Challenges and possible solutions for inspection of field spot spraying robots

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Outline

- Overview of technology used in Norway needing adapted inspection
- Kilter spot sprayer robot working system
- Solution for inspection of Kilter robot
- Third party equipment and inspection
- Discussion of solutions
- Briefly orientation about the new web-based inspection protocol system in Norway

Kilter

“We’re here to accelerate the restoration and rebalancing of the food and earth systems“

Kilter AS, Berghagan 3, 1405 Langhus

Our global food system is under threat

We are facing a global food gap

10bn | Expected global population by 2050

7.4Ktn | Global calorie gap faced by 2050[1]

56% | Increase in food production needed to feed our growing population[1]

Agricultural resources are running low

-61% | Decrease in global employment in agriculture between 1991 & 2019[3]

-33% | Loss in arable land in the last 40 years[4]

593m | Gap in required hectares of agricultural land needed by 2050[1]

Farmers globally are challenged to produce considerably **more and better food, with significantly less resources**

Sources: (1) World Resources Institute & FAO 2019, (2) WHO 2016 Estimates, (3) ILOSTAT 2021, (4) The University of Sheffield's Grantham Centre for Sustainable Futures

Problem

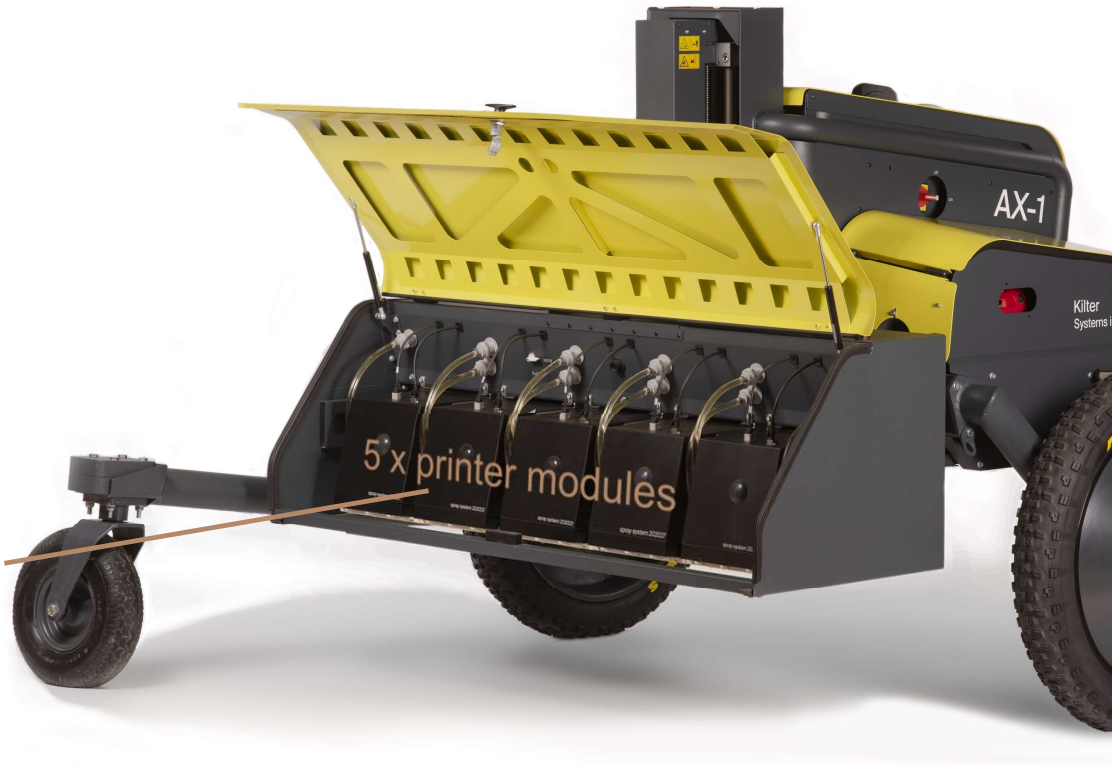
The vegetable fields of Europe are blanket sprayed with herbicides appx. four times pr season

Underlying magic

Artificial Intelligence

Patented droplet generator

Self-driving platform

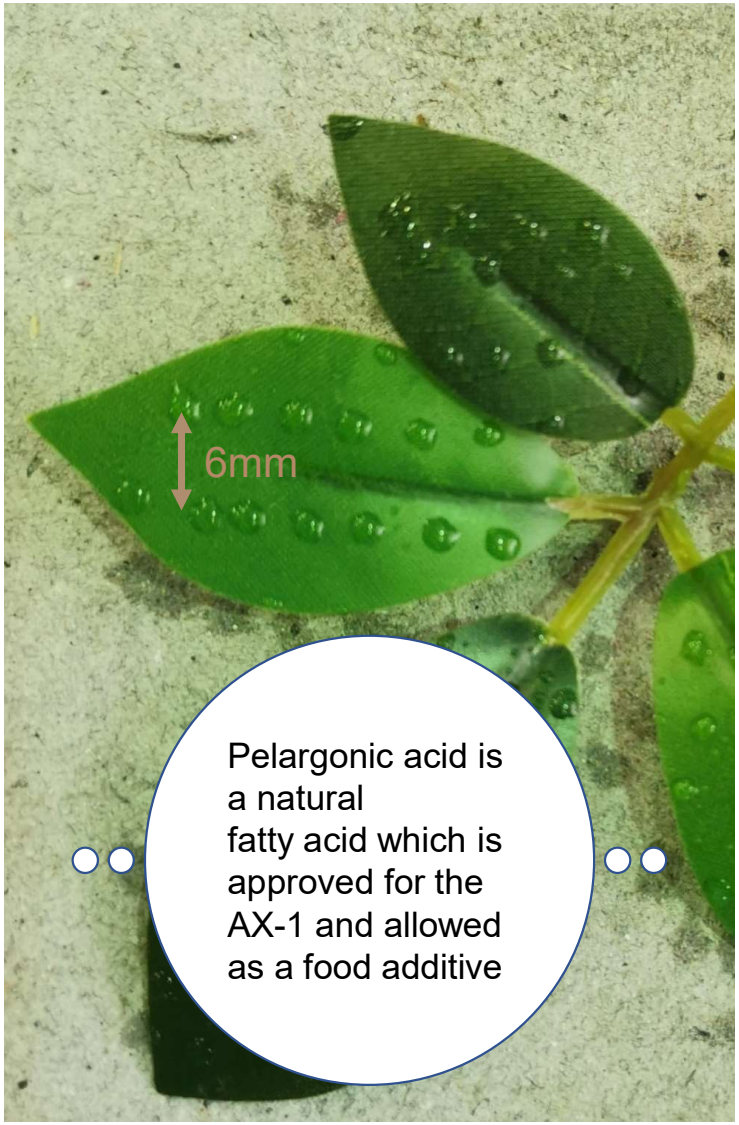


Kilter
Systems in balance

AX-1 marks a paradigm shift

- Selectivity moved from chemistry to software (AI)
- Precision allows early treatment
- Patented droplet generator with revolutionizing spraying precision

Kilter's **tested, proven and patented** droplet technology drops a precise amount of herbicide onto weeds, **which allows for the use of bioherbicides** such as pelargonic acid without touching and killing the crop.



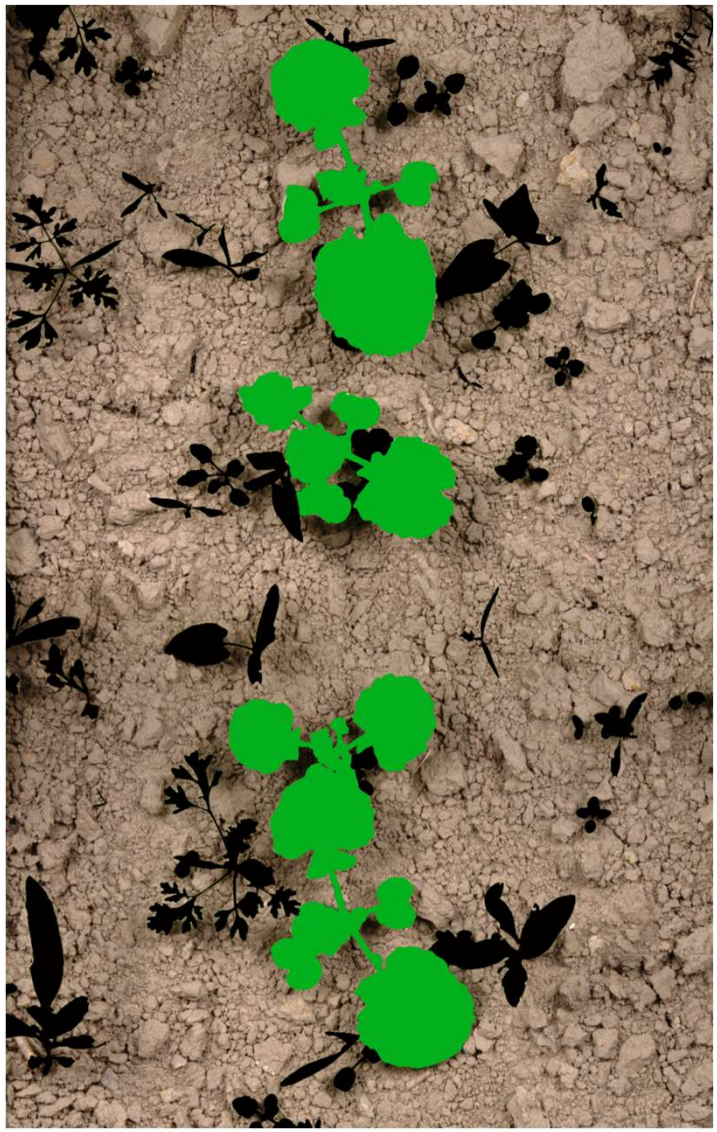
Emerging vegetable
Nice timing for weed handling

Emerging vegetable

Nice timing for weed handling

Conventional spraying

Kilter
Systems in balance



Emerging vegetable

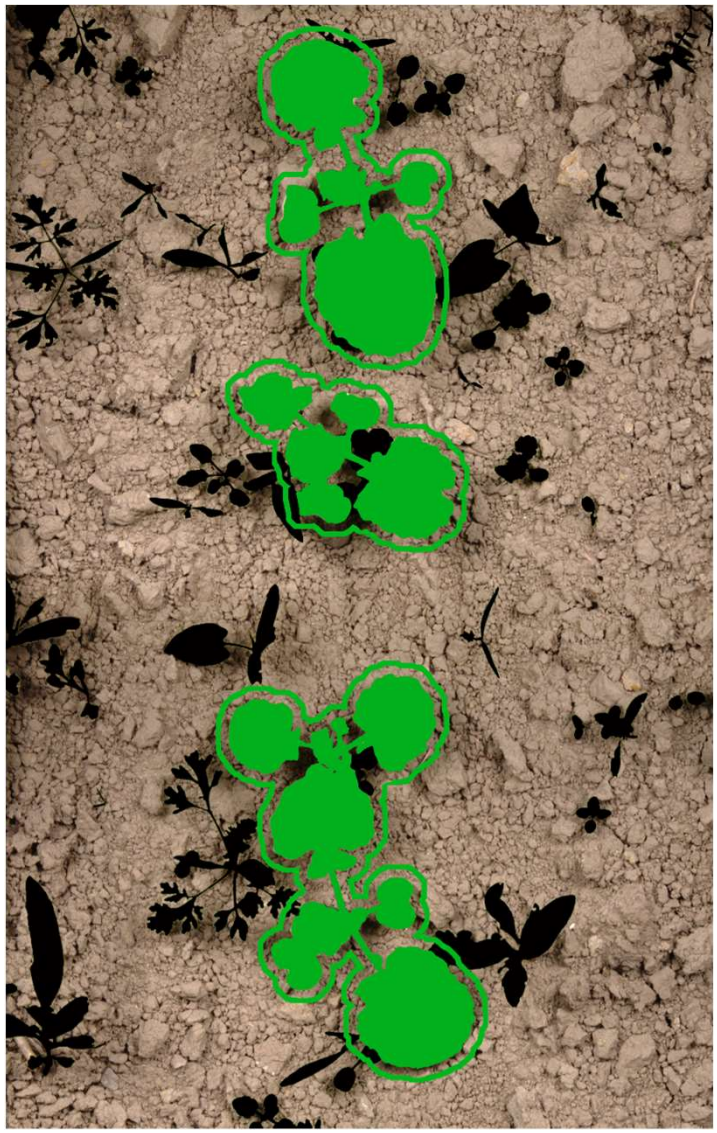
Nice timing for weed handling

Conventional spraying

With Kilter technology

Kilter

Systems in balance



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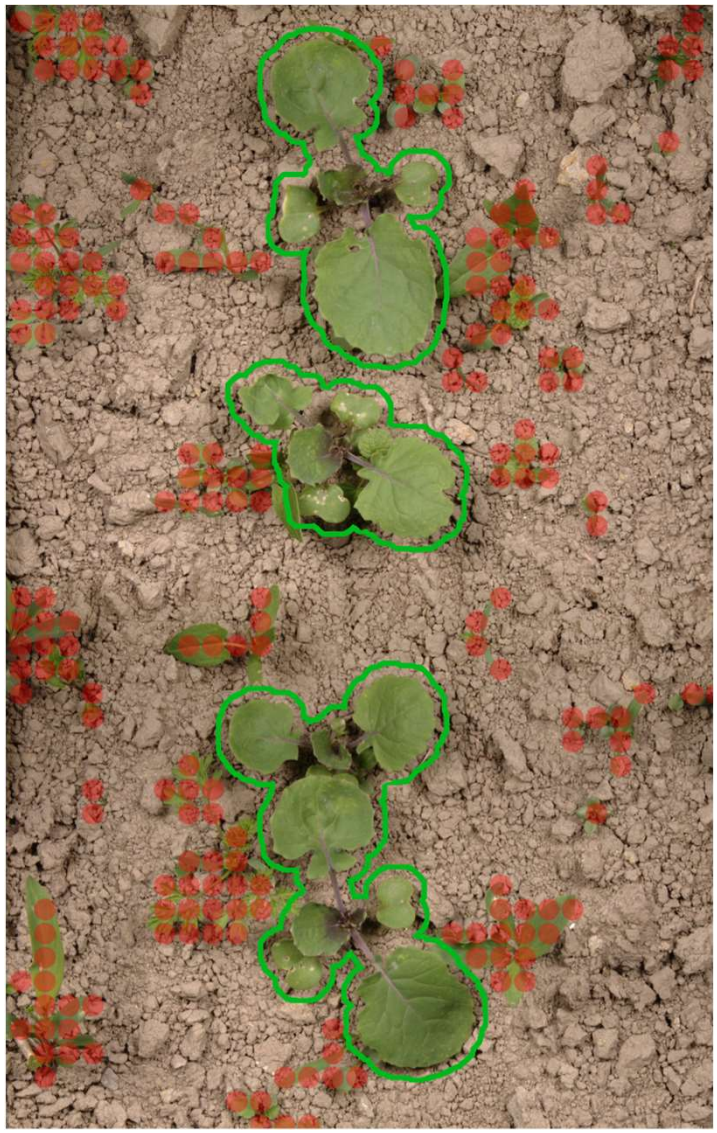

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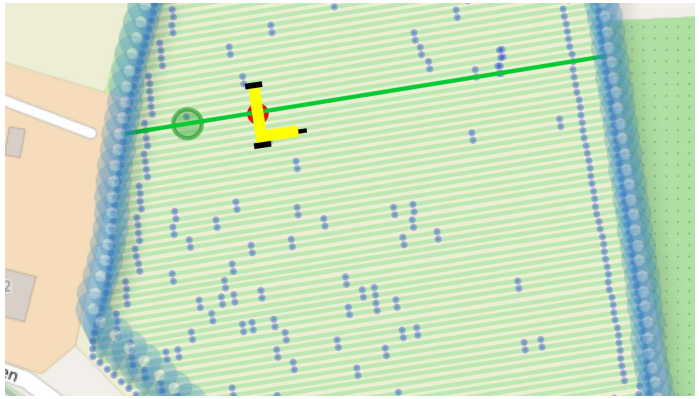


Self-driving

Autonomous operation

- RTK GNSS
  - IMU
  - Wheel sensors
- Predefined GNSS points
- Fault detection
  - Low on gas or herbicide
  - Geofencing (RTK GNSS)
  - Forward looking camera
  - Bumper sensor

Development and Production

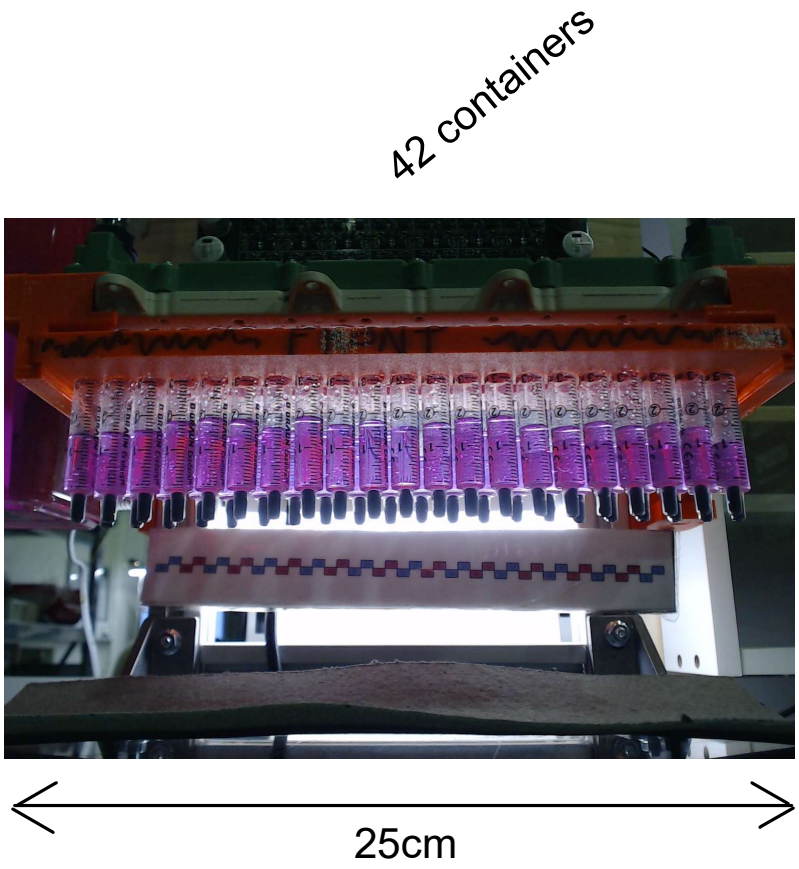
Machinery directive
2006/42/EC
EMC, 2014/30/E
EN ISO 12100:2010
Agricultural machinery
ISO 4254-1:2013
ISO 4254-6:2020
ISO 16119-1:2013
ISO 16119-2:2013
ISO 16122-2: 2015
ISO 3600:2015
Robots and robotic devices
ISO 10218−1:2011
Nozzle design
ISO 5682-1:2017
ISO 25358:2018

And some more
ISO 14982:1998
ISO 25119:2010
ISO 10625:2018
ISO 16236:2013
ISO 18497:2018
ISO 19732:2007
ISO 22368-3:2004
ISO 13850:2015
ISO 12100:2010
ISO 11684:1995
ISO 3767:2016
ISO 9357:1990

SIS/TK 224 - Lantbrukssprutor
SIS/TK 228 - Lantbruksmaskiner

Regulations and conformity

- Engaged RISE SMP in 2019 to assist with the process of complying with EU regulations and directives.
  - Screening
  - Inspection report
  - Risk assessment
  - Implement means
  - **Certification Report**
  - CE marking



Function test

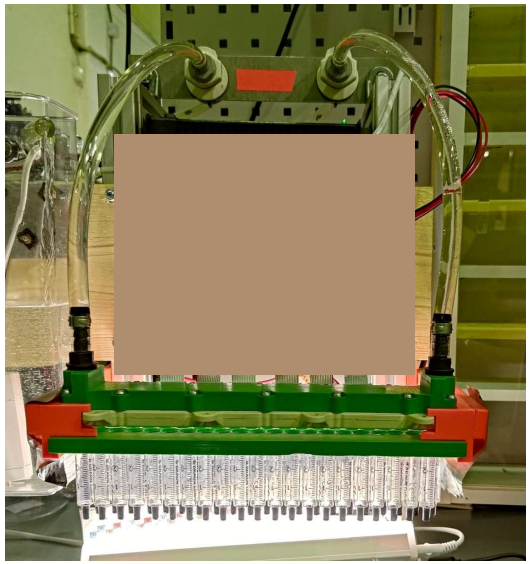
Volume distribution and droplet size

- Each nozzle shoots a known number (1000) of droplets to a container
- Randomly nozzle-shooting pattern
- Average droplet size per nozzle
- Distribution
- Automatic volume measurement through computer vision

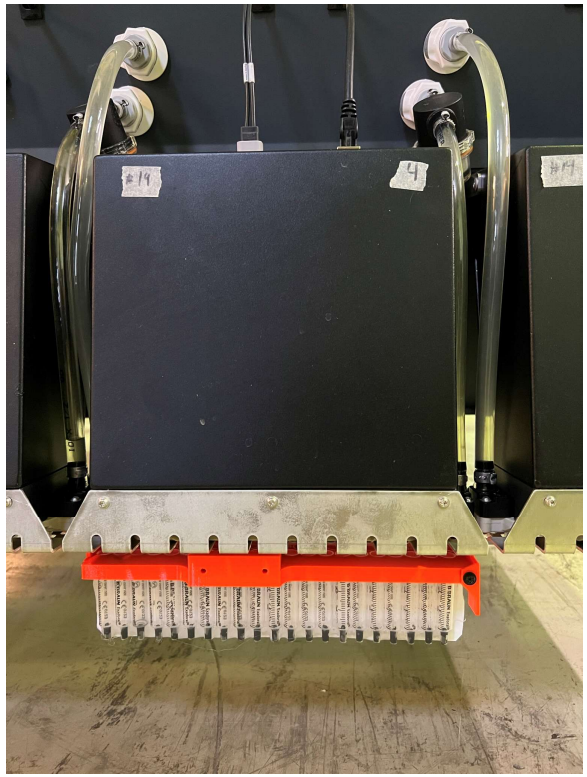
Function test

Volume distribution

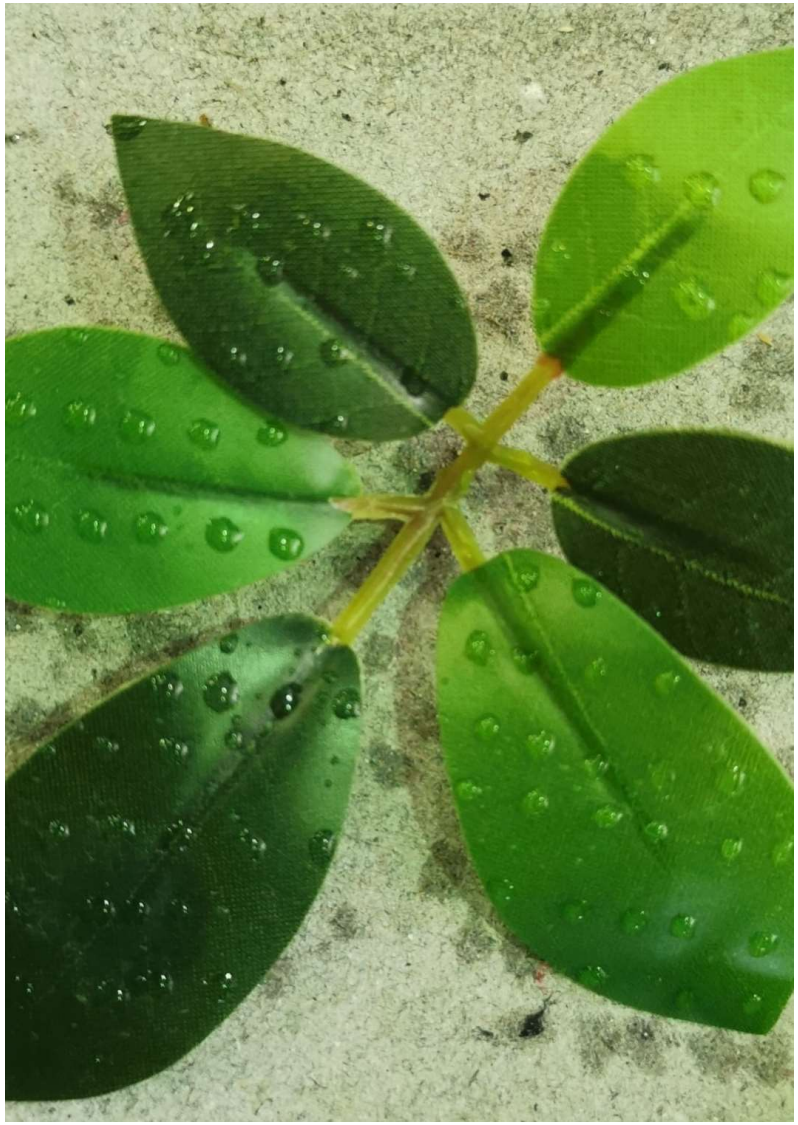
Conventional testing at JKI



High precision nozzles tested during production



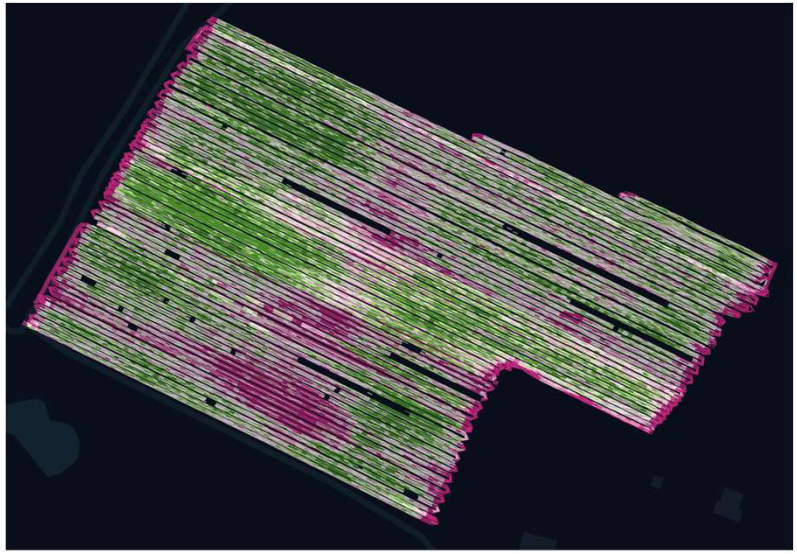
On-site function test



Function test

Self testing

- On robot
  - AX-1 detects and spray plastic plants or water sensitive paper
  - AX-1 takes pictures of the plastic plant or water sensitive paper and evaluates the results
  - AX-1 generates reports
- Tests Camera, mechanics and nozzles.



Reporting

cm level reporting

- Droplet distribution
- Crop distribution
  - And stages
- Weed distribution
  - And types of weed
- High detailed Images

To be discussed

- How to inspect spot sprayer robots;
  - Important to control the working system
  - Dependent of the equipment & robot
  - Should be possible also for the farmer to execute calibration and control
- Solution
  - Involve the manufacturer to implement a tool or solution for inspection
  - Autonomous and documented control if possible
- Start the work now in order to ensure adapted and proper solutions

Third-party solutions and inspection

DAT

Dimensions Agri Technologies

INTRO TO DAT

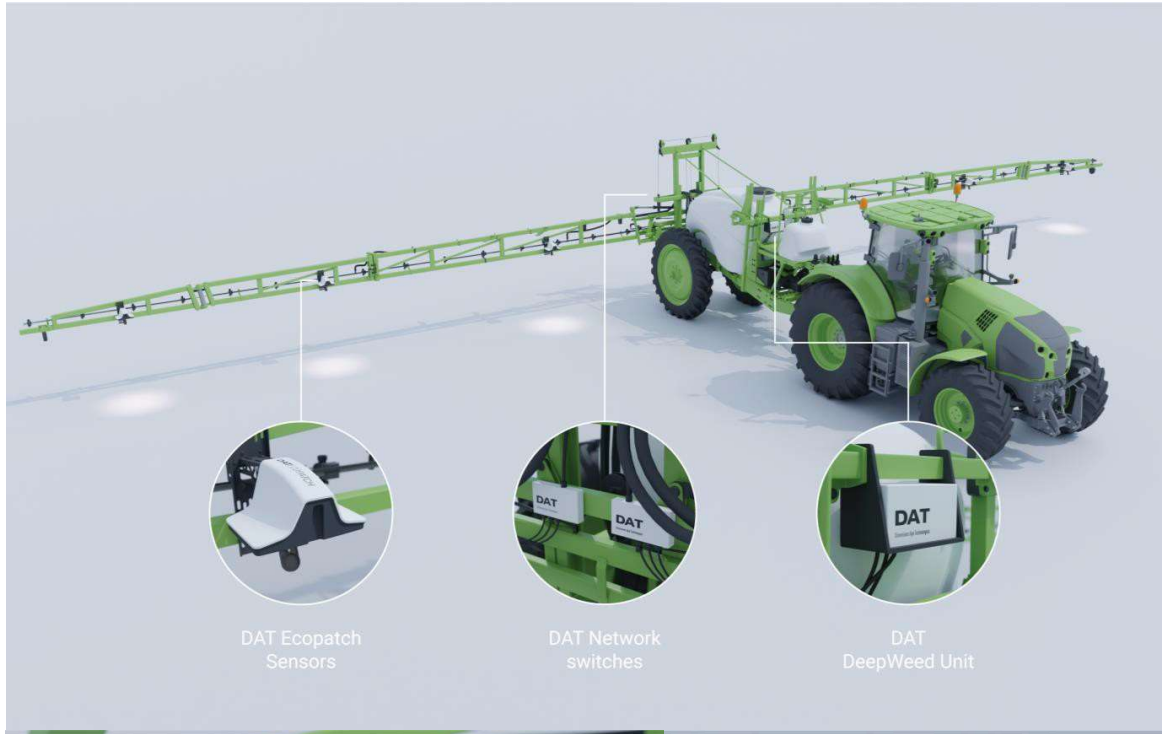
APRIL 2023

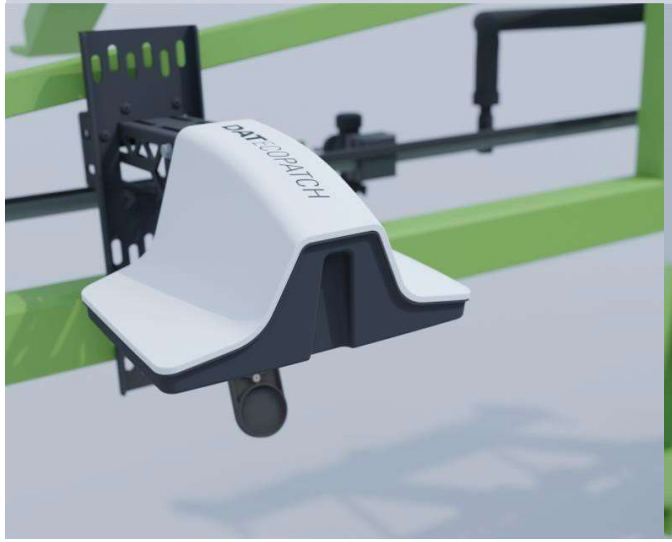
DAT ECOPATCH

One Page Summary

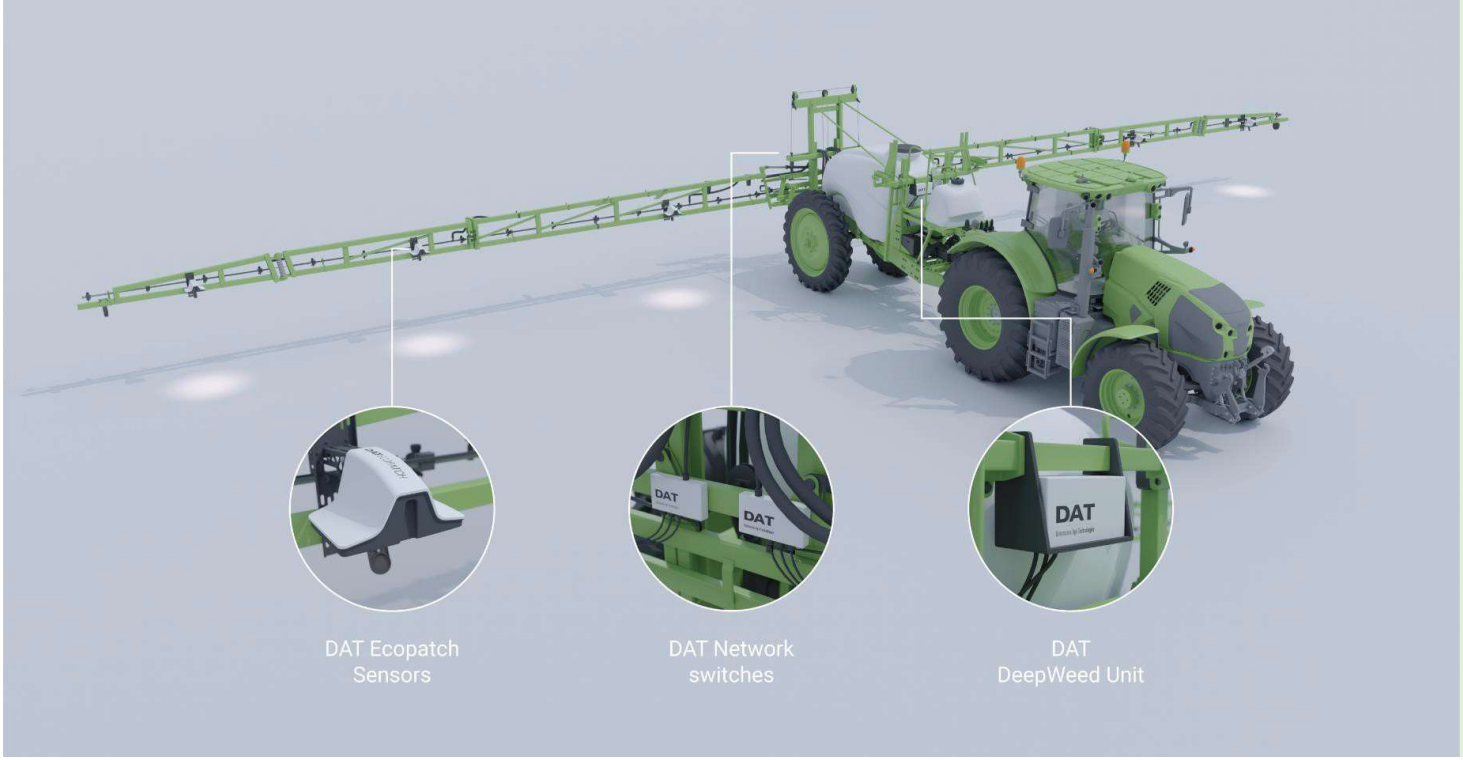
- AI technology for patch spraying during growth season (green-on-green) in small cereal: Wheat, Barley, Oats, Rye
- Camera technology separates weeds from crop in real time and shut off sections where spraying is redundant
- Retrofit to all trailed and self-propelled sprayers (ISOBUS)
- Online to support OTA updates
- 2022-season: 40% herbicide reduction with DAT active
- Unsprayed areas experience increased yields (2-10%)
- Cover larger area before refill and hinders development of resistant weeds
- Weed heat map integrated to existing farm management platforms
- Developed and produced in Norway
- 2022: Commercial launch, 10 contracts (Norway + Germany)
- 2023: Actively approaching partners for commercialization and scaling
- Active systems in: Norway, Germany, Czech Republic, Lithuania and Spain

DAT
Dimensions Agri Technologies





System overview – DAT EcoPatch



- 6-8 sensors mounted on exisiting spray boom taking high resultion images in real time
- Images are sent via switch boxes to processing in DAT DeepWeed Unit (ECU) which is connected via ISOBUS
- Sections are activated/deactivated based on signals sent from DAT DeepWeed Unit

DAT
Dimensions Agri Technologies


Patch spraying
A pragmatic and agronomic approach to precision spraying

Weed Patches

- Research shows the spatial distribution of weed populations aggregates in patches.
- Result of the combination of the biological traits of the weed species and the inherent characteristics of the field like topography.
- In cereal fields patchy distribution has been shown for both monocots and dicots (grass and broadleaves)

DAT
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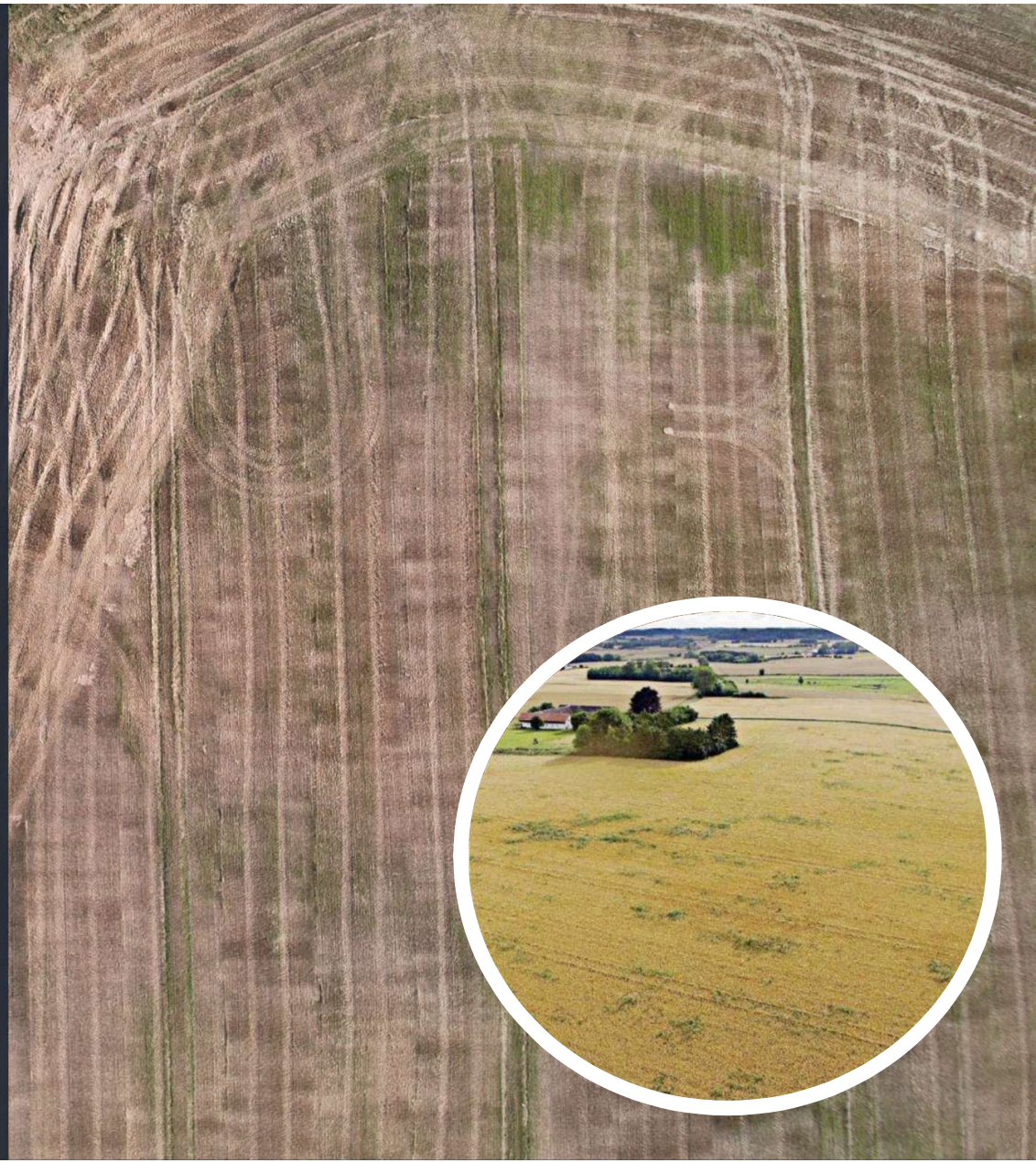

Sampling

Why Sampling

- Optimization between image resolution, field coverage and system cost
- Enables the use of high resolution images to pick up small weed details
- Allows real-time spraying (i.e no extra work or drone piloting required)

DAT
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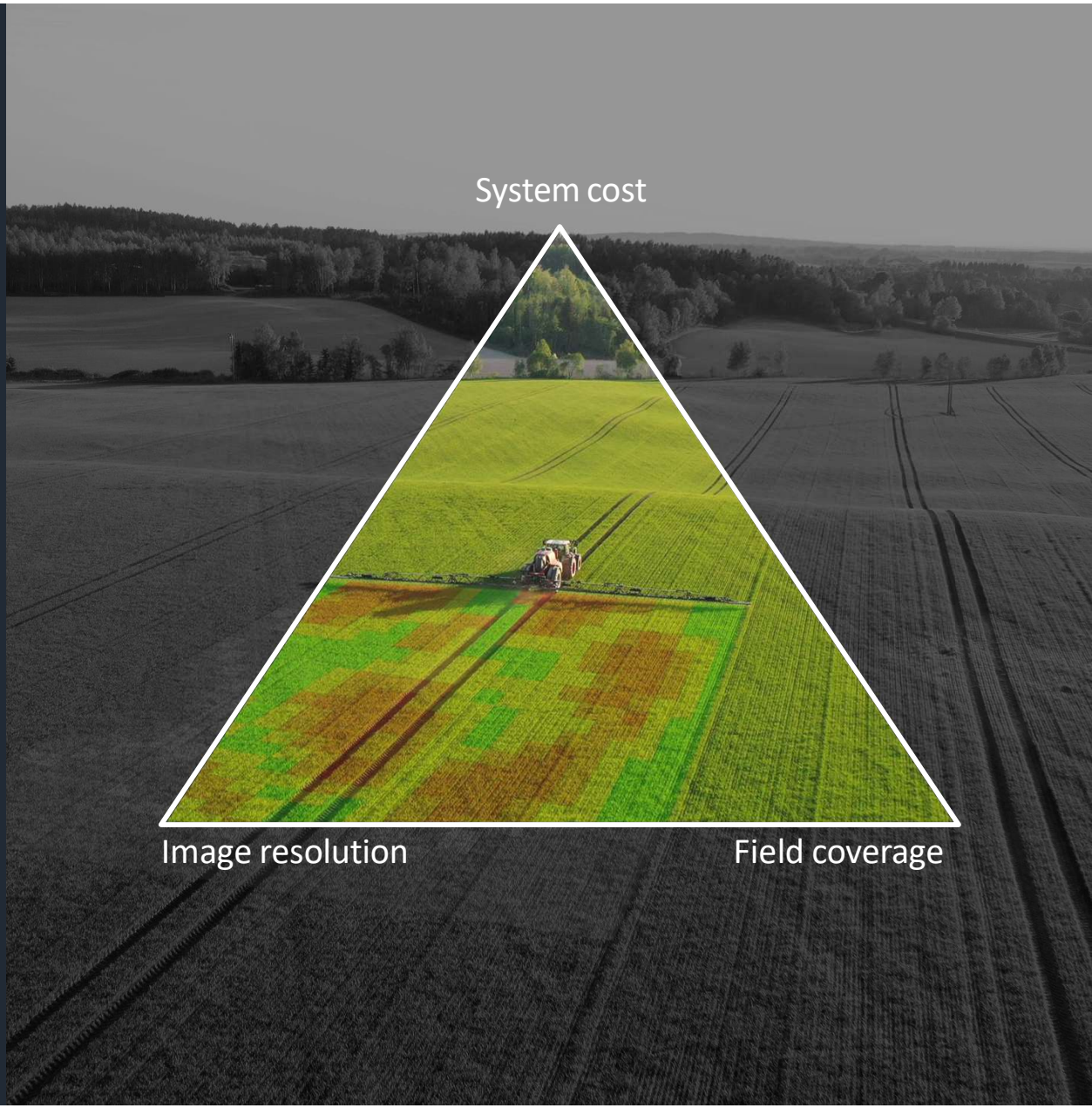


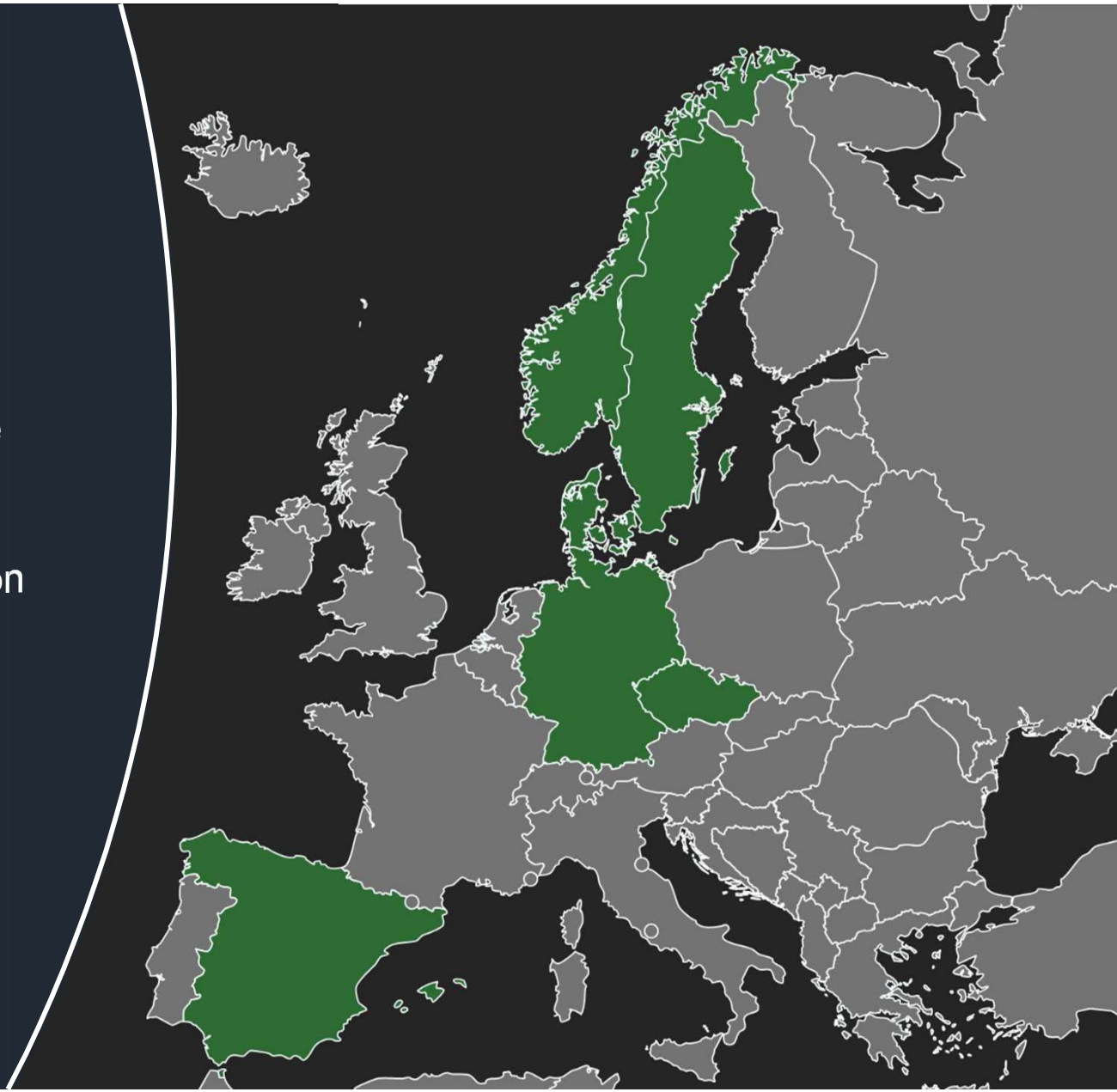
“Chess board effect ”

- ~2 week after spraying
- Dark green patches unsprayed and clearly healthier
- Explaining the increased yield?

Data collection

- A decade of data collection in multiple countries to train a robust, scalable machine learning algorithm
- Collected during spring and fall season
- Data added to the AI network daily
- Images are curated by skilled annotators and domain experts

DAT
Dimensions Agri Technologies

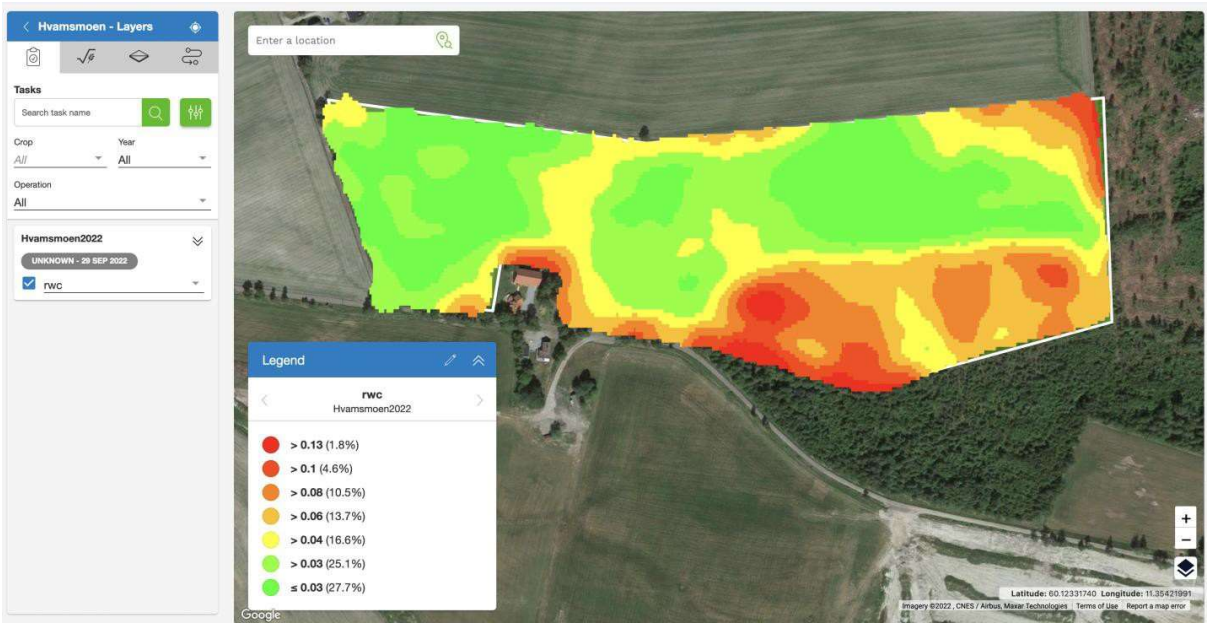



HORSCH


AMAZONE


HORSCH

Example: DAT Weed Heat Map uploaded to Topcon Agriculture Platform (TAP)



- Data from each sample point is related to a GPS coordinate and stored in CSV files
- **The data is easily converted to shapefiles that can be uploaded to TAP** (as seen on the left)
- The different data can be split into layers such as
  - Weighted relative weed cover (RWC)
  - Above / below threshold
  - As applied
  - Future opportunity to separate weed groupings such as monocot/dicot and specific weeds (*Tripleurospermum inodorum, Galium aparine, Poa annua and others*)
- **Likely that DAT data can be uploaded directly via the TAP API**

To be discussed

- How to inspect third party equipment;
  - Important to control the working system
  - Dependent of sensor technology and AI solutions
  - Should be possible also for the farmer to execute calibration and control
  - Could be challenging due to;
    - Responsibility between sprayer manufacturer and third party company
    - Inspector knowledge
    - Involvement of companies and level of costs

1. Krav til sprøyte FØR test

Klikk her for å markere alle bokser med alternativet 'ikke relevant'.

1. Sprøyten skal være ren

Godkjent | Reparert | Avvist

2. Kraftoverføring og avskjerming - slitasje eller defekter

Godkjent | Reparert | Avvist

3. Bevegelige deler - avskjerming og sikkerhet

Godkjent | Reparert | Avvist

4. Rør og Slanger- Slitasjer eller defekter

Godkjent | Reparert | Avvist

5. Konstruksjonsdeler og bærenderamme

Godkjent | Reparert | Avvist

6. Sikkerhetsventil fungerer

Godkjent | Reparert | Avvist | Ikke relevant

7. Foldbare deler

Godkjent | Reparert | Avvist

8. Vifte - intakt og fungerer

Godkjent | Reparert | Avvist | Ikke relevant

2. Utettheter

1. Statiske utettheter

Godkjent | Reparert | Avvist

2. Lekkasjetest (ingen sprøyting)

Godkjent | Reparert | Avvist

3. Lekkasjetest (ved sprøytning)

Godkjent | Reparert | Avvist

4. Væskedusj og drypp på komponenter

1. Krav til sprøyte FØR test

Klikk her for å markere alle bokser med alternativet 'ikke relevant'.

1. Sprøyten skal være ren

Godkjent | Reparert | Avvist

2. Kraftoverføring og avskjerming - slitasje eller defekter

Godkjent | Reparert | Avvist

Verwijder foto

3. Bevegelige deler - avskjerming og sikkerhet

Godkjent | Reparert | Avvist

4. Rør og Slanger- Slitasjer eller defekter

Godkjent | Reparert | Avvist

5. Konstruksjonsdeler og bærenderamme

Godkjent | Reparert | Avvist

6. Sikkerhetsventil fungerer

Godkjent | Reparert | Avvist | Ikke relevant

7. Foldbare deler

Godkjent | Reparert | Avvist

8. Vifte - intakt og fungerer

Godkjent | Reparert | Avvist | Ikke relevant

Måling av manometer og/eller trykksensor

Måling av manometer og/eller trykksensor

Manometer visning	Testresultat	Forskjell i trykk		Pumpekapasitet
1 bar	1 bar	0.00 bar	0.0 %	102 l/min
1,5 bar	1,4 bar	-0.10 bar	-6.7 %	102 l/min
2 bar	2 bar	0.00 bar	0.0 %	101 l/min
3 bar	3,1 bar	0.10 bar	3.3 %	l/min
4 bar	4 bar	0.00 bar	0.0 %	l/min
5 bar	5 bar	0.00 bar	0.0 %	99 l/min
6 bar	6 bar	0.00 bar	0.0 %	l/min
8 bar	8,1 bar	0.10 bar	1.3 %	98 l/min
6 bar	6 bar	0.00 bar	0.0 %	l/min
4 bar	4 bar	0.00 bar	0.0 %	l/min
3 bar	3,1 bar	0.10 bar	3.3 %	l/min
2 bar	2 bar	0.00 bar	0.0 %	l/min
1,5 bar	1,4 bar	-0.10 bar	-6.7 %	l/min
1 bar	1 bar	0.00 bar	0.0 %	l/min

6. Betjening, målesystem og regulering

Klikk her for å markere alle bokser med alternativet 'ikke relevant'.

1. Manometer (trykkmåler) - lett lesbart, størrelse og skala

Godkjent | Reparert | Avvist | Ikke relevant

2. Manometer (trykkmåler) - nøyaktighet og stabilitet

Godkjent | Reparert | Avvist | Ikke relevant

3. Reguleringsventiler og betjening

Godkjent | Reparert | Avvist | Ikke relevant

4. Trykkreguleringsventil

Godkjent | Reparert | Avvist | Ikke relevant

INSPEKSJONSRAPPORT ÅKERSPRØYTE

Denne inspeksjonen er utført i henhold til ISO 16122-2:2015

Inspeksjon av firma -1000: Demonstration Company

-, -, - , http://www.sonima.nl/ , norway@inspecting.online

Funksjonstest

Funksjonstest dato	27-04-2023 ved Demo Account
Frist for neste funksjonstest	27-04-2026
Resultat	Godkjent etter reparasjoner
Testprotokoll nr	1001

Eier

Kunde-ID	Kaptein Krok
Navn	Kaptein Krok
Adresse	krokveien, 1722, Sarpsborg, Norge

Kommentarer / forslag

Reparert kraftuttaksaksel

Åkersprøyte

Serienummer	00111	**Pumpekapasitet**	100 l / min
Fabrikat	Hardi	**Pumpetrykk**	15 bar
Type	NK800	**Omrøring**	Hydraulisk
Produksjonsår	1999	**Sprøytebom: Arbeidsbredde**	10 meter
Sprøytetype	3pkt montert	**Sprøytebom: Antall seksjoner**	3
Kategori	Åkersprøyte	**Avstand mellom dyser**	50 cm
Tankkapasitet	800 liter	**Antall dyser**	20
Pumpe: Fabrikat	Hardi	**Max. capacity of 1 nozzle**	2.3 l / min
Pumpetype	Stempel / Membran		

1 Krav til sprøyte FØR test

2 Kraftoverføring og avskjerming - slitasje eller defekter — **Godkjent**

Se bilde 1

3 Væskepumpe

1 Pumpekapasitet — **Godkjent**

Min. omrøring: 40.0 l / min
Pumpekapasitet nødvendig for dyser: 46.0 l / min
Målt pumpekapasitet: 98 l / min
Tilgjengelig kapasitet for omrøring: 52.0 l / min
Maks kapasitet for 1 dyse: 2.64

Måling av manometer og/eller trykksensor

Manometer visning (bar)	1.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00
Testresultat (bar)	1.00	1.40	2.00	3.10	4.00	5.00	6.00	7.00	8.10	9.00	10.00	11.00	12.00	13.00	14.00
Forskjell i trykk (bar)	0.00	-0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.00	0.00
Forskjell i trykk %	0.0	-6.7	0.0	3.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Pumpekapasitet (l / min)	100	100	101		0	99		99							

12 Dyser og væskefordeling

5 Trykktap - Bruk kontrolldyse ved måling av trykktap — **Godkjent**

Hvis dysekapasiteten er målt **2.00 bar** **lik 1.20 liter/min og dyse**
Så er trykket ved dyse ut på bommen ved **1.15 liter/min lik 1.84 bar**
Trykktap i prosent **8.16 %**
Trykktap i bar **0.16 bar**

Utstyr som brukes til måling av distribusjon: Lurmark
Utstyr som brukes til måling av dysekapasitet: Sylindre/målebegre

Testresultat dyser - bruk av Lurmark fordelerbord
Hardi, ISO F-, 110 / 03 , Testhøyde **40 cm** , Testtrykk **2 bar**
Resultat: Godkjent

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Testresultat	1.00	1.02	1.00	1.02	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avvik fra snitt	0.00 l/min	0.02 l/min	0.00 l/min	0.02 l/min	0.00 l/min	0.00 l/min	-0.03 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min	0.00 l/min
Avvik fra snitt	0.0 %	2.0 %	0.0 %	2.0 %	0.0 %	0.0 %	-3.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %

Signatur av: Demo Account

INSPEKSJONSRAPPORT ÅKERSPRØYTE

Denne inspeksjonen er utført i henhold til ISO 16122-2:2015

Bilde 1

Thank you for your attention!