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AGRISUN – COOPEERATION BETWEEN SOLAR POWER AAND GRAIN PRODUCTION

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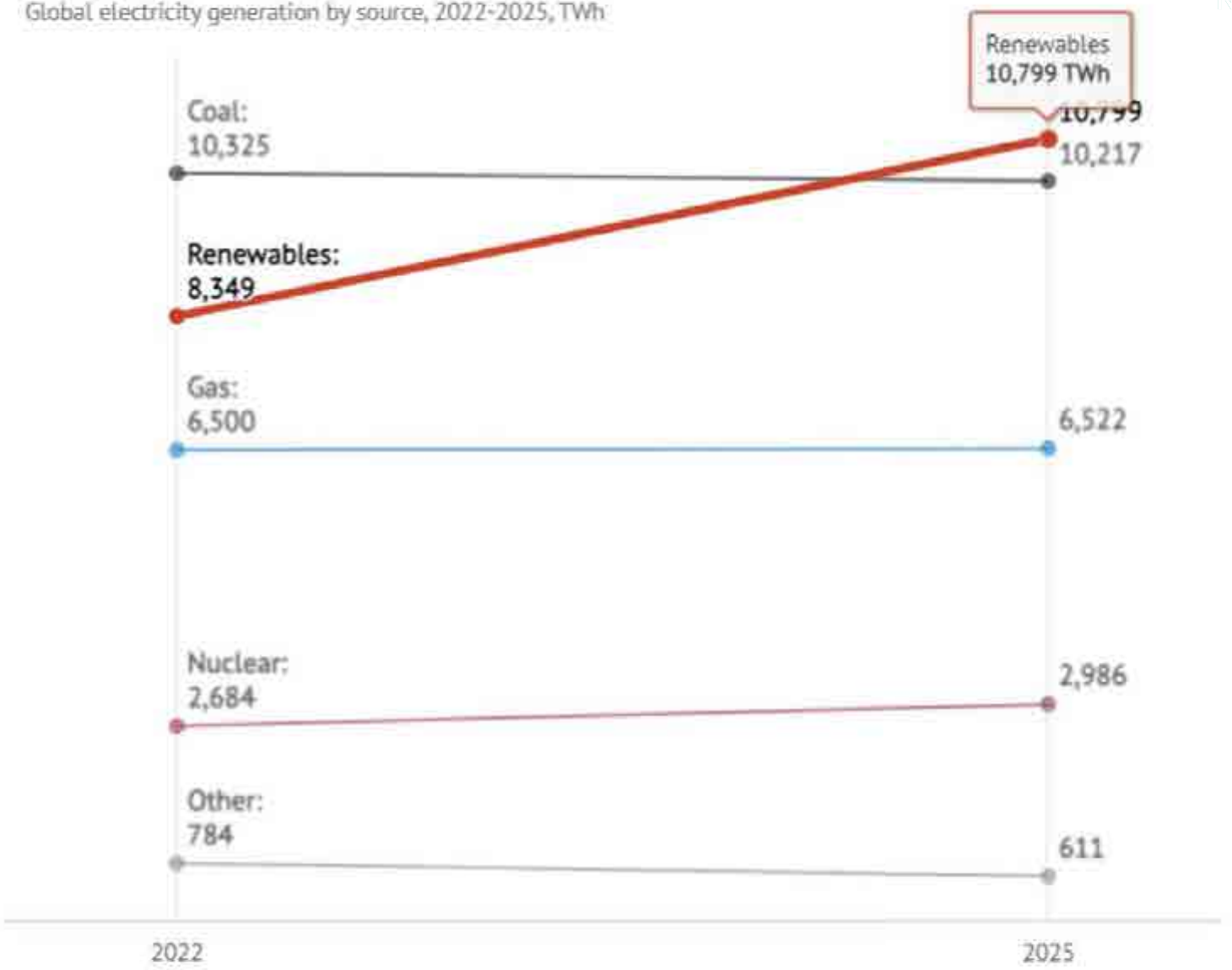
Advances and Innovations in Agricultural EngineeringThe 5th NJF – EurAgEng – Agromek Joint Seminar, Herning, Denmark, 26.-27. November 2024

Renewables will become world's largest electricity source within three years, IEA data reveals

Global electricity generation by source, 2022-2025, TWh



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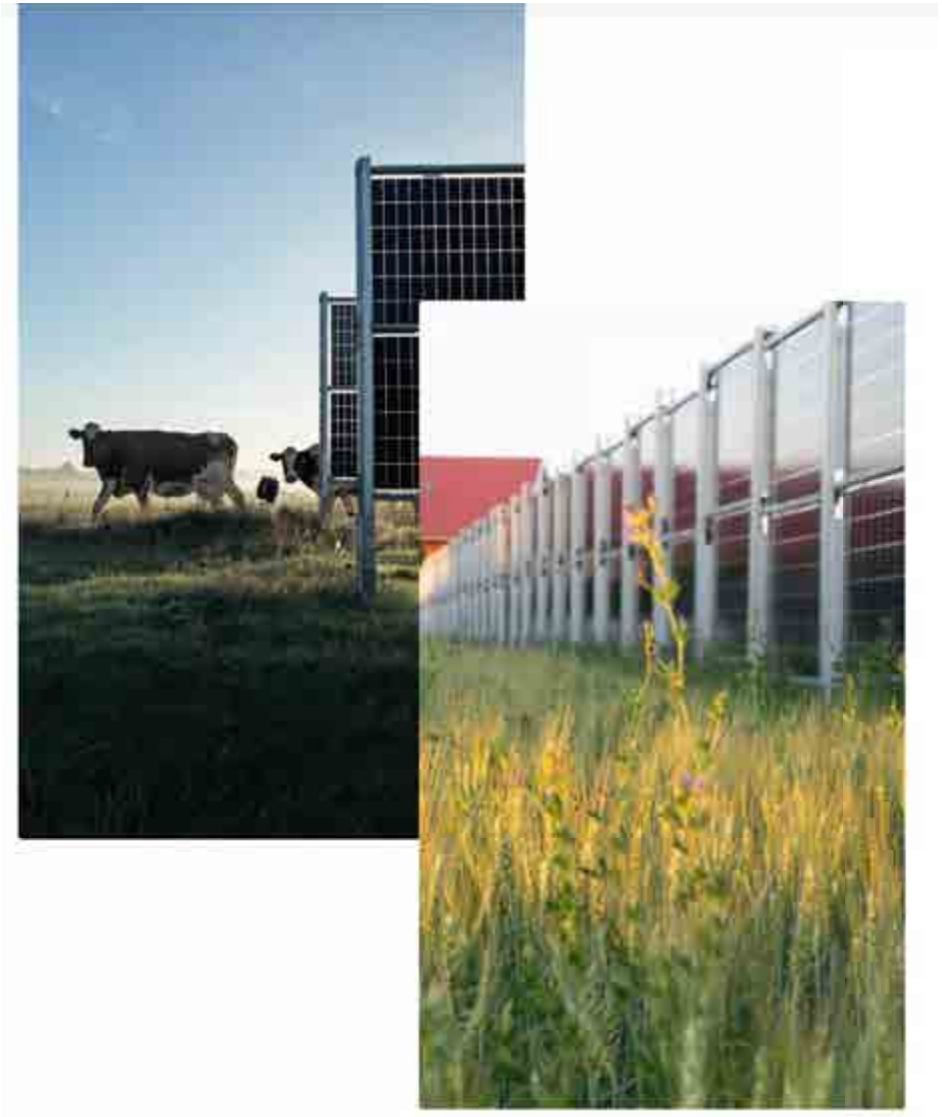

next2sun

Modernebolig.no

With agrivoltaics ‘we don’t have to choose between solar power and producing food’

By **Angeli Mehta**

March 20, 2023 1:17 PM GMT+1 · Updated a year ago

Industry Insight from Ethical Corporation Magazine, a part of Thomson Reuters.

Sheep browse among solar panels in a field. Jake Janski/Enel Green Power/Handout via REUTERS Purchase Licensing Rights

Different ways of combining agricultur and solar energy around the world

Fraunhofer, Germany

Lanai, Hawai

Engie, France

Italian scientific entities publish new regulatory practices for agrivoltaics

Italian scientific institutions have published new regulatory practices for agrivoltaics, with a specific focus on electricity production, agricultural output, and landscape preservation.

AUGUST 8, 2023 SERGIO MATALUCCI

COMMERCIAL & INDUSTRIAL PV | MARKETS | MARKETS & POLICY | TECHNOLOGY AND R&D | UTILITY SCALE PV | ITALY

Image: BayWa r.e.

Vertical bifacial PV-modules

Justwe.com

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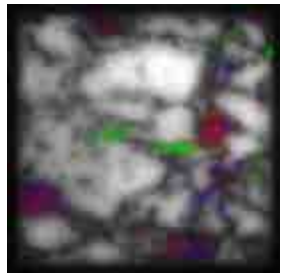
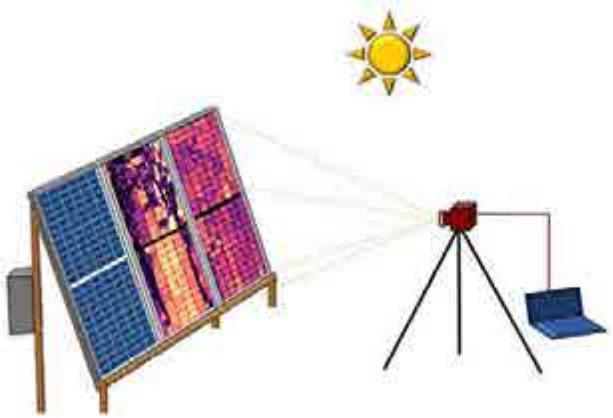
AgriSun in arctic areas

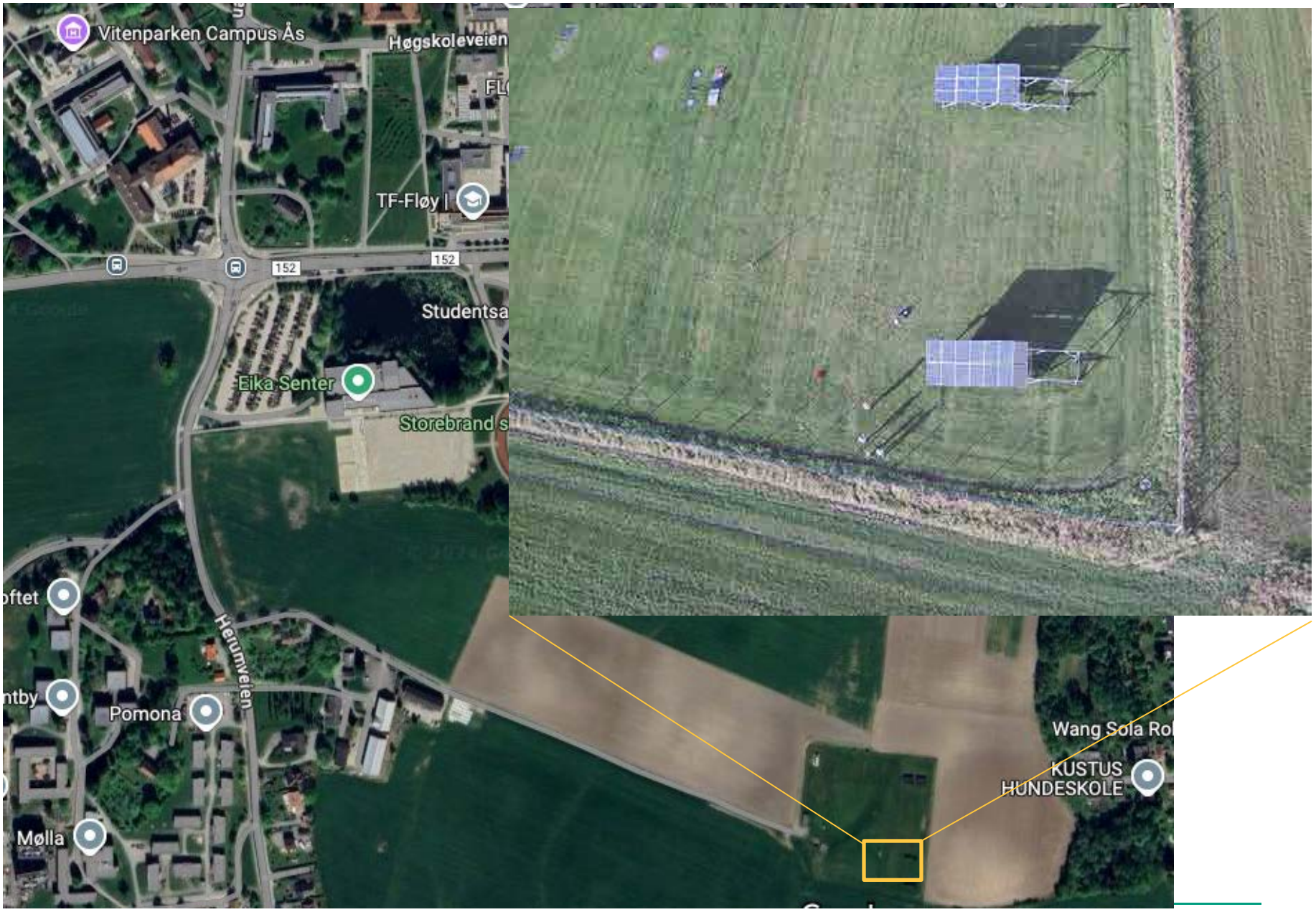
- Special challenges related frost and snow
- The solar position in the sky
- Solar radiation and plant growth
- Only 3% arable land

Solar cell research at NMBU/Realtek






SMART
FARMING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Møllа
Wang Sola Rol
KUSTUS
HUNDESKOLE

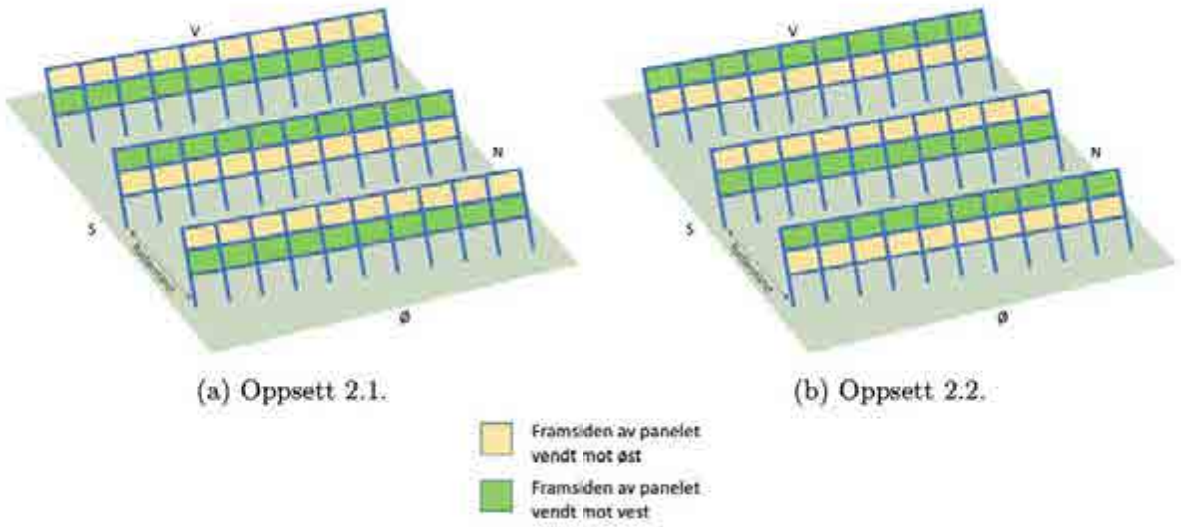
Kjerringjordet Sun Farm

Next 2 Sun

DEUTSCHER SOLARPREIS GEWINNER 2020

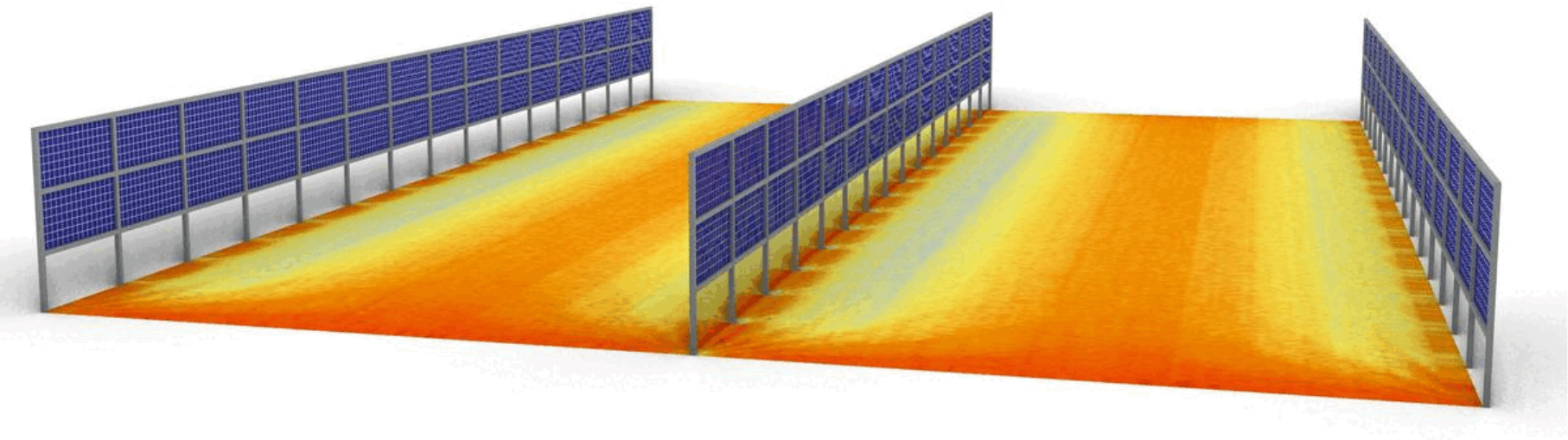
Simulation of energy production

- 3 rows with vertical bifacial-modules
  (Huasun Himalaya M6 Series 460 W, 144-cell Bifacial HJT Half Cell Solar Module)



(a) Oppsett 2.1.

(b) Oppsett 2.2.



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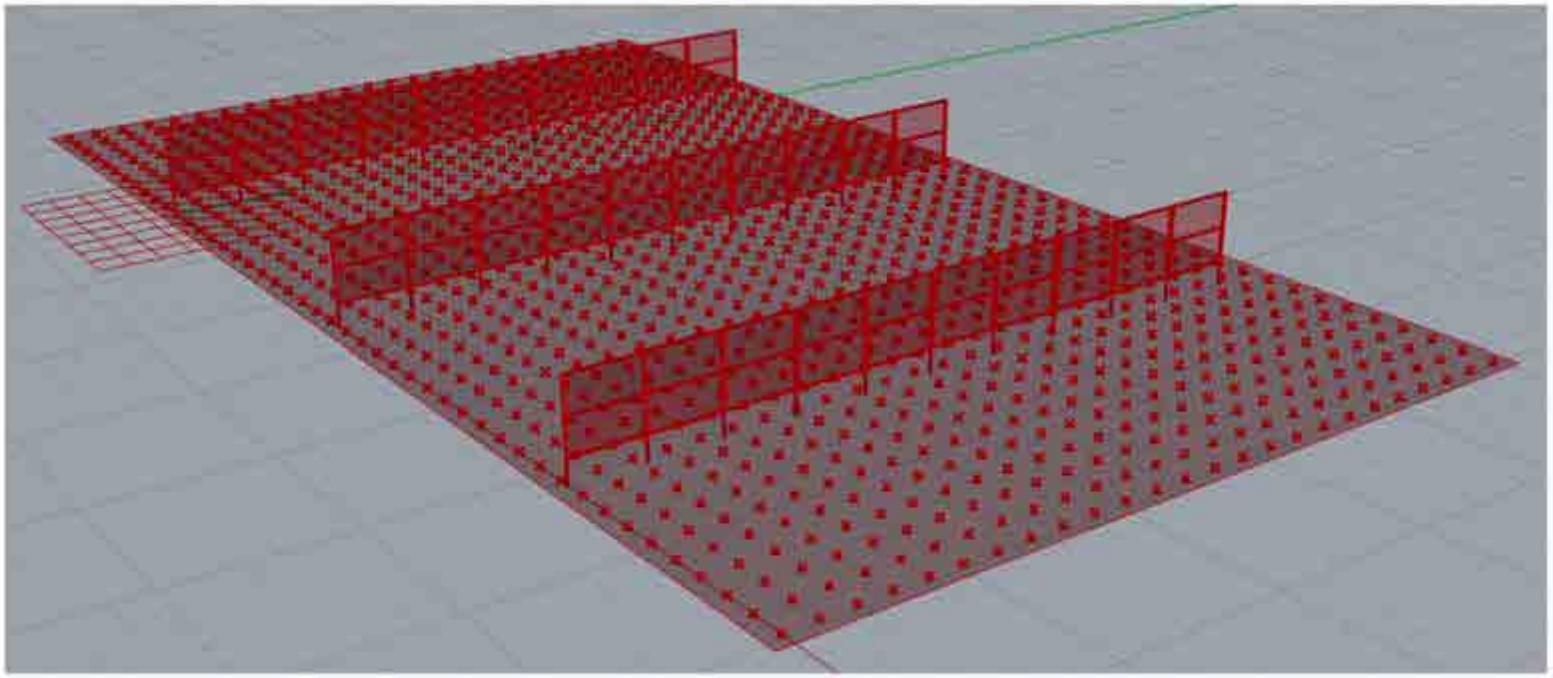
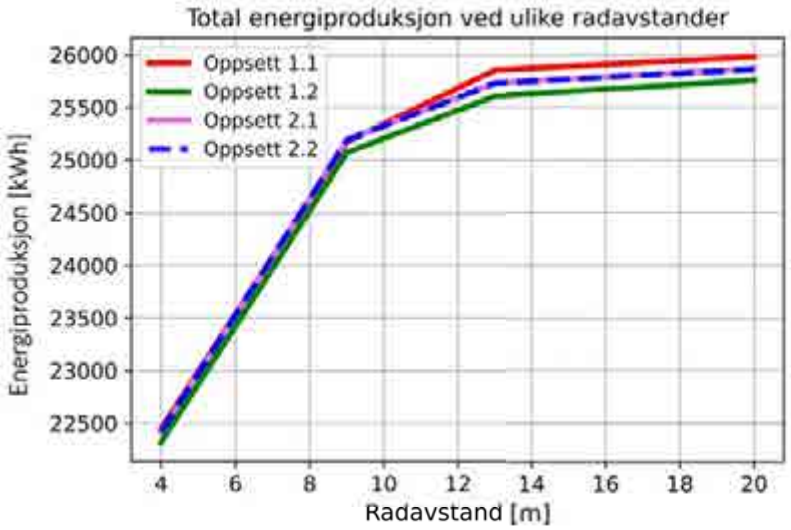
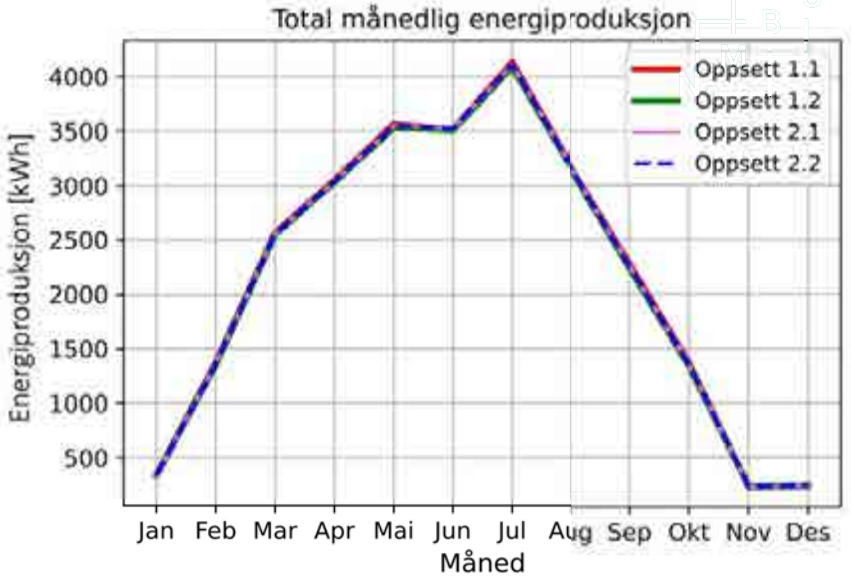
Simulation of plant growth

- Canadian Timothy Model (CATIMO) (Helge Bonesmo og Gilles Bélanger)





Figur 4.1: Årlig energiproduksjon for de ulike oppsettene fremstilt grafisk.



Figur 4.2: Månedlig produksjon for alle oppsett fremstilt grafisk.

Tabell 4.7: Årlig gjennomsnittlig gressproduksjon med og uten skygge fra solceller og festeutstyr. Prosentandelen er gitt som prosent av mulig produksjon på arealet som er undersøkt.

	Gressproduksjon [kg/1000m²/år]		
Radavstand	**Årlig gj.snitt med skygge**	**Årlig gj.snitt uten skygge**	**%**
4 m	832,1	933,3	89,1 %
9 m	880,4	933,3	94,3 %
13 m	893,3	933,3	95,7 %
20 m	903,5	933,2	96,8 %

Conclusion from simulations

- Yearly production from a 27kWp plant mounted East-West will have yield of ca 1000 kWh/kWp (similar to a conventional plant facing South

- Grass production expected to be 90-97% (4m – 20m row distance) compared to area without PV (100% including uncertainties)

Skjetlein videregående skole

FINN ANSATT SØK

Skjetlein videregående skole / Nyhetsarkiv / Soldeling

Soldeling - å dele på sola

September 2024

LANDBRUK NORGES MILJØ- OG BIOVITENSKAPELIGE UNIVERSITET FORNYBAR ENERGI SOLCELLER

Solcellepanel-forsøk på Universitetet i Ås: – Hvis det lykkes, vil det være en ekstra inntektskilde for bøndene

EKSPERIMENT. Panelene kan bekrefte eller avkrefte effekter på jordbruket. Foto: Espen Olsen/NMBU

Av Anders Brekke

Publisert: 25.09.24 09:52

Del

Mandag dukket det opp noe nytt på forsøksjordet til Norges miljø-og biovitenskapelige universitet. Forskerne er spent på hva resultatene kan si for landbruket og bøndene.

Plans for 2025

- Planting grains between and around the solar park
- Monitoring plant growth with multispectral images and LiDAR
- Sensors for temperature and moisture
- Yield measurements
- Snow depth

Power production

- Logging power production
- Monitor degradation of PV panels


… to be continued…
Thanks

HandsFree Hectare

An Innovate UK funded collaborative feasibility study between:

Precision Decisions

Harper Adams University

Agricultural Engineering Innovation Centre

TEF 2023 Gold

THE TIMES THE SUNDAY TIMES GOOD UNIVERSITY GUIDE 2024 SPECIALIST UNIVERSITY OF THE YEAR

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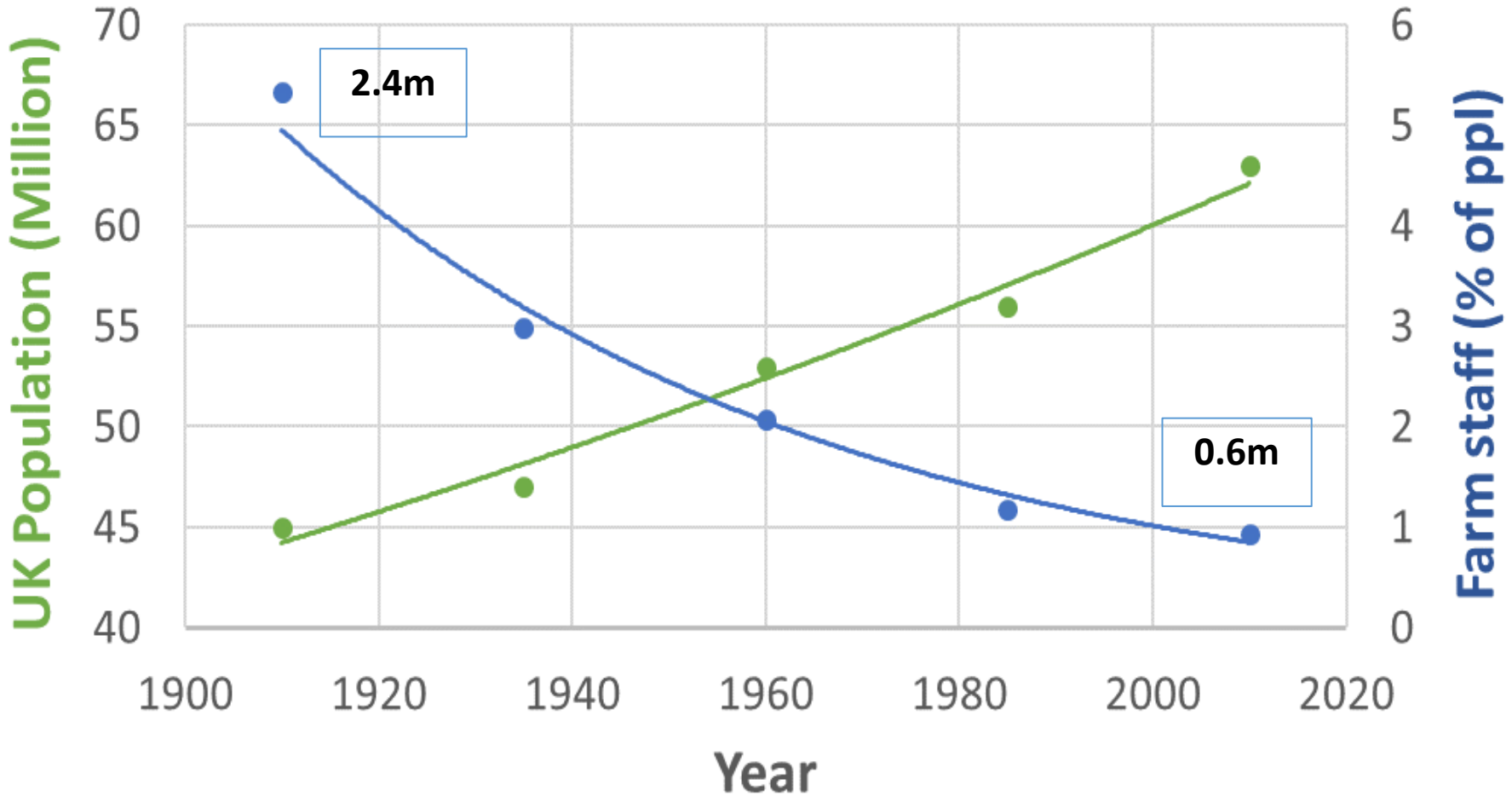
What is agriculture? The few feeding the many



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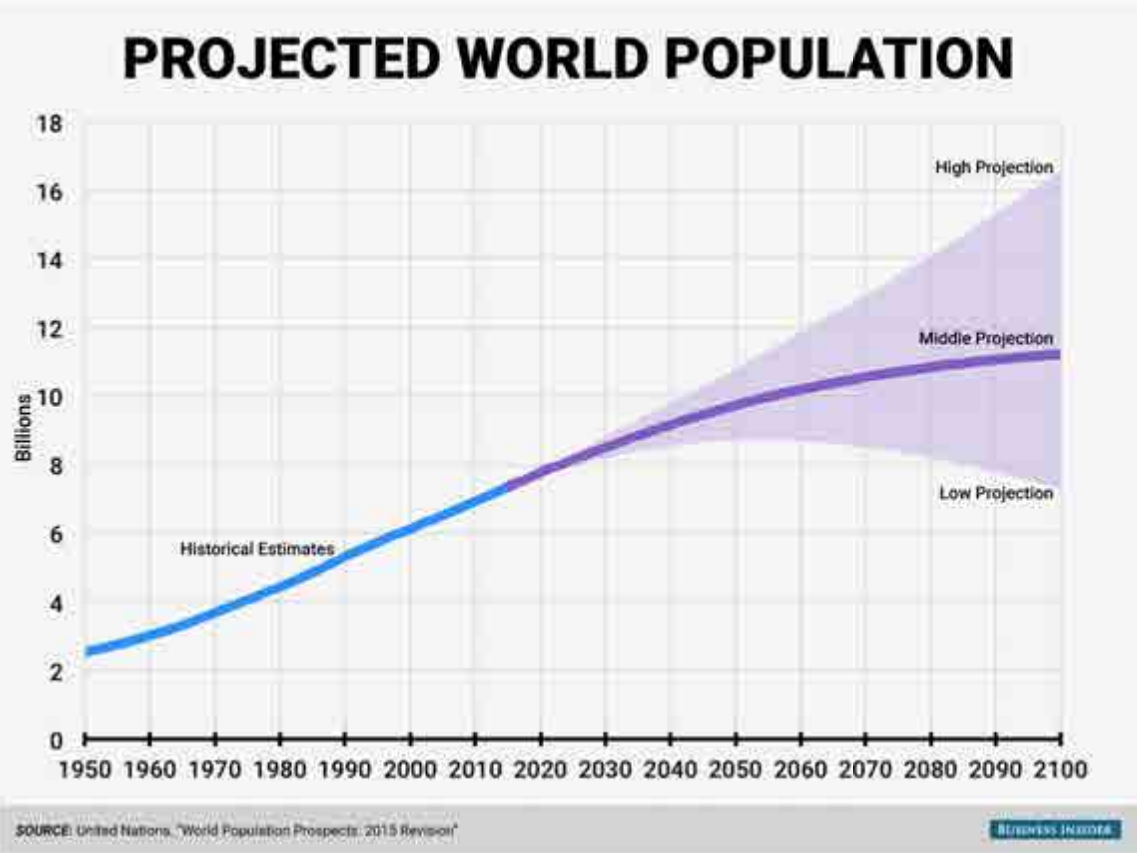
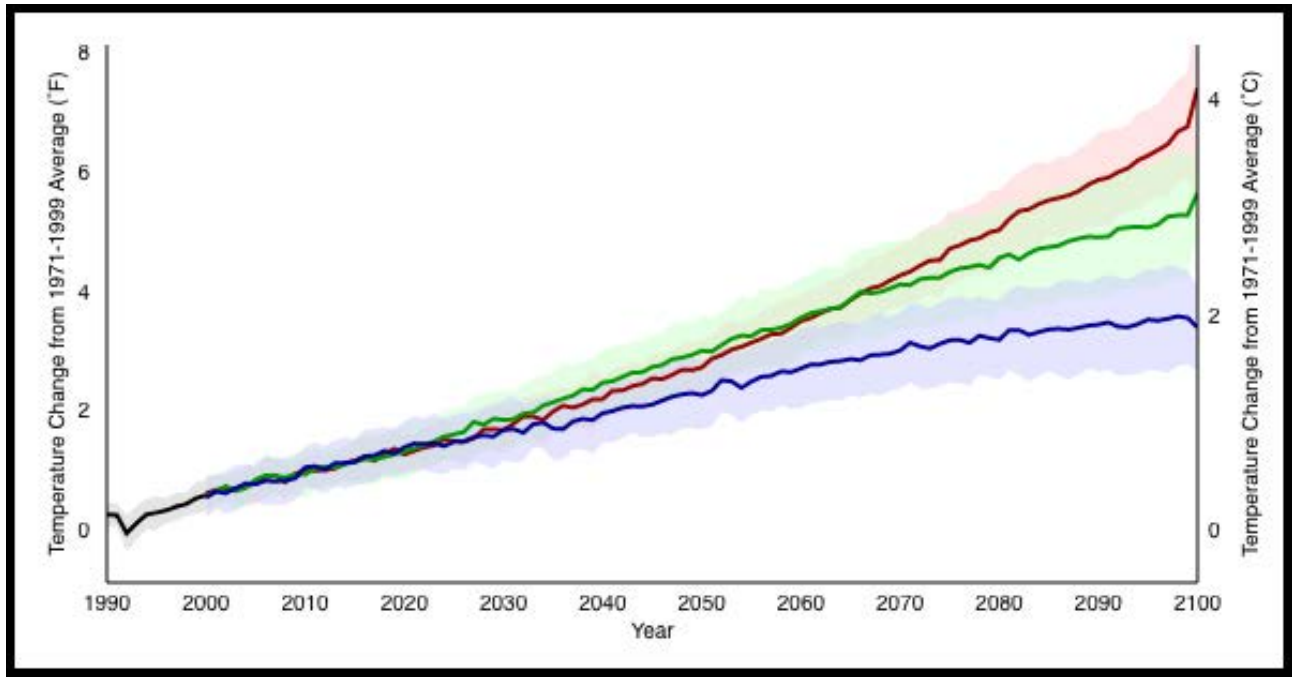
What are the challenges to come?



1. To feed a growing global population
2. Whilst the climate changes
3. Limiting use of resources – Net Zero



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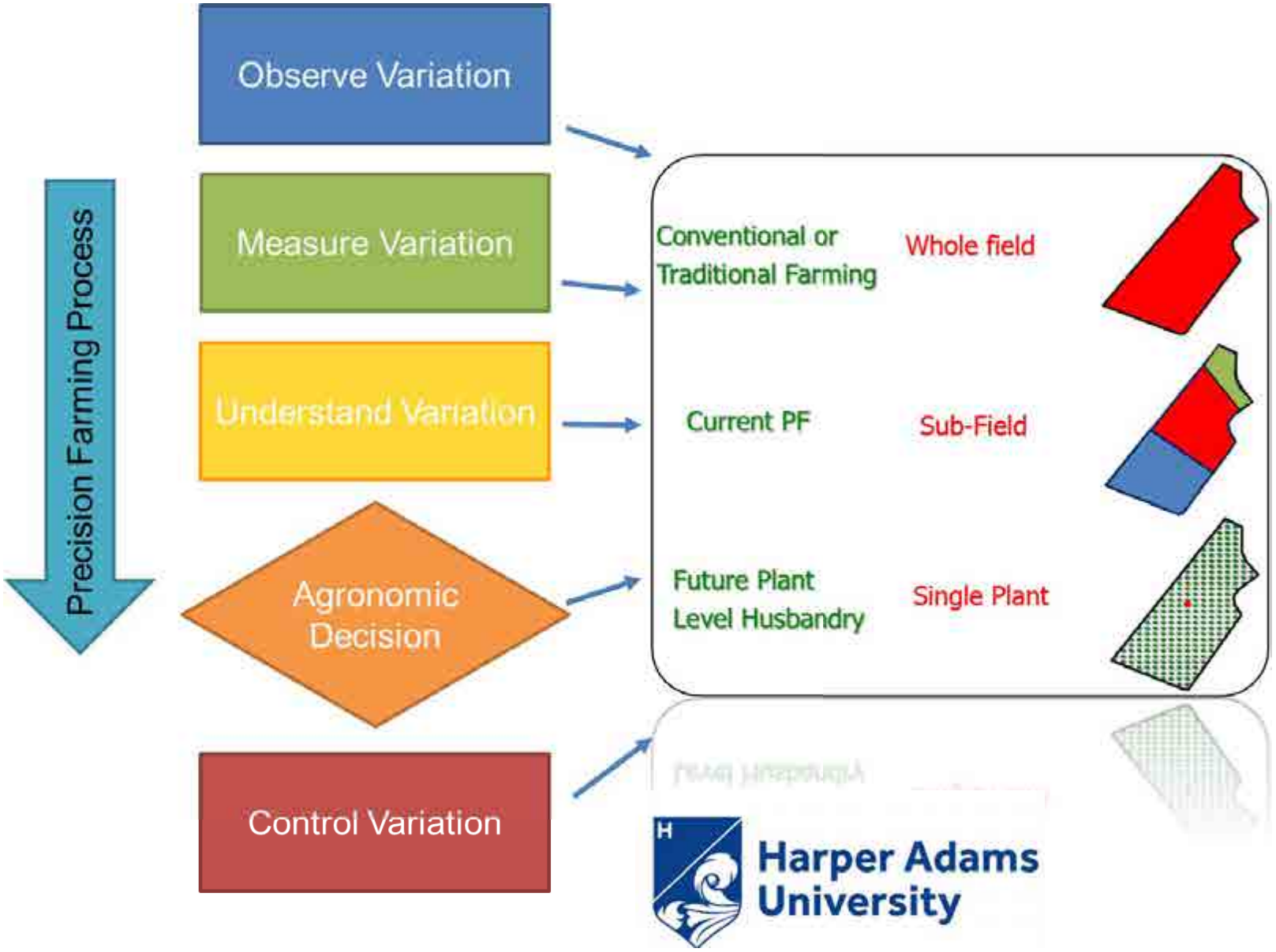
How to meet the challenge? – Precision Farming

- Improve sustainability: reduced waste & increase efficiency
- Adopt Precision Farming management methods: **4x Rights**



Agricultural problems

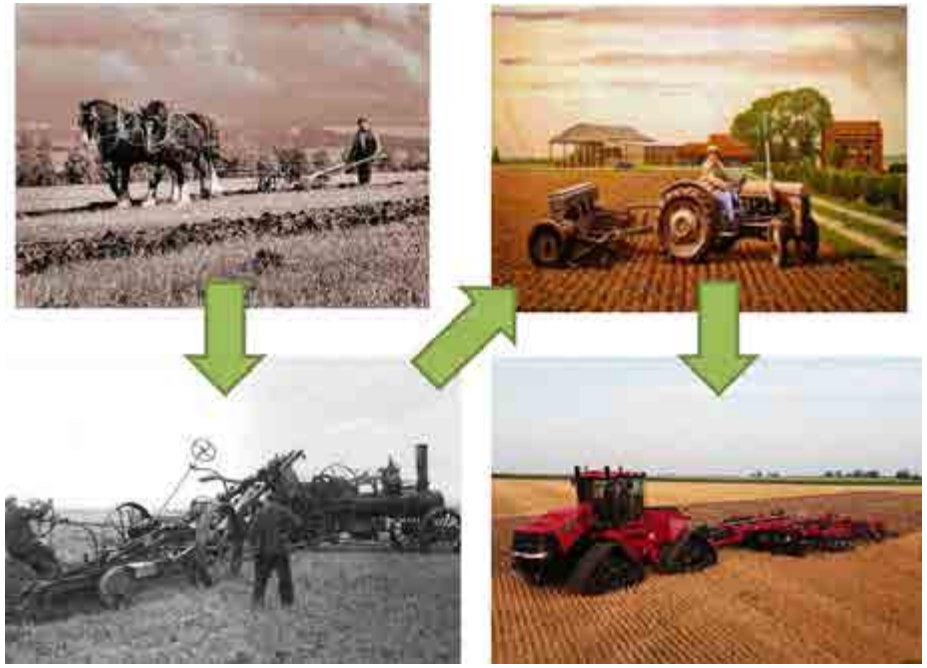
Reduced rural labour **=** ever larger machines

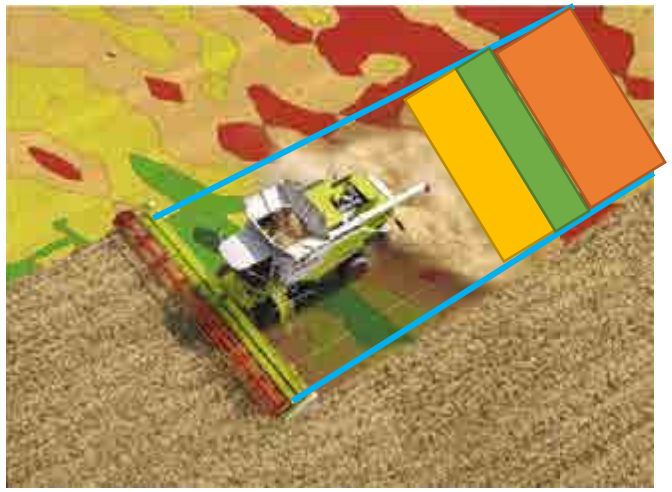
Limited time windows **=** ever larger machines

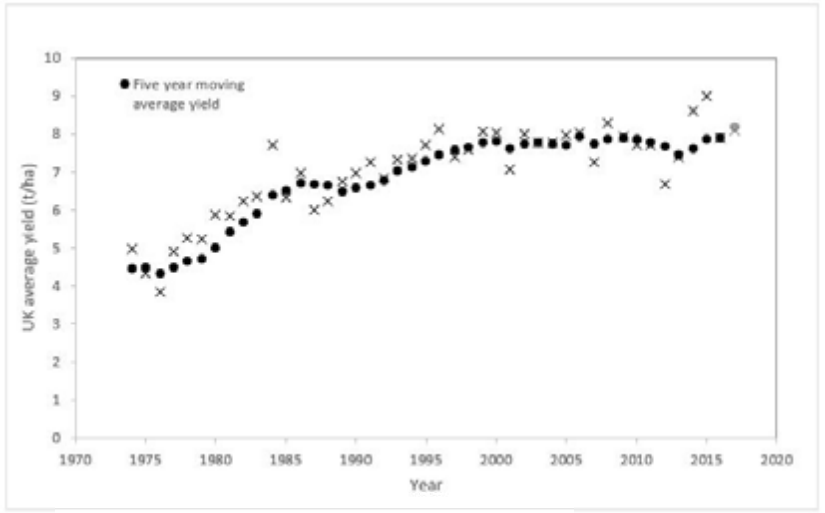
One-upmanship = ever larger machines

Lack of resolution for PF **cause** large machines

Compaction limiting yield **cause** large machines







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Small robot paradigm - the future?

Increased resolution = improved PF = margin gain?

Reduced compaction (tackle cause) = increase yield?

Robots operate in “swarms” = same area covered

Swarm requires management = job retained

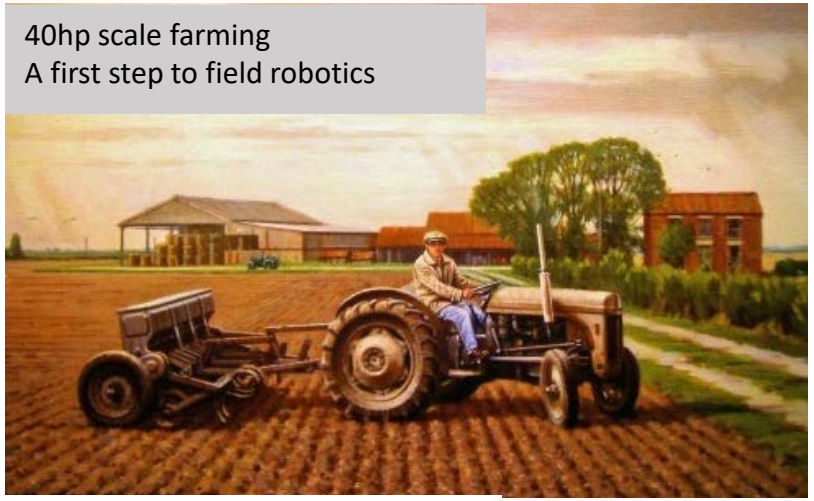
Small vehicles are intrinsically safer

Future plant scale robotic management

1875 tonne/ha to 11.27 tonne/ha

Over a 150 times reduction

40hp scale farming
A first step to field robotics



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Energy implication???

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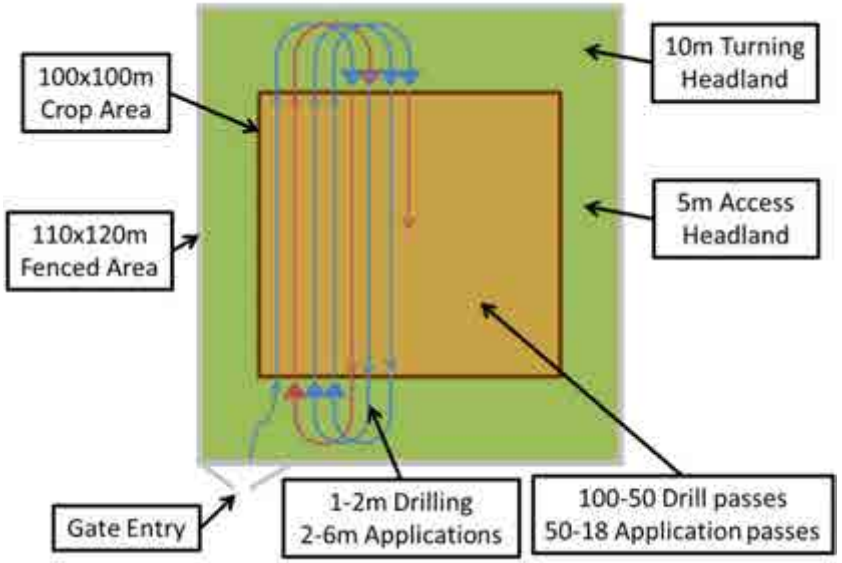
Hands Free Hectare

"Automated machines growing the first arable crop remotely, without operators in the driving seats or agronomists on the ground"



KWS

YARA

BAYER

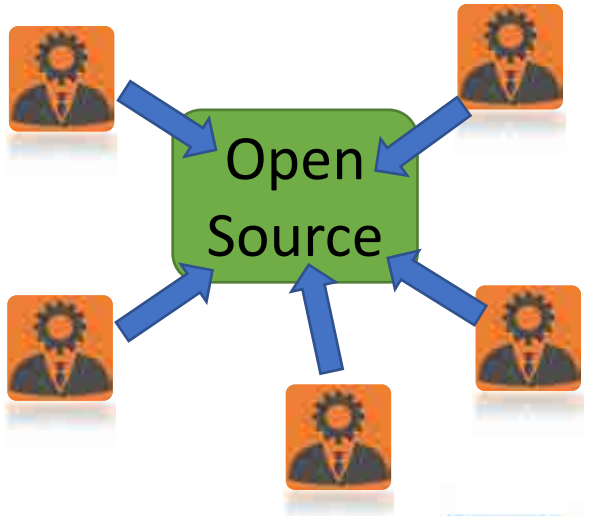
HUTCHINSONS
Crop Production Specialists

Project objective

1. World first automated field growing cycle: drilling, husbandry/agronomy and harvest
2. Challenge perception of automation capability and inspire through media coverage
3. Utilising machinery and technologies that are available and affordable **not** bespoke and expensive:

   Commercial compact Ag machinery

   "Open source" automation
4. 1 year project…. One chance - KISS!!



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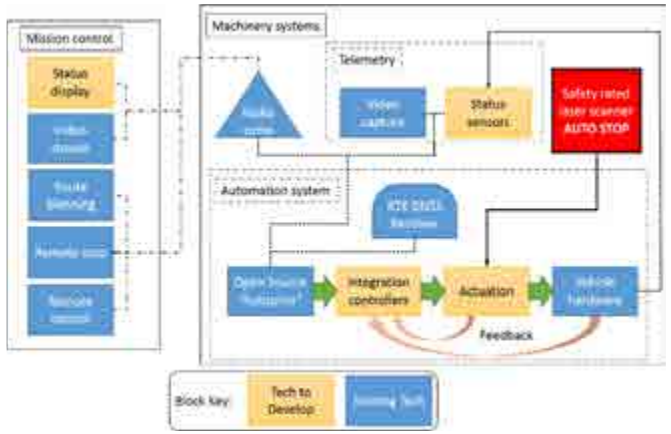
Hands Free Hectare – getting funded

WHY did they back us: Innovate UK

1. Strong Collaboration
2. World First
3. Value - £200k
4. Clear plan



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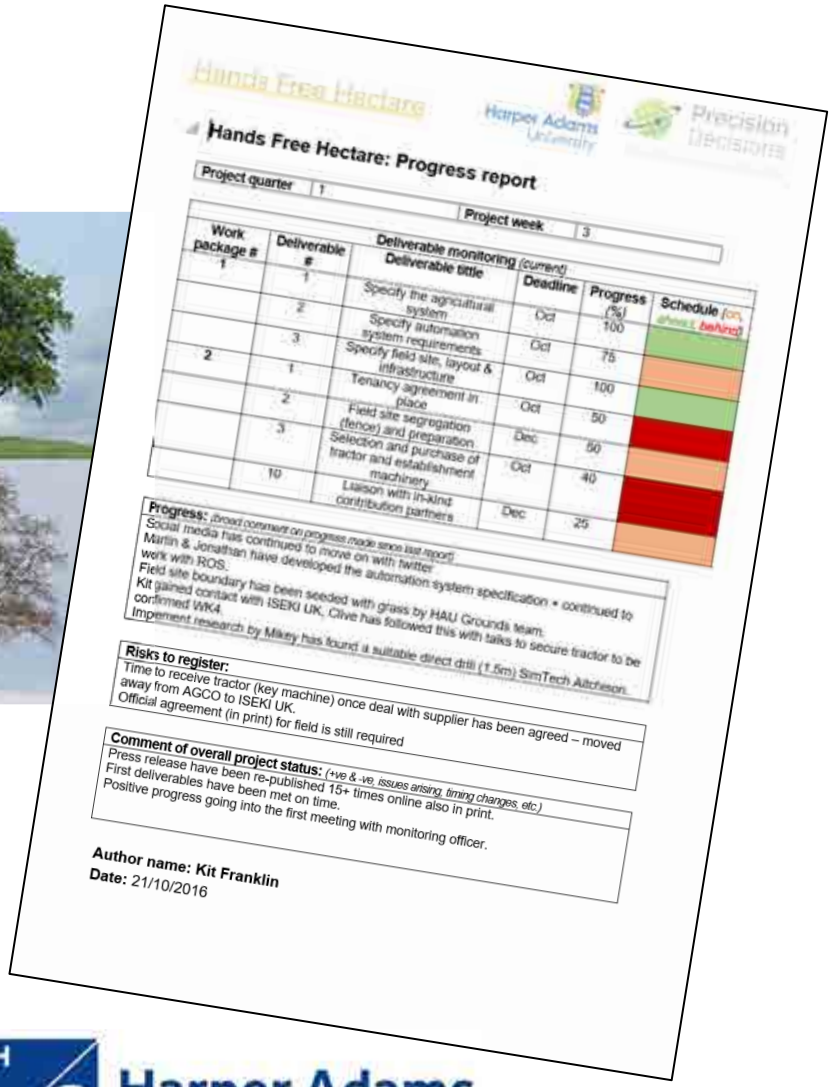
Hands Free Hectare – collaborate successfully

1. Integrated autonomous working – Skunkworks
2. Weekly progress and planning meeting
3. Time and reputation pressure



Hands Free Hectare

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Hands Free Hectare: Progress report

Project quarter	1	Project week	3

Work package #	Deliverable #	Deliverable monitoring (current) Deliverable title	Deadline	Progress (%)	Schedule (on, ahead, behind)
1	1	Specify the agricultural system	Oct	100	
	2	Specify automation system requirements	Oct	75	
	3	Specify field site, layout & infrastructure	Oct	100	
2	1	Tenancy agreement in place	Oct	50	
	2	Field site segregation (fence) and preparation	Dec	50	
	3	Selection and purchase of tractor and establishment machinery	Oct	40	
	10	Liaison with in-kind contribution partners	Dec	25	

Progress: *(brief comment on progress made since last report)*
Social media has continued to move on with twitter
Martin & Jonathan have developed the automation system specification • continued to work with ROS.
Field site boundary has been seeded with grass by HAU Grounds team.
Kit gained contact with ISEKI UK, Clive has followed this with talks to secure tractor to be confirmed WK4.
Implement research by Mikey has found a suitable direct drill (1.5m) SimTech Aitcheson.

Risks to register:
Time to receive tractor (key machine) once deal with supplier has been agreed – moved away from AGCO to ISEKI UK.
Official agreement (in print) for field is still required

Comment of overall project status: *(+ve & -ve, issues arising, timing changes, etc.)*
Press release have been re-published 15+ times online also in print.
First deliverables have been met on time.
Positive progress going into the first meeting with monitoring officer.

Author name: Kit Franklin
Date: 21/10/2016

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Outwood communication

- Regular press releases
- Regular multi planform social media updates
- Formal-ish press days with real work
- Mixed media – wide audience
- Take over GOOGLE!!

17/11/2016

0 Comments

Press release 1

Field to be farmed exclusively by robots - a world-first

In a world-first, members of Harper Adams University engineering staff, supported and led by precision farming specialist Precision Decisions Ltd, are attempting to grow and harvest a hectare of cereal crops; all without stepping a foot into the field.

The project entitled 'Hands Free Hectare' has recently got underway, with the team having to create their first autonomous farming machinery, ready for drilling a spring crop in March.

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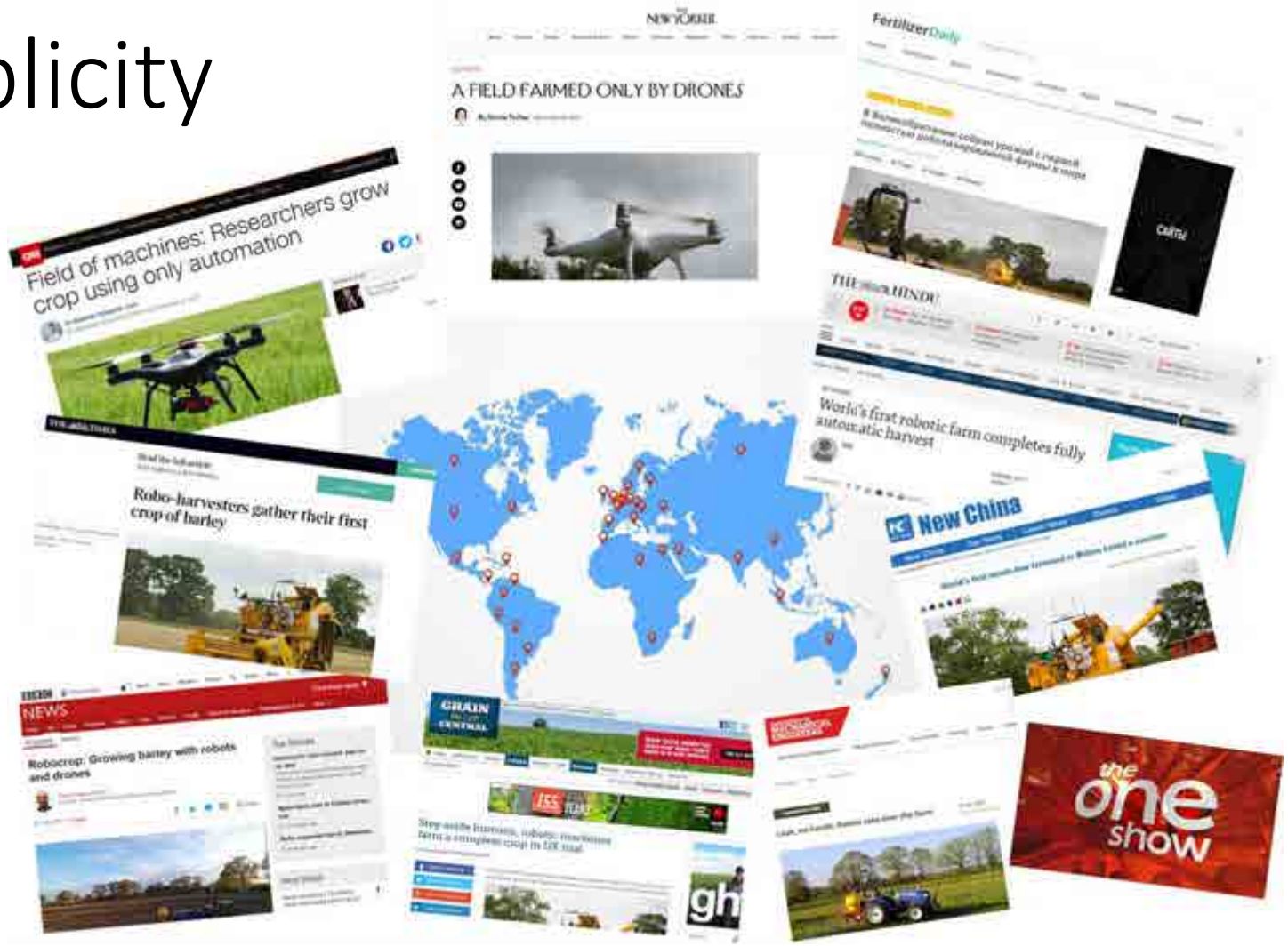
Impact – “good” publicity

- **Twitter**
  - 3,944 Followers
- **Facebook**
  - 1,654 Followers
  - Posts reaching 40,000
- **YouTube**
  - 534 Subscribers
  - 105,000 Views



Publications across **85+ Countries**

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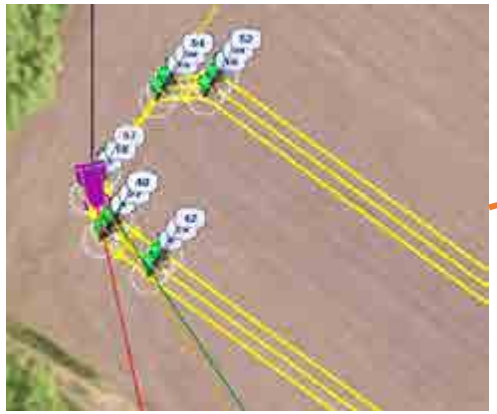
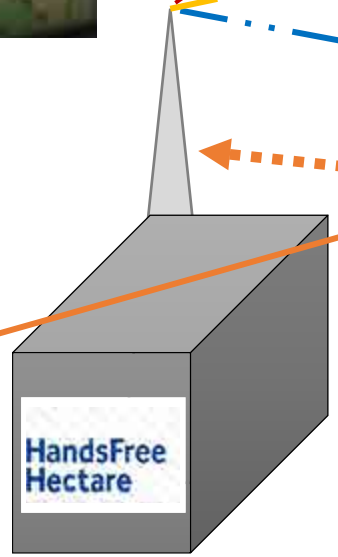
Hands Free Hectare – **original system**



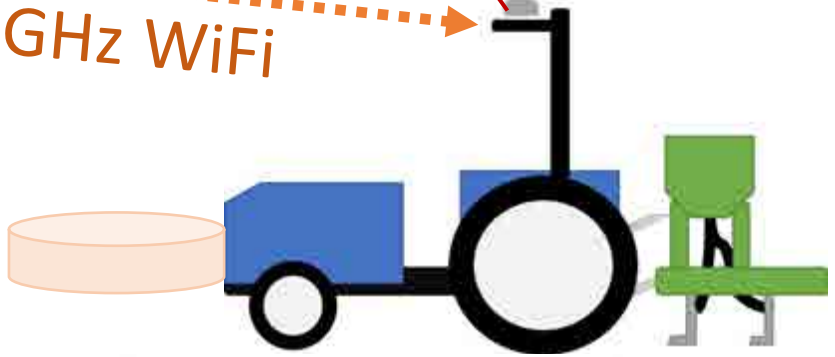


GPS

Multi Channel Video 5.6Ghz radio

RTK 433Mhz radio

Telemetry 2.4GHz WiFi



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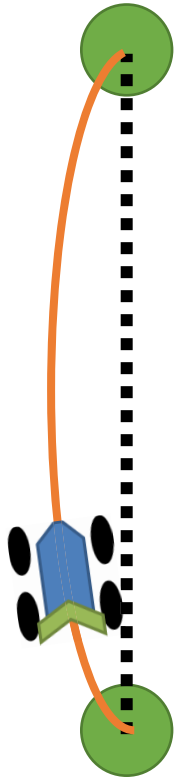
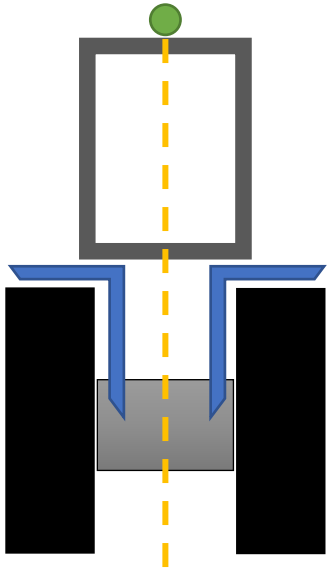
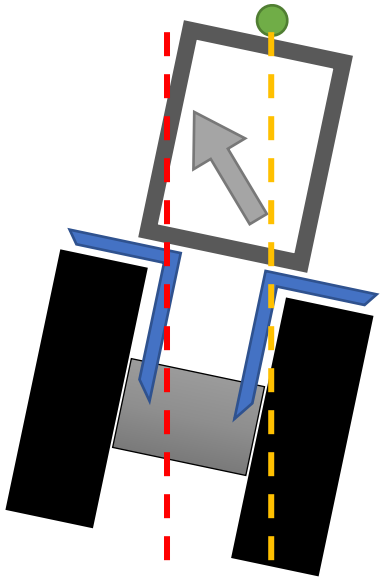
Hands Free Hectare – Precision issues







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HFH2 AHDB funding – Autonomy improvements

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HandsFree Farm

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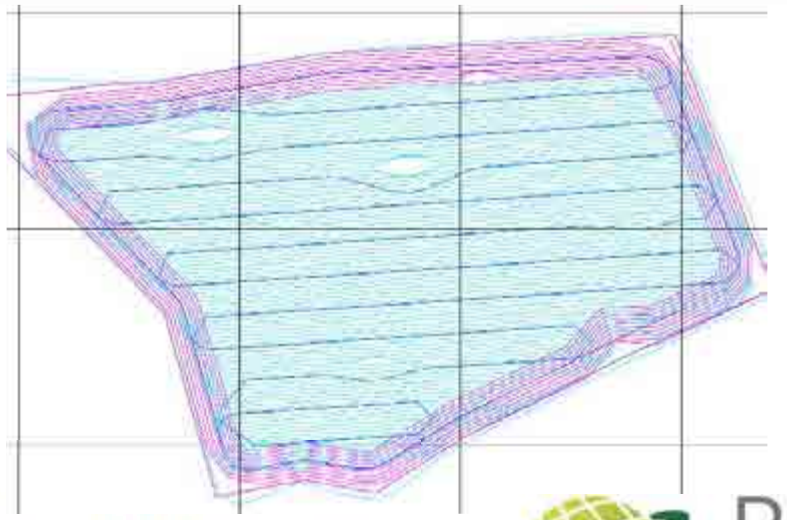
Hands Free Farm – Route planning



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Hands Free Farm – winter crop establishment

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Hands Free Farm – follow me

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Hands Free Farm – “swarm” establishment

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Hands Free Farm – Wheat Harvest

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Hands Free Farm – Yield Results 2022

Harvesting 4ha (c10 acre) per day at peak

Winter wheat:
Blue Pit 14.98T/1.6ha = **9.19t/ha**
Top Adney 32.86T/3.4ha = **9.67t/ha**
A = 9.56t/ha

Spring barley:
Middle Moor 41.44T/9.92ha = **4.18t/ha**
Near Moor 49.36T/12.61ha = **3.91t/ha**
A = 4.03t/ha

Winter beans:
Poors Land 22T/5ha = **4.4t/ha**

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Output – HFH Linear Programming Farm Model

Economics of autonomous equipment for arable farms

James Lowenberg-DeBoer, Kit Franklin, Karl Behrendt & Richard Godwin

- **HFH autonomous equipment (28kW tractor), 10% supervisor intervention**
- **HFH sized conventional equipment (28kW tractor)**
- **Medium conventional equipment (112kW tractor)**
- **Large conventional equipment (221kW tractor)**

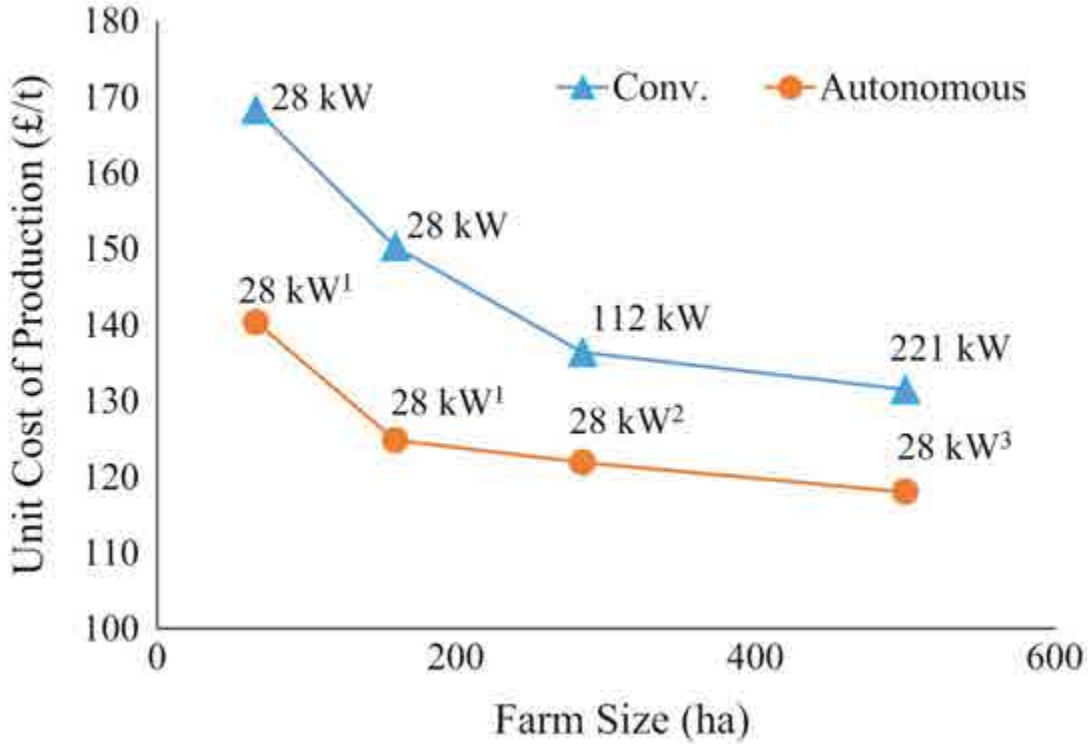


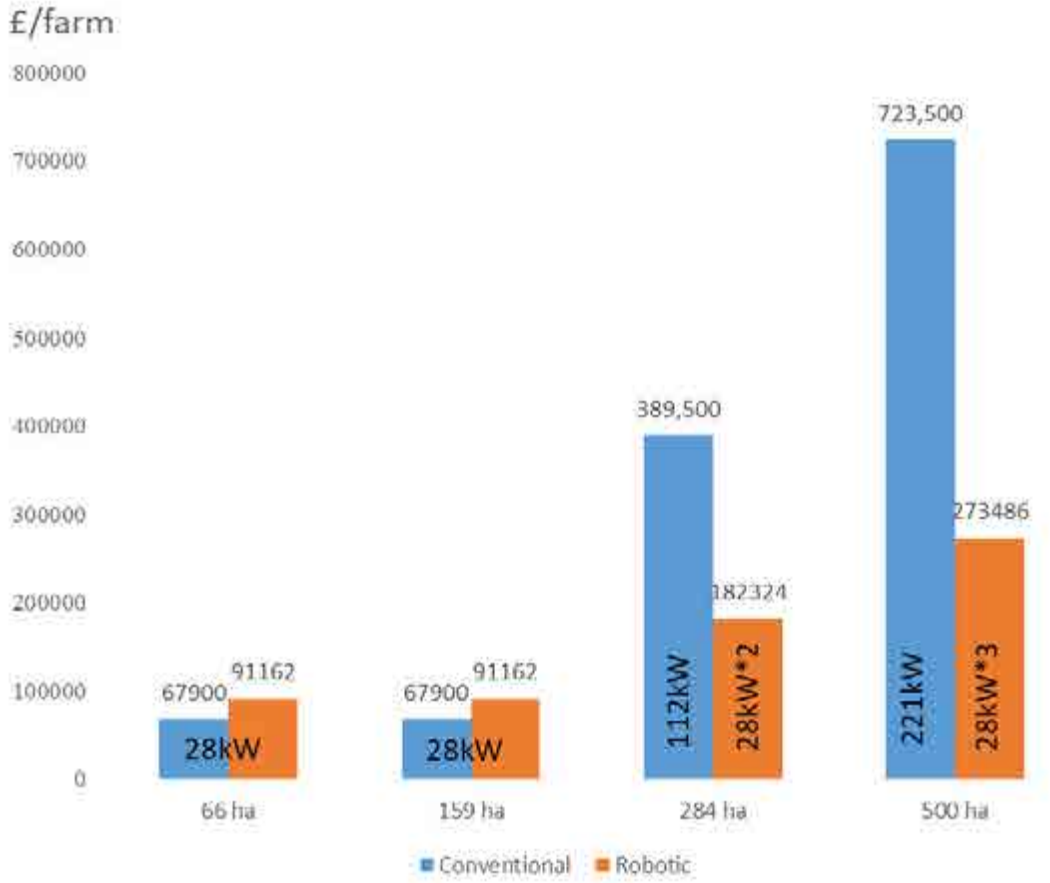
Figure 1. Wheat Unit Production Cost (£/ton) for Farms Equipped with Conventional or Autonomous Machines across a Range of Farm Sizes and with Operator Labour Cost Allocated

Harper Adams University

Output – HFH Linear Programming Farm Model

With crop robotics equipment investment could be reduced by greater than 50%

- The HFH economic analysis was based on cost of retrofitting conventional small scale farm equipment
- In the HFH example, equipment investment reduced because small equipment used more intensively
- With crop robotics, expansion occurs with multiple small units, instead of larger machines



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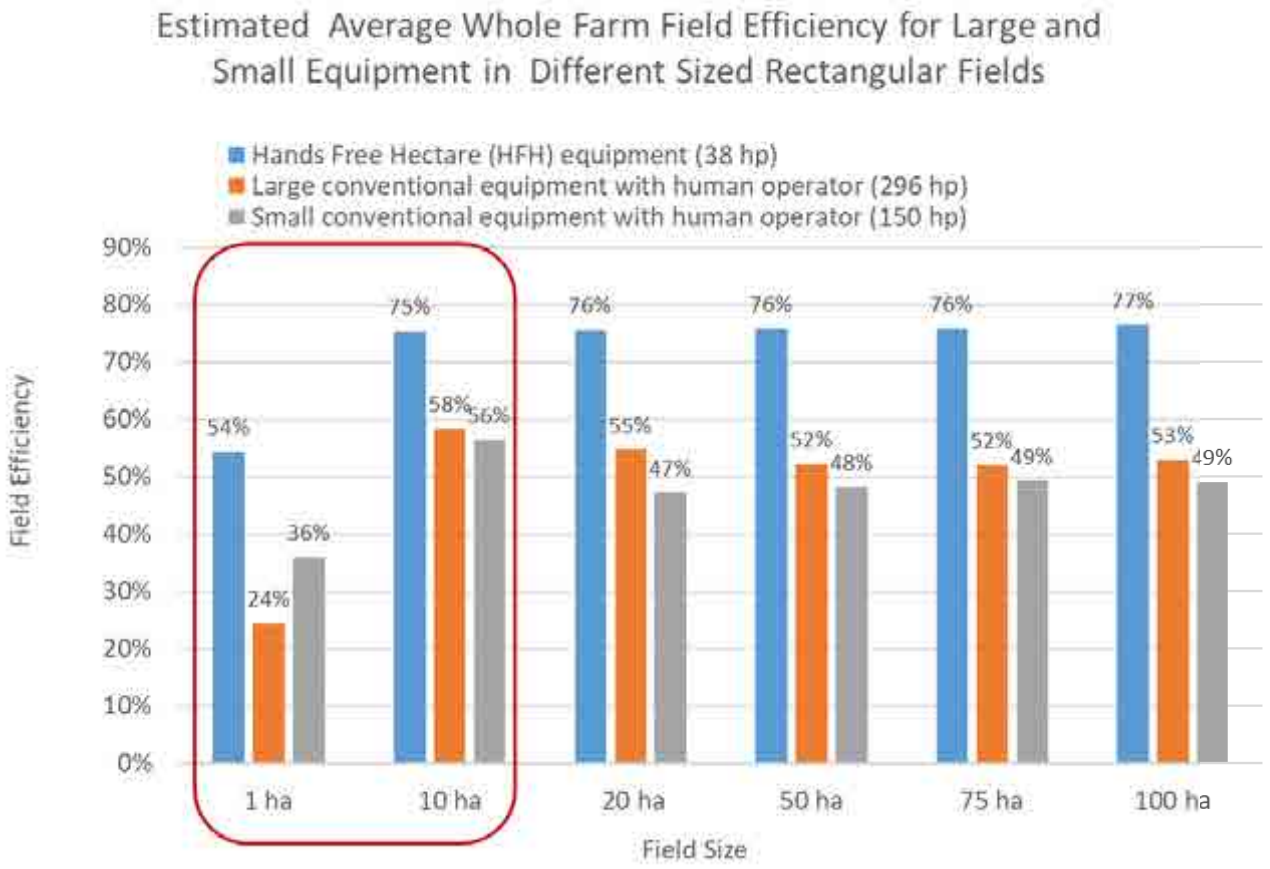
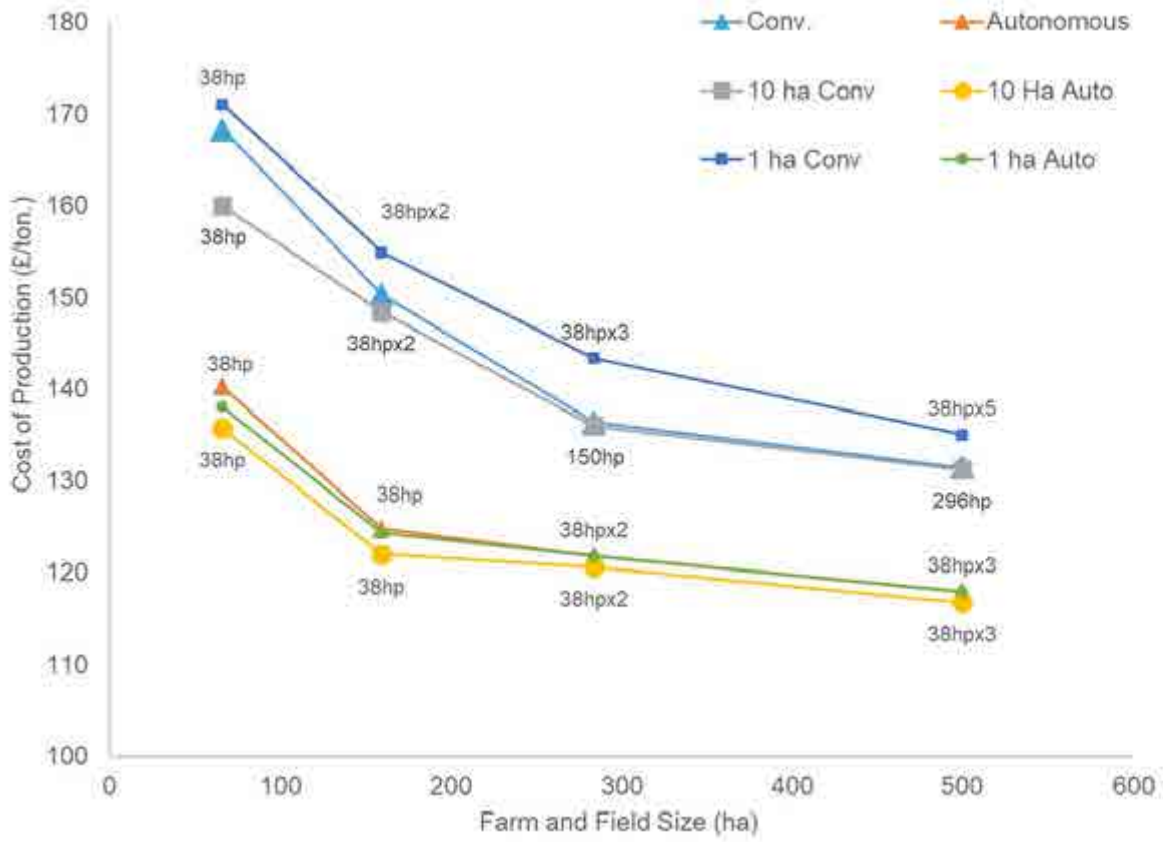
Output – HFH Linear Programming Farm Model

Field Efficiency: Subject to Field Sizes





Al-Amin et al. (2021).
Economic Implications of Field Size for Autonomous Crop Robotics

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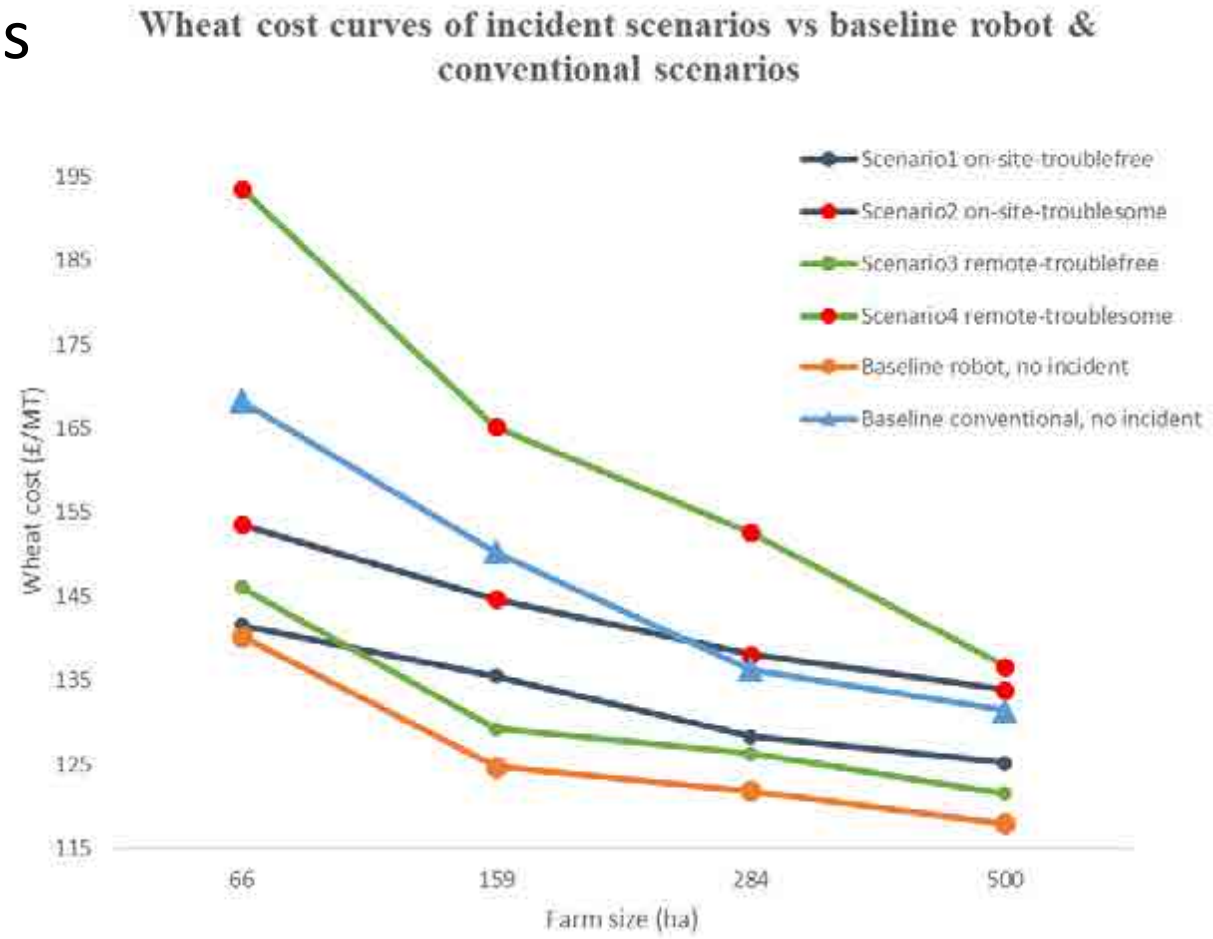
Output – HFH Linear Programming Farm Model

Economically optimal supervision of robots depends on human involvement needed

- Some countries require on-site human supervision of crop robots.
- If economics were allowed to determine robot supervision it would depend several factors, including:
  - Frequency of incidents requiring human intervention.
  - Human reaction time
  - Travel time from the remote supervision site to the field.
- Preliminary estimates indicate that farmers would choose remote supervision if the robot is relatively trouble free and on-site supervision if intervention was required frequently.



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Hands Free Farm – Time

TG405: 851hr

TLE 3400: 360hr

TG6507: 224hr

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Precision Decisions

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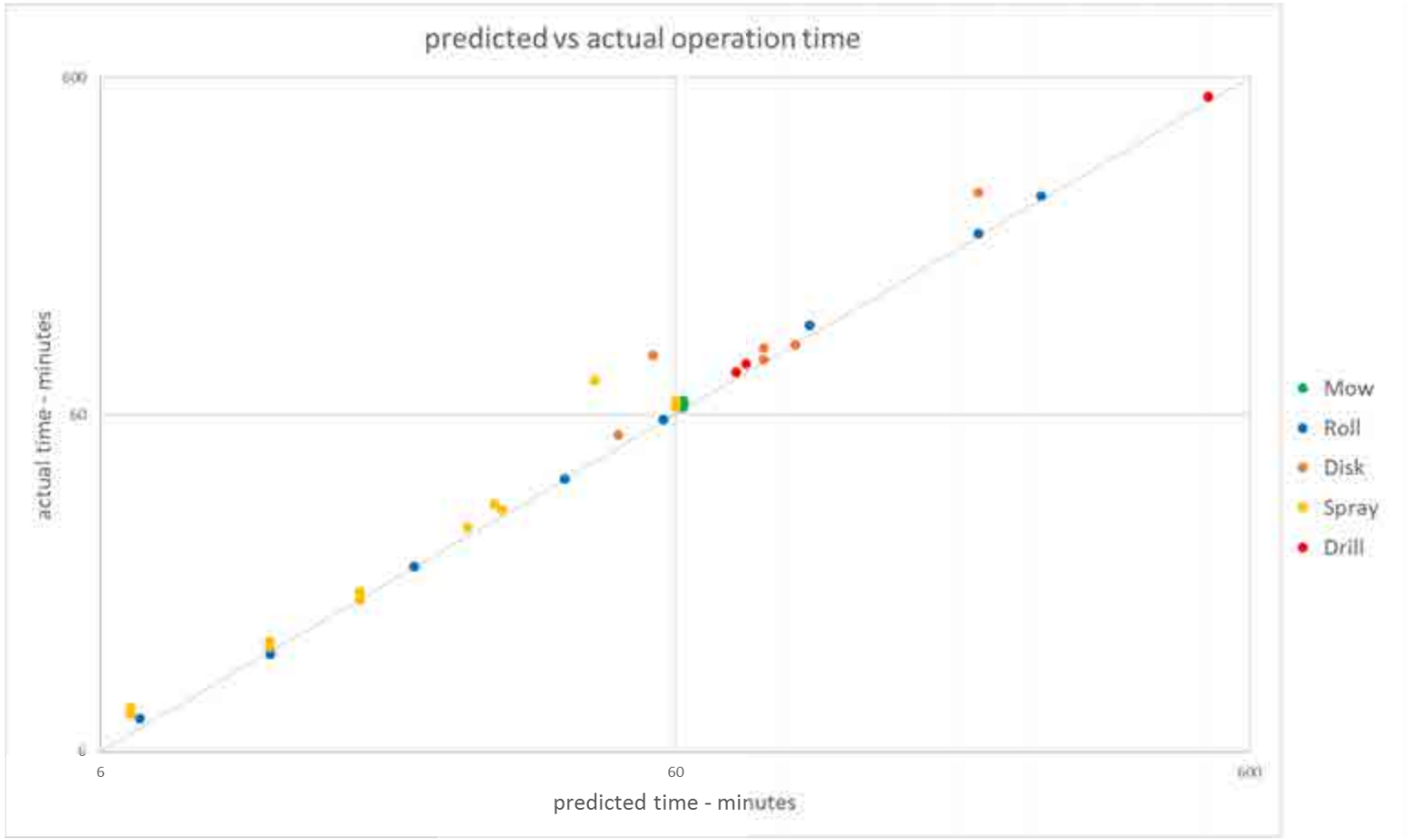
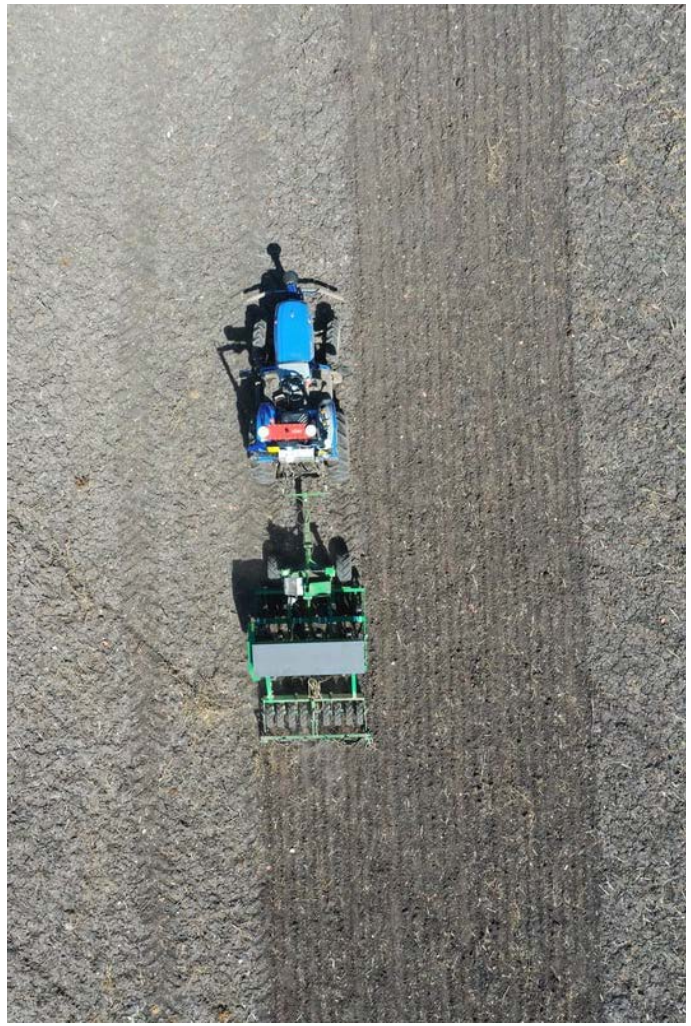
Data analysis opportunities





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Precision Decisions

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Output – Safe/Certified operation collaborations

UK Gov Code of Practice:
Automated vehicle trialling

bsi.

BS 8646:
Use of crop robots in agriculture and horticulture – Code of practice

NFU Mutual
INSURANCE | PENSIONS | INVESTMENTS

Ofcom
making communications work for everyone

TRL THE FUTURE OF TRANSPORT

Off-Highway Automated Vehicles Code of Practice

HSE

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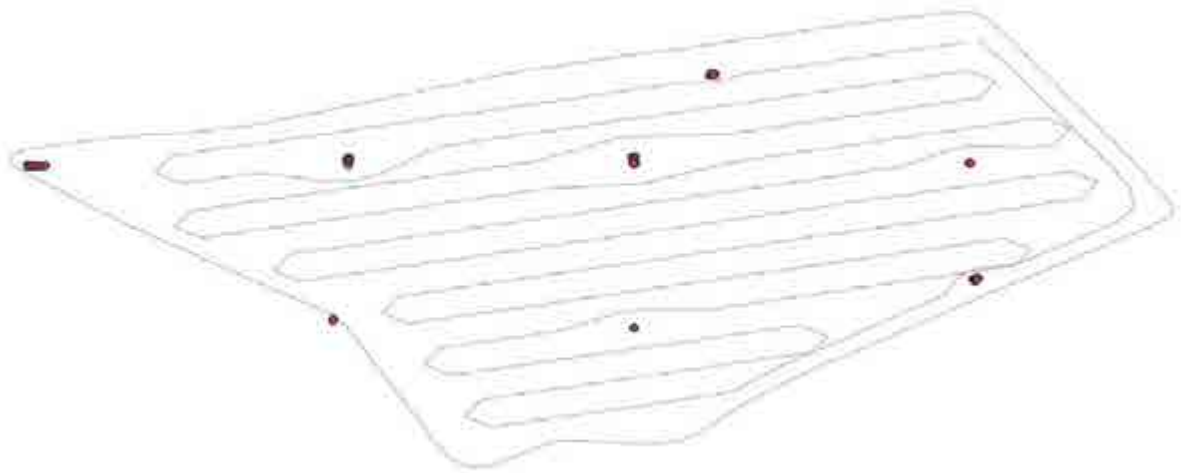
Hands Free Farm – Route planning/accuracy



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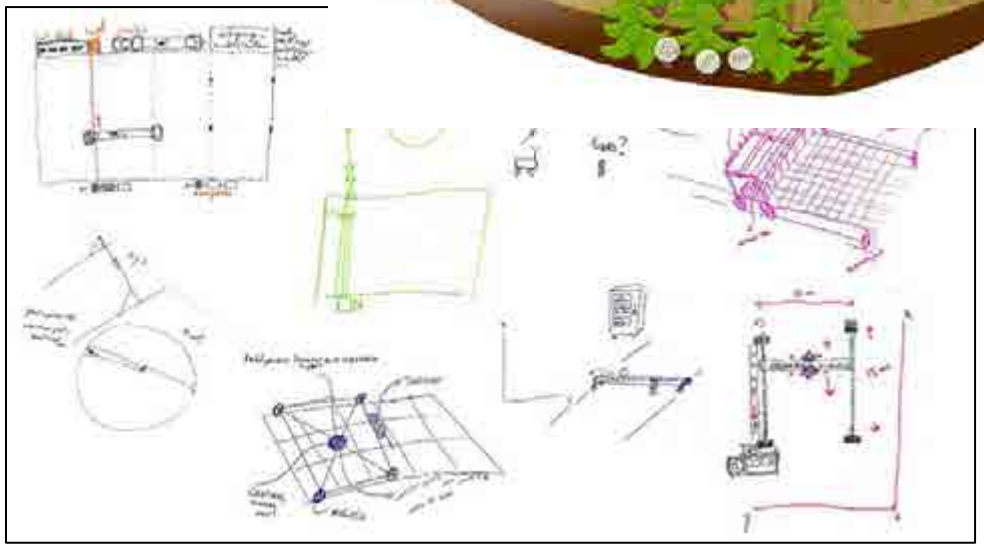
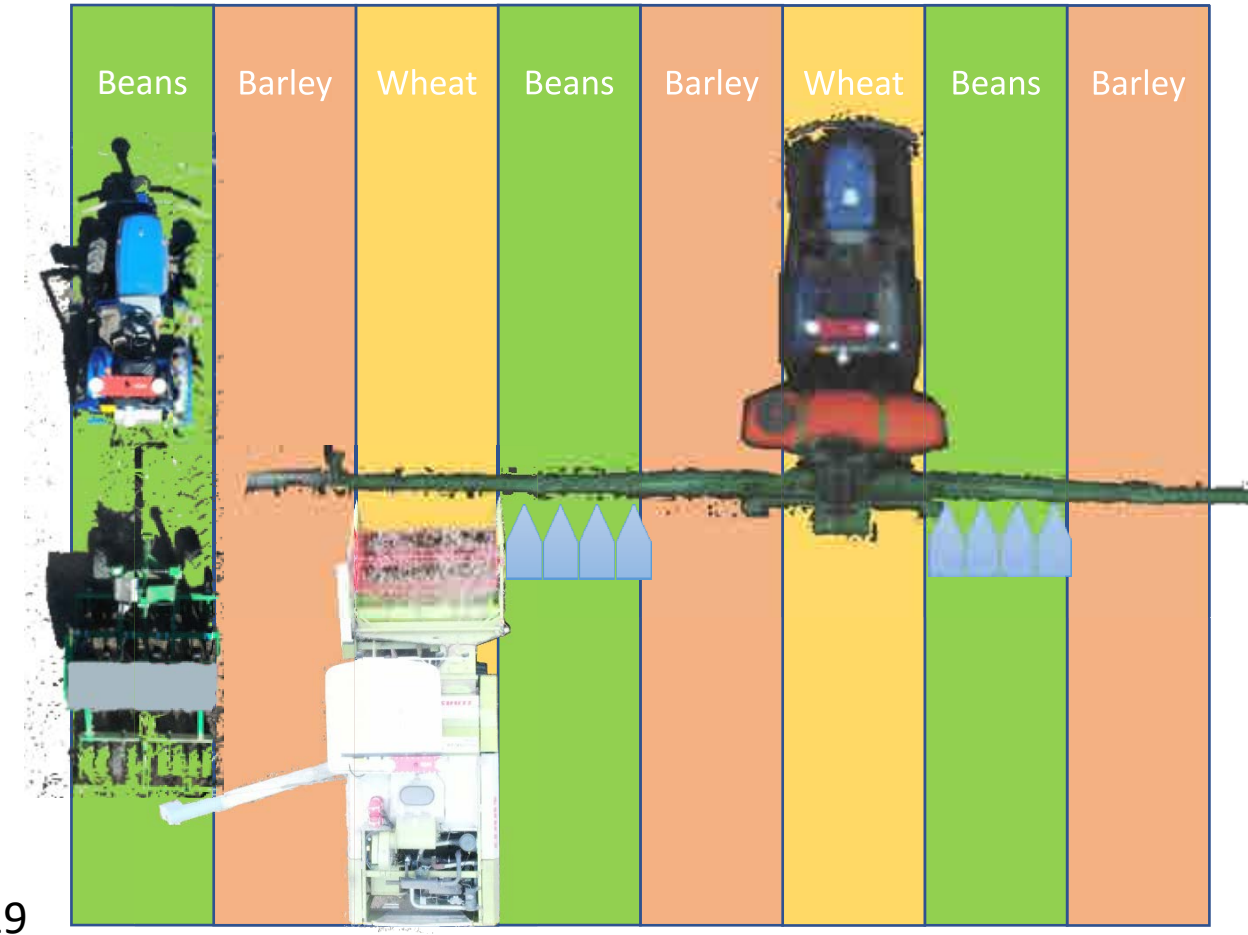
Autonomous enabled agroecology





Source: Ditzler and Driessen, 2022 – Wageningen workshop 2019

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Hands Free Strip Cropping

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Hands Free Strip Cropping

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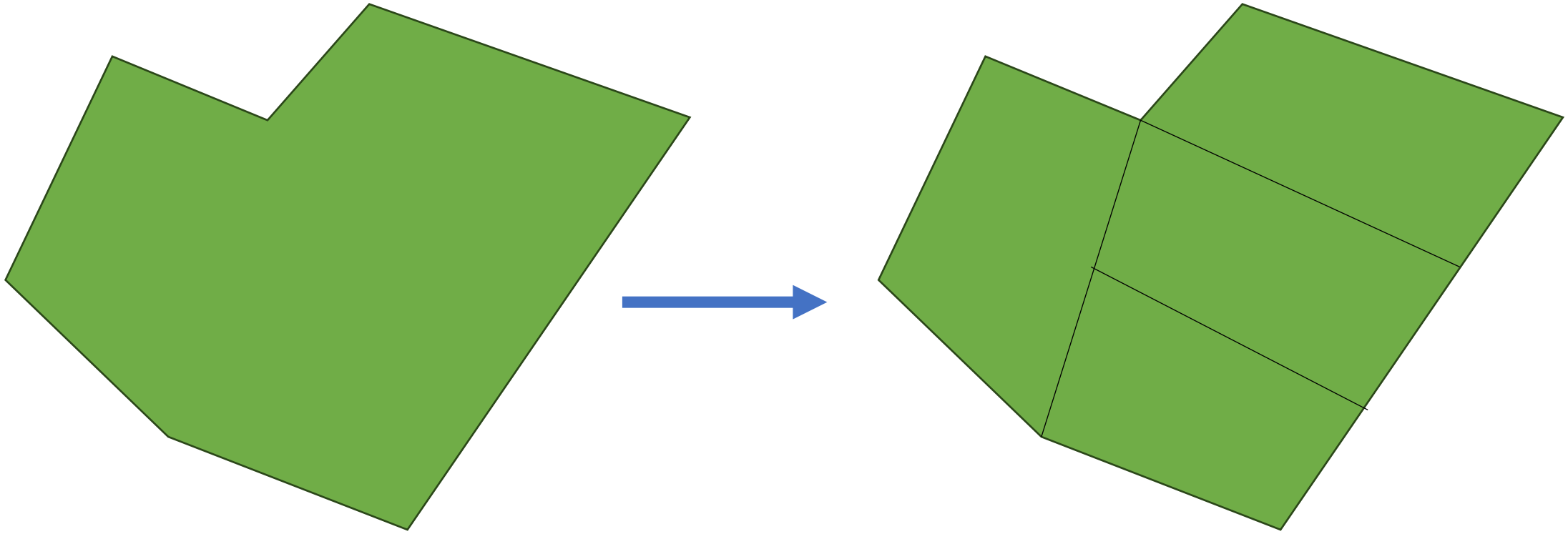
Hands Free Regenerative paddock fencing “RotoFence”



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A vision of the Agricultural future: Thank you

Brash Ag podcast

Constable’s “Wheat Field” reimagined for 2050

Royal Academy of Engineering

ENHANCING PRECISION WEEDING WITH YOLOV11 OBJECT TRACKING FOR ROBUST EARLY CROP DETECTION AS A FOUNDATION FOR FUTURE ORGANIC PRECISION SPRAYING TRIALS

Michael Søndergaard Nørbo MADSEN*, Søren Kelstrup SKOVSEN, Bo MELANDER, Rasmus Nyholm JØRGENSEN

PRECISION WEEDING ENHANCED WITH YOLOV11: A GAME-CHANGER FOR CONVENTIONAL & ORGANIC FARMING ?

Core Results:

- YOLOv11 tracking improved early sugar beet detections in 8.75% of detected cases in challenging conditions
- Tracking reduced weed misclassification rates and improved temporal consistency, critical for effective weeding.

Practical Impact:

- Enables targeted weed management, reducing chemical use and promoting sustainability.
- Lays the foundation for organic precision spraying trials in 2025.

Source: https://farmdroid.com/products/mikrospray-system

MICHAEL SØNDERGAARD NØRBO MADSEN*, SØREN KELSTRUP SKOVSEN, BO MELANDER, RASMUS NYHOLM JØRGENSEN

COMPUTER VISION CONCEPTS

Object Detection

- Finding and classifying plants in images
- Examples: YOLOv5, YOLOv8, YOLOv11

Instance Segmentation

- Precisely outlining each individual plant (masking)
- Examples: YOLOv8-seg, YOLOv11-seg, Mask R-CNN

Object Tracking

- Following the same object across multiple images
- Examples: ByteTrack, DeepSORT

MICHAEL SØNDERGAARD NØRBO MADSEN*, SØREN KELSTRUP SKOVSEN, BO MELANDER, RASMUS NYHOLM JØRGENSEN

COMPUTER VISION TERMINOLOGY

Object Detection

- Just boxes

Instance Segmentation

- Boxes + masks

Object Tracking

- Boxes + masks + ID numbers that persist across frames

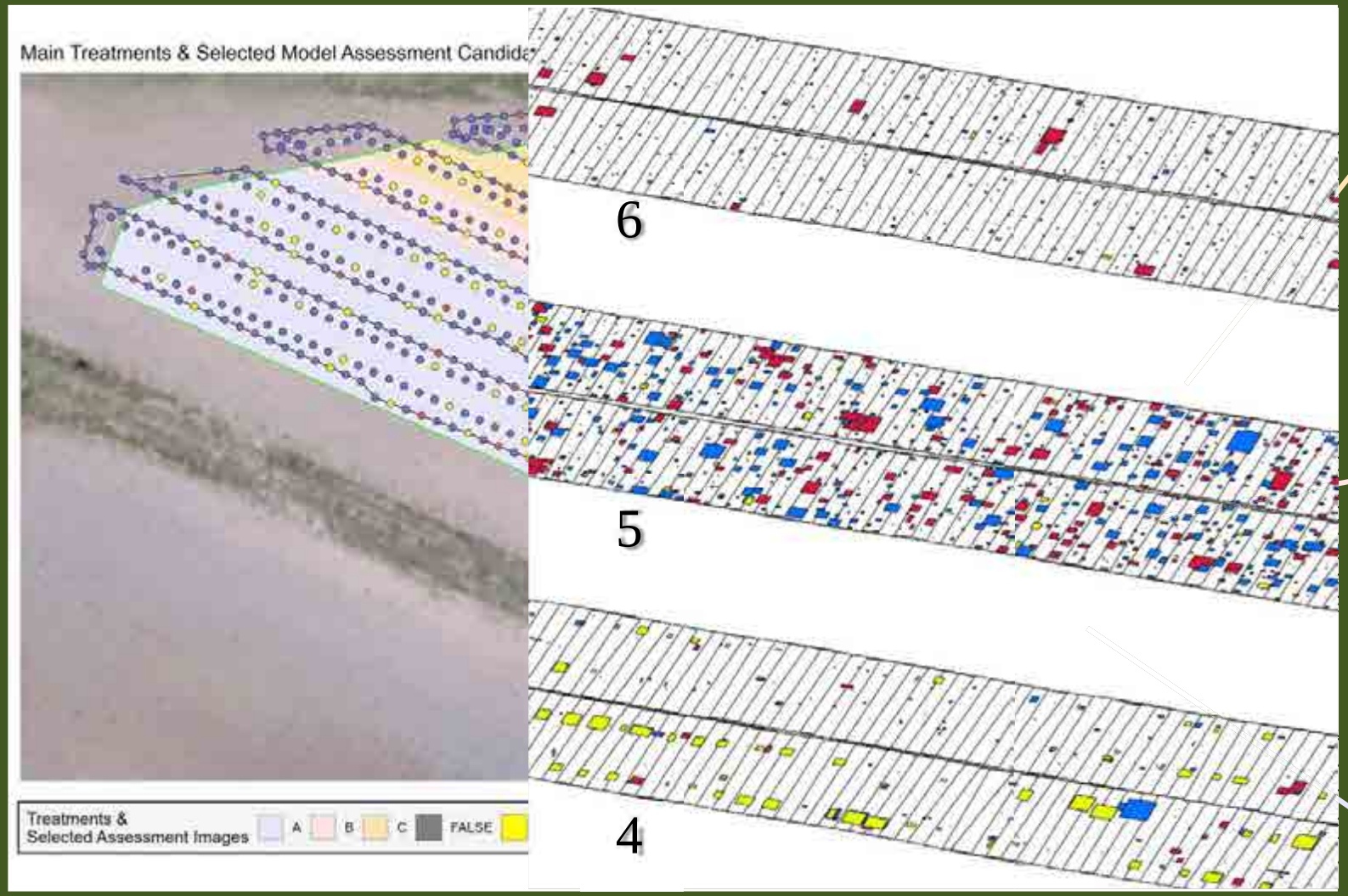
MICHAEL SØNDERGAARD NØRBO MADSEN*, SØREN KELSTRUP SKOVSEN, BO MELANDER, RASMUS NYHOLM JØRGENSEN

Source: Semi-automated Crop & Weed Annotation Support: https://i-gis.dk/roboweedmaps/

CHALLENGING THE DETECTION MODEL

MICHAEL SØNDERGAARD NØRBO MADSEN*, SØR
RASMUS NYHOLM JØRGENSEN

CHALLENGING THE DETECTION MODEL



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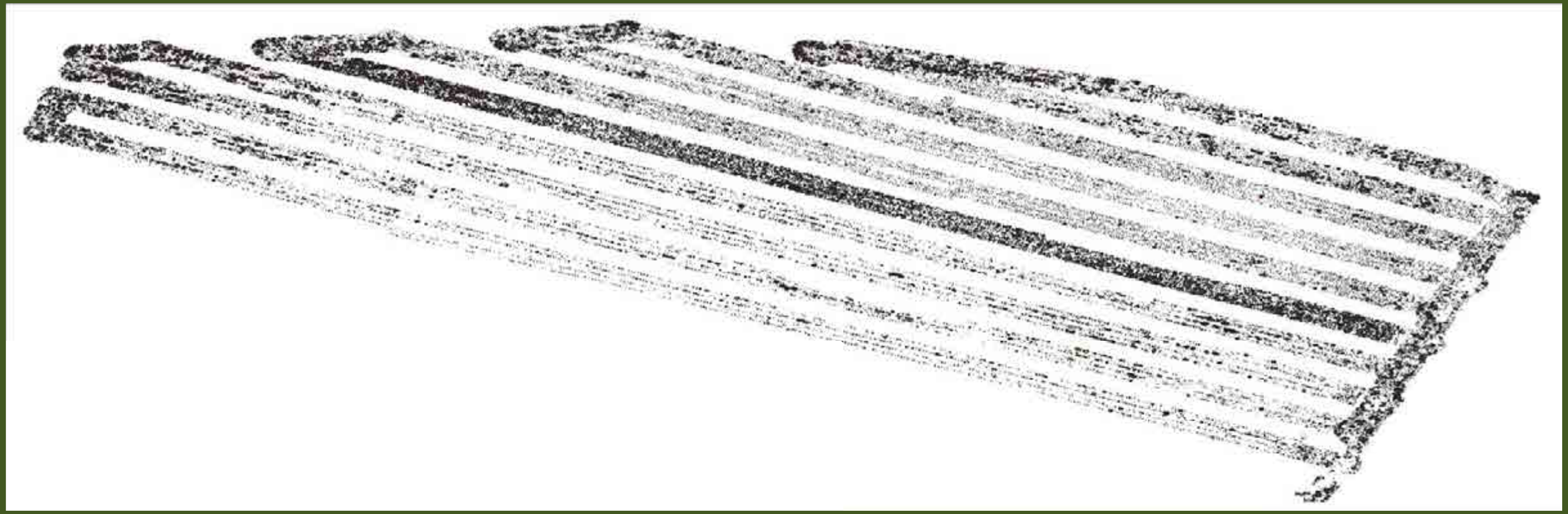
CHALLENGING THE DETECTION MODEL



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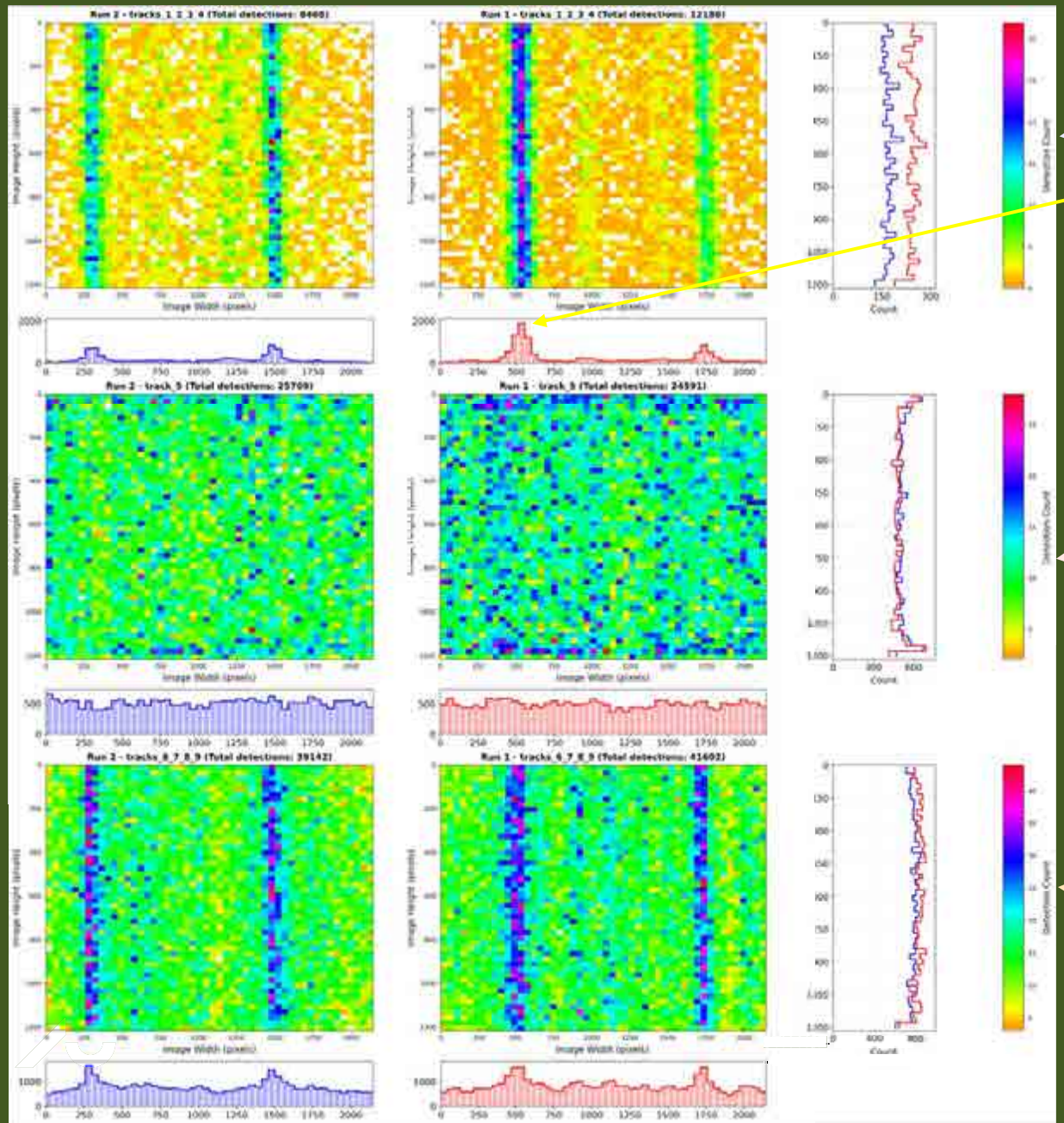
DOES YOLO RAW DETECTION WORK FOR DICOT WEEDS?



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