Scaling Digital Agriculture for Small and Medium Farms

Research opportunities in AI, sensing, spatial intelligence and automation

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Digital agriculture is advancing — but not equally

The issue is no longer whether smart agriculture is possible, but whether it can be made accessible, useful and viable across different farm realities.

LARGE-SCALE AGRICULTURE

Advanced technologies increasingly integrated

- Advanced machinery and automation
- GNSS, precision inputs and telemetry
- Sensors, computer vision and AI
- Digital farm-management platforms
- Higher operational scale for technology adoption

SMALL & MEDIUM-SIZED FARMS

Many still face simultaneous adoption barriers

- High costs and uncertain return on investment
- Limited or unstable rural connectivity
- Need for training and technical support
- Technologies that do not fit smaller or diversified systems
- Difficult integration, maintenance and interoperability

COST
High investment

CONNECTIVITY
Rural internet gaps

DIGITAL SKILLS
Training & support

TECHNOLOGY FIT
Scale and context

The challenge is not only to develop better technologies — it is to make them affordable, robust and meaningful under very different farming conditions.

From technology development to technology adoption

Semear Digital is organized around real production constraints and the practical conditions needed for digital transformation.

1 Understand needs

Farmer demands
Adoption barriers

→

2 Develop & adapt

Combine new and existing solutions

→

3 Validate in the field

Real conditions
Robustness and usability

→

4 Enable adoption

Connectivity
Training and partnerships

Problem-driven logic: farmer needs → production constraints → co-design → field validation → deployment

Scaling depends on an innovation ecosystem: Embrapa • universities • farmers • cooperatives • companies • connectivity providers • extension services

The objective is not to introduce more technology, but to introduce technology that solves real problems.

What does inclusive smart agriculture look like in practice?

The technology portfolio spans sensing, interpretation and action across crops, livestock and field operations.

AERIAL OPERATIONS

Seeding • scouting
Livestock monitoring

AI & COMPUTER VISION

Detection • segmentation
Explainability

LIVESTOCK INTELLIGENCE

Growth • behavior
Feeding patterns

CROP INTELLIGENCE

Weeds • pests • diseases
Yield-related signals

SPATIAL AI

3D mapping • tracking
Localization

AUTOMATION

Field scanning
Autonomous platforms

Different technologies — one objective: solutions that work under real farm conditions.

The next slides illustrate how this portfolio is being translated into concrete applications.

Aerial seeding for pasture and cover crops

A practical example aimed at increasing operational efficiency on small and medium-sized farms.



APPLICATION

Pasture and cover-crop establishment in family-farming contexts

TECHNOLOGY STACK

UAV seeding + remote sensing + AI-based monitoring

60–80%

Emergence rate

≈90%

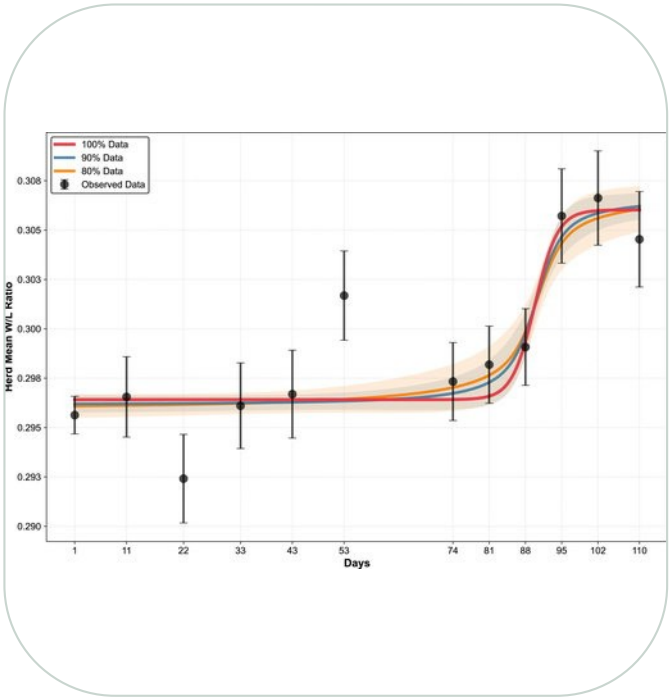
Detection accuracy

The key advantage is not the drone alone, but the combination of aerial operation, monitoring and geospatial decision support.

UAV-based cattle monitoring: from images to growth curves

Computer vision turns repeated aerial observations into quantitative indicators for herd management.





PIPELINE

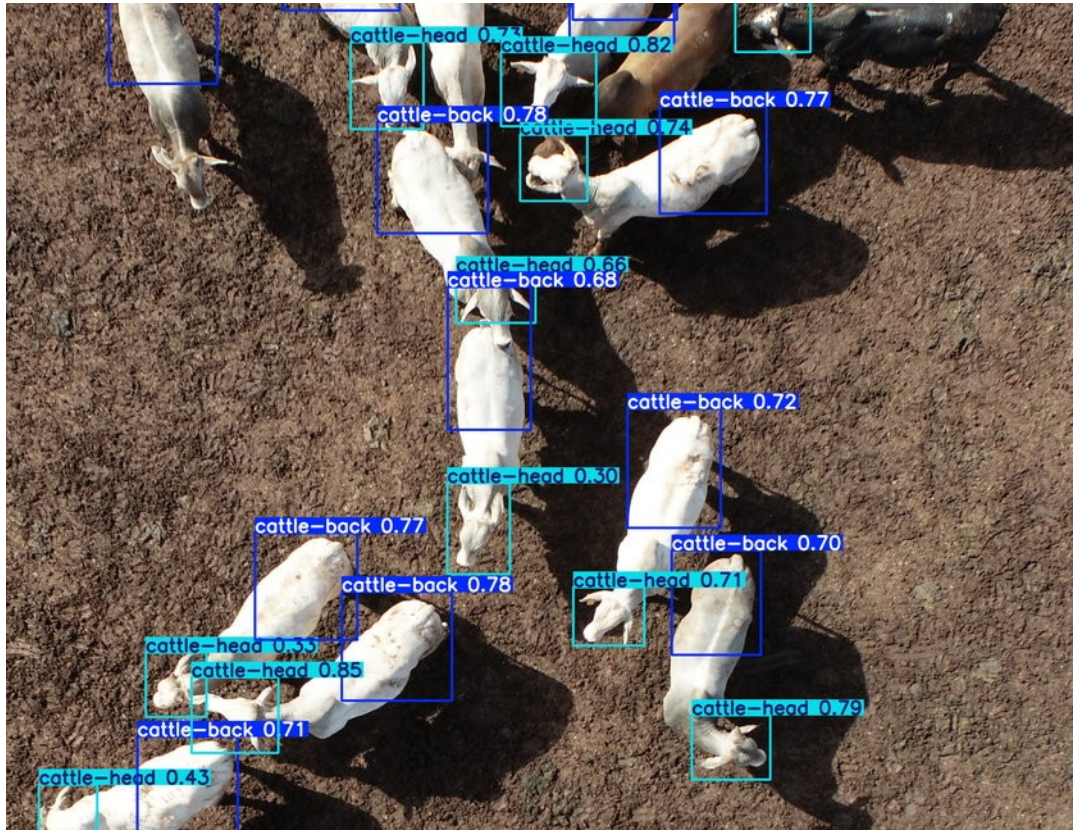
YOLOv11s detection → SAM 2.1 segmentation → body-trait extraction → growth modeling

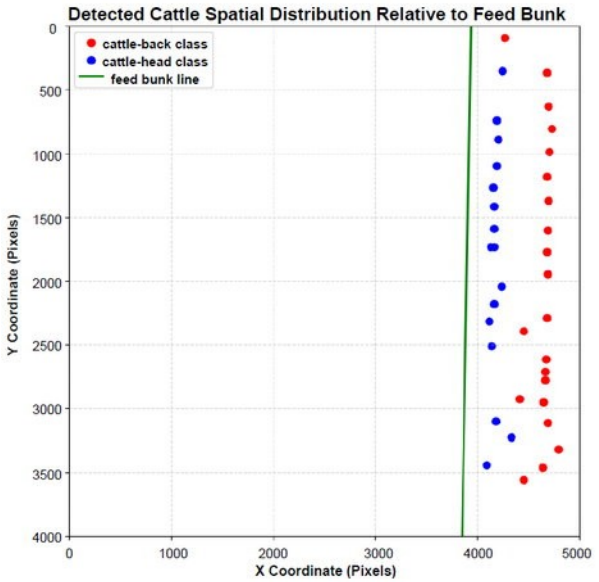
95.56% Precision	**98.36%** Recall
112 d Production cycle	**3** Growth phases

Scale-invariant body proportions enable repeated monitoring without requiring direct animal handling.

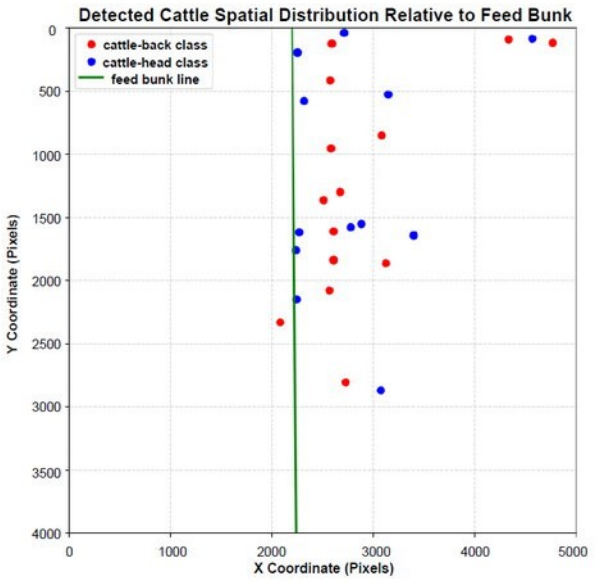
Feeding behavior and feed-bunk alignment

Spatial AI can transform aerial detections into actionable indicators of feed access and distribution.





(a) Example with ideal cattle alignment.



(b) Example with poor cattle alignment.

ANALYSIS

Alignment • spacing • clustering • feeding position

INPUT

UAV imagery + cattle detection + spatial coordinates

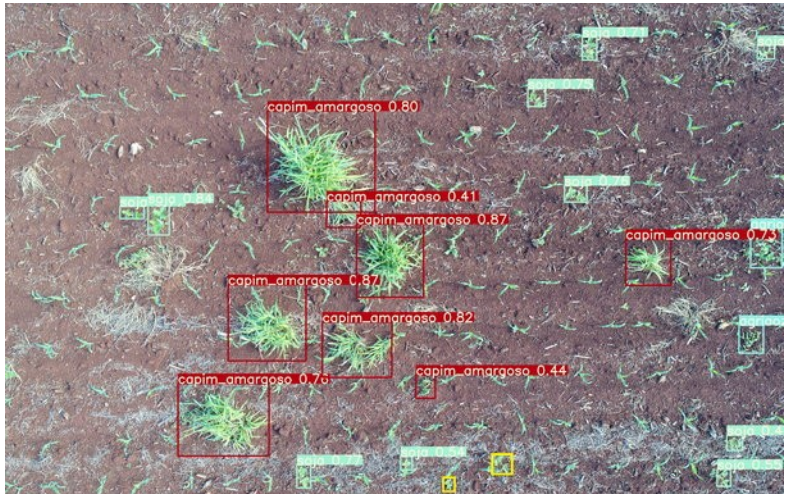
DECISION SUPPORT

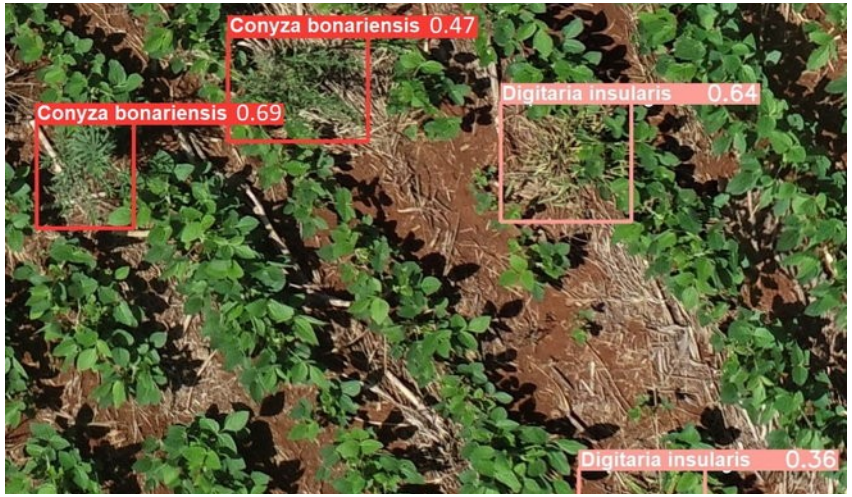
Identify non-uniform feeding patterns and support welfare-oriented nutritional management

Weed detection: species-level intelligence

Early detection can support site-specific control instead of uniform treatment across the entire field.







CORN — WEED6C

Best overall: Faster R-CNN
mAP50 ≈ 0.71 • R^2 ≈ 0.92

SOYBEAN — WEED2C

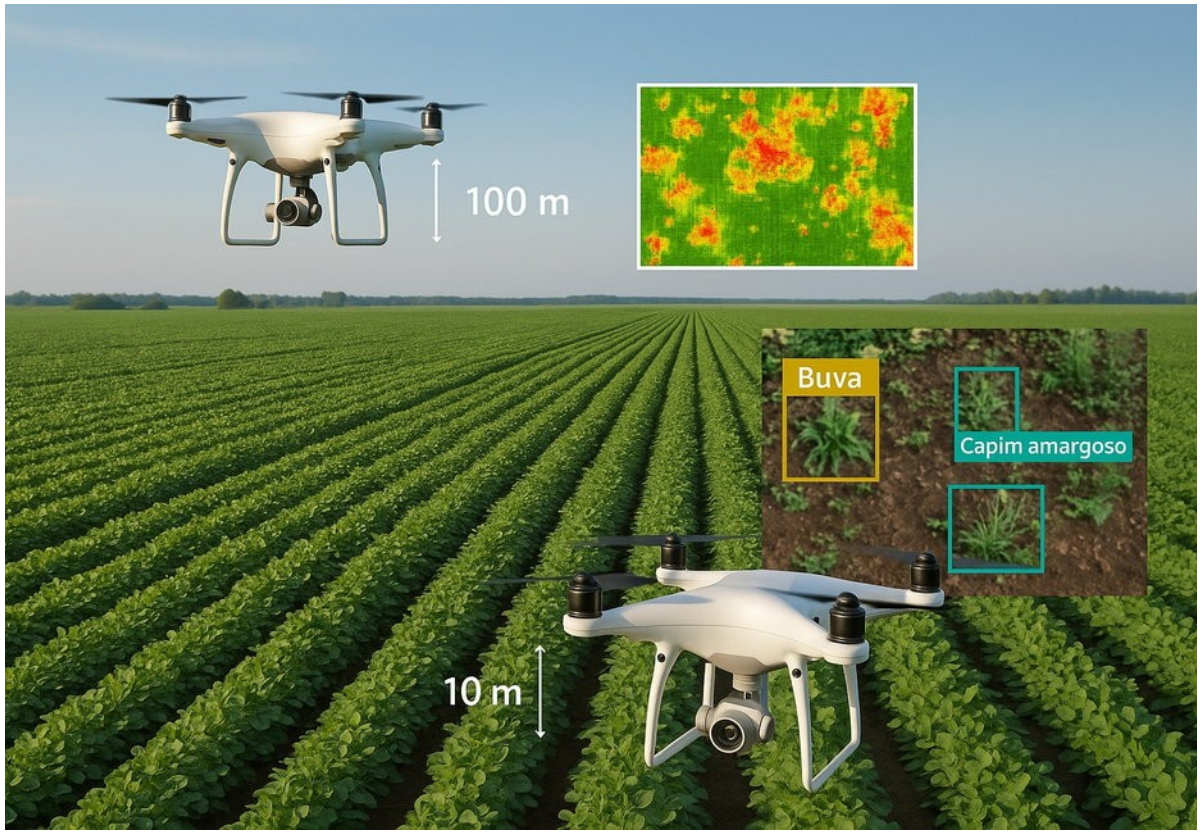
Best model: YOLOv5s6
Precision ≈ 94.9% • R^2 ≈ 0.93

DEPLOYMENT GOAL

Fast species-level detection for targeted management

Multi-scale UAV scouting: patch first, species second

Two flight scales can combine broad coverage with the detail needed for precise intervention.



HIGH ALTITUDE
50–100 m
Detect weed patches and prioritize areas

LOW ALTITUDE
≈10 m
Identify species and quantify local infestation

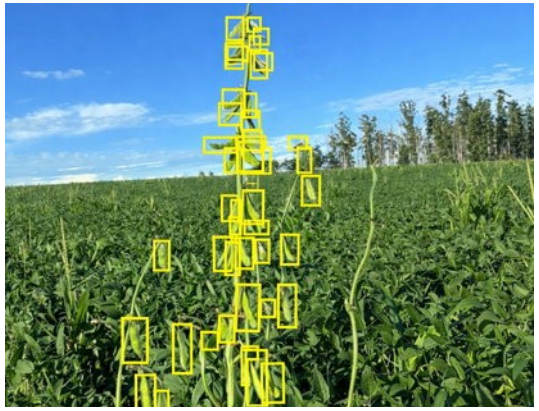
SITE-SPECIFIC RESPONSE
Generate localized herbicide recommendations or mechanical-control targets instead of treating the full field.

Multisource crop monitoring and yield prediction

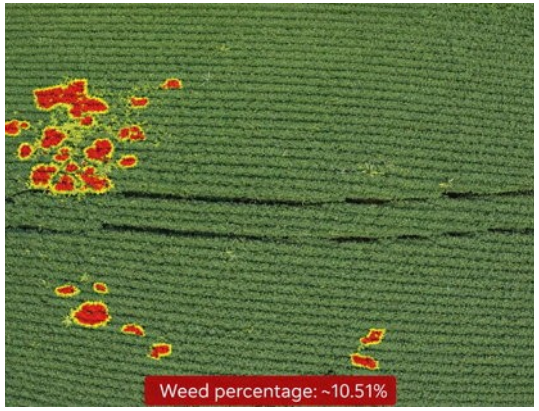
Combining agronomic, climatic and image-derived variables provides a richer representation of field variability.



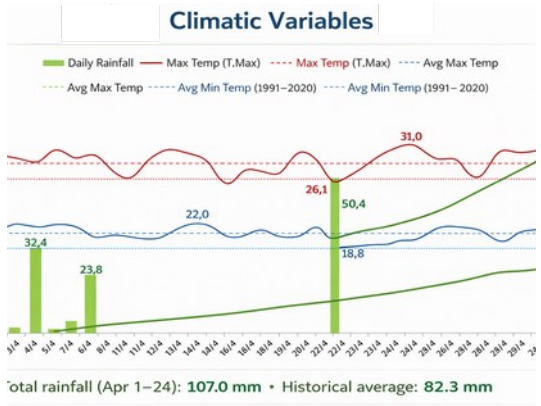
Stand establishment



Pod-level vision



Weed pressure



Climate time series

DATA FUSION

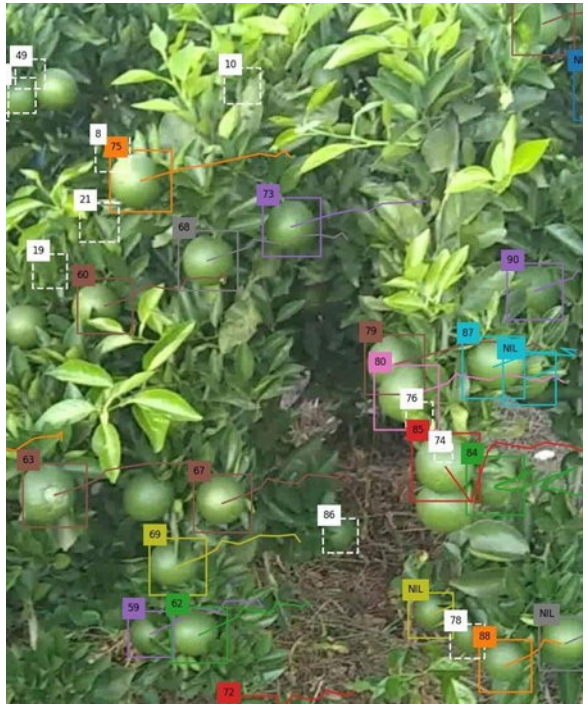
Agronomic + stand + weed + pod + climatic information

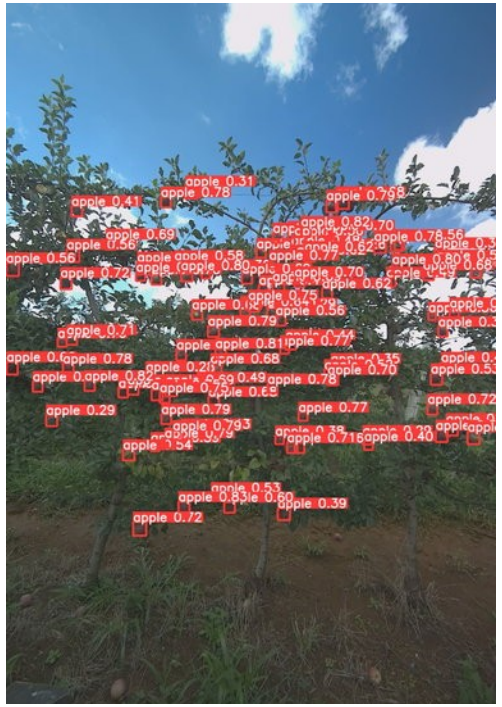
OUTPUT

Field variability characterization and soybean yield prediction

Spatial AI for orchard automation: knowing what is where

Orchard robots need more than object detection — they need persistent 3D understanding of the environment.







PERCEIVE
Fruit • plants • symptoms

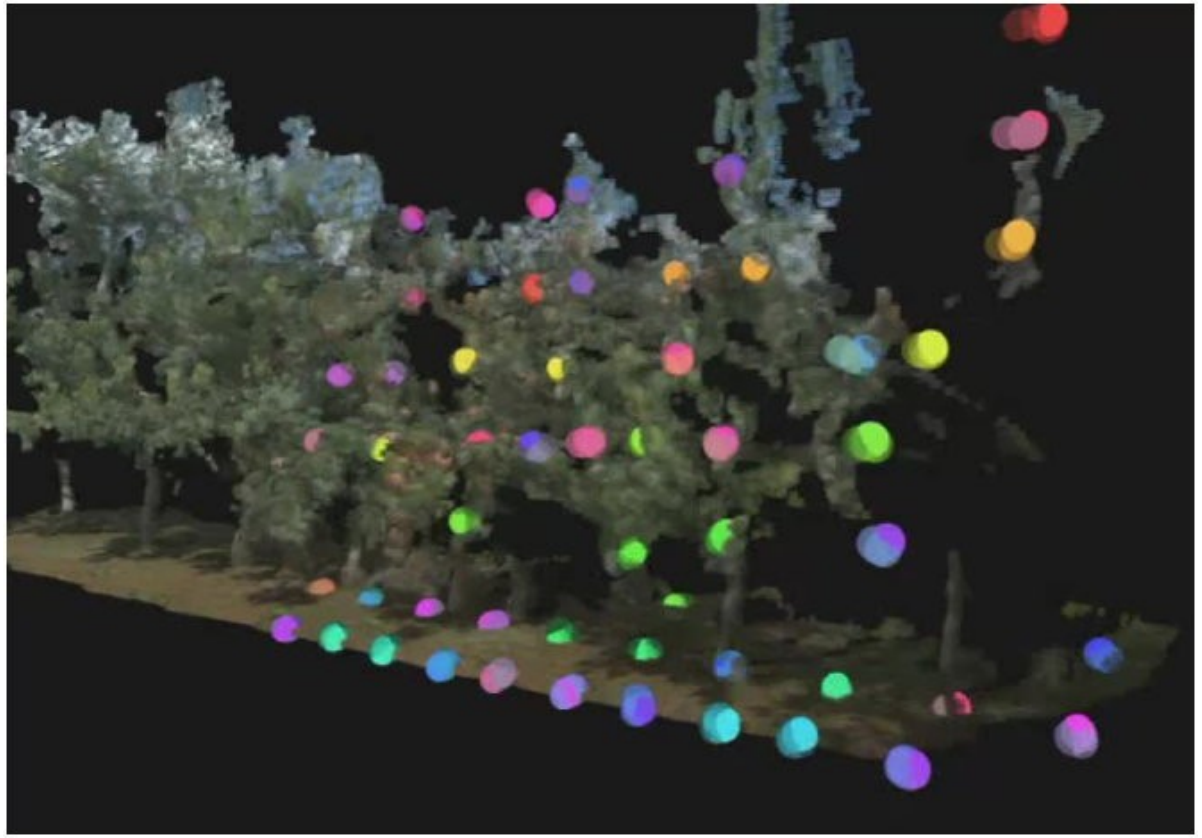
TRACK
Maintain object identity over time

LOCALIZE
Robot/UAV pose + target position

Detection → tracking → 3D association → actionable spatial intelligence

Orchard-scale 3D reconstruction and yield estimation

Geo-referenced sensing and SLAM can turn repeated passes through rows into a persistent digital representation of the orchard.







SENSING

High-resolution geo-referenced RGB-D data + camera motion

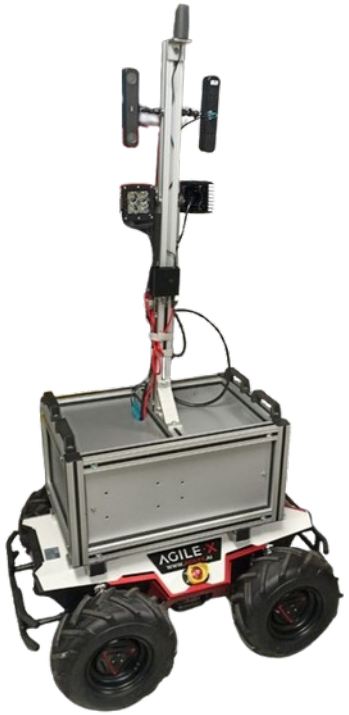
COMPUTATION

Visual SLAM / factor graphs → 3D orchard reconstruction → fruit localization and yield estimation

Field-scanning vehicles: bringing sensing into the rows

Mobile platforms can collect dense, repeatable data where aerial sensing alone is insufficient.





SENSOR SUITE
Cameras • GNSS • LiDAR • depth sensing

TASK
Large-scale plot and orchard scanning between rows

INTELLIGENCE
AI-based pattern detection and spatial mapping

A natural path toward semi-autonomous and autonomous operations.

Where international collaboration can accelerate impact

For potential partners, the most interesting questions are now at the interface between AI, sensing, robotics, field validation and deployment.

RESEARCH FRONTIERS

- Generalizable multimodal AI across farms, seasons and sensors
- Edge AI and low-connectivity operation
- Autonomous sensing, navigation and task execution
- Spatial AI, SLAM and persistent 3D farm representations
- Interoperability between sensors, machines and decision systems

WHAT WE OFFER

- Diverse crops, livestock systems and real production constraints
- Field sites centered on small and medium-sized farms
- Multisource datasets and ongoing technology-validation activities
- Multidisciplinary teams spanning AI, remote sensing and automation
- A pathway from research prototypes to farmer-facing deployment

Potential collaboration: joint projects • comparative field trials • shared datasets • technology co-development

The opportunity is to connect complementary expertise and validate technologies under contrasting agricultural conditions.

Thank you — let's collaborate

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Areas for collaboration

- Multimodal AI & edge intelligence
- Robotics, spatial AI & autonomous systems
- Comparative field validation & shared datasets

Institutional support: