Data-driven agriculture

How cloud and AI can help reimagine the food chain from farm to plate

Ranveer Chandra
The world has a food problem

- Over **820 million** people worldwide suffer from hunger
- More than **2 billion** people lack vital nutrients
- **70%** more food is needed by 2050
- Climate change and challenged resources challenge even our **current farming** yields
Data-driven agriculture

Precision Agriculture has been shown to:

- Improve yield
- Reduce cost
- Ensure sustainability
Data-driven Agri-Food systems

Bringing data to the cloud enables key insights for individuals and organizations.

When this data is shared, we unlock greater efficiencies and productivity across the supply chain.
Creating new opportunities for farms

**Traceability**
Gain visibility across the food chain to improve safety

- Track and trace
- Blockchain

**Precision agriculture**
Made possible by data collection with IoT sensors and data processing to inform site specific inputs

- Robotics and equipment
- Farm management and sensing

**Sustainable Farming**
Provide outcome-based solutions, including sustainable practices, through better data from farms

- Research and development
- Outcome-based services

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According to USDA, **high cost of manual data collection** prevents farmers from using data-driven agriculture.
Challenge 1: Connectivity on farms

Cloud

Too much distance between farm and the house/office

Farmers home/office

Drone video
Soil moisture sensors
Wind speed/Direction sensors
pH sensors
A solution in white space

Increasing wireless reach with TV White Space

- Cloud
- Base station
- Farmers home/office
- Drone video
- Soil moisture sensors
- Wind speed/Direction sensors
- pH sensors

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Challenge 2: 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?
Use aerial imagery and AI to enhance spatial coverage
77% of the planet is covered in clouds.

Optical reconstruction machine learning fills the gaps created by cloud-cover.

This allows for long-term imaging and research without interruption.
Challenge 3: Cloud Connectivity

- Weak cloud connectivity
- Farmers home/office

Cloud

- Drone video
- Soil moisture sensors
- Wind speed/Direction sensors
- pH sensors
Edge Compute in the Farm

- Cloud
- Azure IoT Edge
- Farmers home/office
- Soil moisture sensors
- Wind speed/Direction sensors
- Drone video
Azure IoT Edge

**SENSOR INTERFACE**
- MQTT Broker
- FTP Server
- Video Processor

**LOCAL COMPUTATION**
- HeatMap Gen
- Panorama Gen
- Edge CNN
- Storage

**AGRICULTURAL SERVICES**
- Precision Irrigation
- Precision pH
- Yield Prediction
- Pest Infestation
- Precision Fertilizer

**Cloud Sync**

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

**Web Server**
- HTTP/AMQP

**Stream Analytics**

**Storage**
Deployment

Deployments in several locations including WA, CA, NY

Farm sizes range from 0.5 – 9000 acres

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

Cloud Components: Azure IoT Suite
Micro-Climate Forecasting

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

**Impact:**
Knowing microclimate enables better modeling of plant diseases, application timing, and risk management.

**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%.

Forecast for low temp was 42 degrees. Micro-Climate forecast was 31 degrees in lower areas of the field. Actual was 30 degrees. Instead of spraying grass herbicide, the farmer waited and avoided large crop damage in some of the most productive areas.

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

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Example: Panorama

- Water puddle
- Cow excreta
- Cow herd
- Stray cow
Precision Map: Panorama Generation
Precision Map: pH
Application: Cow-Shed Monitor
From research to products
AgTech Solutions

- Connected Cows
- Digital Advisories
- Sustainability
- Data Ingestion
- Data Store
- Analytics/AI
- Viz
- ML
- IoT Hub
- GIS
- Sensor
- Custom Data
- Farm Equipment
- Drone
- Weather
- Satellite
Azure FarmBeats
Partnerships

Land O’Lakes
Innovate on new agriculture technologies & support rural communities

PepsiCo
Fuel product innovations & meet sustainability goals

USDA ARS
Sustainability, Partnerships on Data Innovation
Societal Impact:

Rural Broadband, Skilling, Sustainability
Microsoft is investing in rural broadband

Closing the rural broadband gap requires an innovative, disruptive technology approach, combining fixed wireless solutions including those leveraging **TV White Spaces**, alongside **traditional fiber-based connectivity** and satellite coverage.

In the US...

<table>
<thead>
<tr>
<th>Population Covered</th>
<th>Population Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,778,136</td>
<td>594,918</td>
</tr>
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</table>

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Sustainability: Beyond Reduction – Carbon Negative by 2030

Carbon negative by 2030

Remove our historical carbon emissions by 2050

$1 billion climate innovation fund
Microsoft’s pathway to carbon negative by 2030

Annual carbon emissions

- Net carbon emissions
- Microsoft and its supply chain carbon emissions
- Microsoft operational carbon emissions
- Avoided emissions offsets
- Carbon removal

FY30: Microsoft and its supply chain carbon negative
Future Farmers of America + FarmBeats

The Microsoft TechSpark initiative is bringing precision agriculture and AI to classroom with FarmBeats student kits.
Farm to Plate and Food Supply Chain Risk

![Diagram showing food supply chain and COVID-19 cases](https://via.placeholder.com/150)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Cases</th>
<th>Total Commodity</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td></td>
<td></td>
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<tr>
<td>Ag Workers COVID</td>
<td>23.41k</td>
<td>108244296</td>
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<tr>
<td>Ohio</td>
<td>124.9k</td>
<td>76729172</td>
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<td>Georgia</td>
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<td>Michigan</td>
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<td>Maryland</td>
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<td>Michigan</td>
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<td>Minnesota</td>
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</tr>
<tr>
<td>Mississippi</td>
<td>236.9k</td>
<td>14429374</td>
</tr>
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</table>
Emerging Agribusiness Ecosystem

Representative Customers & Partners, not exhaustive
Defining small scale producers

1. Developing a Resilience Buffer
2. Farm Intensification
3. Land Consolidation
4. Transition to Formal Enterprise
5. Transition to Service Provision
6. Conversion to Rural Employment
7. Migration to Urban Areas

https://evans.uw.edu/policy-impact/epar/categorizing-smallholder-farmers

Digital hype curve for small scale producers

- **Innovation Trigger**
  - Blockchain
  - Soil Sensors
  - Nano-Satellites
  - Voice Technology
  - Artificial Intelligence
  - UAV Delivery
  - Indoor Farming
  - On-Plant Sensors
  - Robotics

- **Peak of Inflated Expectations**
  - Farm IoT
  - UAV Imagery
  - Amazon for Inputs
  - BI Dashboards
  - Scouting Apps
  - Uber for Tractors
  - Hyper-Local Weather
  - Big Data
  - Blockchain

- **Trough of Disillusionment**
  - Call Centers
  - Soil Mapping
  - Satellite Imagery
  - IVR Advisory
  - SMS Advisory
  - Yield Monitors
  - Indoor Farming
  - UAV Delivery
  - On-Plant Sensors
  - Robotics

- **Slope of Enlightenment**
  - Hyper-Local Weather
  - Big Data
  - Blockchain
  - Scouting Apps
  - Uber for Tractors
  - Amazon for Inputs
  - BI Dashboards
  - UAV Imagery
  - Farm IoT

- **Plateau of Productivity**
  - Call Centers
  - Soil Mapping
  - Satellite Imagery
  - IVR Advisory
  - SMS Advisory
  - Yield Monitors
  - UAV Delivery
  - Indoor Farming
  - On-Plant Sensors
  - Robotics

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Motivation: existing sensors are expensive
- ~100s of dollars

Challenge: Affordable sensing

Solution: low-cost soil moisture and EC sensing using Wi-Fi

Strobe design: Wi-Fi cards with 2+ antennas
- Relative time-of-flight and amplitude

Results: Strobe can accurately detect moisture and EC change in soil
## Open research problems to enable DA for Small Scale Producers

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Hardware and Architecture (Affordability)</th>
<th>Vision, Speech, ML/AI (Relevant Data)</th>
<th>Systems, Security (Connectivity, Data Platforms)</th>
<th>Human Interface (Usability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-cost sensing (RF, audio), low-power sensors, sensing roots/carbon</td>
<td>Surrogate sensing Microclimate prediction Advisories e.g., water Livestock health, estrus</td>
<td>Low-cost IoT networks Secure data ingestion Reliable sensor system Data sharing</td>
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<td>Display alerts Automated diagnosis Fault recovery</td>
</tr>
<tr>
<td>High-res optical cams Satellites SAR probes LEO constellations</td>
<td>Cloud removal, SAR AI/ML for yield/disease/etc. Accurate super-res imagery</td>
<td>Satellite downlink speed Merging IoT + remote sensing Timely analysis</td>
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<td>Visualizing form imagery and insights</td>
</tr>
<tr>
<td>Robots and Drones</td>
<td>Battery life Wireless charging Low-cost robots</td>
<td>Localization below canopy ML without labeled data Automation in mixed crops</td>
<td>Edge compute Shared robots Large data transfer Secure sharing</td>
<td>Low-tech operation Interpretation of results</td>
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<td>Low-tech operation Interpretation of results</td>
</tr>
<tr>
<td>Low-power cams Low-cost multispectral</td>
<td>Livestock stress detection Cow health Pest detection</td>
<td>Broadband Edge compute Federated ML</td>
<td>Broadband Edge compute Federated ML</td>
<td>Ease of use Theftproof</td>
</tr>
<tr>
<td>ICT</td>
<td>Low-cost devices with rich UI</td>
<td>Local speech-to-text, digitizing knowledge</td>
<td>Internet systems (e.g., IFTTT) with phones</td>
<td>Geospatial insights on SMS, new apps</td>
</tr>
<tr>
<td>Data Platforms</td>
<td>Secure edge Low-cost sovereign data centers</td>
<td>Obtain ground truth data, AI on unlabeled data, multimodal data</td>
<td>Secure data sharing AI on encrypted data Data collaboratives Models</td>
<td>Ease of data sharing Awareness of misuse</td>
</tr>
</tbody>
</table>

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Machine learning algorithms are able to extrapolate accurate soil moisture and pH by evaluating aerial imagery and sparse soil sensor data.
Bühler ensures food safety with Blockchain

Challenge: A lack of connectivity, transparency, and traceability in the food supply chain caused food waste, inefficiencies, and risk of contaminated crops.

Solution: Bühler and Microsoft developed a blockchain strategy using multilayer QR code labels to track grain and ensure it’s handled according to regulations. Augmented physical machines with an AI-enabled insights platform to ensure all grains processed are toxin-free.

Benefits: Digitally verify that all grains are handled compliantly as they move through the supply chain, providing transparency to each counterparty through a shared ledger. Assess any contamination and alert all parties in real-time to avoid a public safety issue.

We’re not only going to get economic results, but hopefully we can transform and save lives at the same time. It’s the most exciting and valuable project I’ve worked on in my 40 years with the company. It’s a really big thing.

— Ben Deefholts
Senior Research Engineer, Bühler
The Yield improves farming decisions with the cloud

**Challenge:** The Yield wants to help feed the world without wrecking the planet. They want to help farmers get high yield, while being able to predict local conditions and minimize uncertainty.

**Solution:** The Yield takes microclimate sensing data (by partnering with Bosch) and combines it with predictive modeling (in Azure) to help growers improve their yield and reduce their risks. They then deliver the data to easy-to-use apps so that growers and industry regulators can make fast, informed decisions. They also use Azure Machine Learning to predict local conditions and reduce uncertainty.

**Benefits:** The combination of technology and data takes the guesswork out of growing. Manual interventions and approximate measures are eliminated and replaced with exact and accurate data. The industry has the potential to save millions by knowing the exact time to harvest.
Microsoft agriculture capabilities

Digital farms
Enable detect, decide & do feedback loops
- Farm & ranch sensing & management

Intelligent machines
Drive insight from machinery
- Mechanization & robotics
- Autonomous calibration & tuning

Supply chain and food safety
Enable detect, decide & do feedback loops
- Traceability, logistics, multiparty, supply networks

Processing and manufacturing
Access real-time, actionable insights
- Factories of the future

Product & services innovation
Improve speed to innovation
- Geno/phenotyping & simulation
- Output-based services

Risk management
Accessing the investment risk for financial and insurance organizations
- Risk exposure, loan/claim disbursement

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Future Farmers of America + FarmBeats

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Customer spotlight

Insert logo here

**Challenge:** [challenge text]

**Solution:** [solution text]

**Benefits:** [benefit text]
Azure FarmBeats

Microsoft Azure

ISV/Partner Solutions

FarmBeats SDK

Datahub API

Connected Cows

Precision Farming

Smart Equipment

PowerApps

Power BI

Azure ML

Marketplace

Device Management

Sample Data Visualization

ML/AI Models

Data Store

IoT Hub

GIS

Custom Data

Sensor

Drone

Weather

Satellite

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Microsoft innovation in agriculture
Our Approach

**Position** Microsoft as the IT leading platform for technology solutions to environmental challenges

- **4** priorities
- **5** pillars
- **4** quarters

**Operations**
Align with science and international goals

**Customers & partners**
Trusted partner for customer’s sustainability journeys

**Products & services**
Preferred platform and products for environmental solutions

**Policy**
Advocate for policies to achieve corporate and societal goals

**Employees**

Innovations helping address two key problems:

Bringing data to the cloud

Turning data into insights
TV white spaces on the farm

What are TV white spaces?
Unused TV channels

Key insights 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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Azure IoT Edge

- MQTT Broker
- FTP Server
- Video Processor
- HeatMap Gen
- Panorama Gen
- Edge CNN
- Storage
- Web Server
- Cloud Sync
- Drone Flight Planner

**Sensor Interface**

**Local Computation**

**Agricultural Services**

- Precision Irrigation
- Precision pH
- Yield Prediction
- Pest Infestation
- Precision Fertilizer
- Storage

**IoT Hub**

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

**Web Server**

**Streaming Analytics**

**Storage**

**FTP**

**TCP**

**MQTT**

**HTTP/AMQP**
Conclusion

Azure FarmBeats
A system that enables seamless data ingestion and processing for agriculture and food

Microsoft’s entire stack for Agriculture & Food

Data Capture
- Azure IoT

Secure Storage
- Azure Data Lake
- Block Chain

Providing Insights
- Power BI
- Azure ML
- Cognitive Services

Execute/Implement
- Teams
- M365
- Dynamics 365
Challenge 4: Affordable sensing
*low-cost soil moisture and EC sensing using Wi-Fi*

**Motivation:** existing sensors are expensive
- ~100s of dollars

**Strobe design:** Wi-Fi cards with 2+ antennas
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**Results:** Strobe can accurately detect moisture and EC change in soil