Microsoft

FarmBeats:
Empowering Farmers with Affordable Digital Agriculture Solutions

Ranveer Chandra

To feed the world's growing population, we need to increase food production by 70% by 2050.

One way to do this is enable
data driven farming.

Data-driven agriculture

Precision agriculture has shown to:

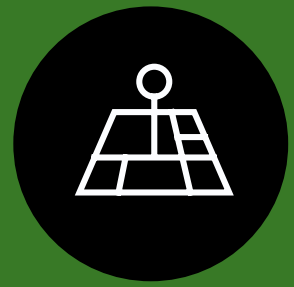
- Improves yield
- Reduces cost
- Ensures sustainability

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

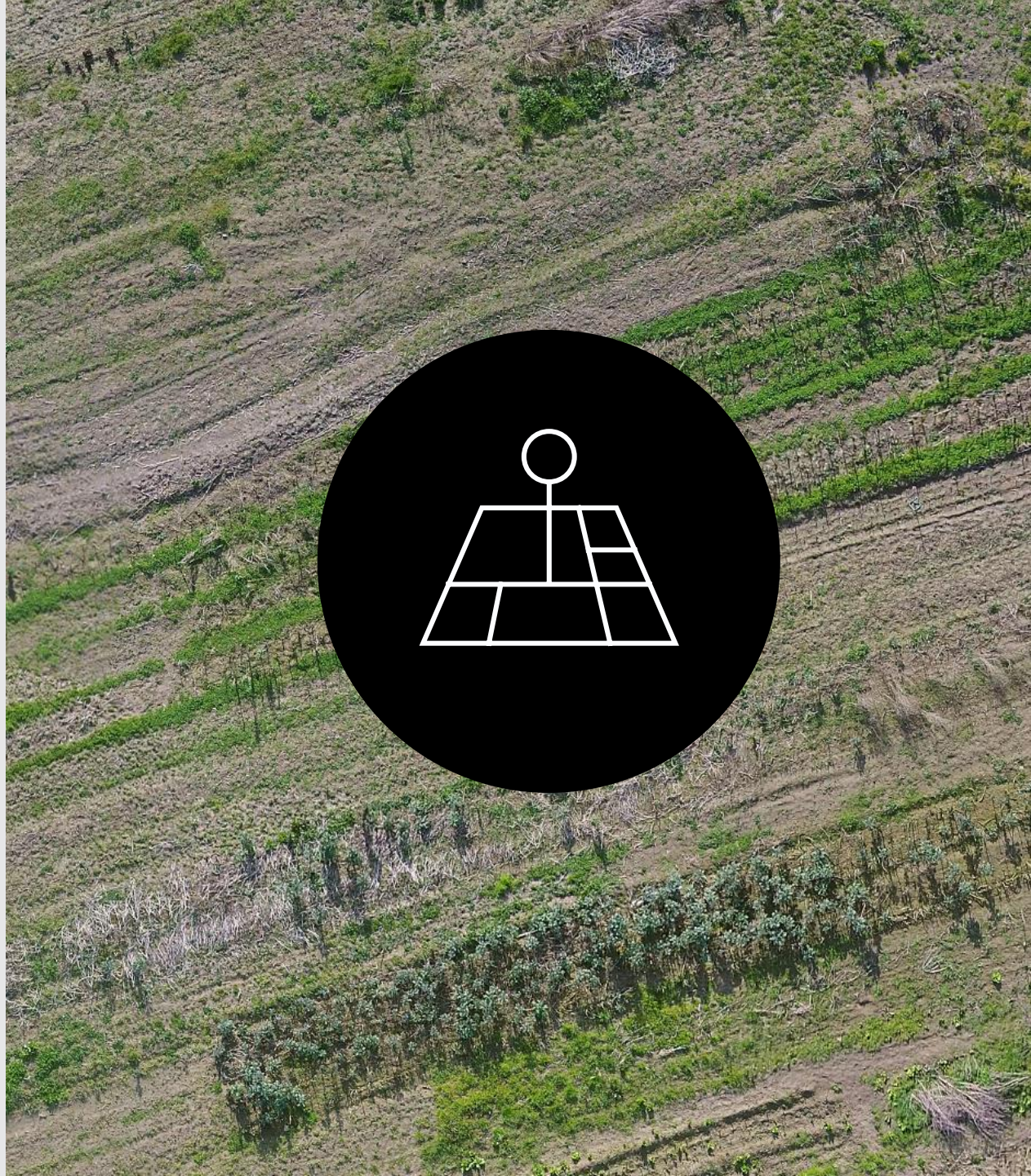
Weather and crops cause signal blockage

Problem 2:
Precision mapping with limited sensors

Obstructs farming activity

Too expensive

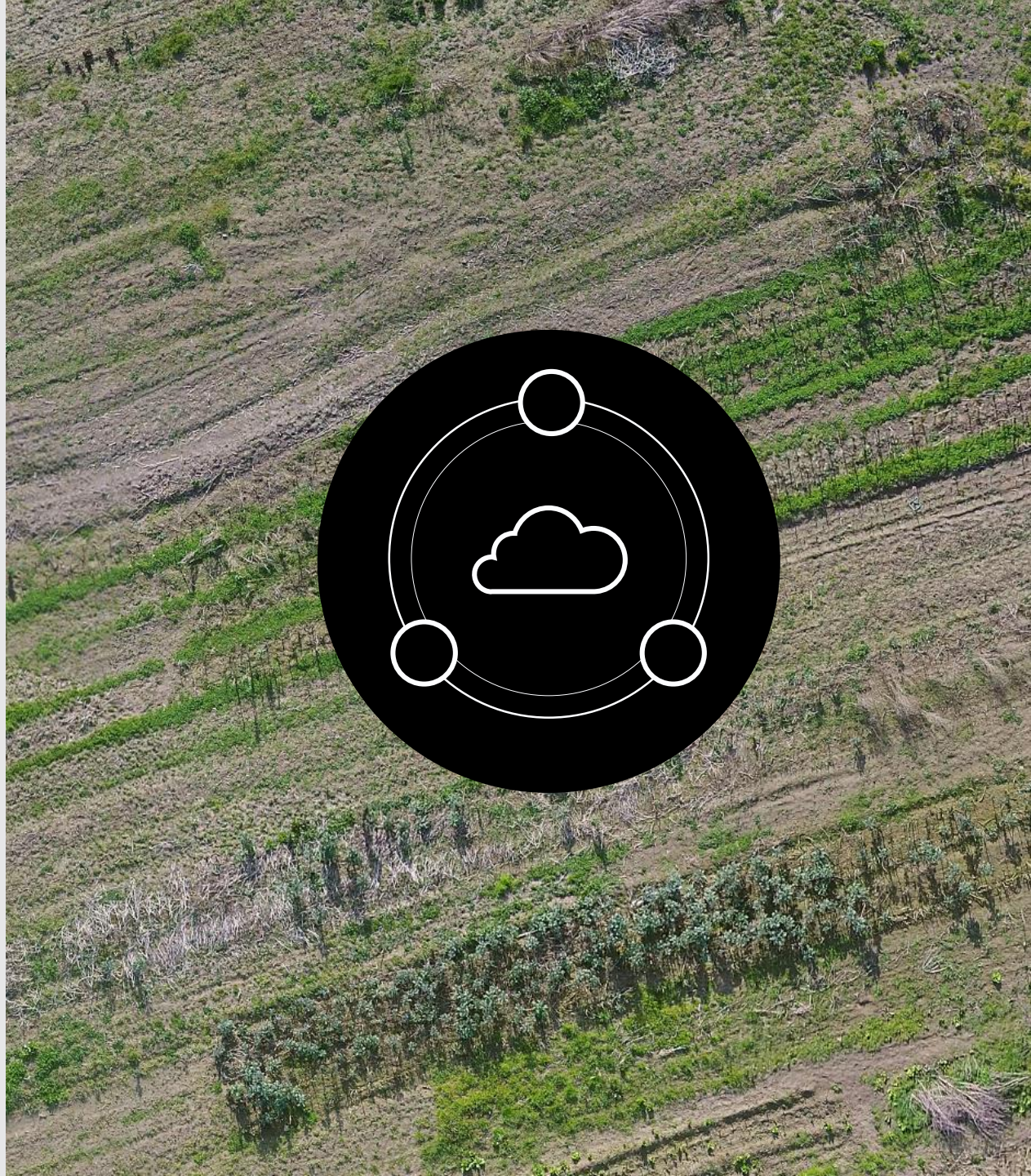
Cumbersome to maintain



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

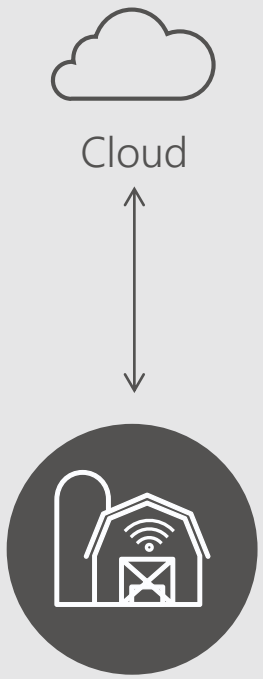
In this talk

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

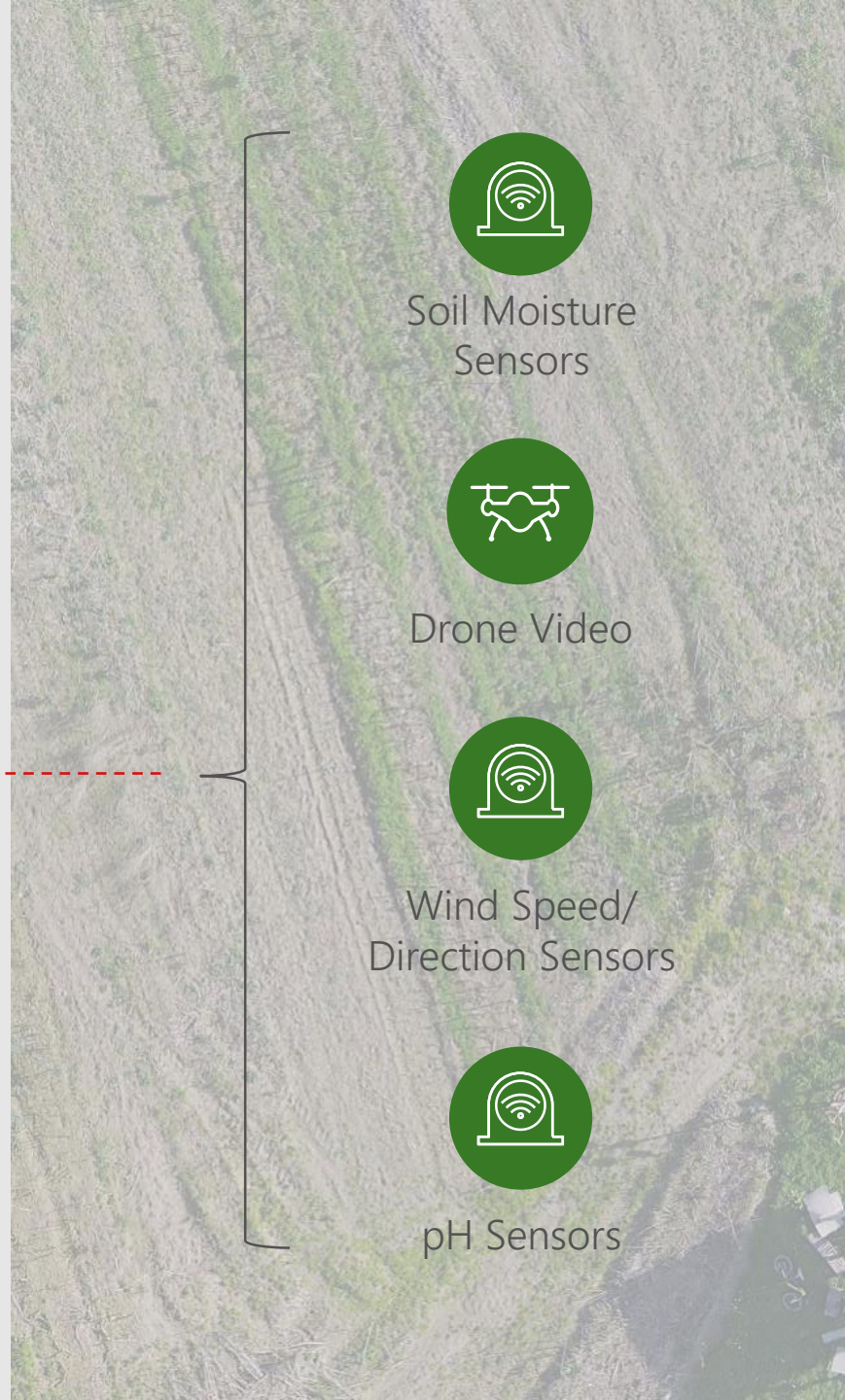
Solves key challenges:

No farm connectivity	Precision Mapping	Slow cloud connectivity	Power on the Farm

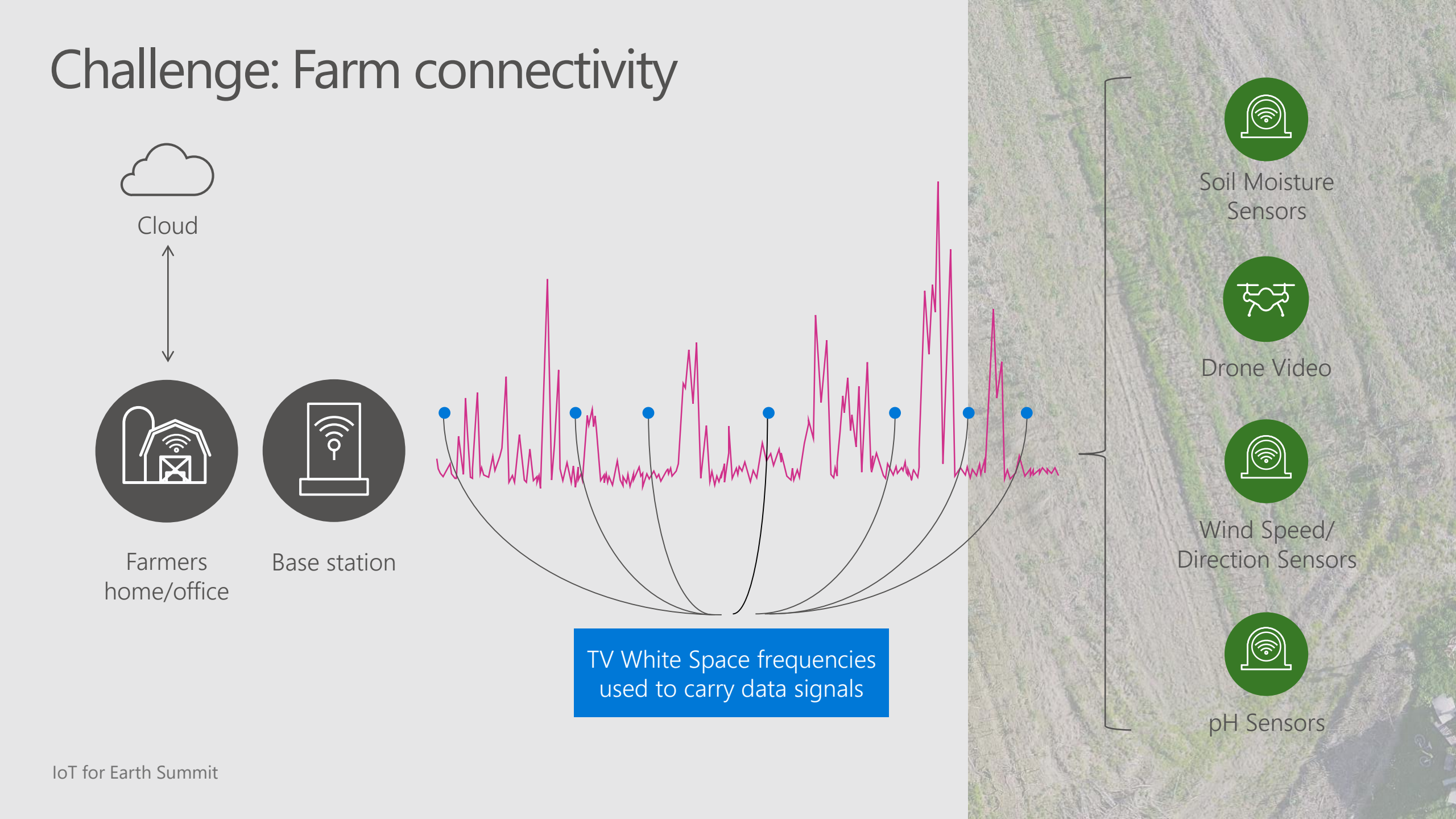
Challenge: Farm connectivity



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



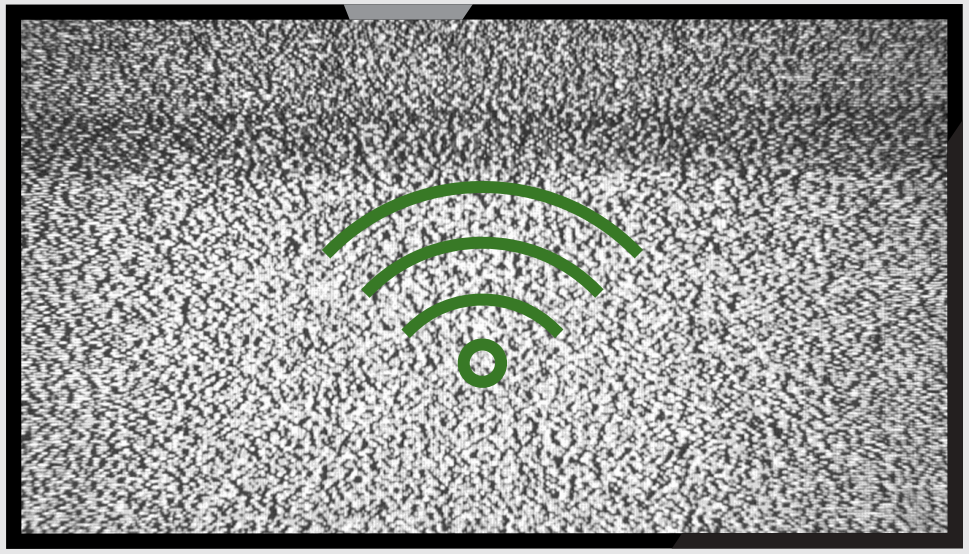
Challenge: Farm connectivity



Microsoft Research has been studying this for over a decade…

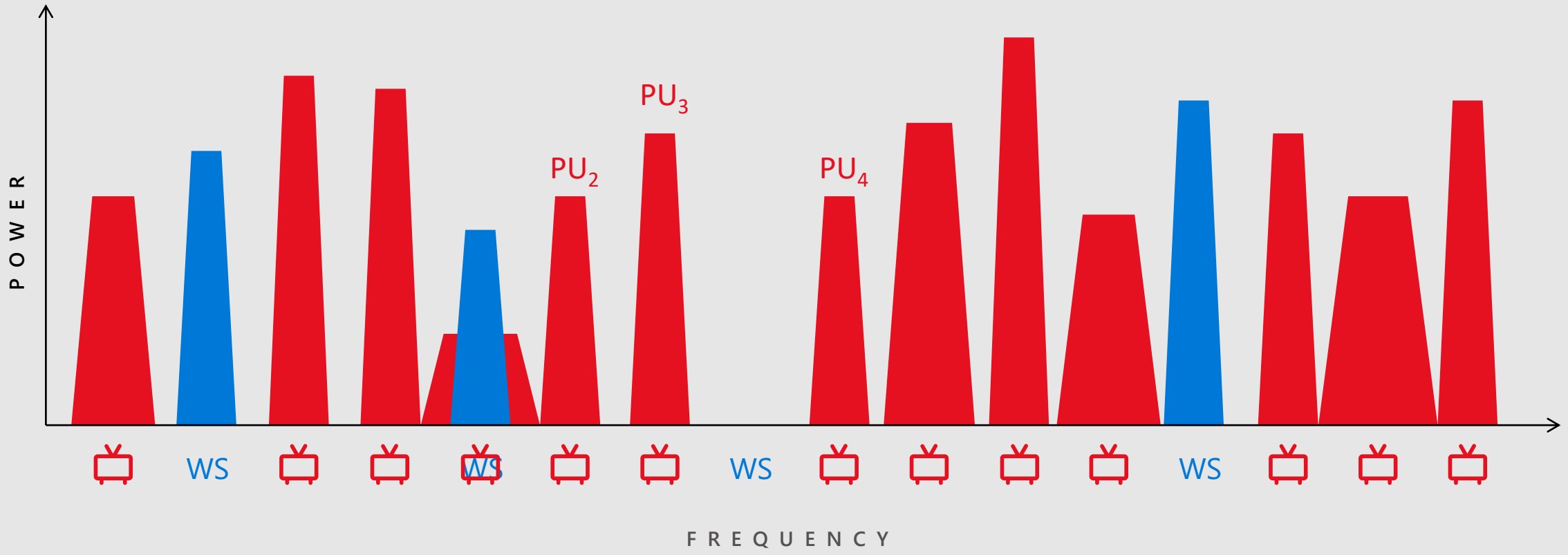
Networking Over White Spaces (KNOWS)

TV channel on network



Unused TV channel

TVWS using Dynamic Spectrum Access (DSA)



Determine available spectrum (**white spaces**)

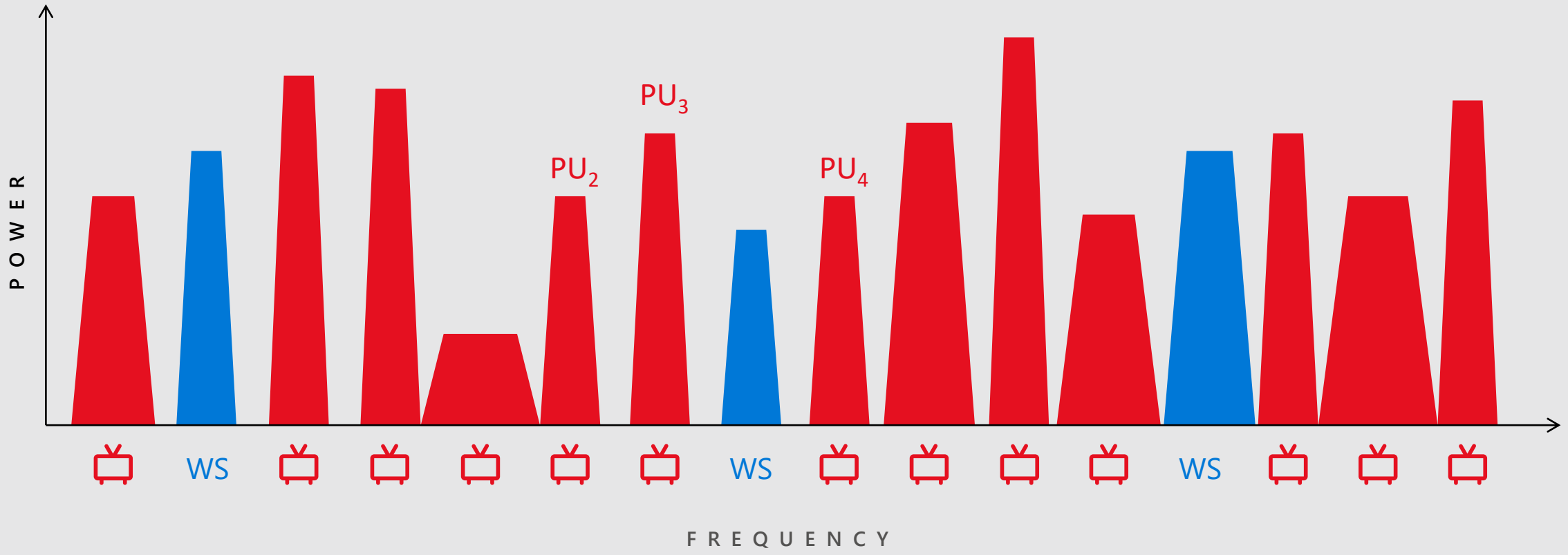
Transmit in "available frequencies"

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

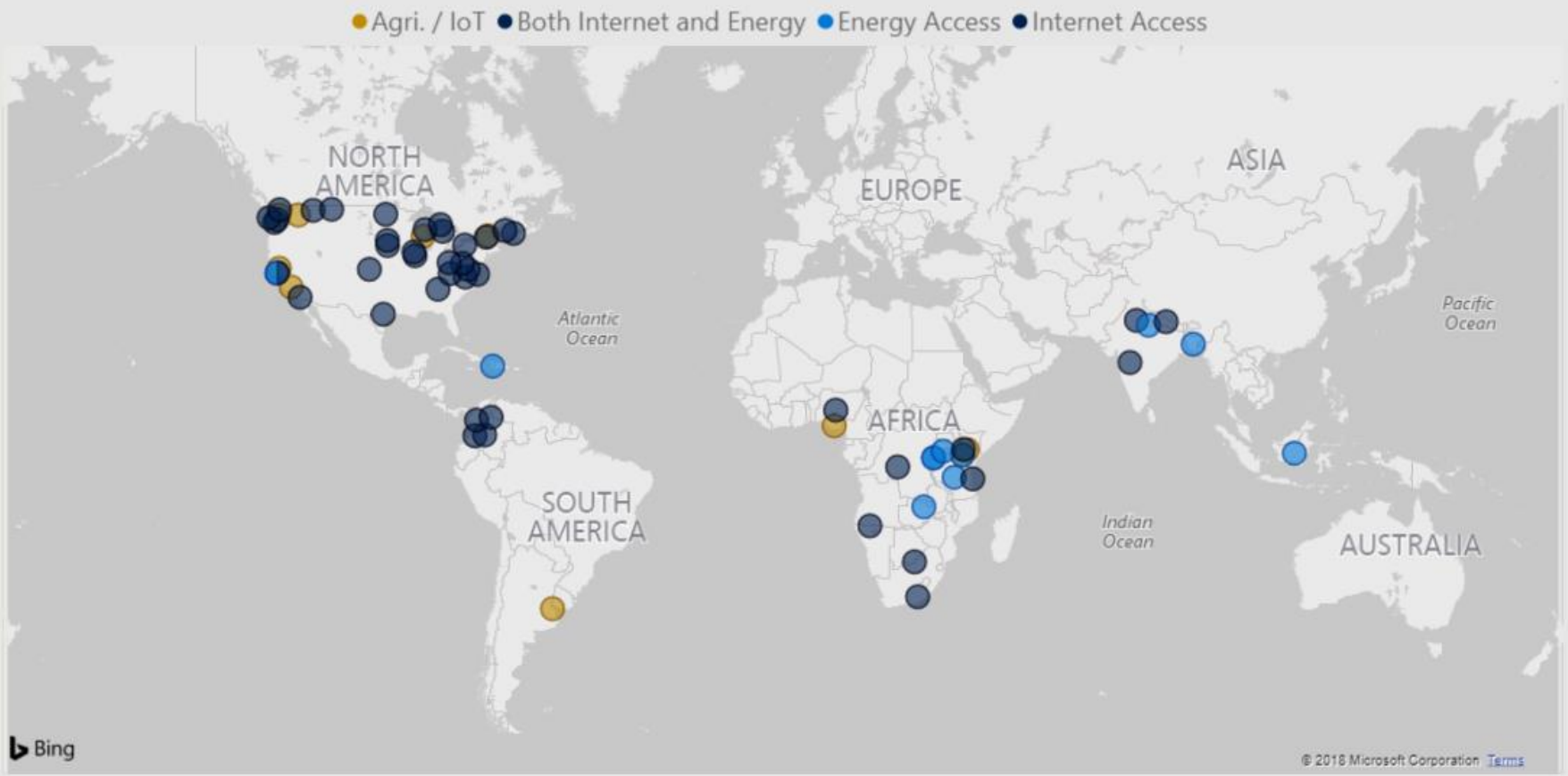
Demo world's first WhiteFi network in 2009

Airband

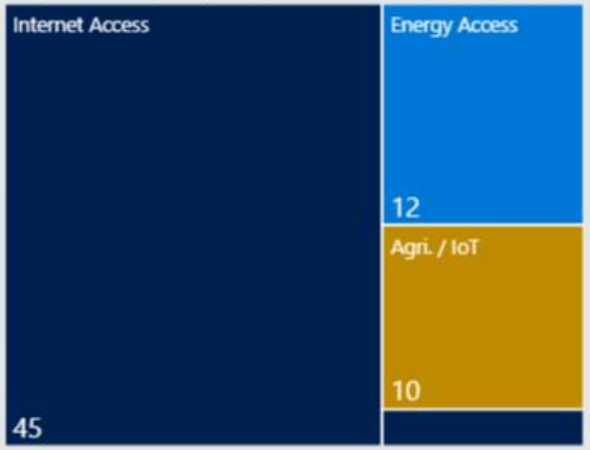
Internet Access

Active Projects	Population Covered	Population Connected	Energy Access
69	11,778,136	594,918	705,360

Project Locations



Project Count by Project Type



Project Count by Funding Type

TV White Spaces in the Farm

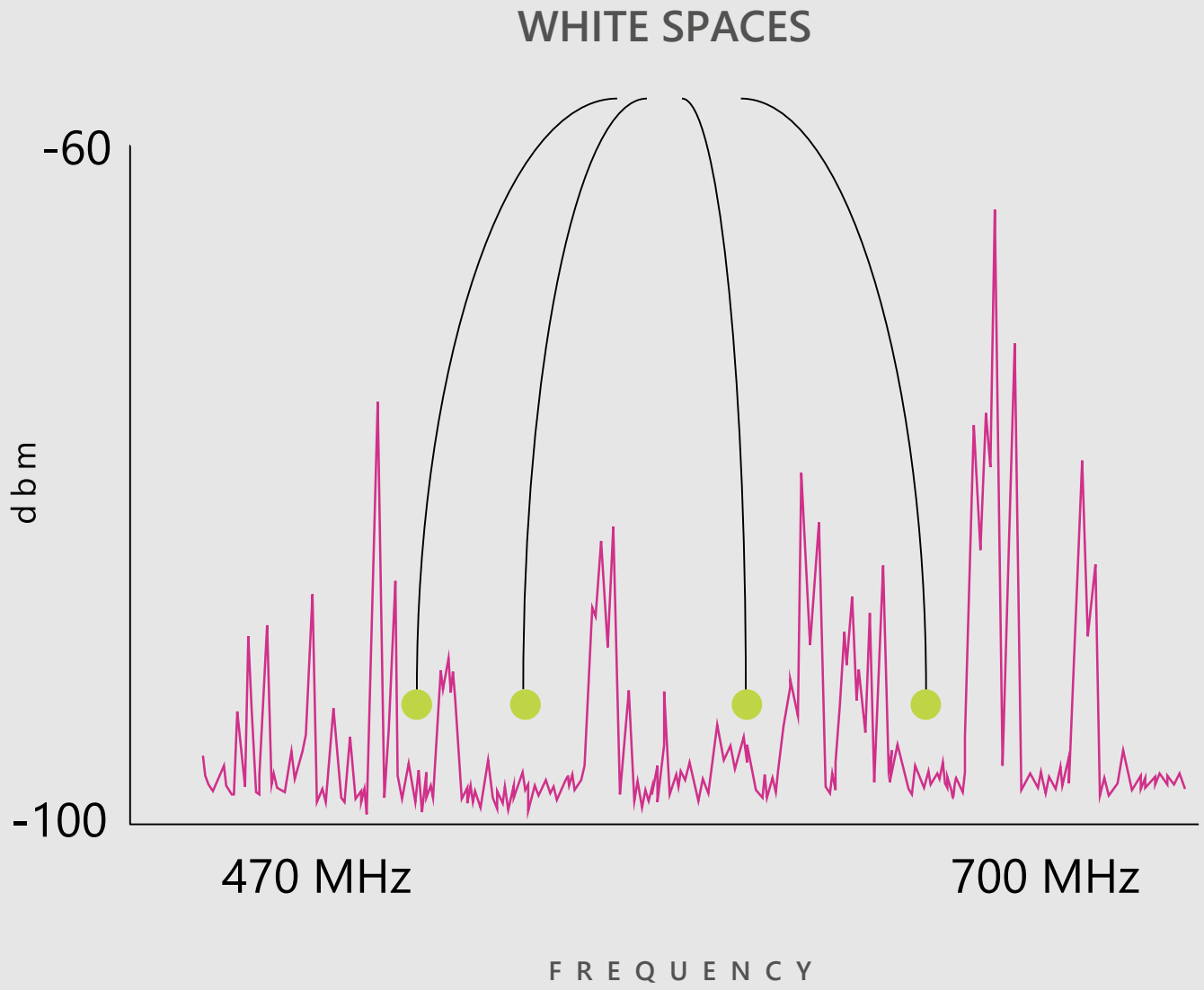
What are the TV White Spaces?

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

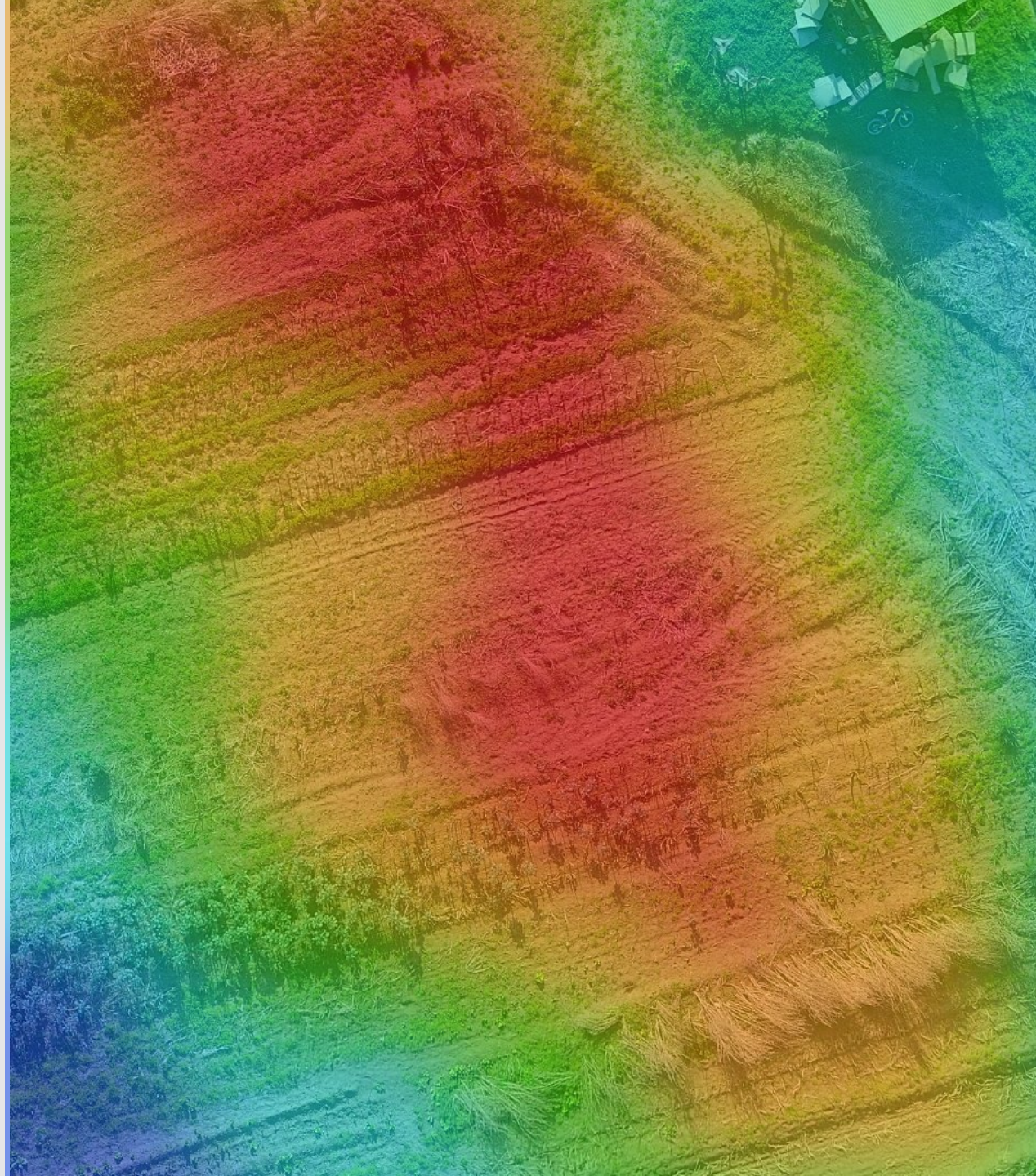
Power on the Farm

Challenge: Limited resources

Need to work with sparse sensor deployments

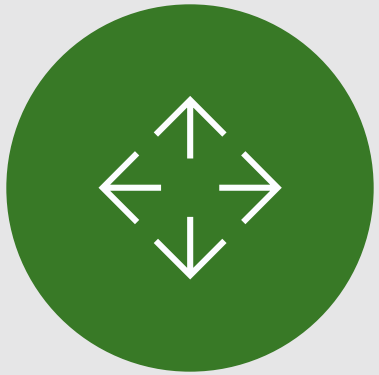
- Physical constraints due to farming practices
- Too expensive to deploy and maintain

How do we get coverage with a sparse sensor deployment?



Idea: Use UAVs to enhance spatial coverage

Drones are ~1000 dollars and automatic



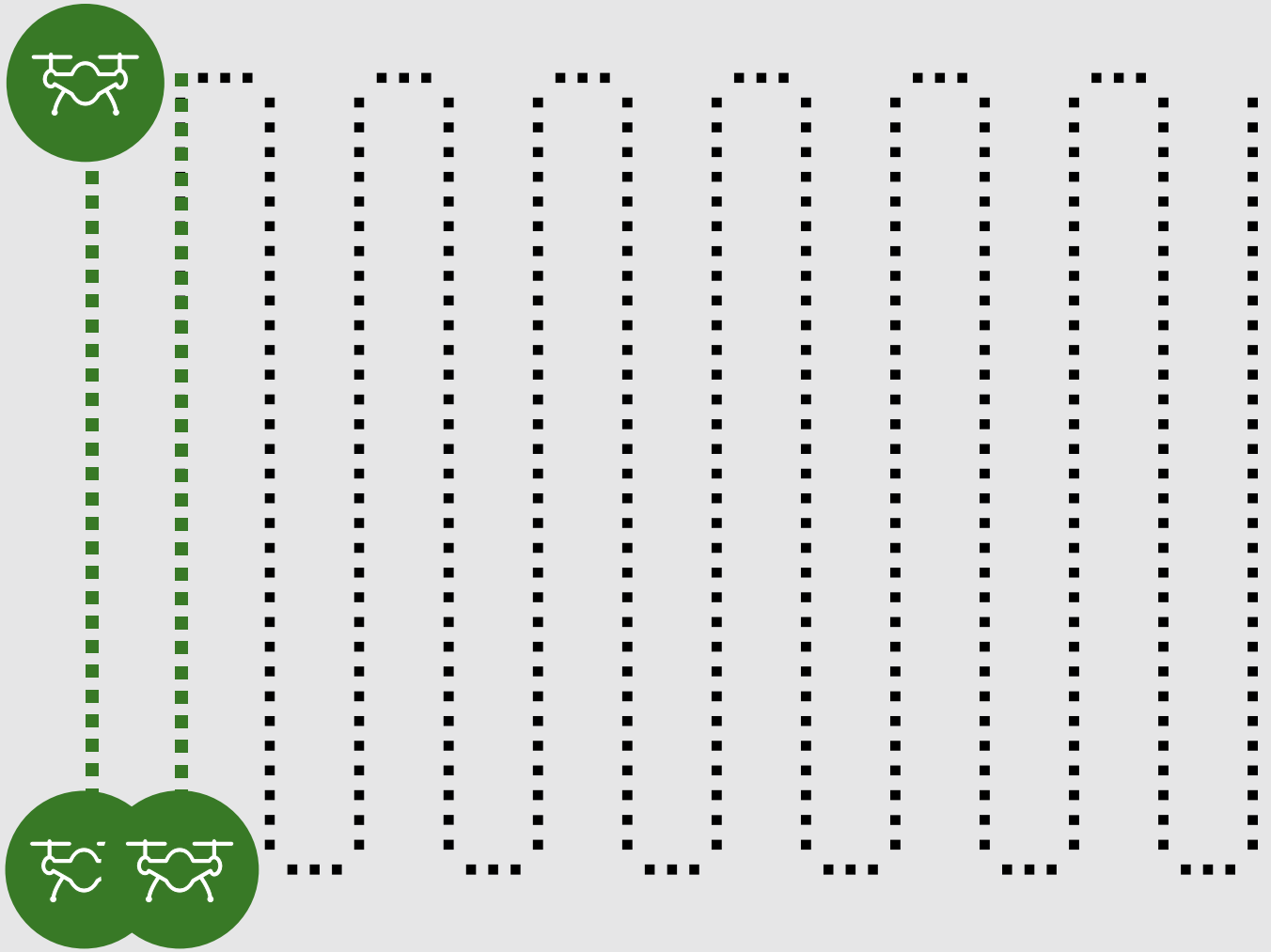
Can cover large areas quickly

Can collect visual data

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

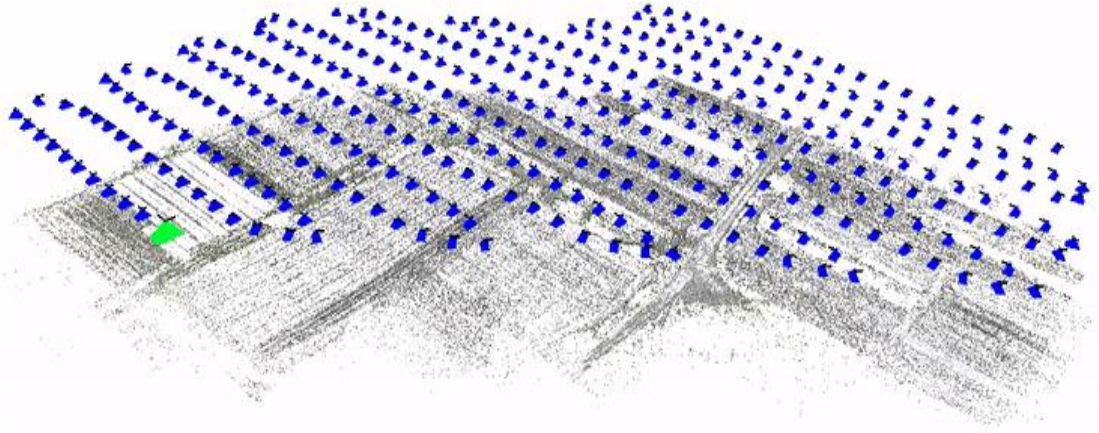
Aerial imagery in precision agriculture

Drone Video



Processing RGB & multi-spectral imagery

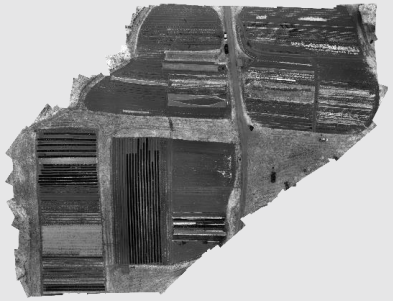
Ariel footage



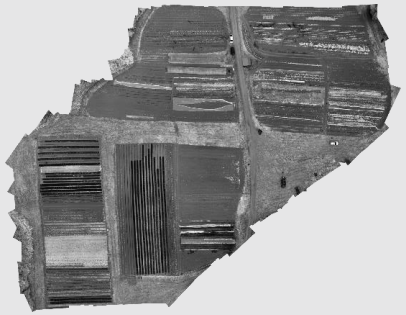
3D point cloud reconstruction

Processing RGB & multi-spectral imagery

Sequoia
multi-spectral
camera

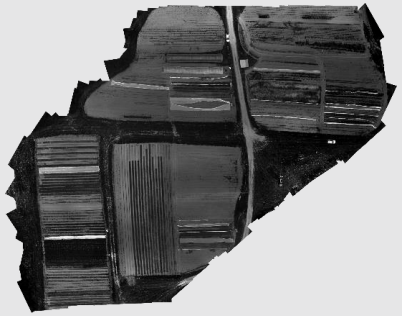


NIR

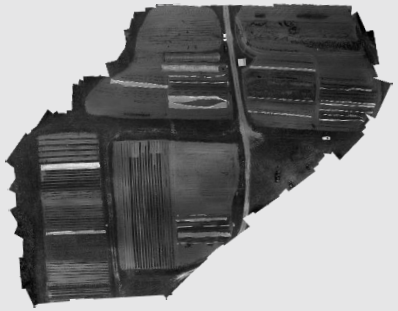


Red edge

RGB



Red



Green

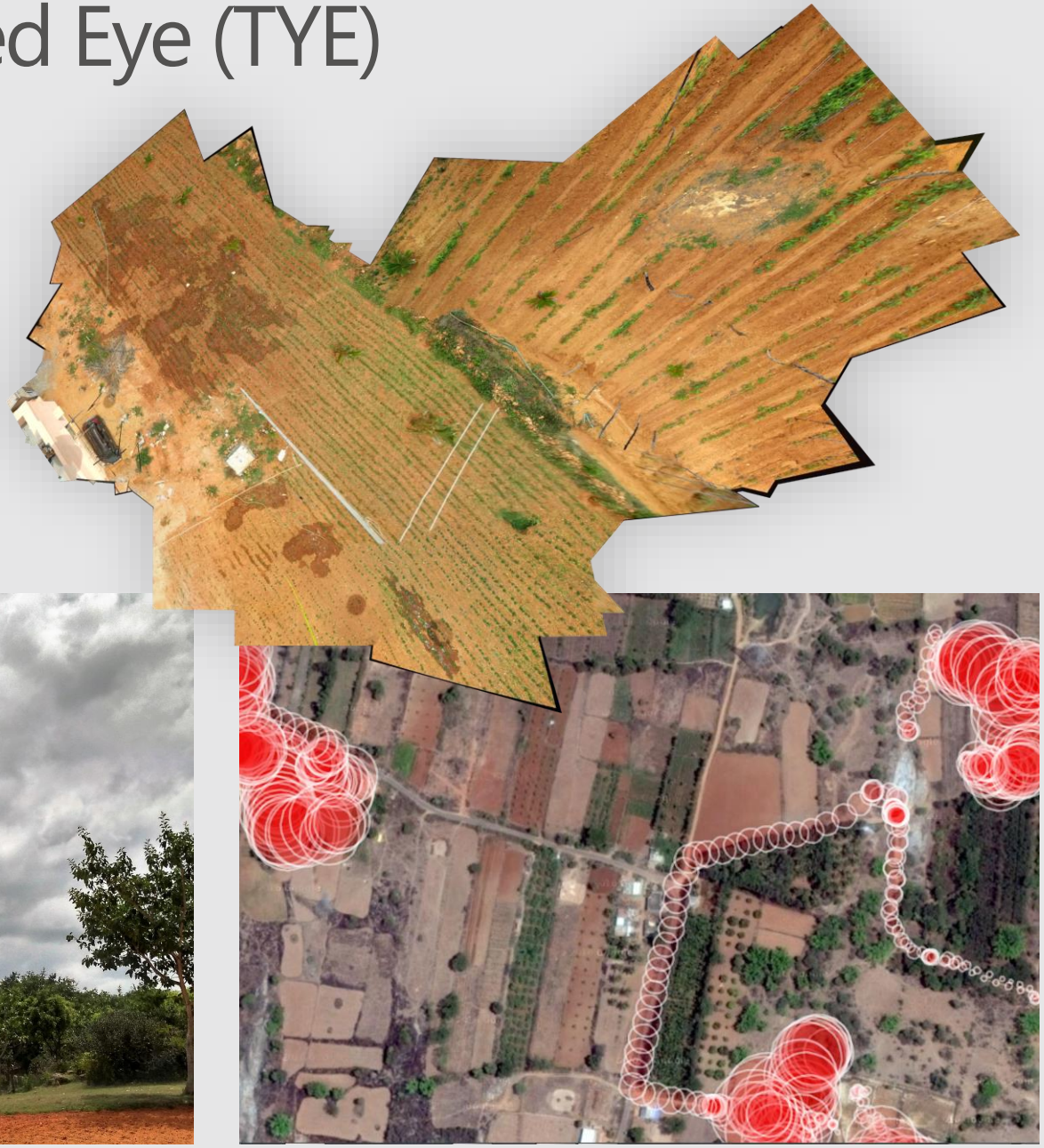
Low-cost aerial imagery: Tethered Eye (TYE)

UAVs have a few limitations:

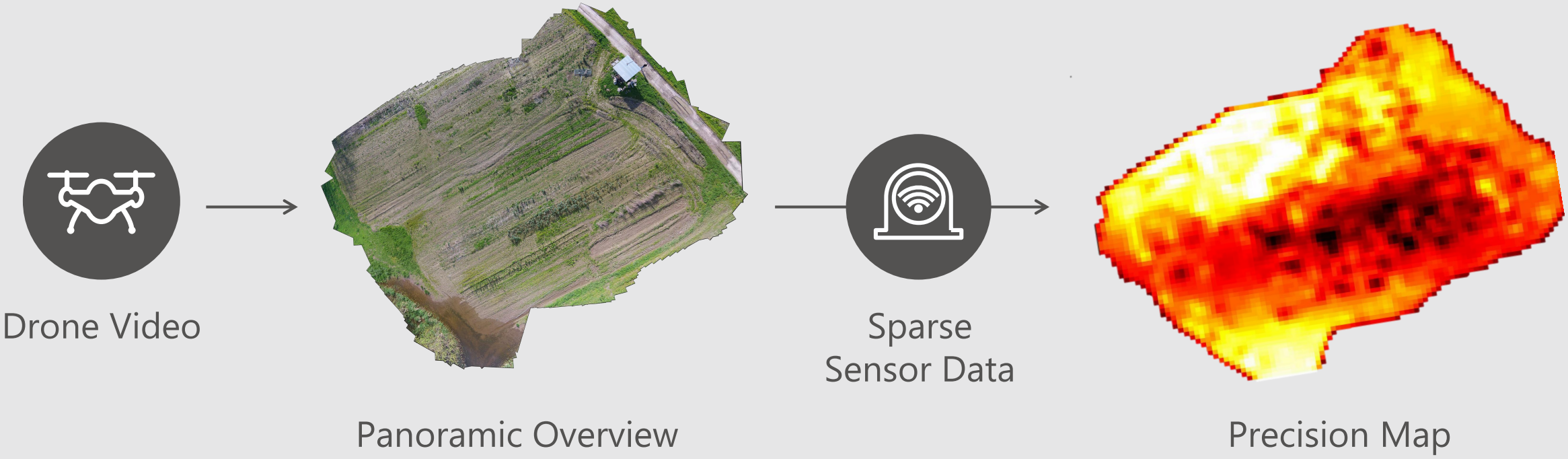
limited battery life

Regulatory concerns

Cost



Idea: Use Drones to Enhance Spatial Coverage



Idea: use drones/balloons to enhance spatial coverage

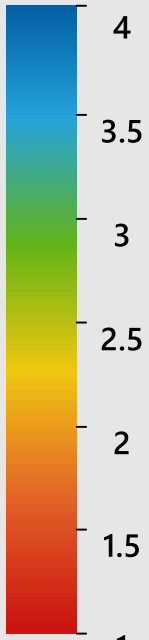
FarmBeats can use drones to expand the sparse sensor data and create summaries for the farm

Orthomosaic Map

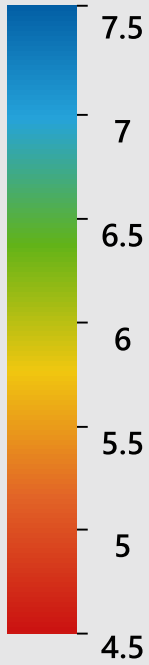
Idea: use drones/balloons to enhance spatial coverage

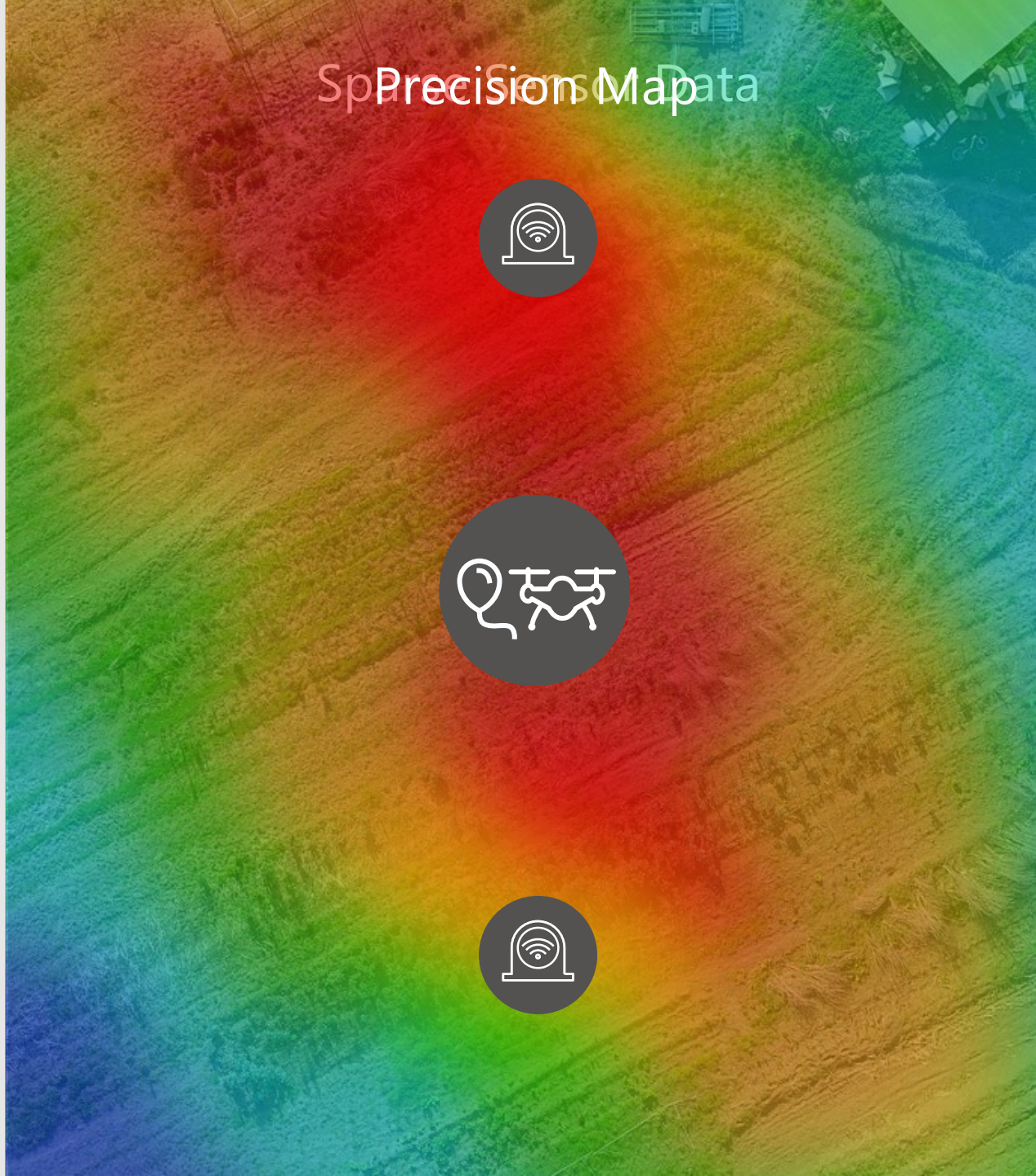
FarmBeats can use drones to expand the sparse sensor data and create summaries for the farm

Precision Map:
Moisture



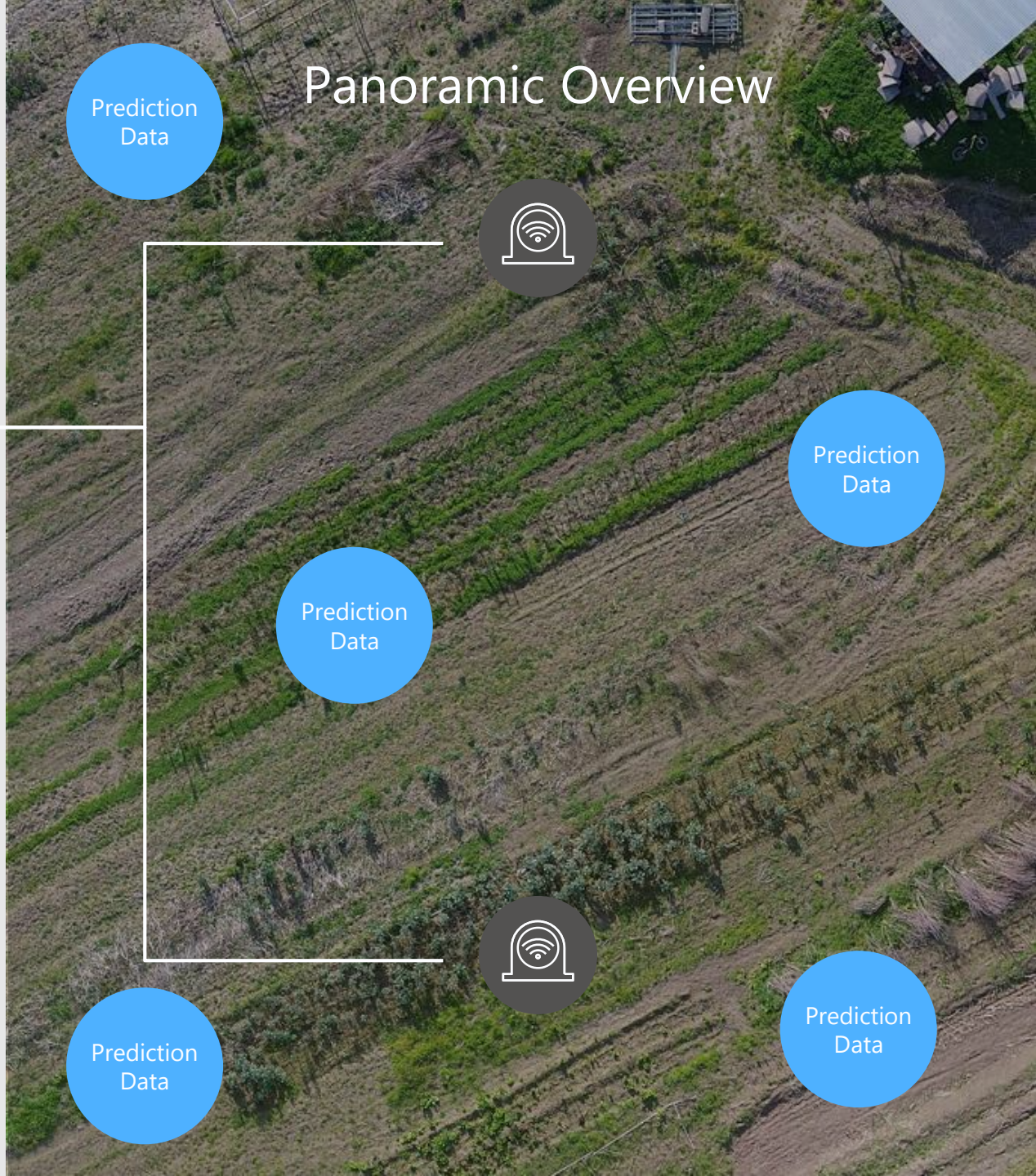
Precision Map:
pH





Formulate as a learning problem

Training Data



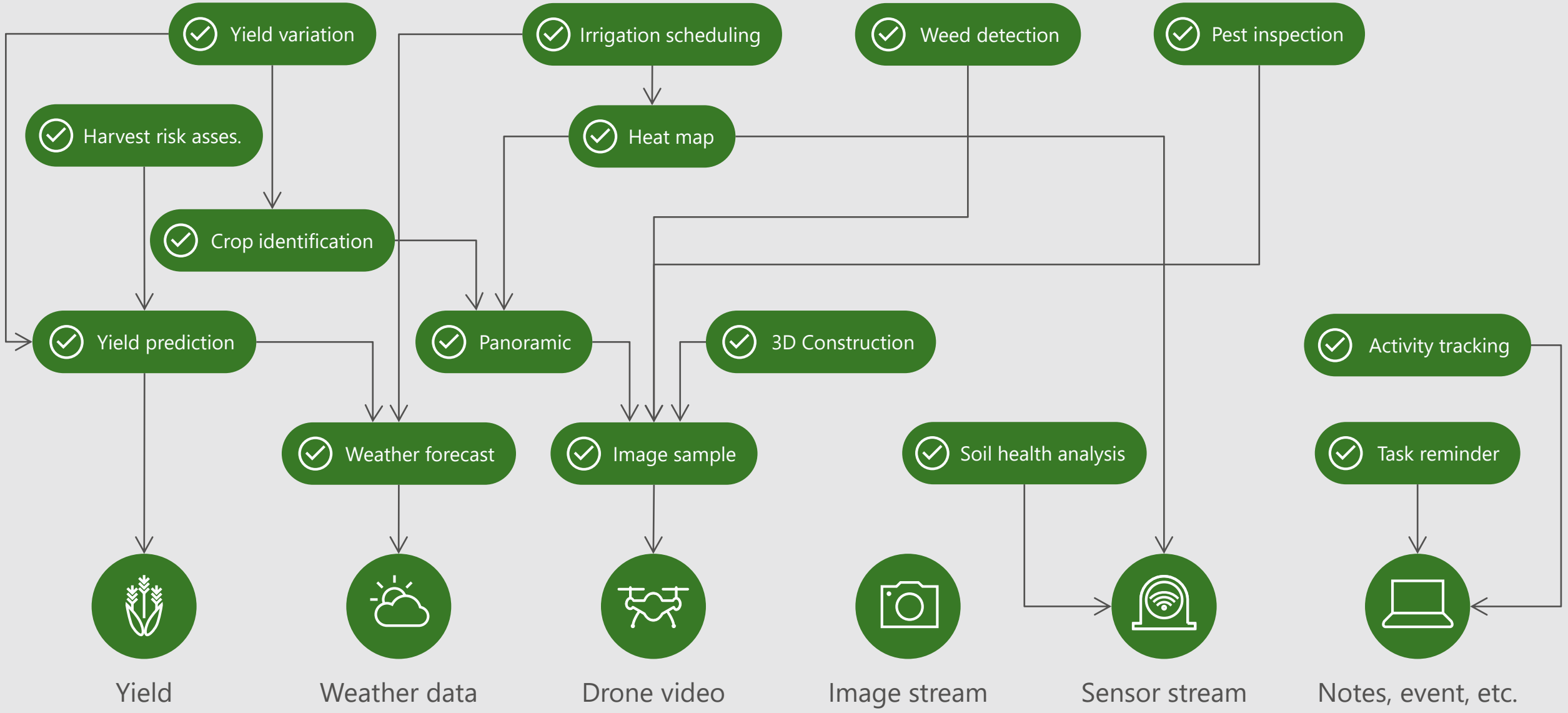
In this talk

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

What services we can provide



Service characteristics

Large inputs

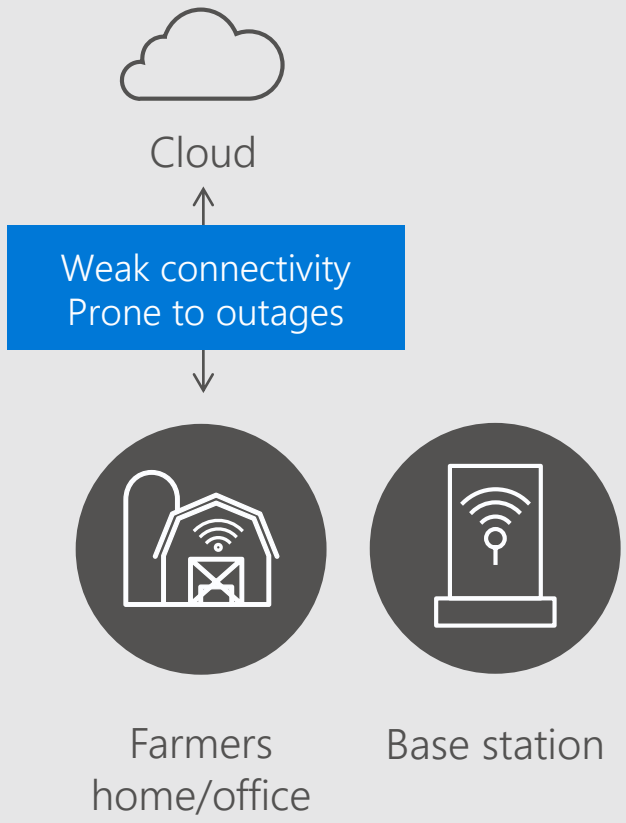
Data source	Daily size
Sensor	70K
Drone video	10G
Drone image	4G
Camera	28M

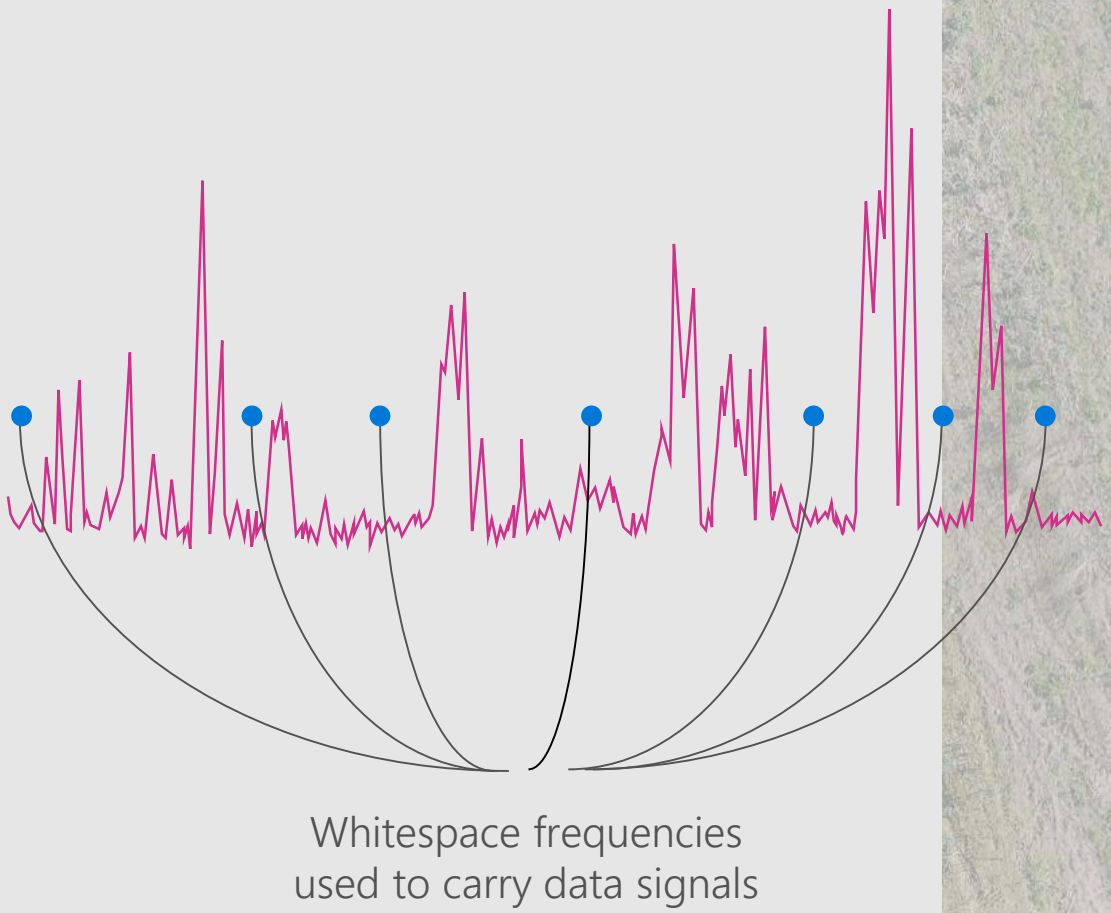
Latency constraints

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

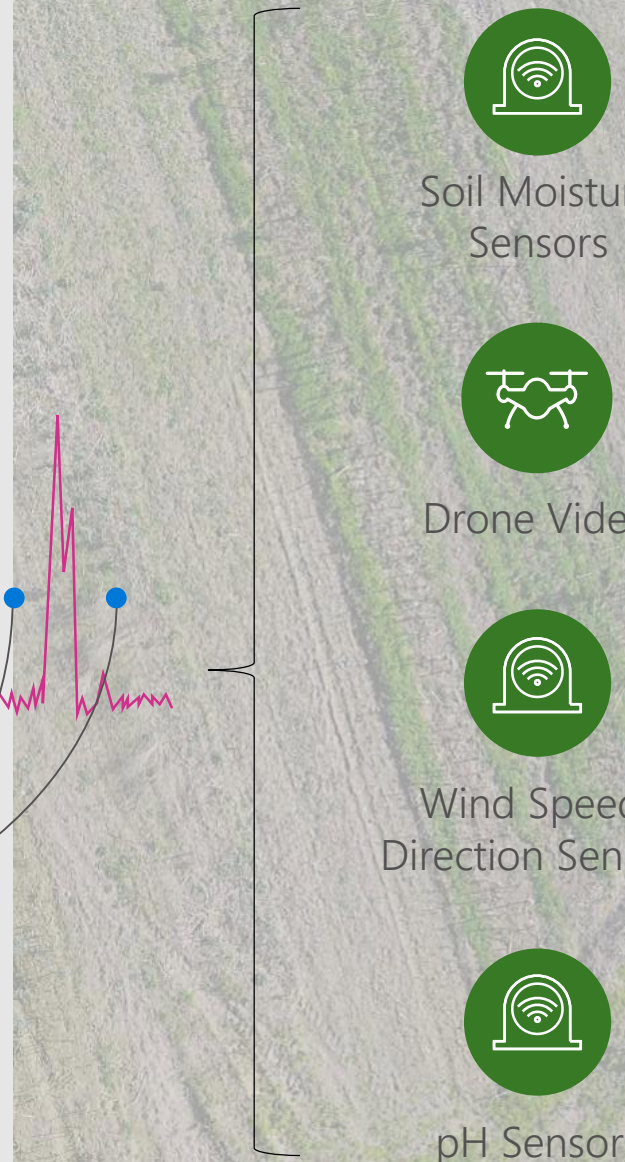
The Ideal World

The Real World

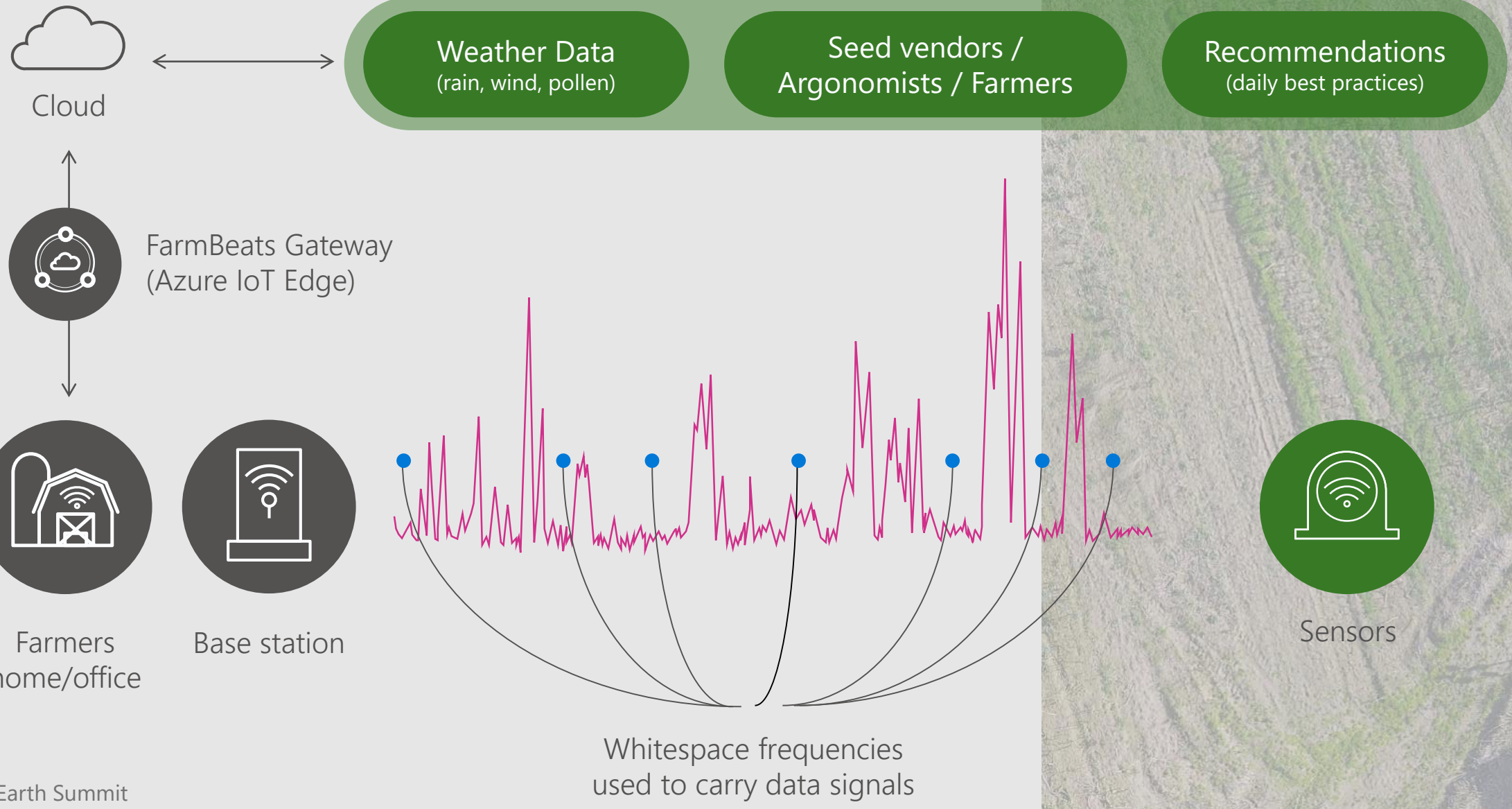




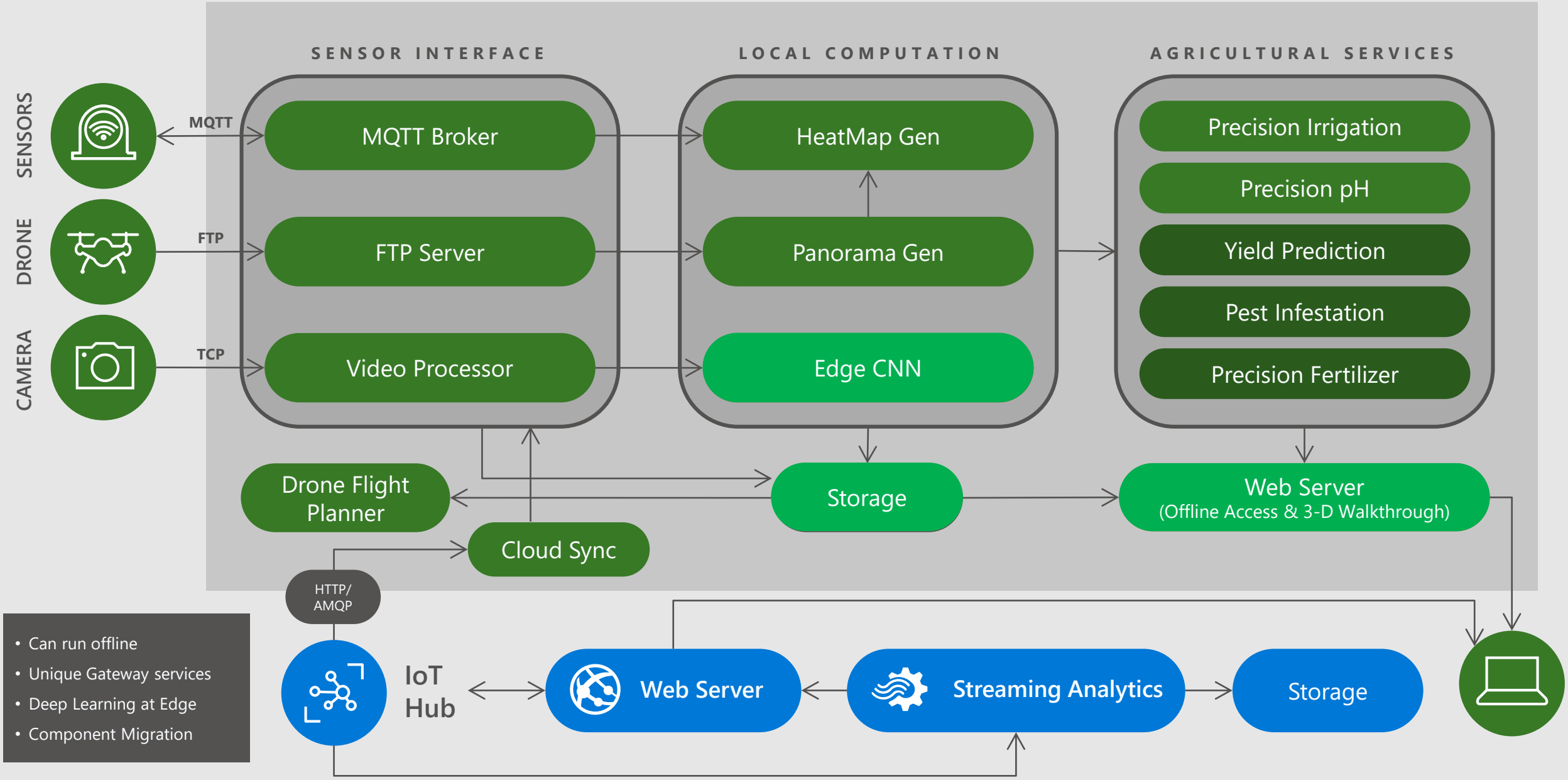
Whitespace frequencies
used to carry data signals



The Real World



FarmBeats Gateway (Azure IoT Edge)



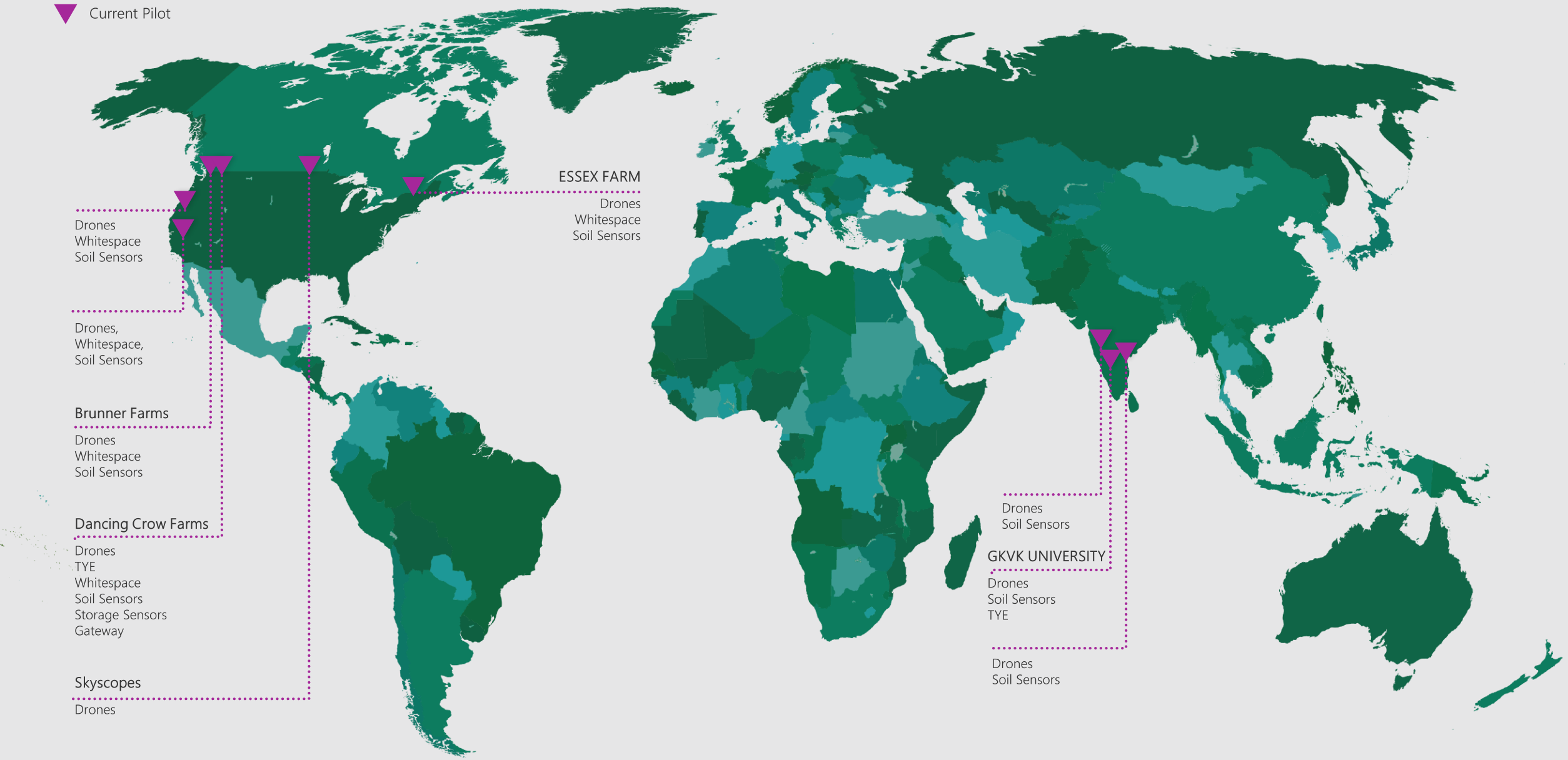
In this talk

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

Pilot Project Status



Deployment

Deployments in several locations including WA, CA, NY

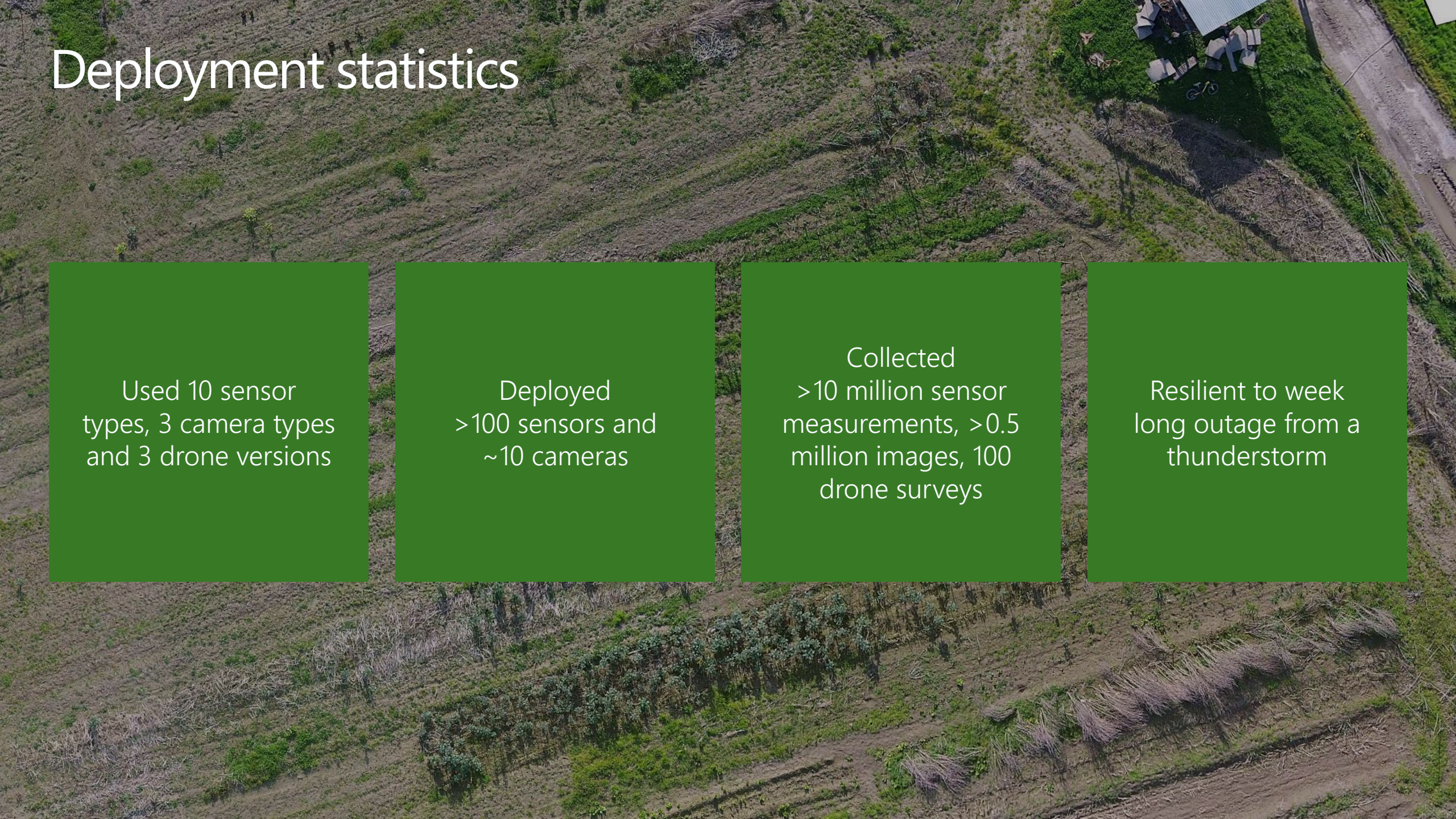
Farm sizes range from 5 – 2000 acres

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

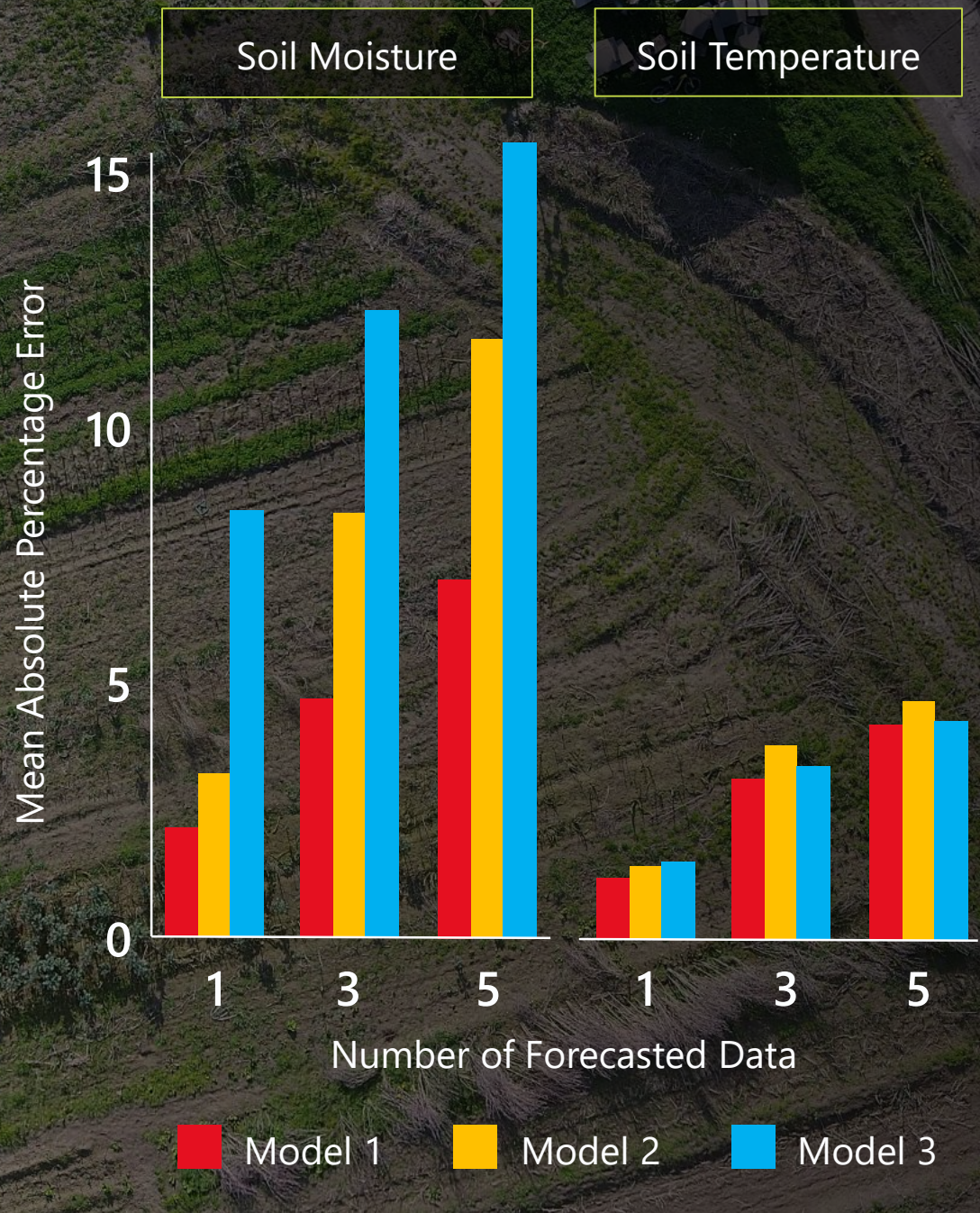
Goal:
Microclimate weather forecasting model based on FarmBeats sensors in the field.

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

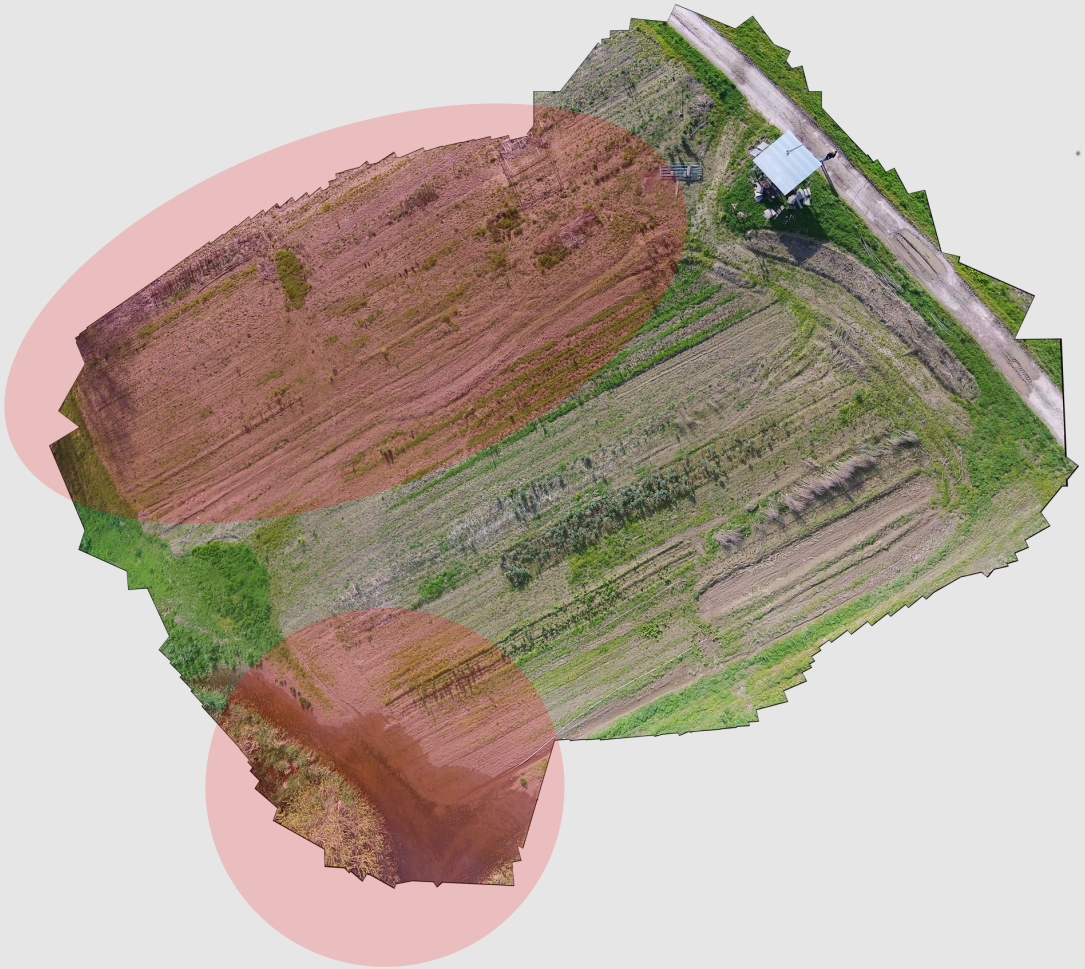
Cow excreta

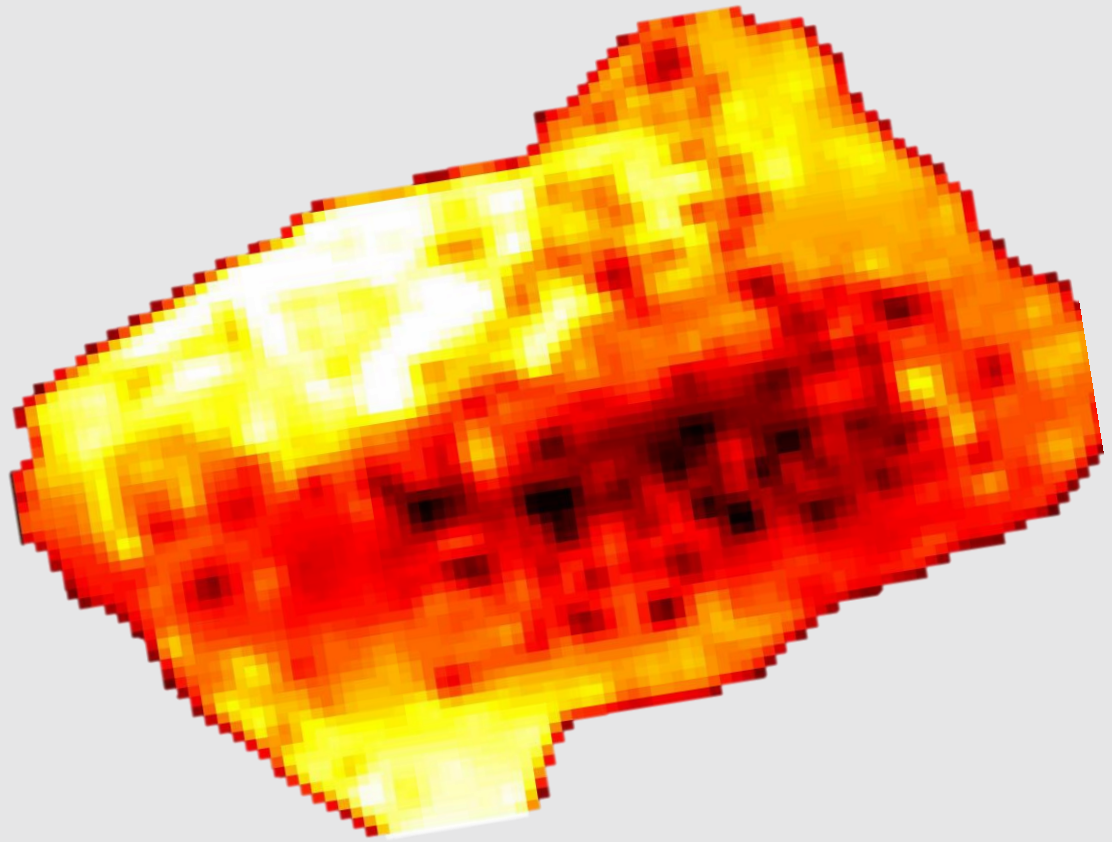
Cow herd

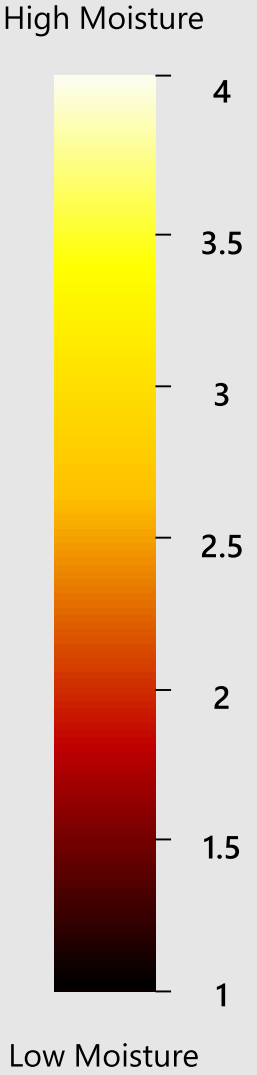
Stray cow

Precision Map: Panorama Generation

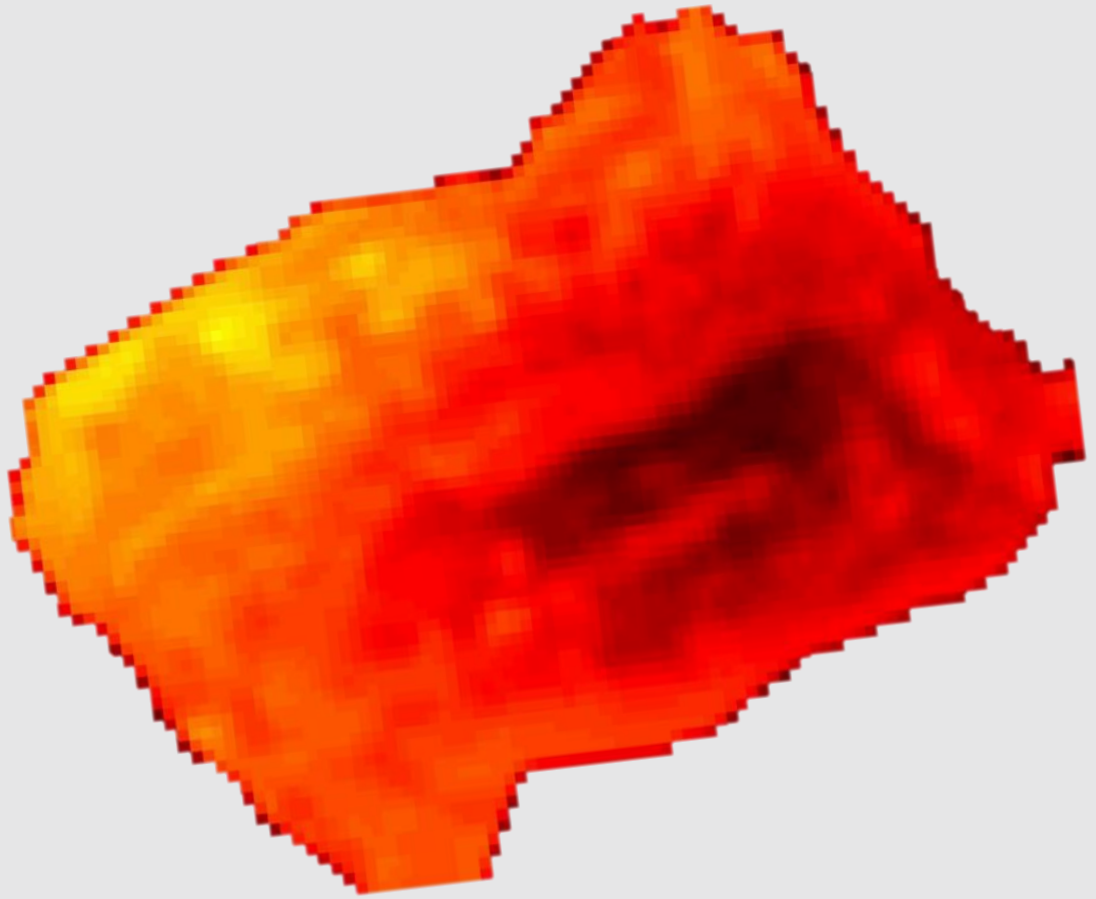
Precision Map : Moisture

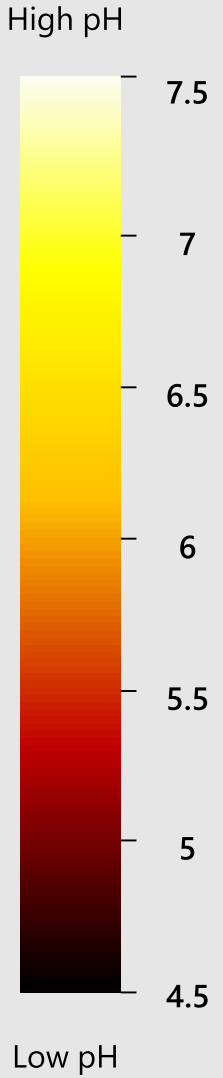




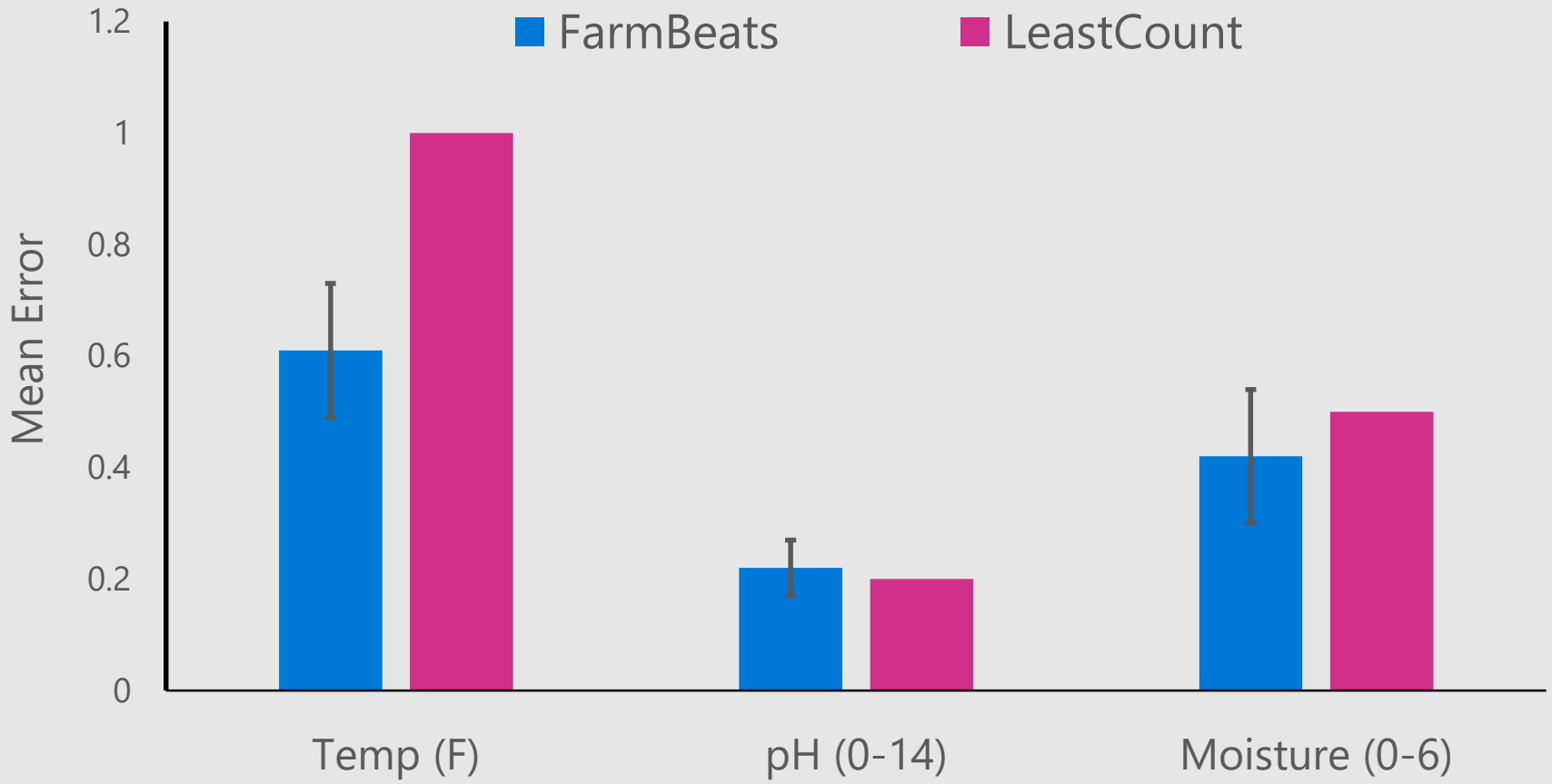


Precision Map : pH



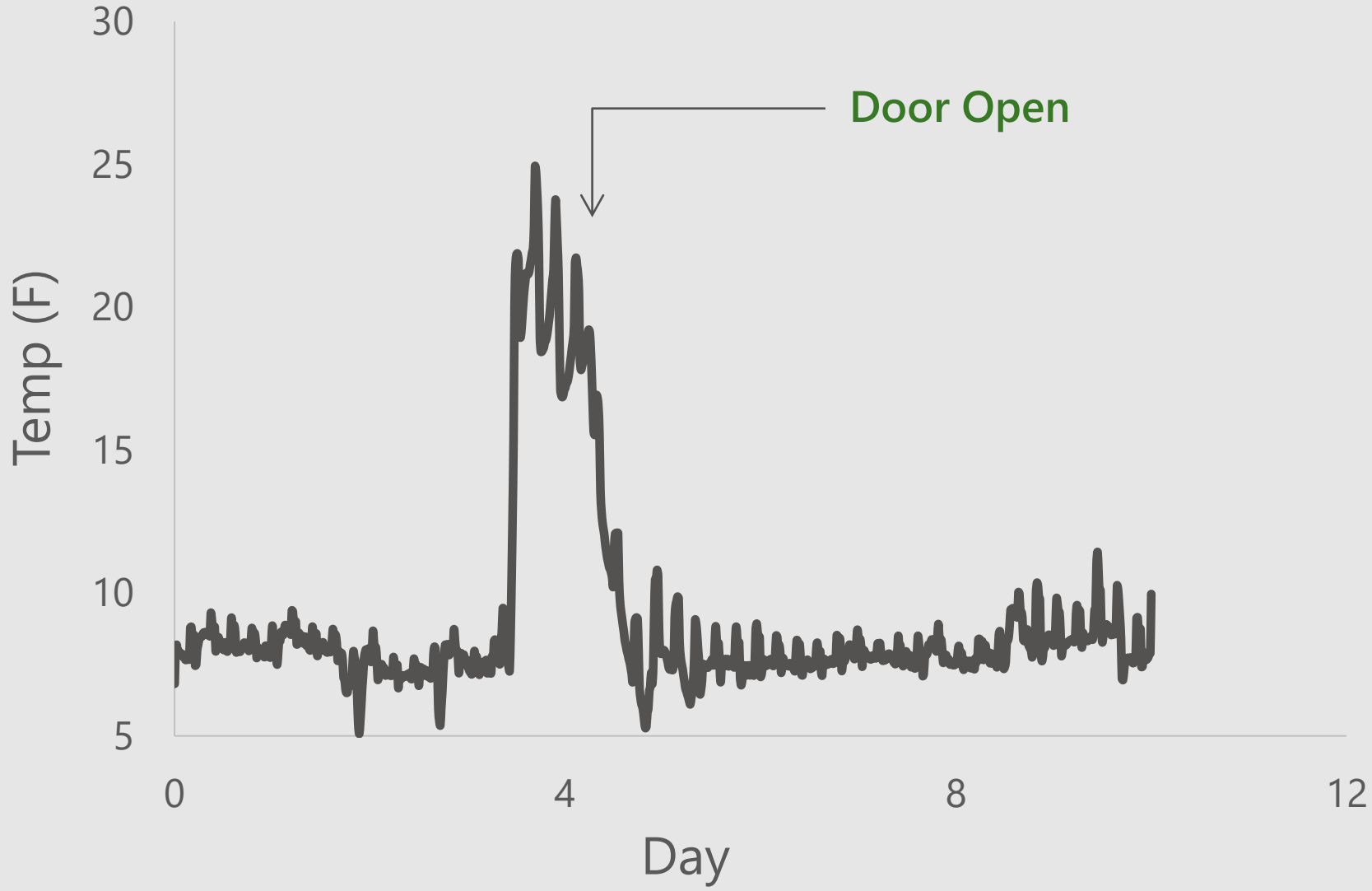


Precision Map: Accuracy



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

Application: Storage Monitoring



Application: Cow-Shed Monitor

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)