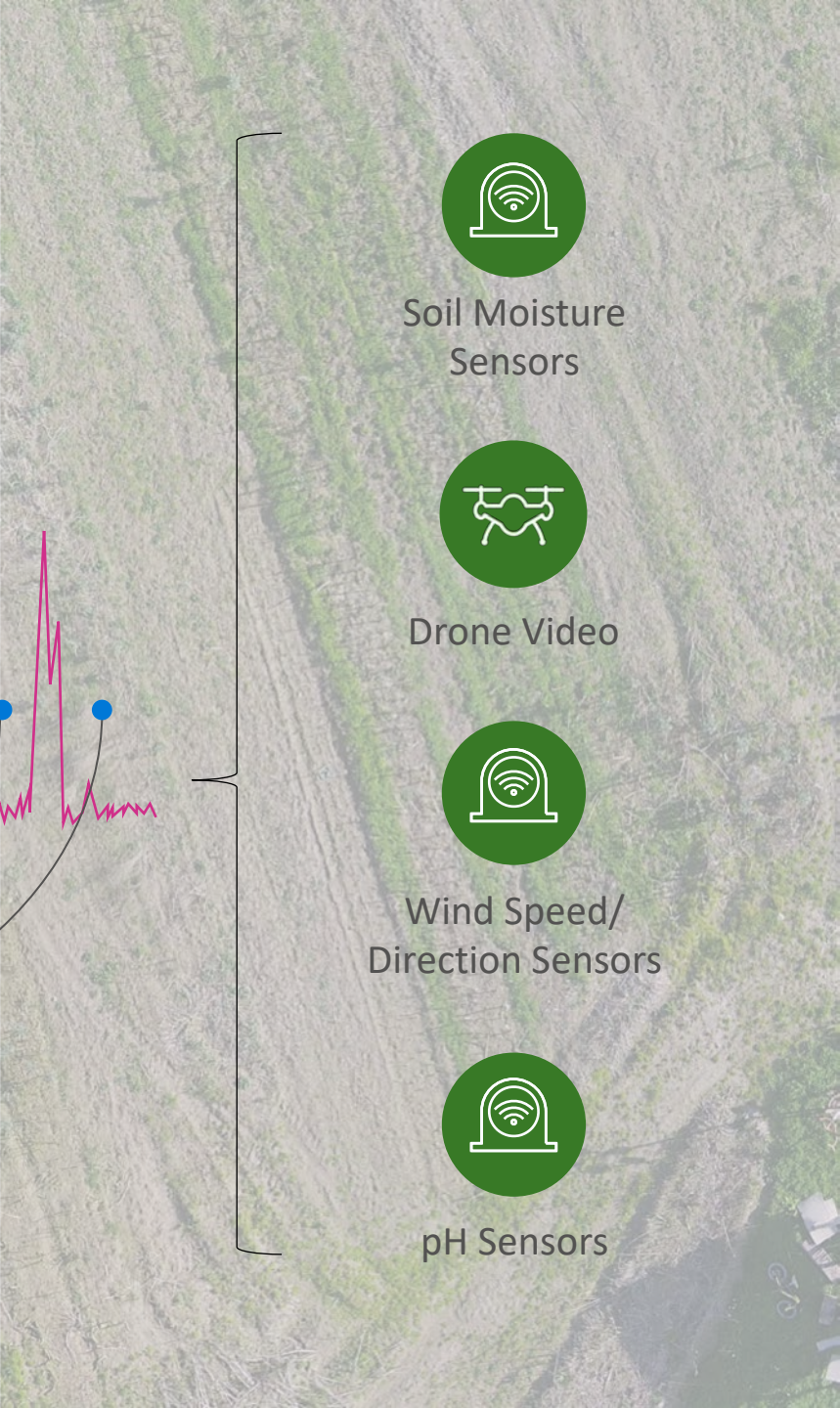
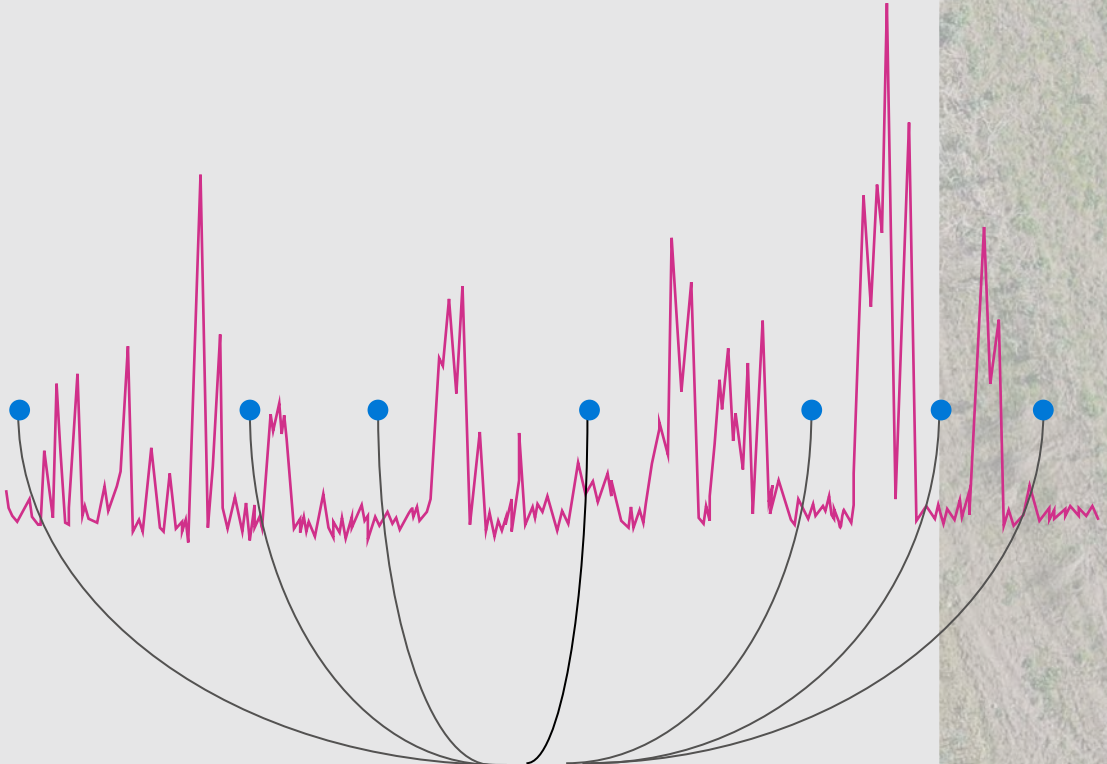
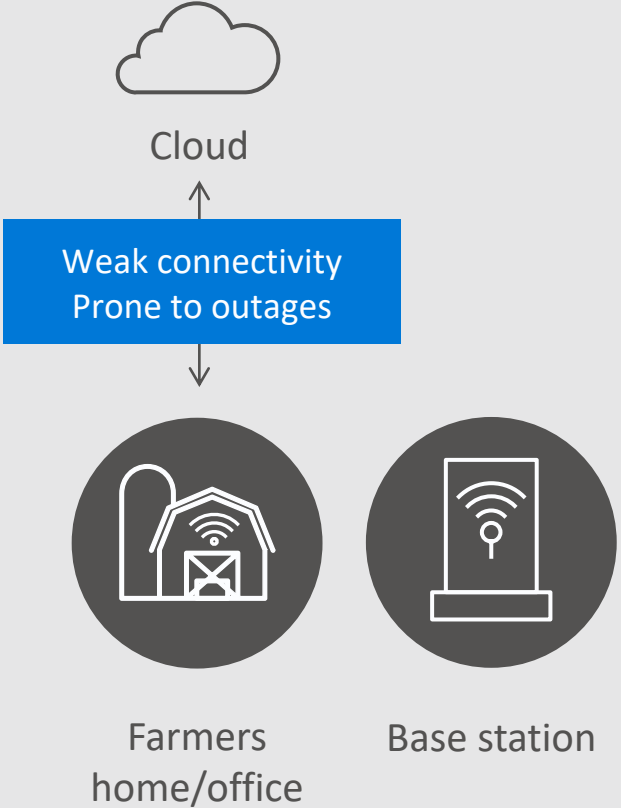
Service	Latency
Query sensor data	seconds
Livestock monitoring	seconds
Irrigation schedules	hours
Pest inspection	hours
Variability analysis	Days



# The Ideal World



# The Real World



Soil Moisture Sensors



Drone Video



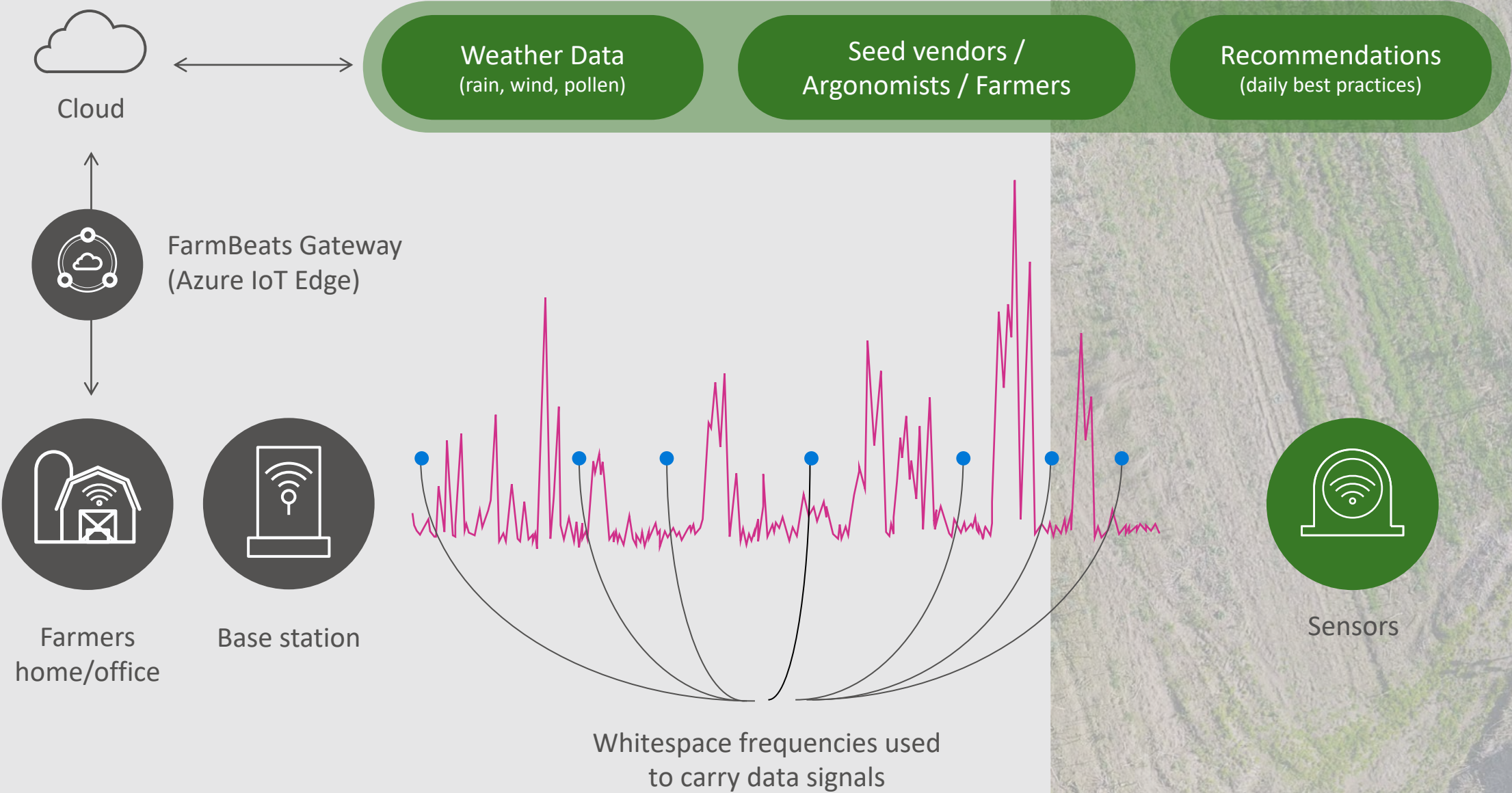
Wind Speed/ Direction Sensors



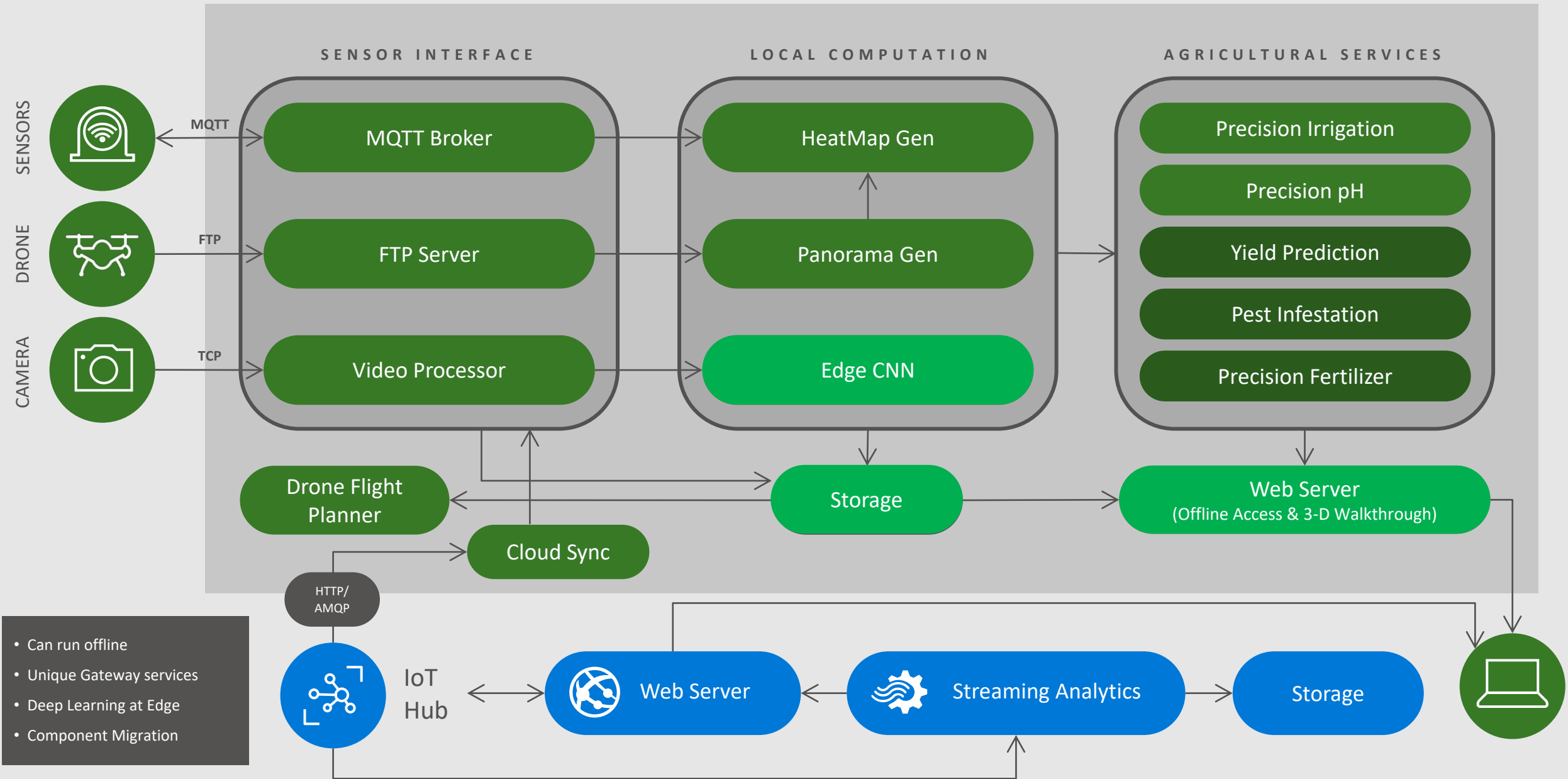
pH Sensors



# The Real World



# FarmBeats Gateway (Azure IoT Edge)





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the Farm



Precision  
Mapping

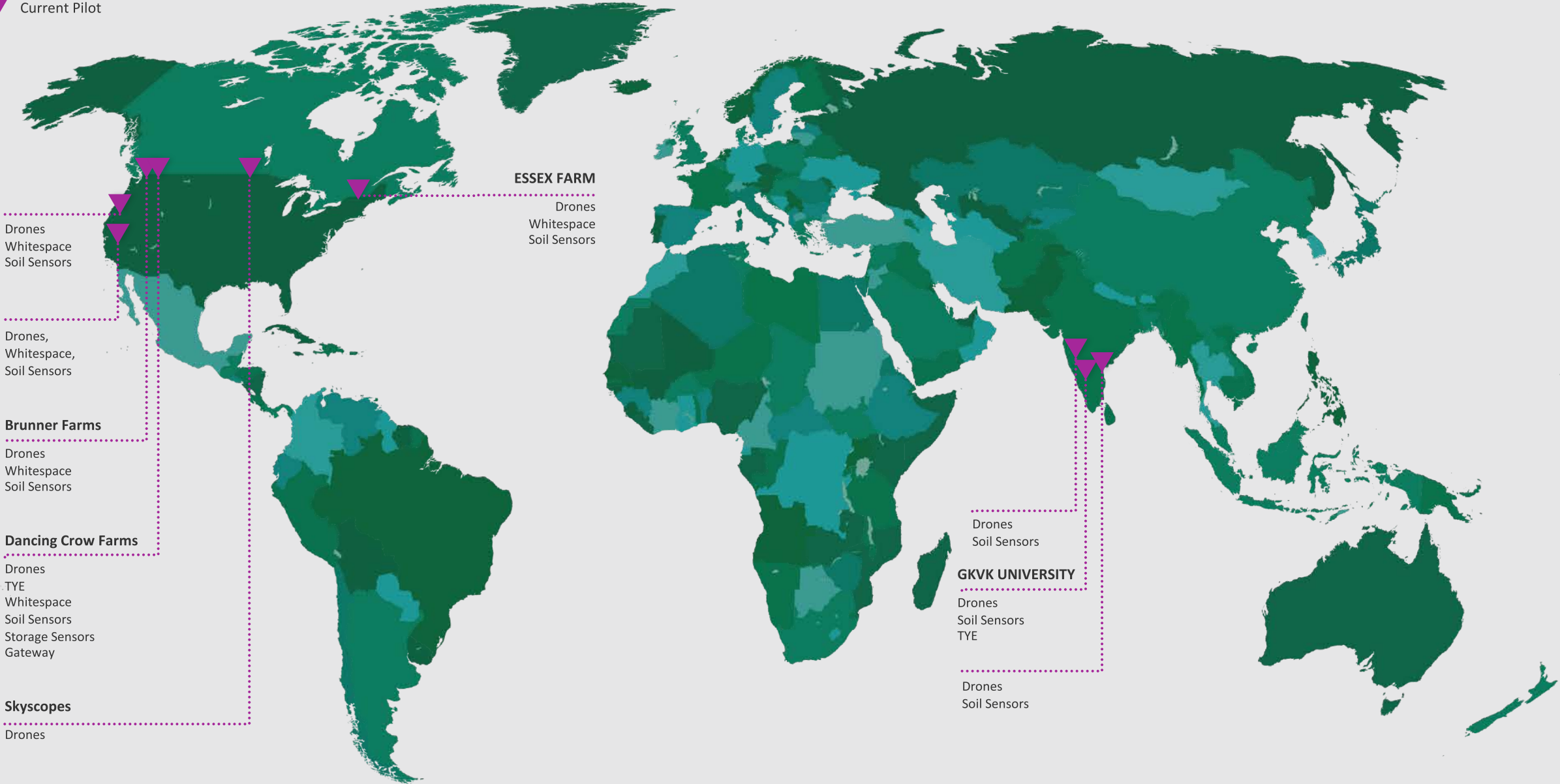


Slow cloud connectivity

Power on  
the Farm

# Pilot Project Status

▼ Current Pilot





# Deployment

Deployments in several locations including WA, CA, NY

Farm sizes range from 5 – 2000 acres

## Sensors:

- DJI Drones
- FarmBeats sensor boxes with soil moisture, temperature, pH, wind speed/direction sensors
- IP Cameras to capture IR imagery as well as monitoring

Cloud Components: Azure 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



# Micro-Climate Forecasting

## Goal:

Microclimate weather forecasting model based on FarmBeats sensors in the field.

## Impact:

Knowing microclimate enables better modeling of plant diseases, increasing overall classification accuracy.

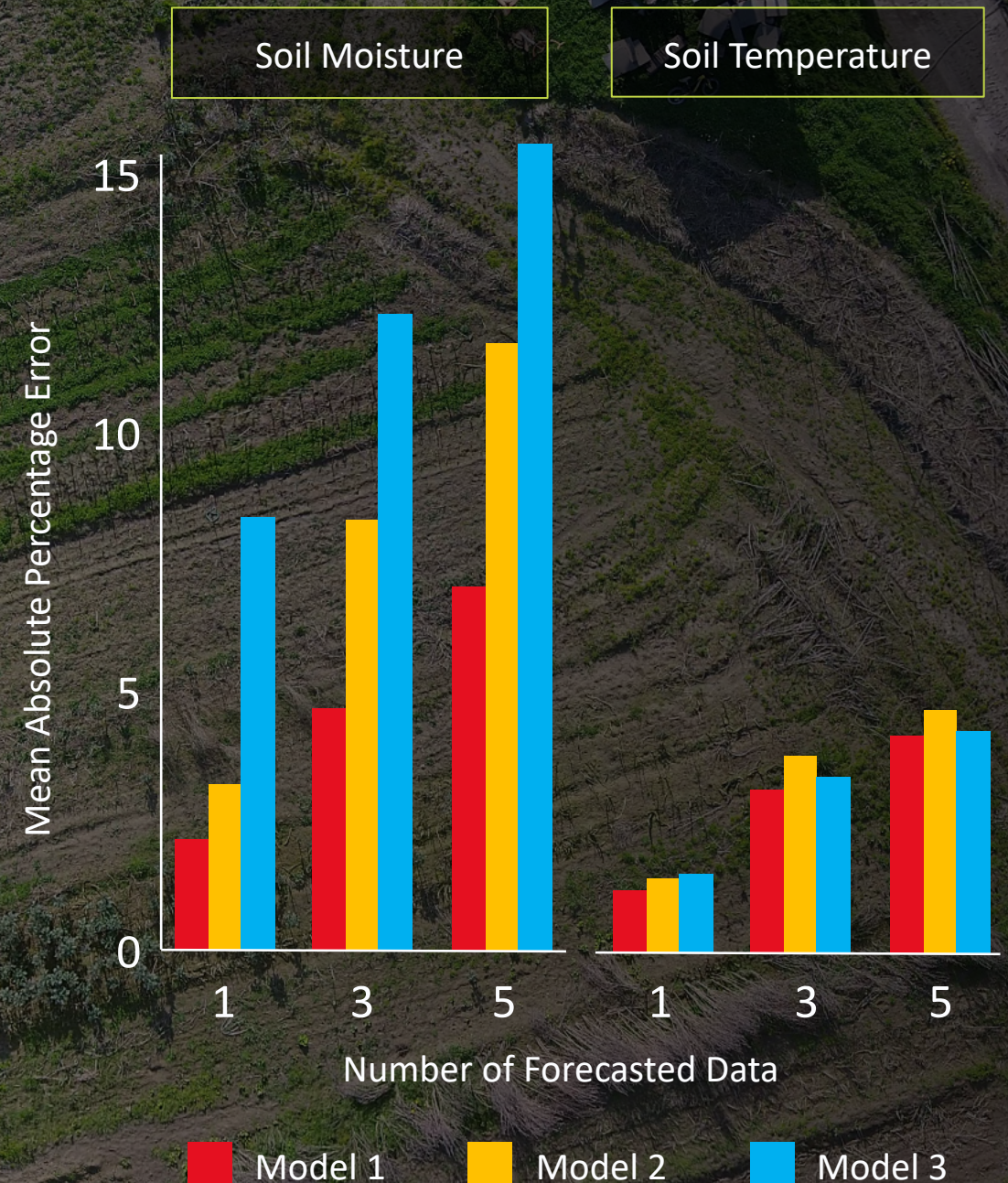
## Challenges:

Forecast important variables for accurate plant disease prediction, not included in current weather forecasts (results shown).

## Results:

Soil moisture & temperature forecasting error less than 10%.

\*The lower the error, the better the prediction.





# Example: Panorama



Water puddle



Cow excreta



Cow herd



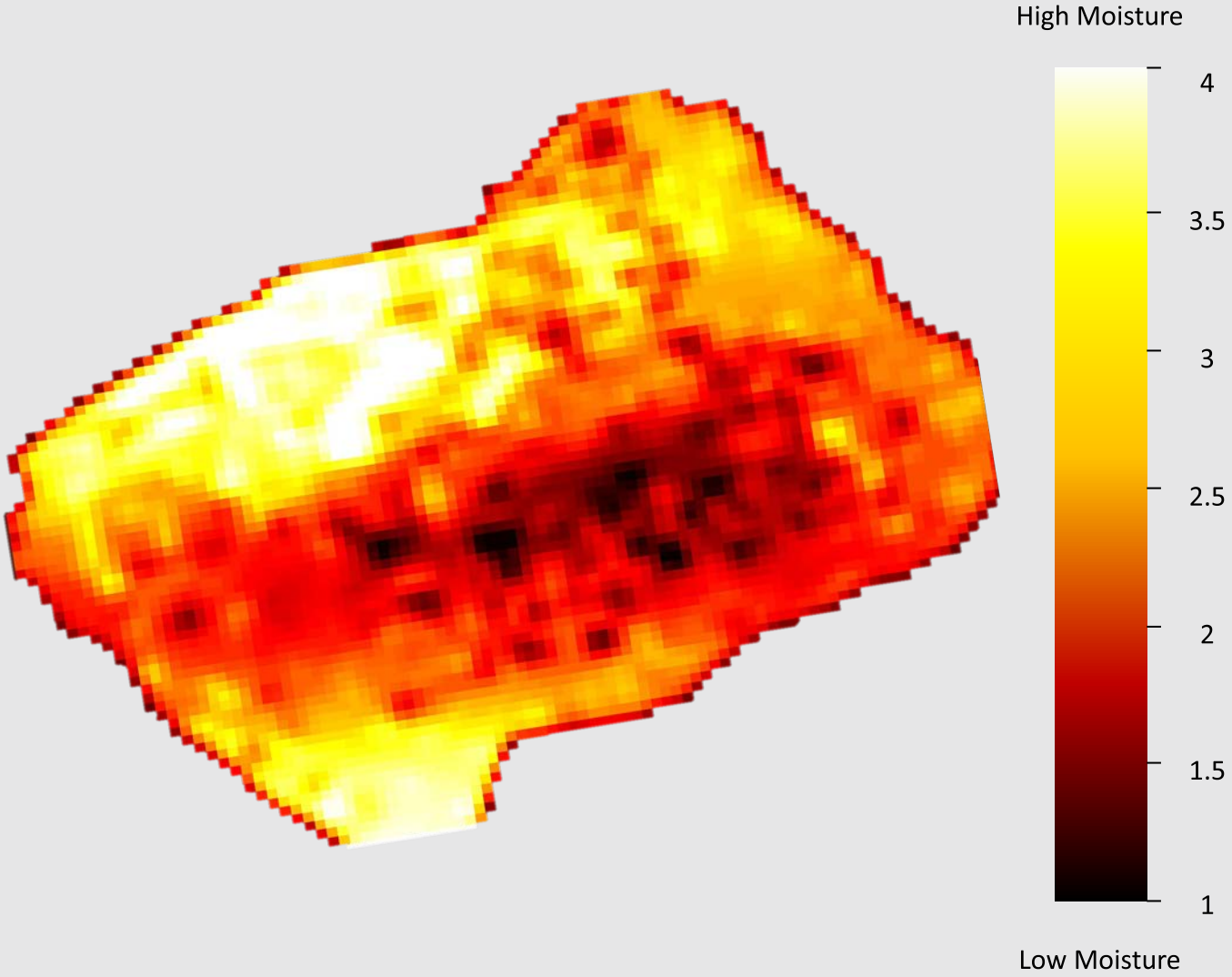
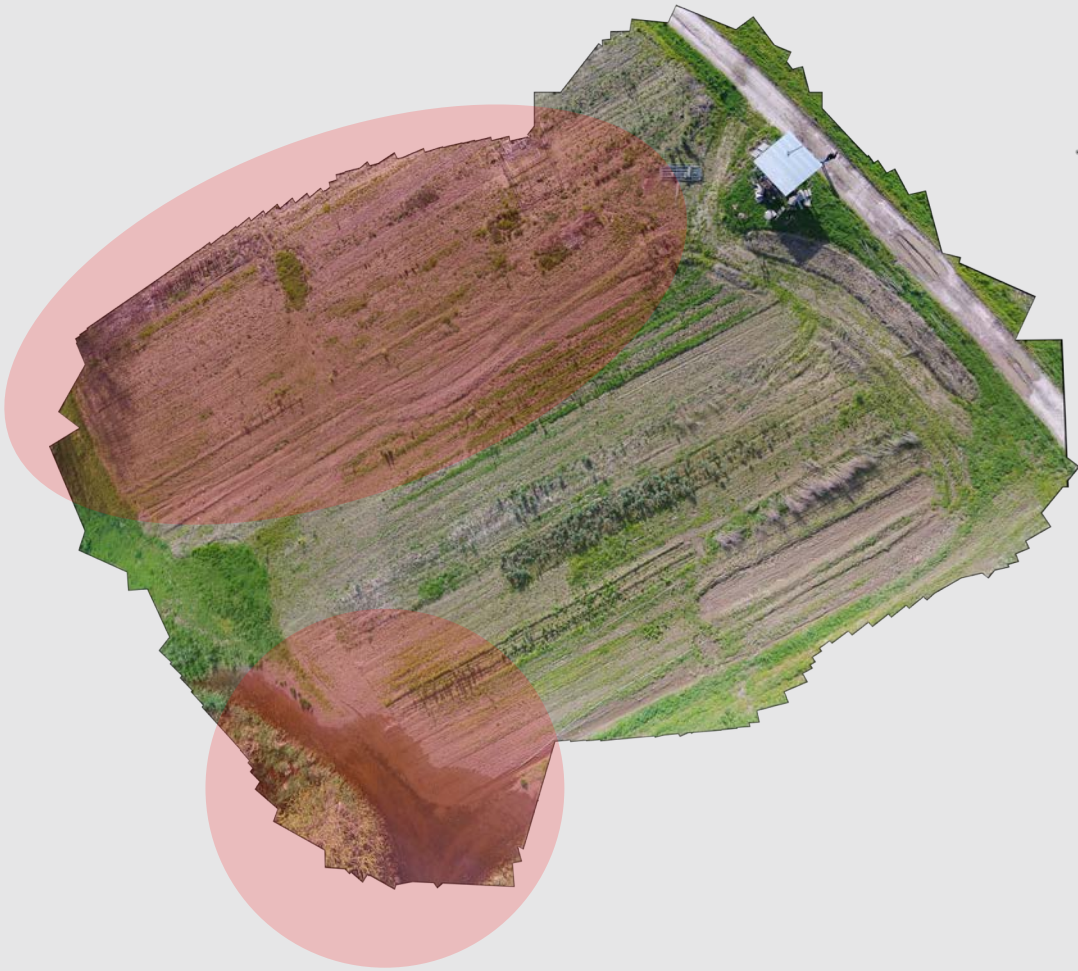
Stray cow



# Precision Map: Panorama Generation

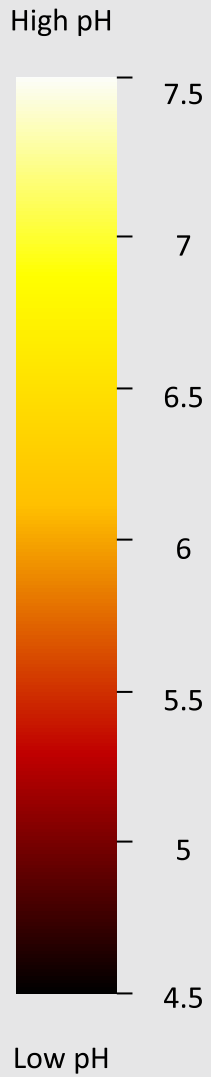
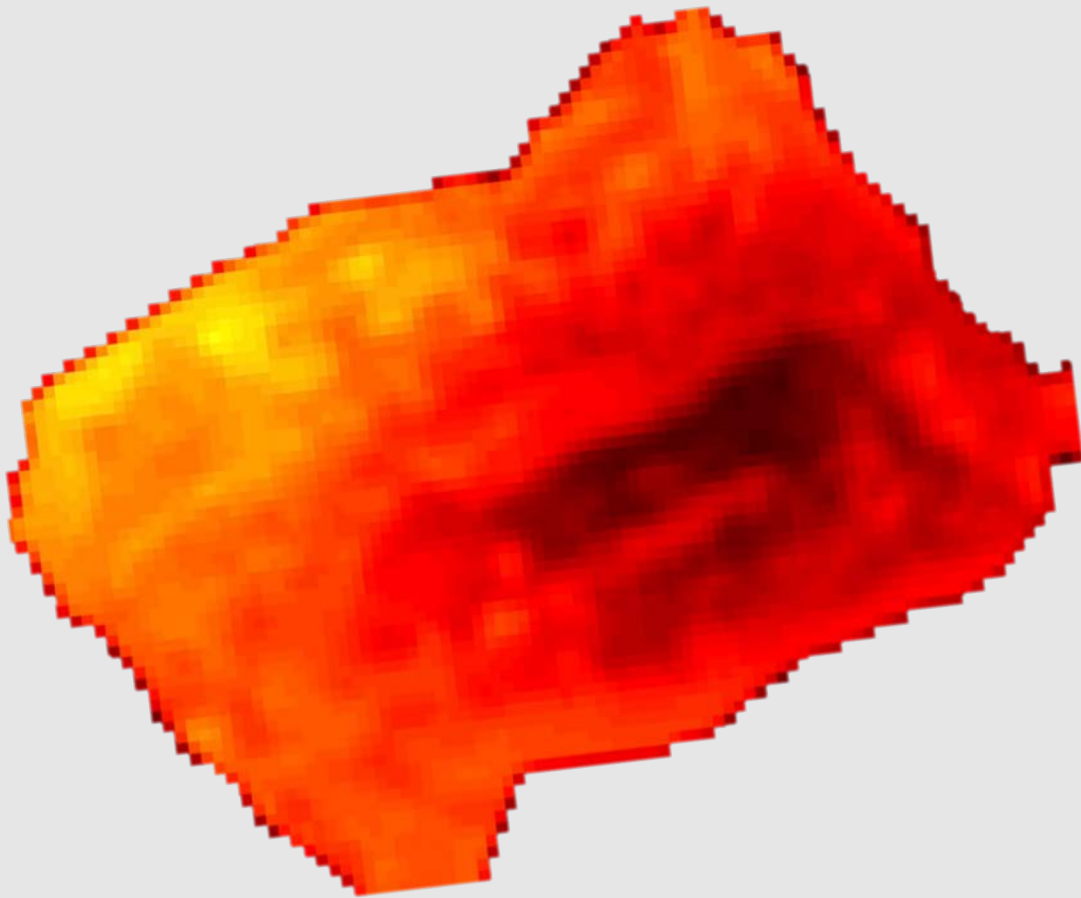


# Precision Map : Moisture

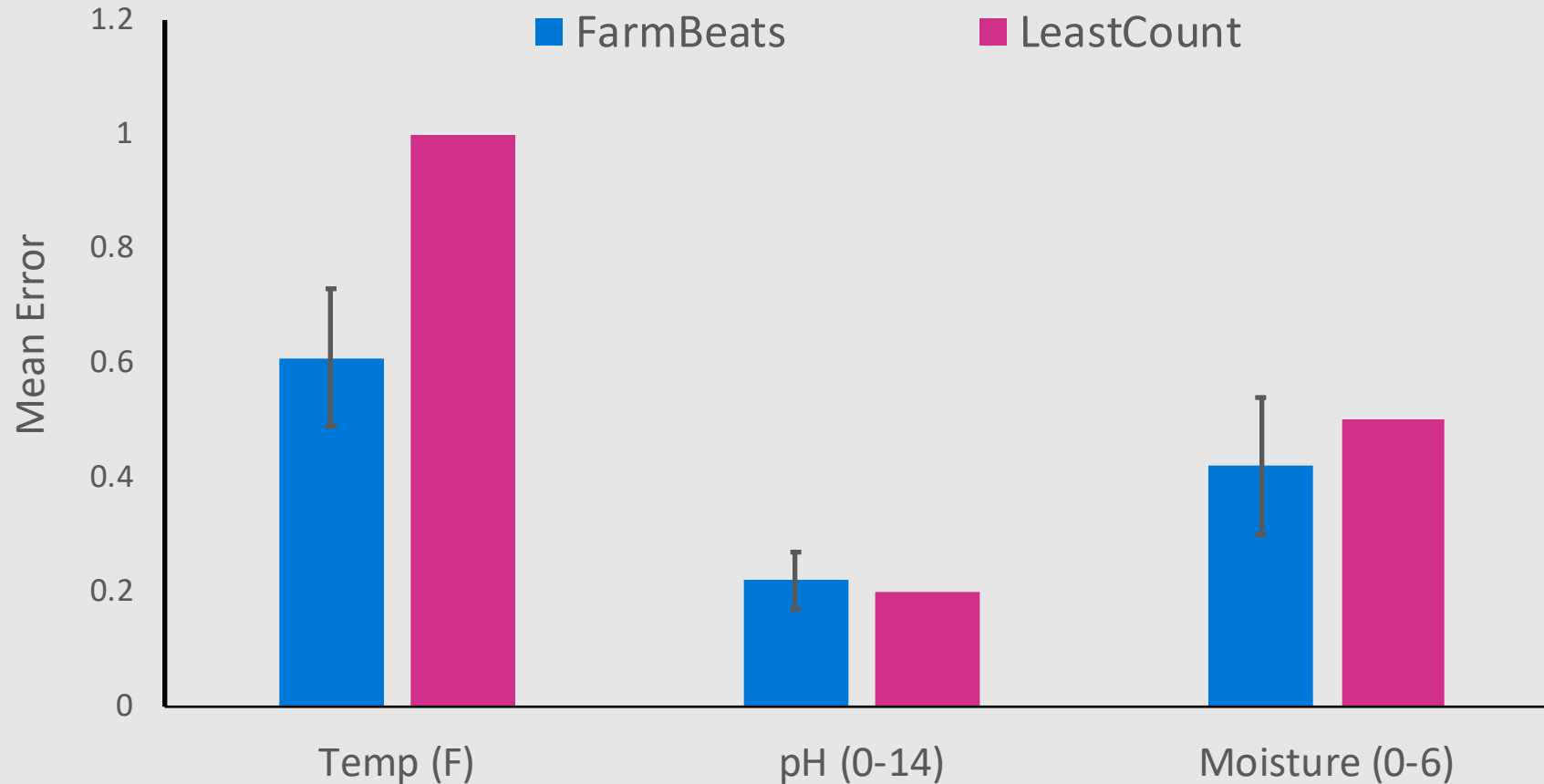




# Precision Map : pH



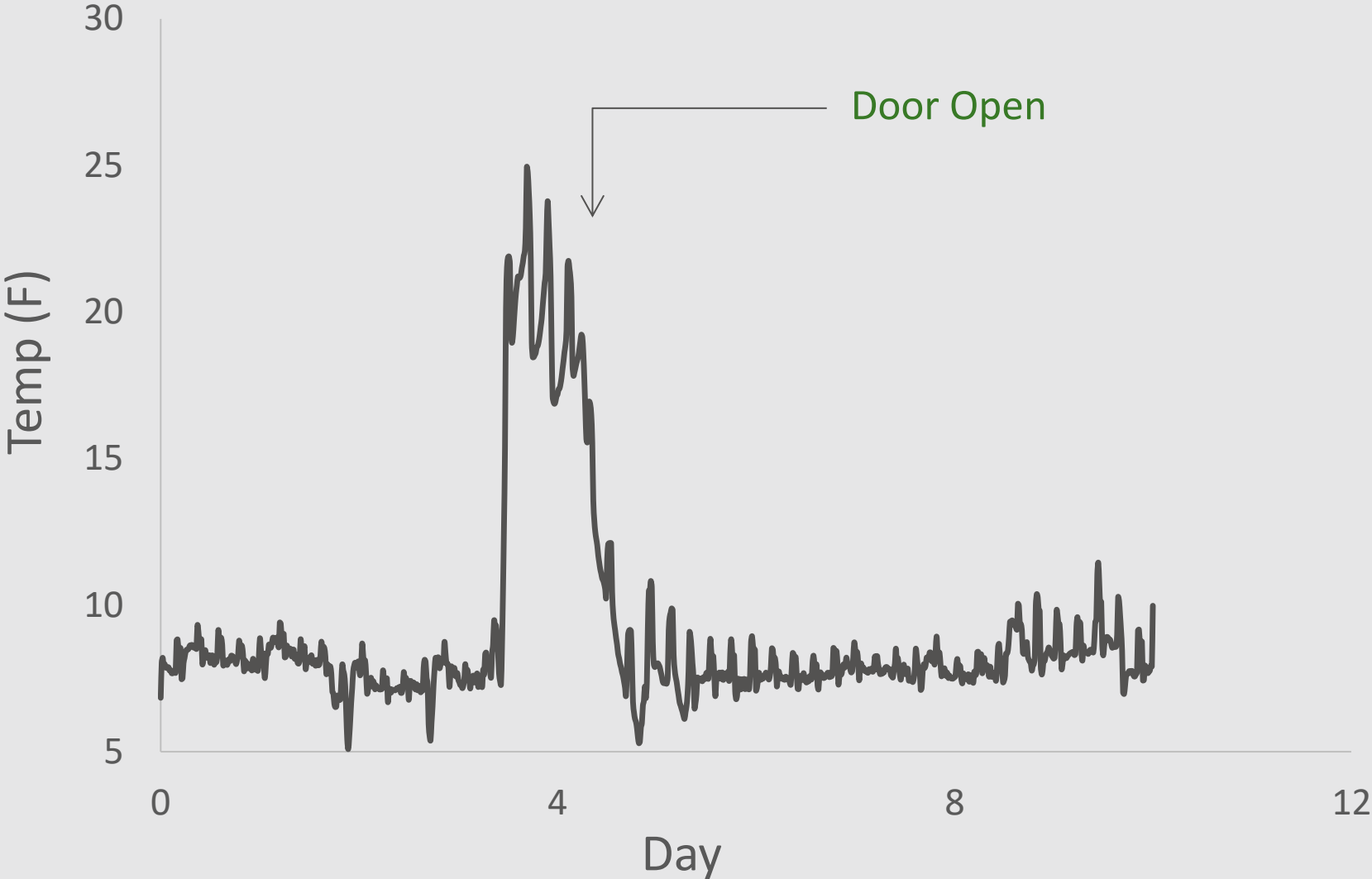
# Precision Map: Accuracy



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



# Application: Storage Monitoring



# Application: Cow-Shed Monitor





# Project FarmBeats

Microsoft Smart Agriculture Cloud Platform

## Agri Solutions



Precision  
Crop Insights



Smart  
Equipment



Farm  
Management



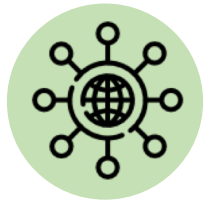
Supply  
Optimization  
  
Demand  
Forecasting



Govt.  
Subsidy  
programs

## FarmBeats

### FarmBeats Accelerator



#### Agri IoT

Plug-n-play deployment of sensors in minutes & ingest data in cloud



#### Agri Data

Marketplace for satellite & weather data, AI models, and data pipelines



Microsoft Azure Platform





# Conclusion

FarmBeats: End to end IoT system for environments constrained by:

- Limited internet connectivity
- Power variability
- Precision mapping
- Azure IoT Edge

Acts as a tool to enhance farm and farmer productivity

Microsoft's entire stack for Agriculture:

Data Capture (Azure IoT), providing Insights (Power BI), secure storage (Azure Data Lake), Traceability (BlockChain), AI & ML (Azure ML & Cognitive Services)

