Presentations

4th NJF Agromek EurAgEng joint Seminar

Advances and Innovations in Agricultural Engineering

29-30 November 2022, Herning, Denmark

Nils Bjugstad
REALTEK, NMBU, Norway

NJF, EurAgEng, Agromek joint seminar. 29th to 30th of November 2022

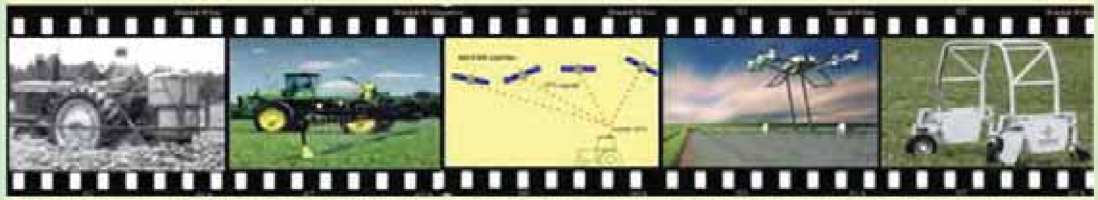
Innovation | Sensors | Robotics | Precision agriculture | Smart farming | Environment

Design
Ergonomics
Soil compaction
Safety
Big data
Data Science
Drones
Navigation

Advances and Innovations in Agricultural Engineering

The 4th NJF - EurAgEng - Agromek Joint Seminar

November 29th - 30th, 2022, Herning, Denmark



Please visit *www.nmbu.no/go/agromek* for more information

Climate neutral
Circular economy
Plant protection
Post harvest
Artifical intelligence
Imaging
GIS Mapping
SD Goals

Logistics | Advisory service | Management | Education | Networking | Horizon Europe

agromek

EurAgEng

NORDIC ASSOCIATION OF AGRICULTURAL SCIENCE

NMBU

Keywords; **Smart Farming, robots & drones, sensor technology, GIS/GNSS, sustainability, innovation**

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Nils Bjugstad* (NO) - chairman. Faculty of Science and Technology, Norwegian University of Life Sciences, Ås

Claus Hermansen (DK). CEO for Agromek & Danish Agroindustry

Claus Sørensen (DK). Former president of the EurAgEng, Department of Engineering, Aarhus University

Alastair James Ward, (DK) Department of Engineering, Aarhus University

Antti Lajunen, (FI) University of Helsinki, Department of Agricultural Sciences, Helsinki

Sven Bernesson, (SE) Swedish University of Agricultural Sciences, Department of Energy and Technology, Uppsala

Sigtryggur V. Herbertsson, (IS) Icelandic Agricultural Advisory Centre

Vitalijs Osadcuks , (LV) Latvia University of Agriculture, Faculty of Engineering, Jelgava

Kęstutis Venslauskas, (LT) Vytautas Magnus University, Department of Mechanical, Energy and Biotechnology Engineering

Oliver Sada*, (EST) Institute of Technology, Estonian University of Life Sciences, Tartu

Maibritt Kindberg, MCH Agromek

Tuesday 29 November 2022

Bus to Agromek leaves 8.45 outside DGI Hotel, Herning. Please be there in advance.

People not showing up at 8.45 are expected to go to the Agromek conference venue on their own. Arrival to venue at Agromek, Herning expected to be around 9.00.

Venue: Sydsalen, Entrance Agromek West Registration from 09.00 to 11.10

Time	Topic	Presentations	Speakers
09.00 -11.10		Registration / networking/ visit Agromek on your own	
11.10 -11.30		Introduction and welcome	Nils Bjugstad, NMBU, N
		What is EurAgEng?	Claus Aage Sorensen, AU, DK
		What is NJF?	Nils Bjugstad, NMBU, N
		Chair of session: Nils Bjugstad	
11.30 – 12.00	Keynote	Agricultural robots for new sustainable crop productions	Hans Griepentrog, University Hohenheim, DE
12.00 - 12.20	Smart farming	Pilot project on Precision Farming	Michael Nørremark, AU, DK
12.20 - 12.40	Smart farming	Reducing the climate impact of Swedish agriculture - Field tractor electrification	Oscar Lagnelöv, SLU, S
12.40 – 13.00	Smart farming	A low-cost robot platform for swarm applications in agriculture	Robert Braunschweig, NMBU, N
13.00 – 14.00		LUNCH	
		Chair of session: Alastair Ward	
14.00-14.20	Smart farming	Smart Farming Sustainable arena established at NMBU	Nils Bjugstad, NMBU, N
14.20-14.40	Imaging	Impact of Sun Elevation Angle and Type of Sensor on Multispectral UAV Imagery Data	Sahameh Shafiee, NMBU, N
14.40-15.00	Imaging	Spectral imaging in crop fields- research activities at NMBU	Ingunn Burud, NMBU, N
15.00-15.20	Solar energy	Exploring solar energy combined with a fleet of electrical vehicles and precision agriculture for reduced GHG-emissions	El Houssein Chouaib Harik, NIBIO, N
15.20-15.40		Coffee & Tea break. incl. brief intro about AGROMEK	Claus Hermansen, AGROMEK, DK
15.40-16.00	Sensor technology	Sensor technology for optimal harvest in strawberry	Siv Fagertun Remberg, NMBU, N
16.00-16.20	Smart farming	Safety concept for robotic silage harvest system	Ari Ronkainen, LUKE, FIN
16.20-16.40	Smart farming	Data infrastructure requirements for Robotics and Smart Farming Research	Annimari Hartikainen, LUKE, FIN
16.40-17.00	Smart farming	Experimental study of laser weed control approach with full canopy area treatment	Vitālijs Osadčuks, LBTU, LV
Ca. 17.30		Bus to Agromek dinner in Herning City (updated times during seminar)	
18.00-23.00		Agromek dinner	

Wednesday 30 November

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People not showing up at 08.45 are expected to go to the Agromek conference venue on their own.
Arrival to venue at Agromek, Herning expected to be around 9.00

Time	Topic	Presentations	Speakers
09.00-10.00		Short visit of Agromek on your own / Venue Sydsalen open & coffee	
		Chair of session: Claus Sorensen	
10.00-10.40	Keynote	Can agtech innovation dissolve goal contradictions?	Per Frankelius, LiU, SE Jonas Engström, RISE, SE
10.40-11.00	Sustainability	Measures for reductions of greenhouse gas emissions in agriculture	Sven Bernesson, SLU, S
11.00-11.20	Biogas energy	Ensiling of straw as a pre-treatment and storage method for biogas production	Alastair James Ward, AU, DK
11.20-11.40		Coffee break	
11.40-12.00	Energy efficiency	Energy efficient grain drying processes	Jens Moller Andersen, AU, DK
12.00-12.20	Soil compaction	Soil compaction from using agricultural robots in complex arable operations	Alvaro Calleja Huerta, AU, DK
12.20-12.40	Soil compaction	Prevention of subsoil compaction: Technologies and strategic planning	Mathieu Lamandé, NMBU/AU, DK
12.40-13.00	Soil tillage	Drawbar Pull Testing for Machine Soil Interaction Characterization	Ole Balling, AU, DK
13.00-13.10		Closing session	Nils Bjugstad, NMBU, N
13.10-14.00		LUNCH	
14.00-15.00		Visit Square meter farm and other involved partners	Claus Sorensen, AU, DK
15.00-16.15		Visit Agromek on your own	
16.15-17.00		How to successfully implement artificial intelligence in your business	Tomas Borovicka, CEO at Datamole[1], Days of future, hall E, see map
15.00-20.00	AGROMEK	Visit Agromek free of charge. Agromek closes 20.00	All

Frequently shuttle buses from Agromek fair to Billund airport.

e notes

Agricultural Robots For New Sustainable Crop Productions Systems with:

Hans Griepentrog

Professor PhD, Dipl.-Ing. university of Hohenheim, Institute of Agricultural Engineering, Germany.

Can agtech innovation dissolve goal contradictions with:

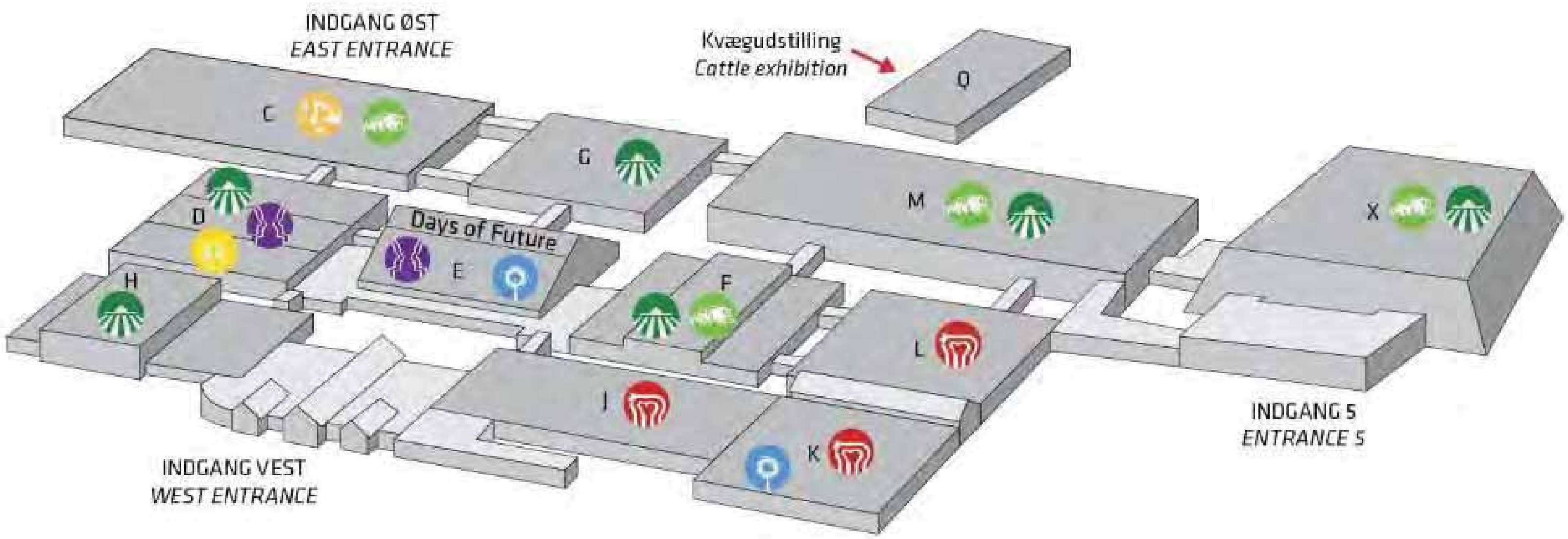
Per Frankelius

PhD, is Associate Professor (Docent) in Business Administration at Linköping University (Sweden).

Jonas Engström

Researcher and senior project manager at RISE, Research institutes of Sweden

Hall overview



traktorer og høstmaskiner
tractors and combine harvesters

kornhåndtering
crop management

energi
energy

viden og service
knowledge and service

markredskaber
agricultural machinery

staldmekanisering
livestock machinery

entreprenør, vej & park
construction, roads and parks



EurAgEng

Prof. Claus Grøn Sørensen
Aarhus University, Denmark

Past President 2016-2018, EurAgEng
Current Executive, Council member

The European Society of Agricultural Engineers

The European Society of Agricultural Engineers (EurAgEng) exists to promote the profession of Agricultural and Biosystems Engineering and the people who serve it.

The Society is particularly active in Conferences, Working Groups, Publications, Networking and International lobbying.

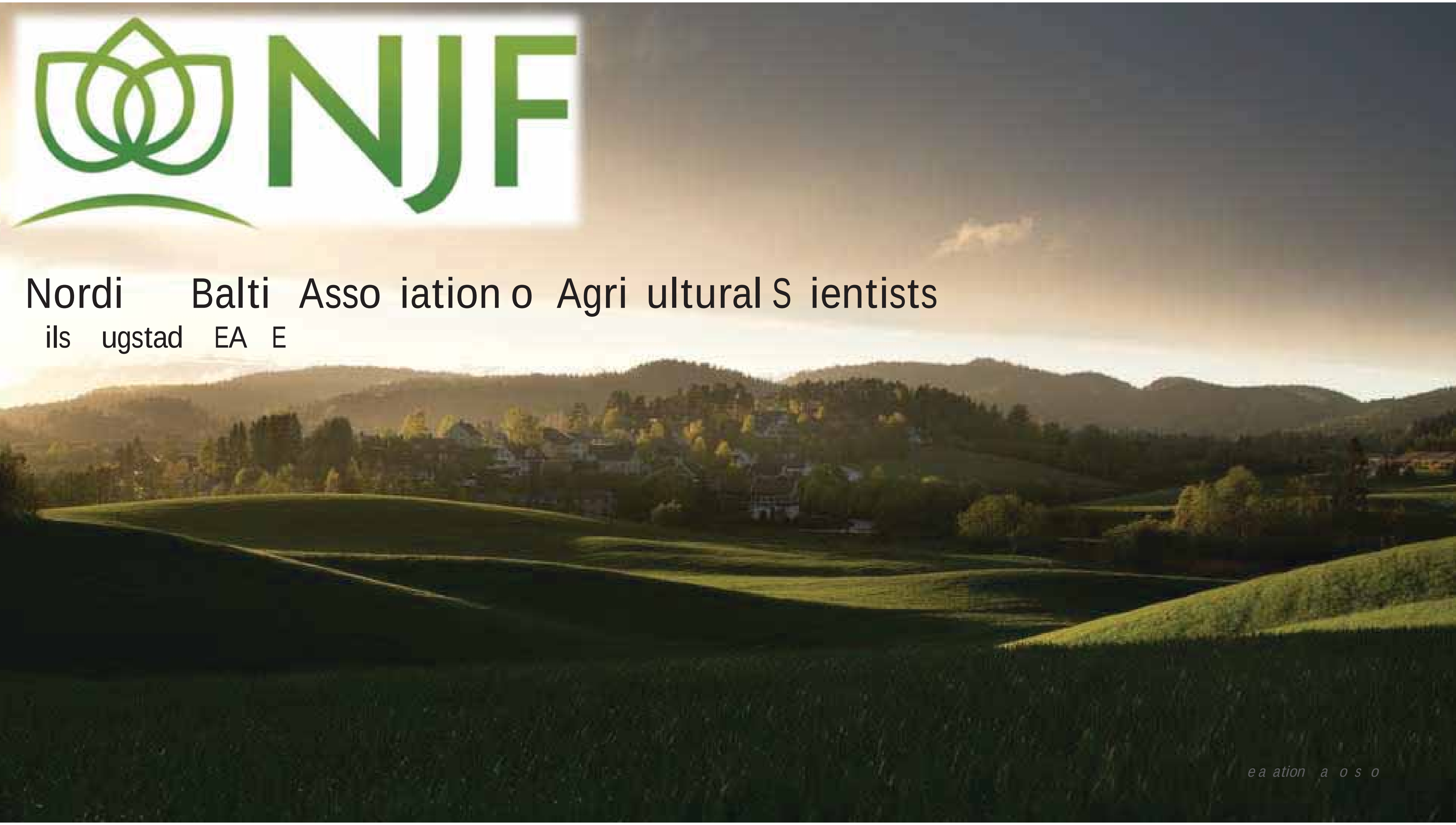
EurAgEng is the European member of CIGR,
the world wide agricultural engineering organization
(International Commission of Agricultural and Biosystems Engineering)

- Founded in the 1980s. Network with over 2000 members of national societies from 23 countries.
- Biennial agricultural engineering conference (AgEng2018, Wageningen, AgEng2020, Evora, AgEng2022, Berlin, etc.)
- Partnering with German National Society, VDI-MEG, for the biennial Land.Technik-AgEng before Agritechnica in Hannover
- Partnering with CIGR for joint conferences (e.g. in Turin, 2026)

- “Biosystems Engineering” – the official scientific journal of EurAgEng
- Supports groups (Agricultural Engineering and Technology) and projects (Agriculture and Energy Efficiency; Smart-AKIS, etc).
- Standardization and harmonization of engineering curricula and student initiatives (Field Robot Event)
- Nine Fields of interest are identified. Eighteen Working Groups (WGs) within these fields of interest
- Institutional network: "European Network for Advanced Engineering in Agriculture and Environment" (ENGAGE)

Conferences

- *AgEng 2018, Wageningen, Netherlands*
- *Feb 2019: AXEMA-EurAgEng-SIMA* Paris "Sustainable agriculture : An opportunity for innovation in machinery and systems"
- *Land.Technik AgEng 2019, Hannover (Agritechnica)*
- *AgEng 2020, Evora, Portugal*
- *Land.Technik AgEng 2021, Hannover (Agritechnica)*
- *AgEng 2022, Germany*
- *Land.Technik AgEng 20223, Hannover (Agritechnica)*
- *AgEng 2024, Athens, Greece*
- *AgEng/CIGR conference, Turin, Italy, 2026*



Nordi Balti Asso iation o Agri ultural S ientists
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ORGANIZATION

- NJF is Non-governmental organization
- About 1,500 members
- Non-profit organization
- Nordic and Baltic countries
- 6 sections:

  Plants, animals, environment, economics, reindeer husbandry and TECHNOLOGY & INNOVATION

MAIN ACTIVITES

- NJF congress, this autumn in Iceland (September 2022)
- Seminars & Workshops
- Active working group meetings
- Section board meetings
- National board meetings
- New president – Jarkko Niemi, LUKE, Finland

In seminars working habits differ according to needs

Key issues in NJF functions are interaction, networking & meeting persons sharing the same interests

NJF

MEMBERSHIP

- Want to join NJF and be a member?
- Costs about 30 € per year (some variation between countries)
- Join us now: visit https://nordicagriculture.eu/

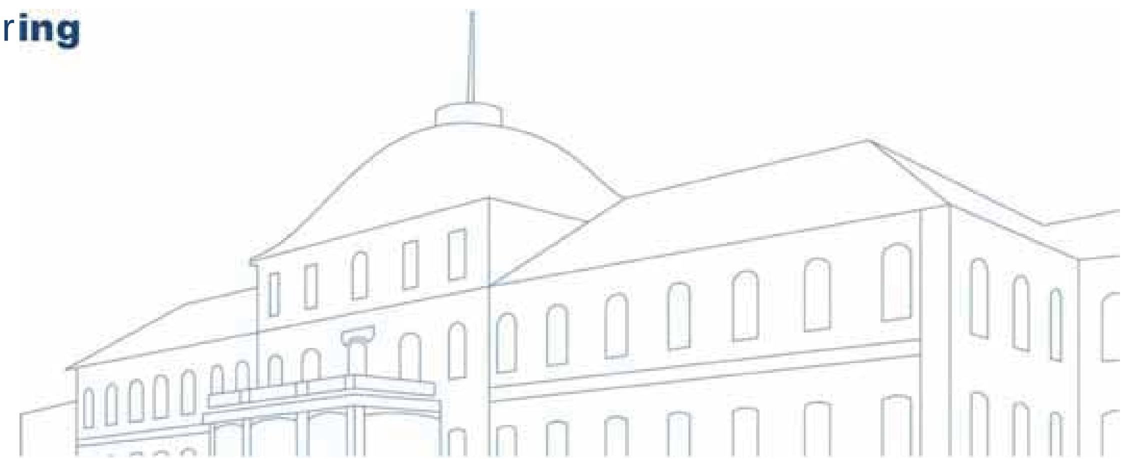
Agricultural Robots For New Sustainable Crop Production Systems

Advances and Innovations in Agricultural Engineering

The 4th NJF - EurAgEng - Agromek Joint Seminar, 29.-30. November 2022

Hans W. Griepentrog
(Professor, PhD)

Institute of Agricultural Engineering
Technology in Crop Production
Germany



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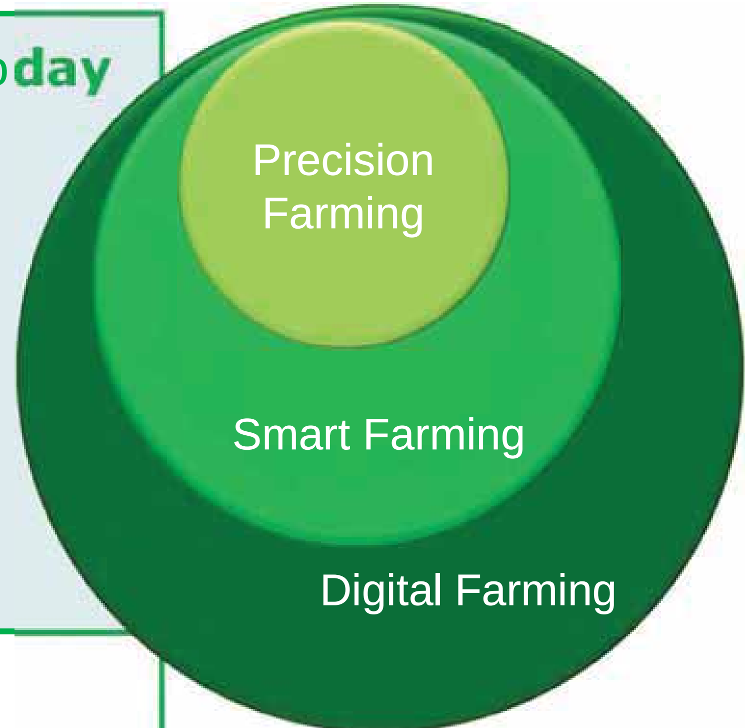
Definition of Terms

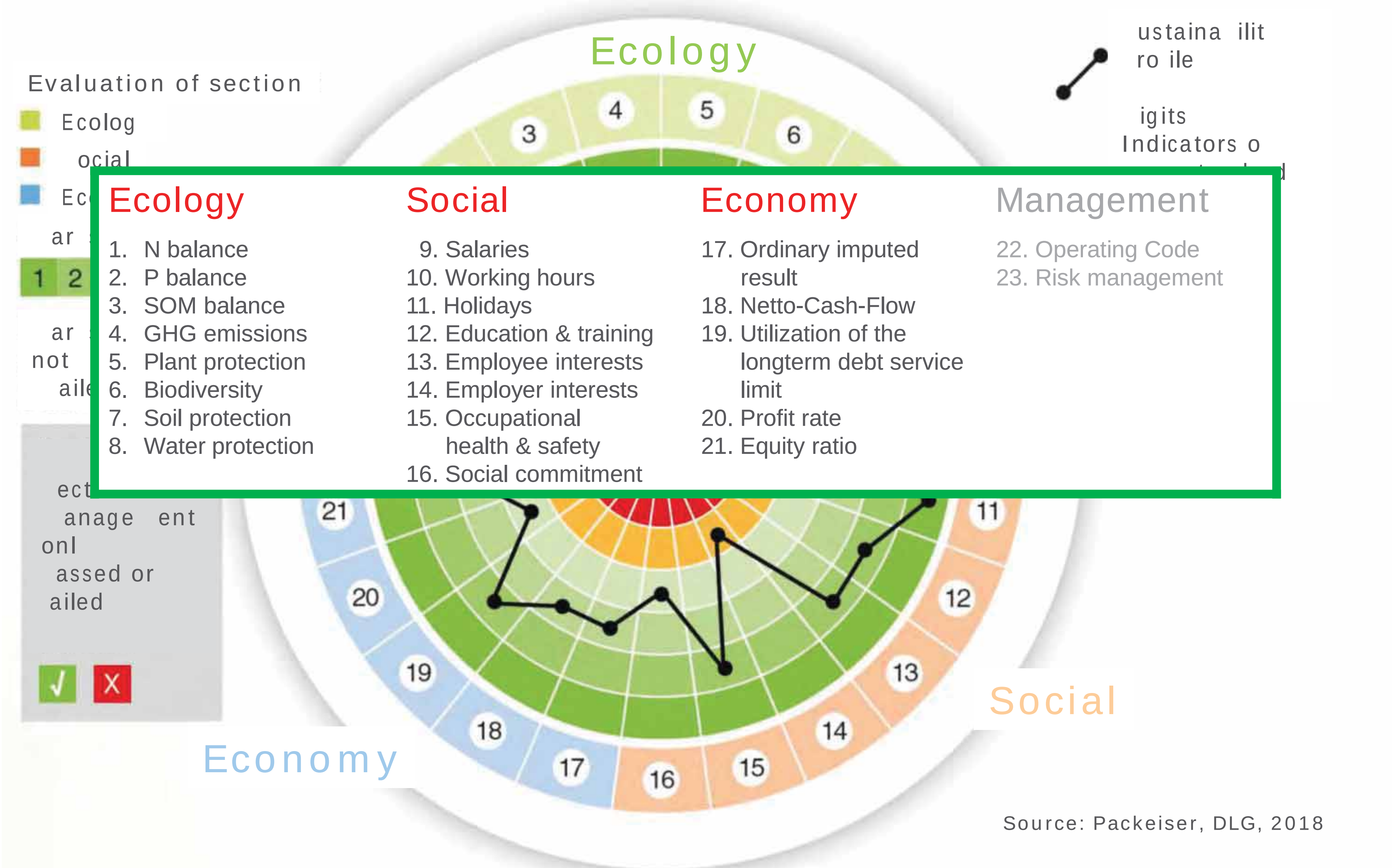
Today

- Precision Farming
  - Site-specific treatment
    Map based variable rate applications
  - Automation
    Automatic steering, section control & self adapting complex machinery
- Smart Farming
  - Realtime systems
  - Fusion & analysis of information
  - Decision support
- Digital Farming & Farming 4.0
  - Internet of things (M2M)
  - Cloud computing
  - Big-data & AI
  - Robots

Future System



Certification of Sustainable Farming (1)



Ecology	Social	Economy	Management
1. N balance	9. Salaries	17. Ordinary imputed result	22. Operating Code
2. P balance	10. Working hours	18. Netto-Cash-Flow	23. Risk management
3. SOM balance	11. Holidays	19. Utilization of the longterm debt service limit	
4. GHG emissions	12. Education & training	20. Profit rate	
5. Plant protection	13. Employee interests	21. Equity ratio	
6. Biodiversity	14. Employer interests		
7. Soil protection	15. Occupational health & safety		
8. Water protection	16. Social commitment		

Source: Packeiser, DLG, 2018

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Certification of Sustainable Farming (2)

Evaluation of section
- Ecolog
- ocial
- Econo

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1	2	3	4	5	6

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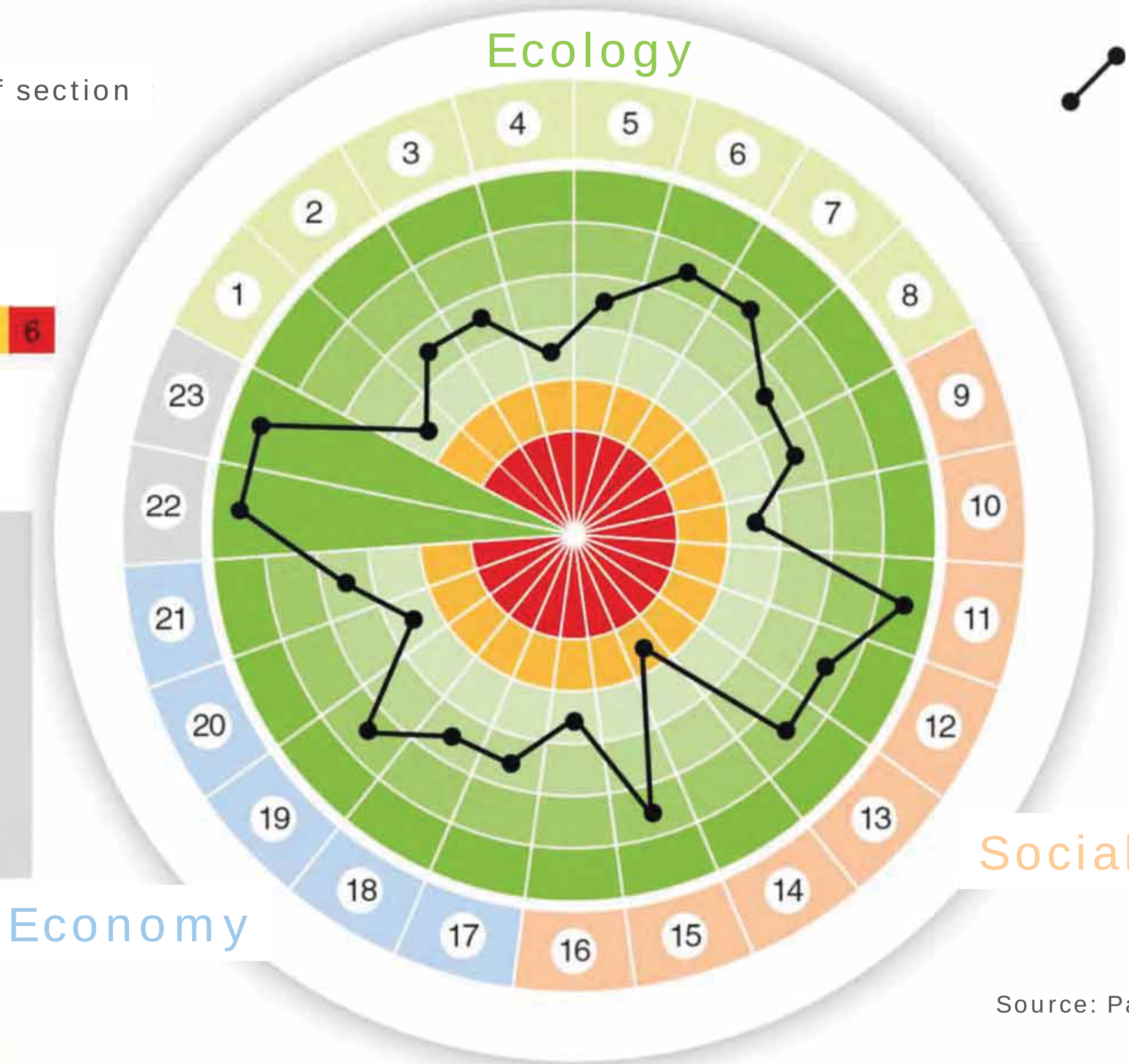

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Source: Packeiser, DLG, 2018

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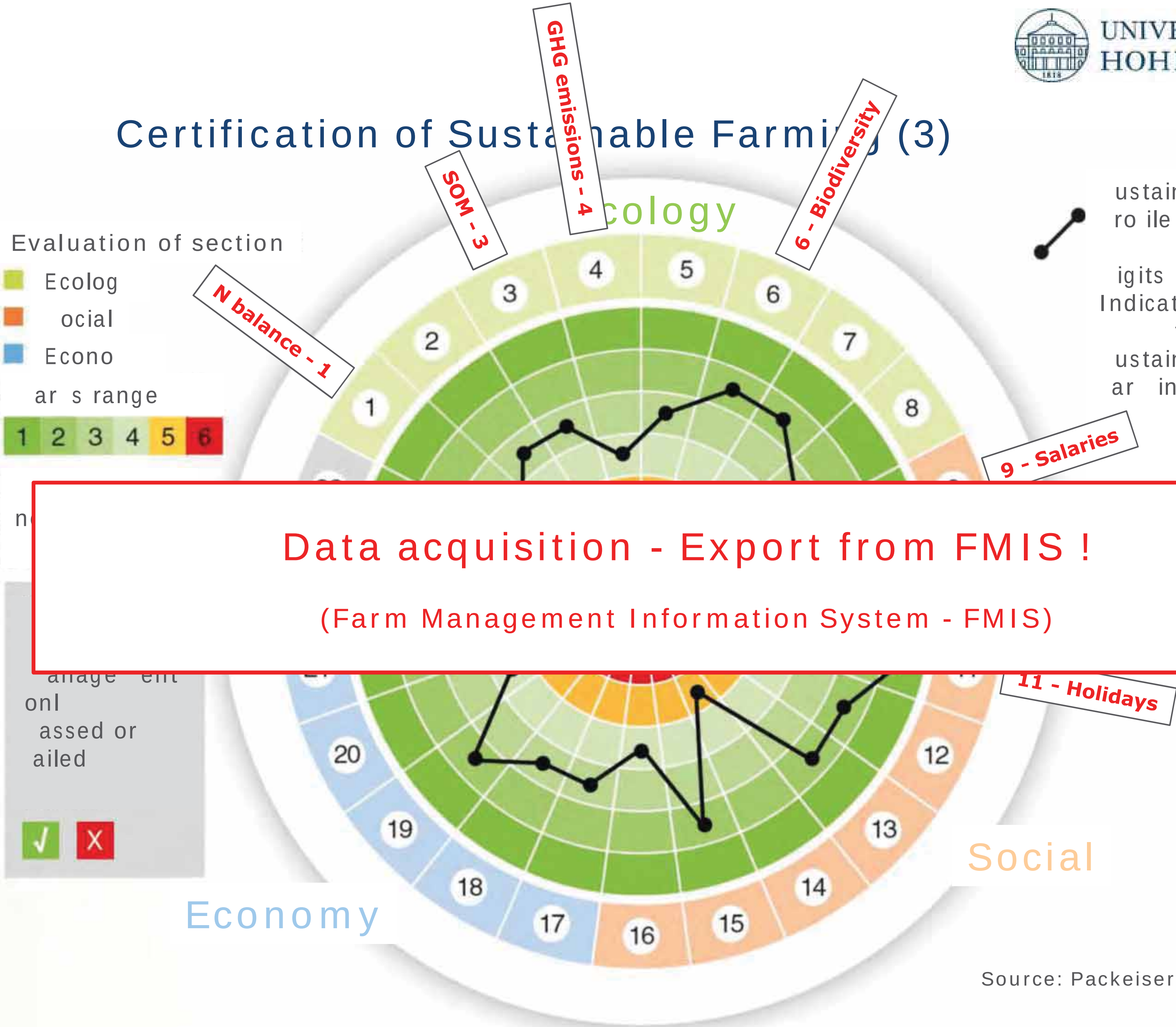
Certification of Sustainable Farming (3)



Data acquisition - Export from FMIS !

(Farm Management Information System - FMIS)

Source: Packeiser, DLG, 2018

Mechanization – Two Strategies (1)
1 - Robots for conventional implements & applications

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Mechanization – Two Strategies (2)
2 - Robots for specialized implements & applications

Mechanization – Two Strategies (3) Overview

- Systems for conventional implements & applications
  - High power (100-500 kW)

New step of mechanization

  - ISOBUS data communication
  - High capacity (ha/h)
  - High costs / investments
  - Crop management
    - Site specific (PF), auto steering, section control etc.

- Systems for specialized implements & applications
  - Low power (5-50 kW)

New step of cropping system

  - ty (scalable)
  - Fits to all farm sizes
  - Scalable costs
  - Crop management
    - Individual plants (high spatial resolution)

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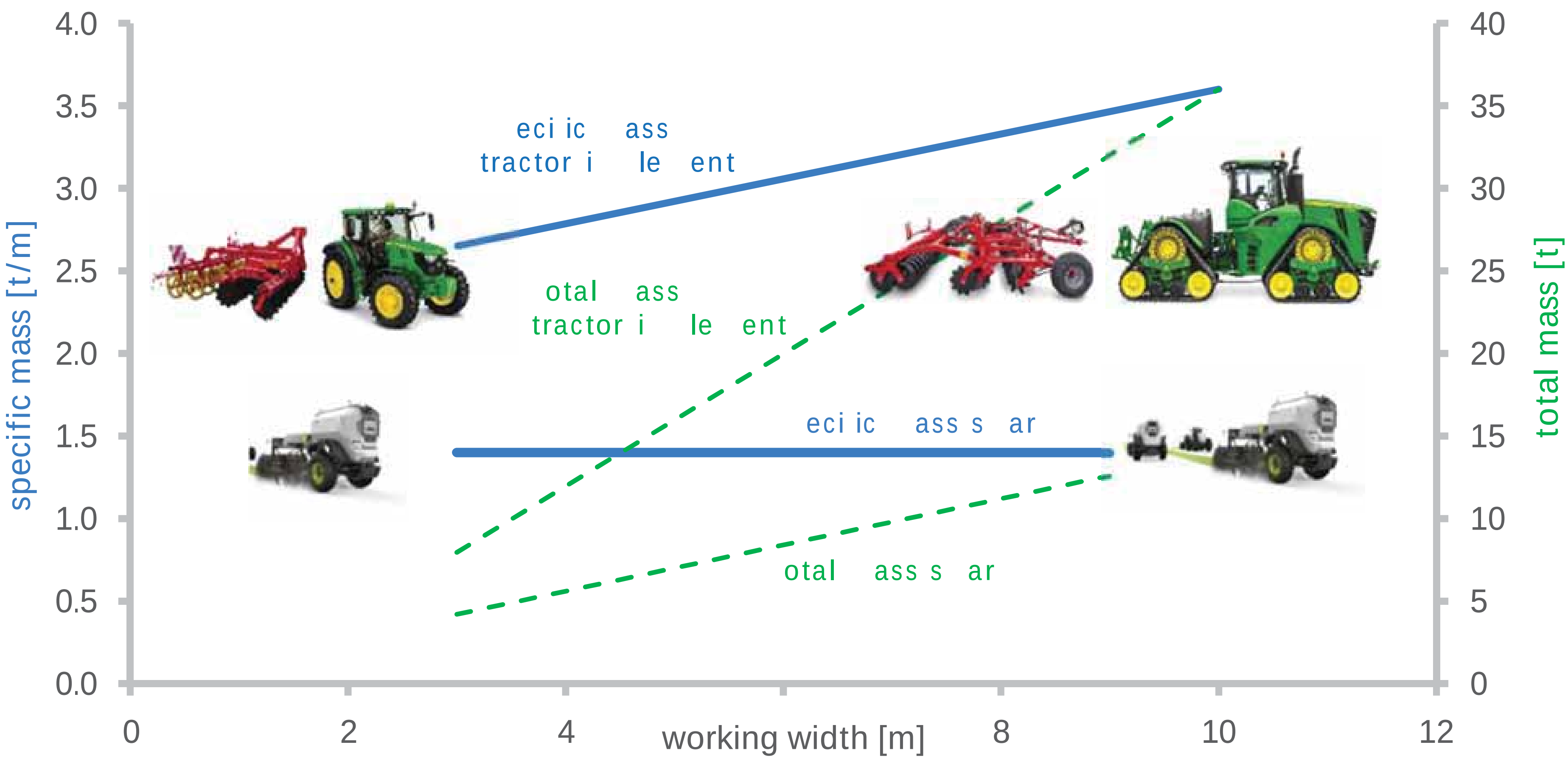
Machine weights
Total and specific mass



Source: T. Herlitzius, TU Dresden

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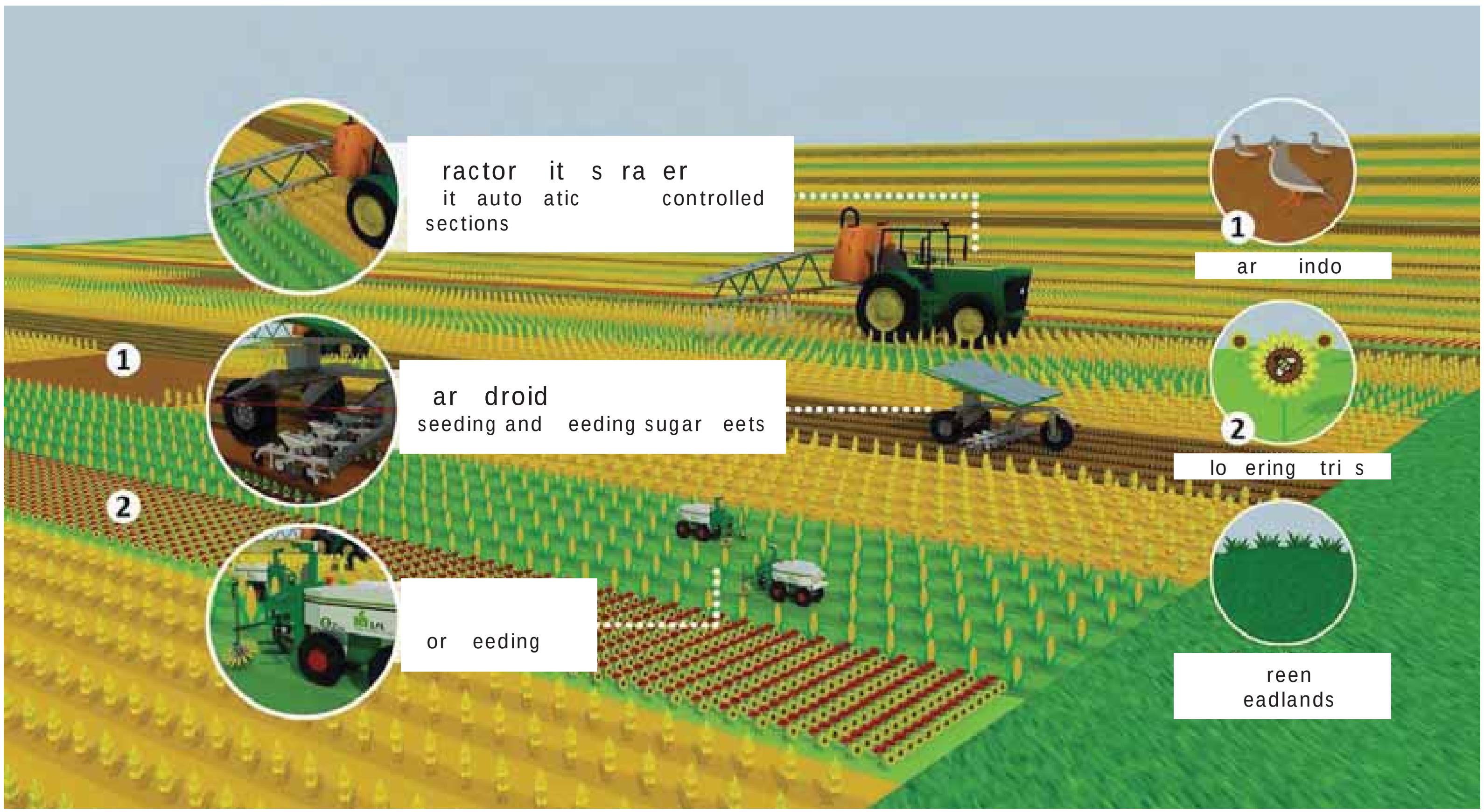
Future Cropping Systems (1)
Biodivers – Soil Preventing – Digital

- Small scale & highly divers crop production system
- Climate resilient production system
- Digital and robotic solution for more opportunities
- Interdisciplinary and systems oriented



Source:
M. Gandorfer
Digital Farming Group
Bayerische
Landesanstalt für Landwirtschaft

LfL

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Future Cropping Systems (2)
Strip Intercropping

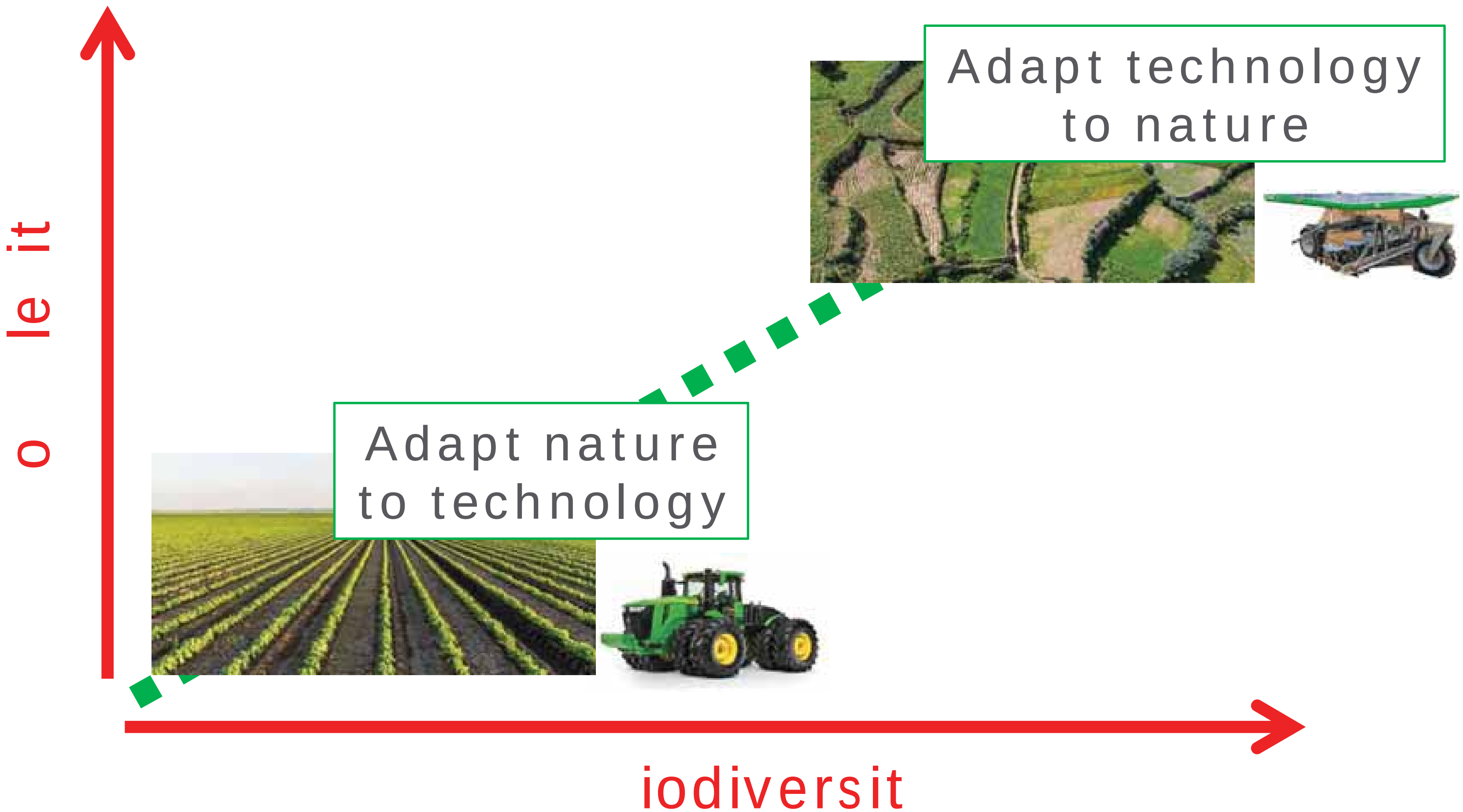
Source:
M. Gandorfer
Digital Farming Group
Bayerische
Landesanstalt für Landwirtschaft

LfL

Small Robots – New Mechanization
Slow speeds with more accurate performance

- High productivity via variable number of small machines (scalable)
- Small units highly flexible, no advantage of large cleared fields
- Higher resource efficiency (lower use of operating resources).
- Preservation or even reintroduction of landscape elements (biodiversity)
- Increased biodiversity
  - mixed crops, landscape features, contour cropping
- Selective treatments e.g. for weeding and harvesting

Paradigm Shift – Biological Intensification



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Outlook – Same mechanization for all?
Conditions of Agricultural Production

Production for the world market; low intensities; low land prices; high automation of subsystems

Appropriate technology; medium and high intensities; low labor costs

High product qualities; high safety and environmental concerns; high labor costs, investments and intensities

Summary

- Sustainability needs more quantitative attention.
  - FMIS data and certifications can help farmers assessing their farms

- Robotics and digitalization allow new possibilities for crop production.
  - High working qualities by driving slowly
  - Soil protection through light vehicles.
  - Increased precision farming effect through high spatial resolutions and individual crop targeting.
  - No more advantages of 'big cleared out fields’.
  - Reintroduction of landscape elements and agricultural biotopes.
  - Machines are scalable in their function, thus flexible and adaptable.

- Paradigm shift: technology adapts to nature, not vice versa.

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Thanks for your attention!

PILOT PROJECT ON PRECISION FARMING

ENVIRONMENTAL IMPACT CALCULATIONS OF PRECISION FERTILIZATION

By:
Michael Nørremark
Aarhus University
Departmen of Elektrical and Computer Engineering

With contributions from:
Jacob Glerup Gyldengren, Iris Vogeler Cronin, Ingrid K. Thomsen og Peter Sørensen
Aarhus University
Department of Agroecology

BACKGROUND

Assumption that technology and principles for precision farming have a reduction potential for leaching of nitrogen (N) in the order of 3-4 kg N/ha on arable farms and 5-6 kg N/ha on livestock farms.

Agricultural and environmental purposes: 8 -10 ha of precision fertilization for 1 ha of catch crop*

The pilot project investigated whether the potential environmental effect is the sum of a total of three sub-elements:

1. Detailed calculation of N requirements,
2. Site-specific application of N and the application of spreading equipment with section control (DAISY and APSIM based model calculations), and
3. Determination of N in livestock manure and precise prescribed amount (NLESS5 based model calculations).

The sub-elements are delimited to only include a typical crop rotation with and without livestock manure.

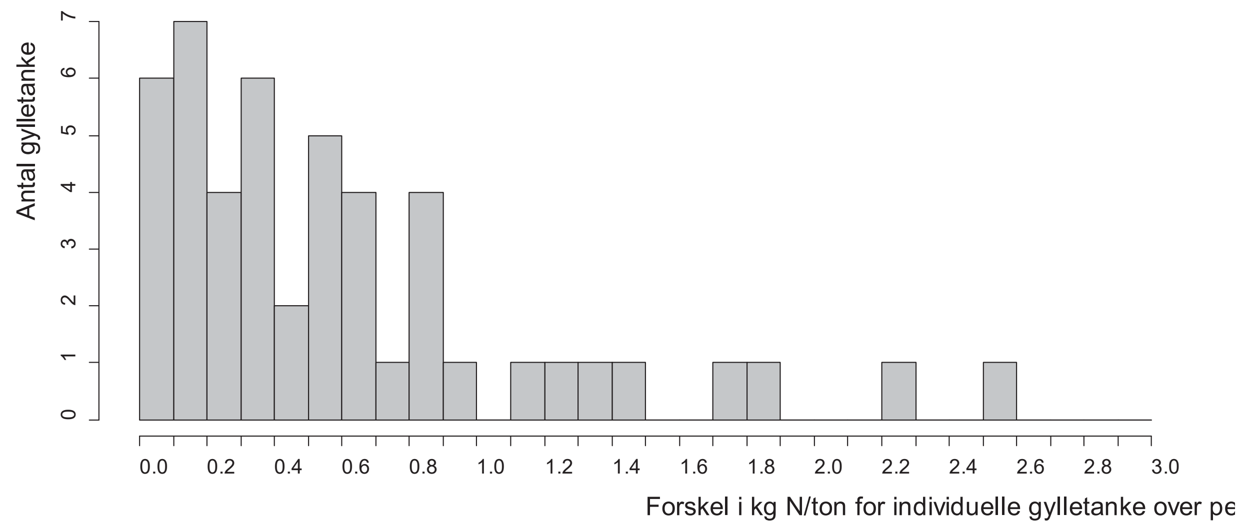
As a starting point, the Danish Agricultural Agency wanted to determine conversion factors for cultivated fields w/o livestock manure fertilization.

* For livestock farms

LIVESTOCK MANURE ANALYZES - STATISTICS

Pig manure total N analysis results (data from 15 pilot project farms, 89 slurry tanks)

Kg N/ton	2018	2019	2020
Gns.:	3.56	3.44	3.41
Std. afv.:	1.25	1.14	1.21
Minimum	1.22	1.72	1.24
Maksimum	7.00	7.64	7.44
CV in %, farms	26	23	21



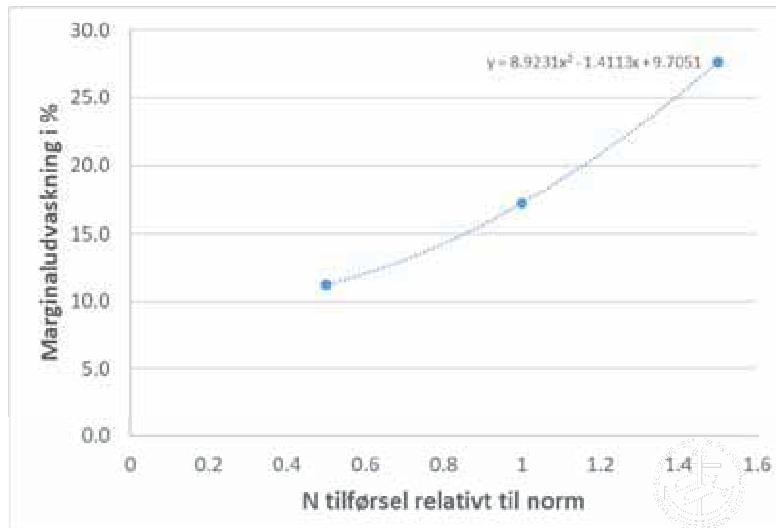
LIVESTOCK MANURE ANALYSES – ENV. IMPACT

The following assumptions have been used to calculate the impact on nitrate leaching of redistribution of manure on the basis of livestock manure analyzes from pilot project participants in 2018 (calculations are shown in brackets).

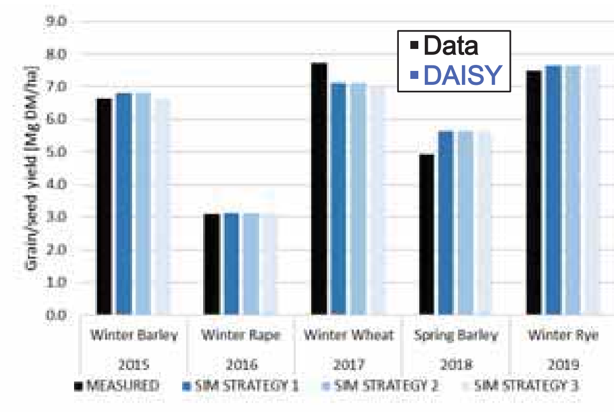
In the calculations, it is also assumed that 50% of the manure is below the norm and redistributed to the norm, and that 50% of the manure is above the norm and redistributed to the norm.

		Assumptions and impact from redistribution of N in manure
a	CV for total N i svinegylle [%]	26
b	Total N-application as manure [kg N/ha]	170
c	N utilisation requirements, av. for cattle- and pig manure [%]	77,5
d	Redistribution [N/ha] gns., (a · b/100 · c/100), 1:1 area ratio	34,3
e	Average N-norm [kg N/ha] (all crop species) (Blicher-Mathiesen et al., 2020)	167
f	Redistribution in % of norm N (d ·100/e) [%]	21
g	Marginal leaching by fertlization f% below norm [%] (cf. figure)	14,2
h	Marginal leaching by fertlization f% above norm [%] (cf. figure)	21,1
i	Average leaching for redistributed N, where 50 % af manure below norm are transferred to norm (17,2+g/2)[%]	15,7
j	Average leaching for redistributed N, where 50 % af manure above norm are transferred to norm (17,2+h/2)[%]	19,1
k	Altered leaching, where 50 % of manure below norm are transferred to norm (d · i/100) [kg N/½ ha]	5,38
l	Altered leaching, where 50 % of manure above norm are transferred to norm (d · j/100) [kg N/½ ha]	-6,55
	Environmental impact, reduction in N leaching (k+l) [kg N/ha]	**1,20**

Marginal leaching in relation to N application estimated on the basis of 54 N response experiments used in calibrating the NLES5 model (Børgesen et al., 2020). The figure shows the equation that describes the average marginal leaching in the experiments relative to the N norm for a crop. The trials included a number of different crops, of which 41 were trials with cereals and winter crops

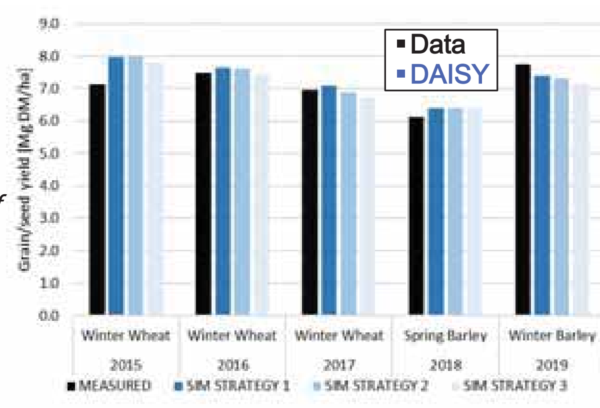


MODELING OF THE SOIL-PLANT-ATMOSPHERE SYSTEM – DAISY AND APSIM



R^2 = 0.94

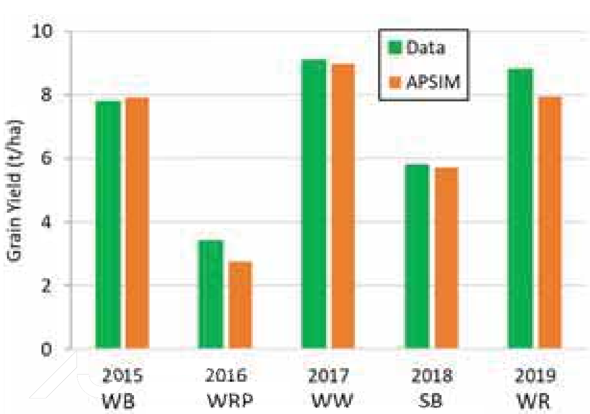
Simulering af bedriftens N-håndtering (mørkeblå)



R^2 = 0.59

JB3 (field 31-0)

JB5 (field 37-0)



R^2 = 0.94

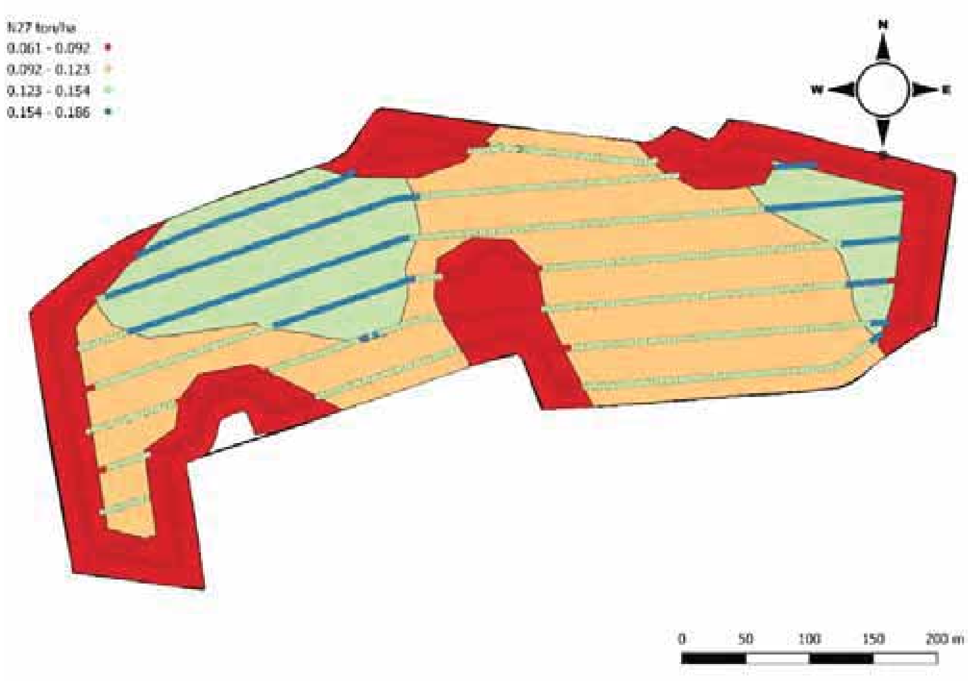
R^2 = 0.90

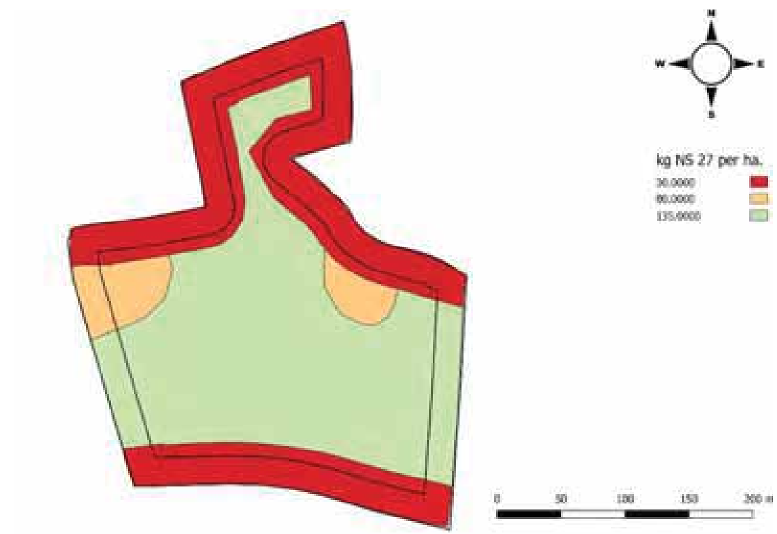
Parameters for every growing season:

Crop	Irrigation
Tillage type	Straw removal
Seed rate	
Seeding data	Harvest date
	Stubble cultivation
Inorganic fertilizer, 1.	Validated crop yield
Date of application	
Inorganic fertilizer, 2.	Farmers knowledge
Date of application	about field variations
Inorganic fertilizer, 3.	
Date of application	Soil type
	Texture:
Organic fertilizer, 1.	A-horisont
Date of application	B-horisont
N in livestock manure	C-horisont
Utilization rate in %	Bulk density, soil
Organic fertilizer, 2.	
Date of application	Weather data
N in livestock manure	
Utilization rate in %	

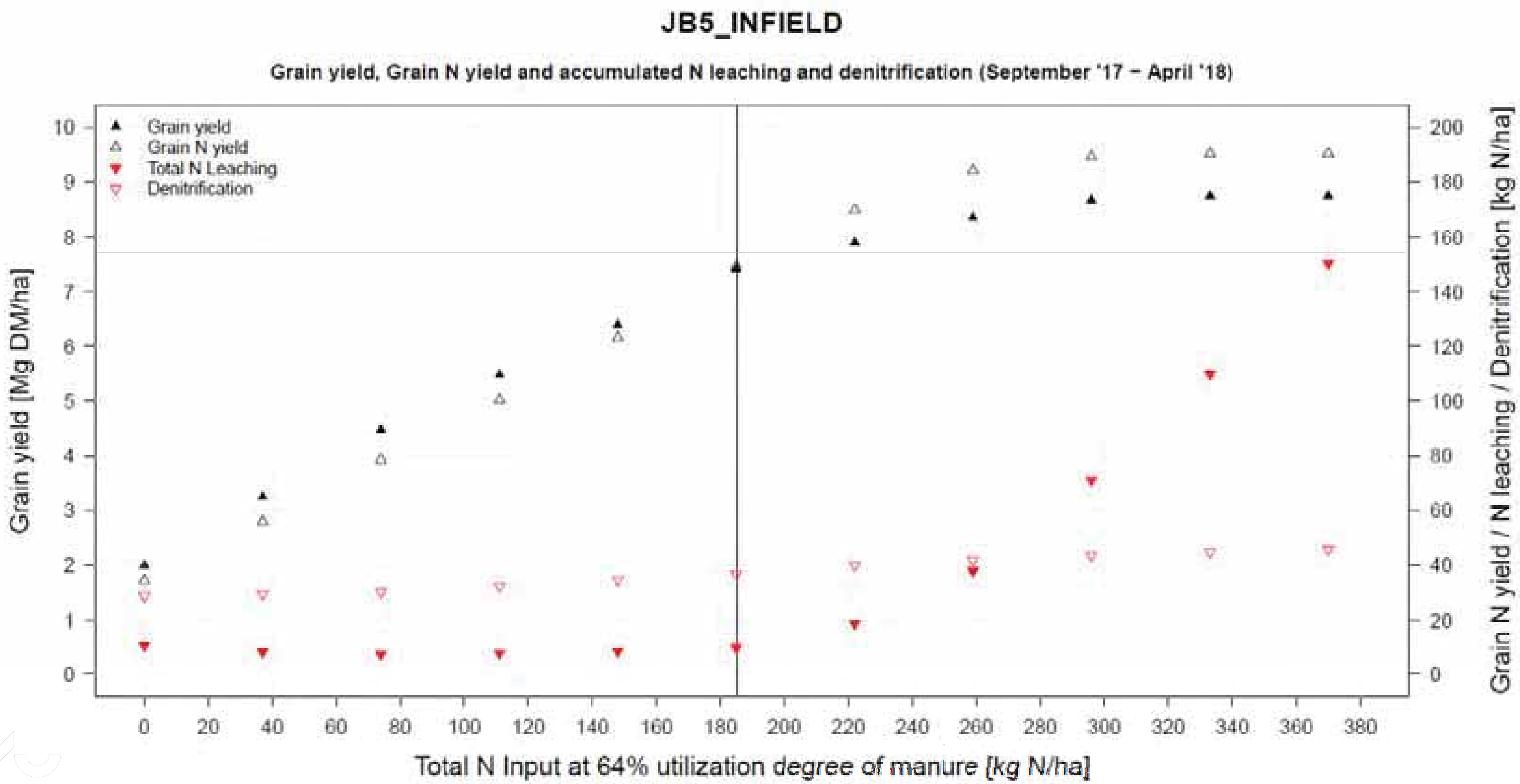
Model configuration require many assumptions

VARIABLE RATE APPLICATION TRENDS

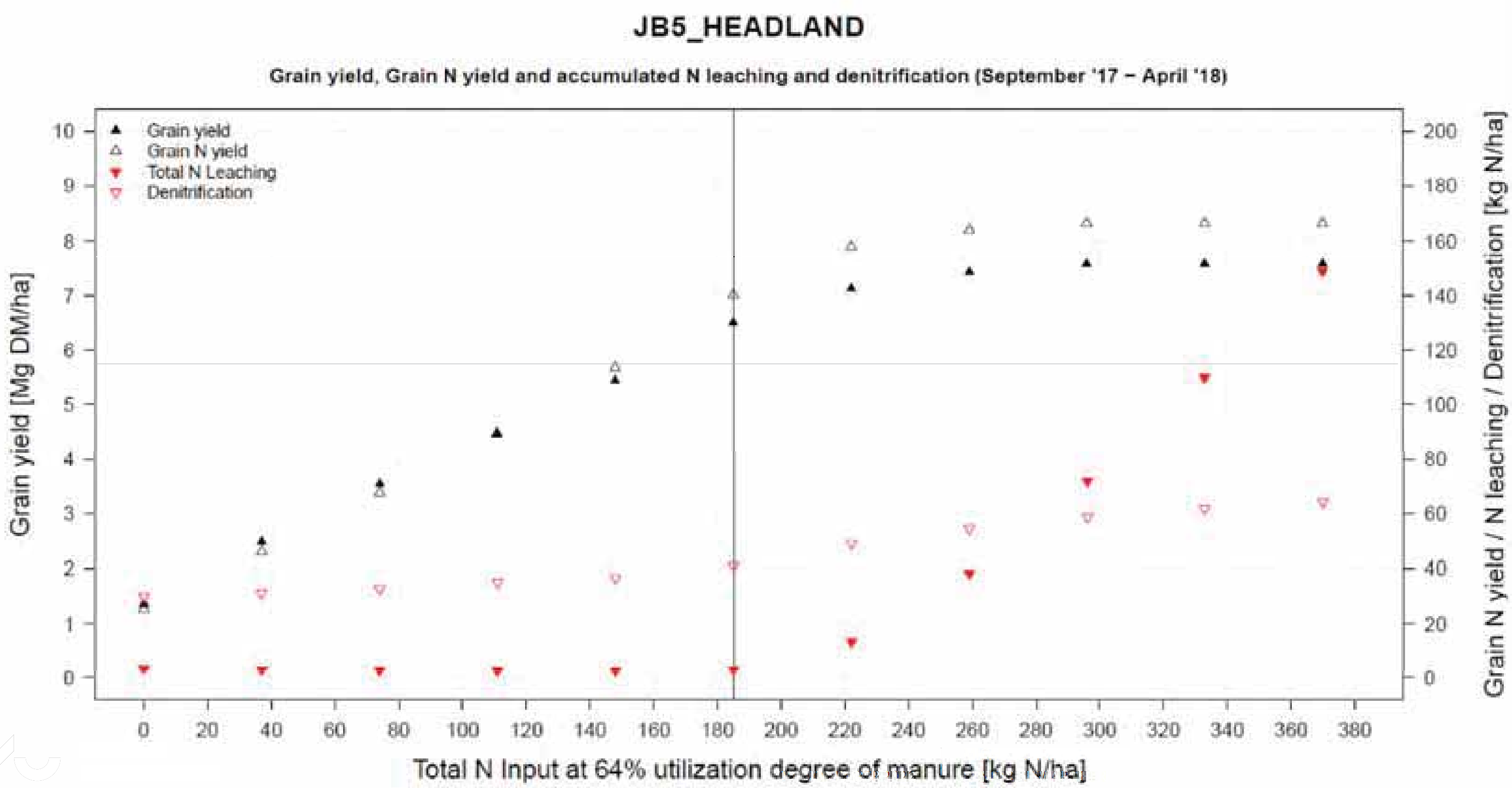




MODELING OF THE SOIL-PLANT-ATMOSPHERE SYSTEM – DAISY AND APSIM



MODELING OF THE SOIL-PLANT-ATMOSPHERE SYSTEM - DAISY AND APSIM



SITE-SPECIFIC APPLICATION OF N – ENV. IMPACT

Based on pilot project participants' reportings (organized by the Danish Agricultural Agency):

- Most widespread crop rotation
- Soil types
- Typical variations in site-specific N supply
- Typical partial field areas with site-specific application of N
- Regional weather data (East/West Denmark)

Particular emphasis has been placed on headland areas, which generally have reduced yield potential, as well as depressions, where both the N dynamics and hydraulic conditions in soil differ from the flat areas.

Soil type	N-application for reference scenario [kg N/ha]		N-application compared to reference [kg N/ha]			
	Norm		Strategi A		Strategi B	
	1. year winter wheat (after winter rapeseed)	2. year winter wheat	1. year winter wheat	2. year winter wheat	1. year winter wheat	2. year winter wheat
JB1 w. irrigation	183	206	0	0	-13	-15
JB2 w. irrigation	183	206	0	0	-13	-15
JB3	156	179	0	0	-11	-13
JB4	162	185	0	0	-12	-13
JB5	189	212	0	+1	-14	-15
JB6	189	212	0	+1	-14	-15

Type 1 field

Subfield type	Area [ha]	Reference N-application	Strategy A (same total N amount)	Strategy B (reduced total N amount)
Headland	1	Norm N	- 30	- 30
Headland depression	0,5		- 30	30
Headland hilltop	0,5		- 30	- 30
Main field	14		+ 5	Norm N
Main field depression	3		- 5	- 30
Main field hilltop	2		+ 5	Norm N
Total area	21			
Total headland area	2 (9,5 %)			

Type 2 field

Subfield type	Area [ha]	Reference N-application	Strategy A (same total N amount)	Strategy B (reduced total N amount)
Headland	3	Norm N	- 30	- 30
Headland depression	0,5		- 30	- 30
Headland hilltop	0,5		- 30	- 30
Main field	50		+ 5	Norm N
Main field depression	4		-20	- 30
Main field hilltop	3		-20	Norm N
Total area	61			
Total headland area	4 (6,6 %)			

SITE-SPECIFIC APPLICATION OF N – ENV. IMPACT

All values in the table are relative to uniform distribution according to the N norm. Rolling crop rotation over the years 2015 to 2018. The table shows the difference between uniform distribution of norm N and strategies A and B respectively.

The N leaching results apply to the first leaching period after harvesting 1st year winter wheat. As the crop rotation was offset by one year in each of the rolling crop rotation scenarios, 2016 and 2017 are represented twice, once with 1st year winter wheat and once with 2nd year winter wheat.

	N leaching (strategy A)				N leaching (strategy B)			
	Type 1 field		Type 2 field		Type 1 field		Type 2 field	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
JB1 w. irrigation[a]	-0,5	0,6	-0,3	0,6	-3,4	-1,7	-1,8	-0,9
JB2 w. irrigation[a]	-0,3	0,5	-0,3	0,5	-3,6	-1,7	-1,9	-0,9
JB3[a]	-0,1	0,4	-0,1	0,6	-2,3	-1,2	-1,4	-0,6
JB4 (sand)[a]	-1,2	0,1	-1,3	0,3	-2,8	-1,3	-1,5	-0,7
JB4 (clay)[b]	-1,0	-0,1	-1,0	-0,1	-4,9	-0,5	-2,7	-0,3
JB5[b]	-0,4	0,1	-0,2	0,2	-5,9	-0,6	-3,2	-0,3
JB6[b]	-0,3	0,3	-0,2	1,0	-5,7	-0,6	-3,1	-0,3

[a] Jyndevad weather data
[b] Flakkebjerg weather data

Conclusions, summarized from notes, data from pilot project participants, latest catalog of N measures and the pilot project simulation results (report not yet published):

- Precision fertilization combined with site-specific application of N based on determination of the nutritional status of crops. N application based on either field variation data in relation to the soil and/or via sensors, in order to determine the actual fertilizer requirement.
  [~1 kg N/ha]
- Precise fertilization, where the application equipment ensures that the fertilizer is applied by means of auto and section control, minimizing overlap when fertilizing
  [~1 kg N/ha]
- It makes sense to analyze the long-term env. impact after the introduction of precision fertilization of N (i.e. perennial accumulation of N leaching after the introduction of precision fertilization)

SUMMARY AND RECOMMENDATION FOR DECISION TO THE DANISH AGRICULTURAL AGENCY

	Below 80 kg N/ha in organic fertilizer	Above 80 kg N/ha in organic fertilizer
Env. impact of catch crops (kg N/ha) (Hansen et al., 2020) *(simple unweighted averages of effect on clay and sandy soils)*	22	35
Env. Impact of precision fertilization (kg N/ha)	2	3,2
Conversion factor (rounded off)	**11:1**	**11:1**

The conversion factors, with the prerequisites and assumptions used in the project in rounded off values, becomes 11:1 both below and above 80 kg N/ in livestock manure. This means that the use of precision farming on 11 ha will be able to replace 1 ha of catch crops

Now implemented in Danish regulation:

- *'Plantedækkebekendtgørelsen', BEK nr 742 af 30/05/2022, The Ministry of Food, Agriculture and Fisheries of Denmark*

Thank you for your attention

AARHUS UNIVERSITET


SLU
SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

Reducing the climate impact of Swedish agriculture - Field tractor electrification

Oscar Lagnelöv, PhD candidate
SLU - Swedish University of Agricultural Sciences
Department of Energy and Technology

SLU

Background

- Agricultural machinery is ~1% of global GHG emissions [1]
- EU: Climate neutral 2050
  - Sweden: Fossil free vehicle fleet 2030
- Agriculture must feed more people, on less land, and be sustainable & profitable

Matthew Kosloki, Unsplash

[1] Tubiello *et al.*, (2015)The Contribution of Agriculture, Forestry and other Land Use activities to Global Warming

Mistra food futures

- *"…enable transformation of the Swedish food system into one that is sustainable (environmental, economic and social), resilient and delivers healthy diets."*
- WP5 - Agricultural systems with net-zero impact of greenhouse gas emissions (in 2045)
- Broad focus – GHG reduction and mitigation potential, implementation rates, system designs, societal changes.
- Broad range of subjects – Animal husbandry, energy production, ley, soil enrichment, fertilizer strategies, machinery…

MISTRA FOOD FUTURES

Reports

Scientific publications

Röös, E., Wood, A., Säll, S., Abou Hatab, A., Ahlgren, S., Hallström, E., Tidåker, P. & Hansson, H. (2023). Diagnostic, regenerative or fossil-free – exploring stakeholder perceptions of Swedish food system sustainability. Ecological Economics. Accepted for publication.

von Greyerz K, Tidåker P, Karlsson J, Röös E. (2023). A large share of climate impacts of beef and dairy can be attributed to ecosystem services other than food production. Journal of Environmental Management 325:116400

Adamie, B., Uehleke, R., Hansson, H., Musshof, O., Hüttel, S. (2022). Dairy cow welfare measures: can production economic data help? Journal of Sustainable Production and Consumption. 32, 296-305.

Guo, A., Bryngelsson, S., Strid, A., Bianchi, M., Winkvist, A., Hallström, E. (2022). Choice of health metrics for combined health and environmental assessments of foods and diets: a systematic review of methods. Journal of Cleaner Production, 365, 132622.

Macura, B., Ran Y., Persson, U.M., Abu Hatab, A., Jonell, M., Lindahl, T and E. Röös. (2022). What evidence exists on the effects of public policy interventions for achieving environmentally sustainable food consumption? A systematic map protocol. Environmental Evidence 11(1):17.

Hammar T, Hansson P-A, Röös E, (2022). Time-dependent climate impact of beef production – can carbon sequestration in soil offset enteric methane emissions?. Journal of Cleaner Production 2022:331

Sieber, P., Ericsson, N., Hammar, T., Hansson, P.-A. (2022). Albedo impacts of current agricultural land use: Crop-specific albedo from MODIS data and inclusion in LCA of crop production, Science of the Total Environment, 2022:835, 155455

Martinsson, E., Hansson, H. (2021) Adjusting eco-efficiency to greenhouse gas emissions targets at farm level – The case of Swedish dairy farms. Journal of Environmental Management. Volume 287, 1 June 2021, 112313.

Bennett, E.M., Biggs, R., Peterson, G.D. and Gordon, L.J., (2021). Patchwork Earth: Navigating pathways to just, thriving, and sustainable futures. *One Earth*, *4*(2), pp.172-176.

Röös, E., Bajzelj, B., Weil, C., Andersson, E., Bossio, D. and Gordon, L.J., (2021). Moving beyond organic – A food system approach to assessing sustainable and resilient farming. Global Food Security, 28, p.100487

Lagnelöv, O., Larsson, G., Larsolle, A., & Hansson, P.-A. (2021). Life Cycle Assessment of Autonomous Electric Field Tractors in Swedish Agriculture. Sustainability, 2021:13, 11285

Electric and Autonomy

Electric

+ High driveline efficiency

+ Fuel independance

+ Low GHG emissions

+ Reduced maintenace

- ~~Low energy carrying capacity~~

- ~~Frequent refuelings~~

- ~~Heavy vehicles~~

Autonomous (self-driving)

+ 24h-operation

+ Frees up qualified labour

+ Lower vehicle weight – less compaction

+ Good economic potential

- Legally a grey area

- Technical complexity

- ~~No emission reduction~~

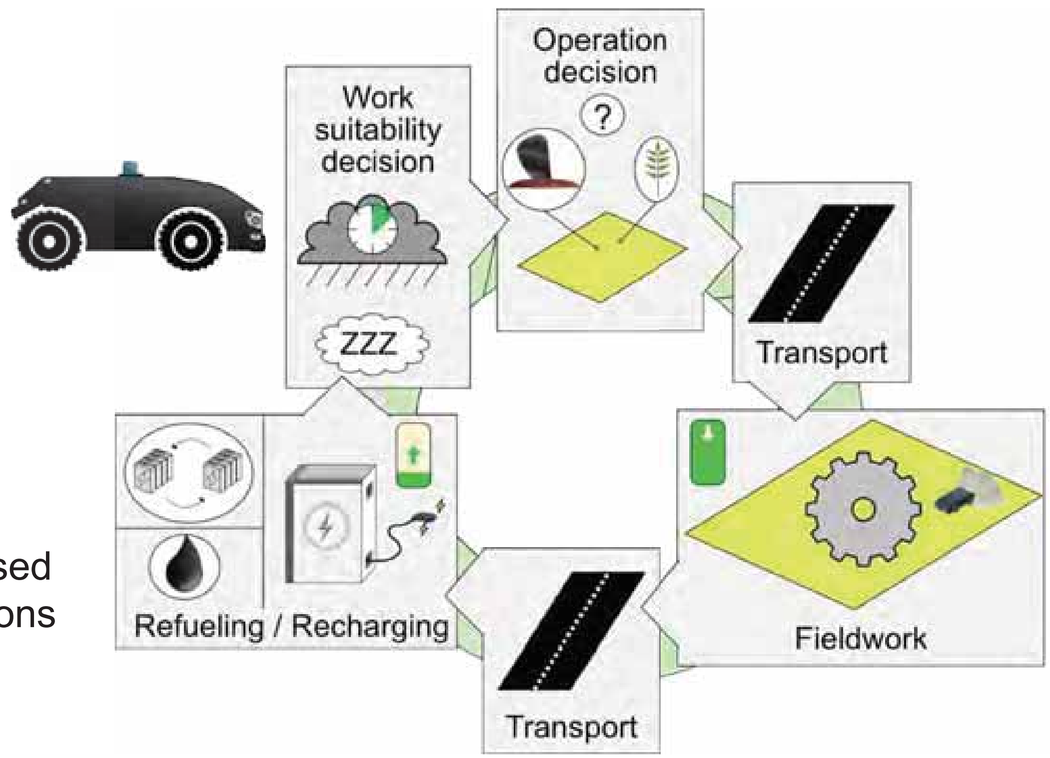
Synergetic effects

Simulation model

Inputs

- Vehicle…
- Battery…*
- Charger…*
- Field…
- Weather…
- Soil compaction

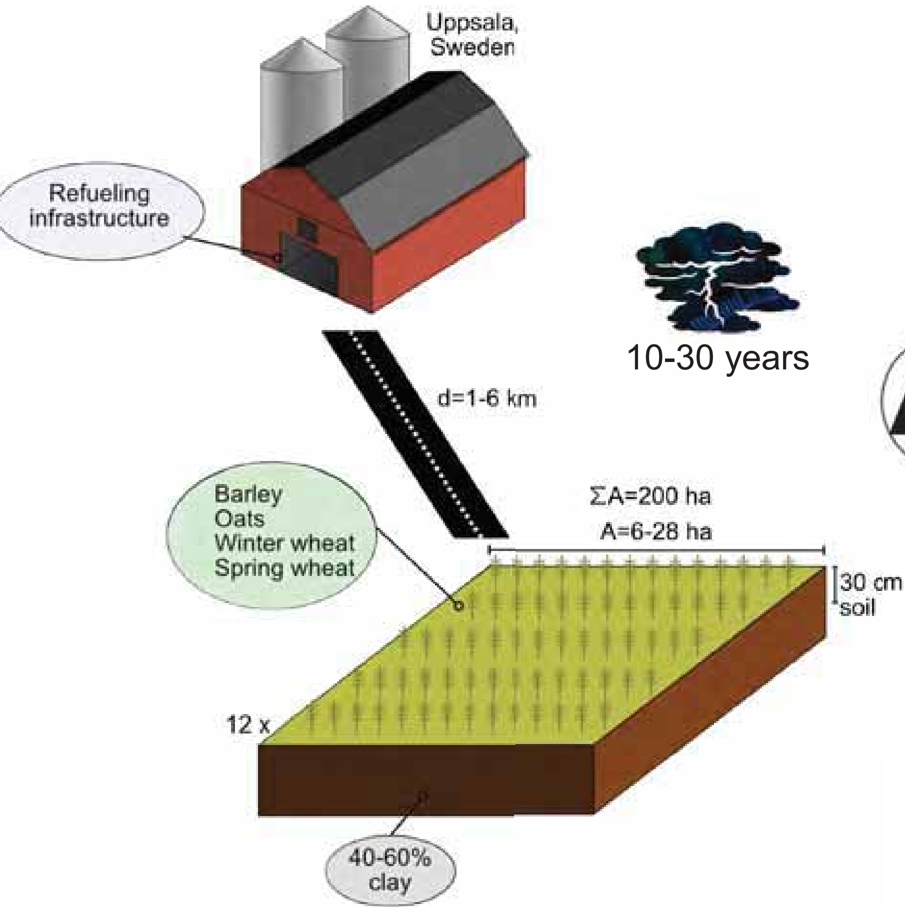
- Modules were based on ag.eng. equations

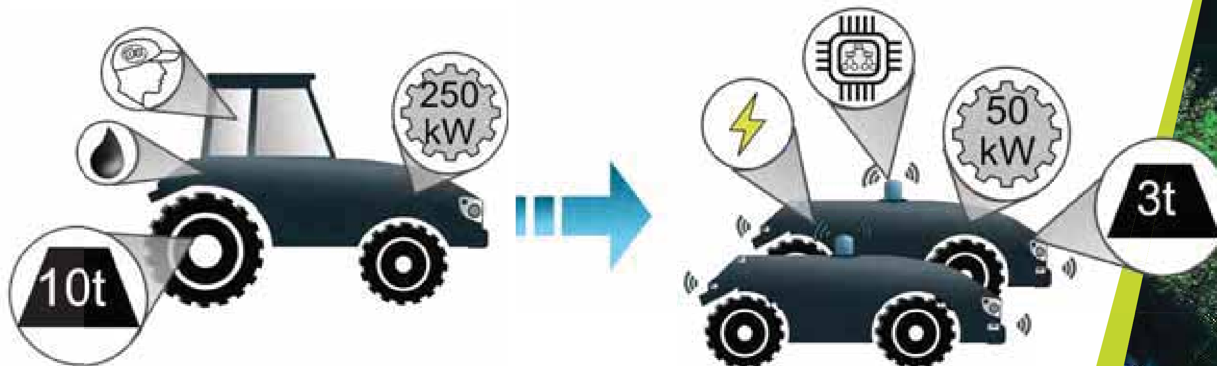


Outputs

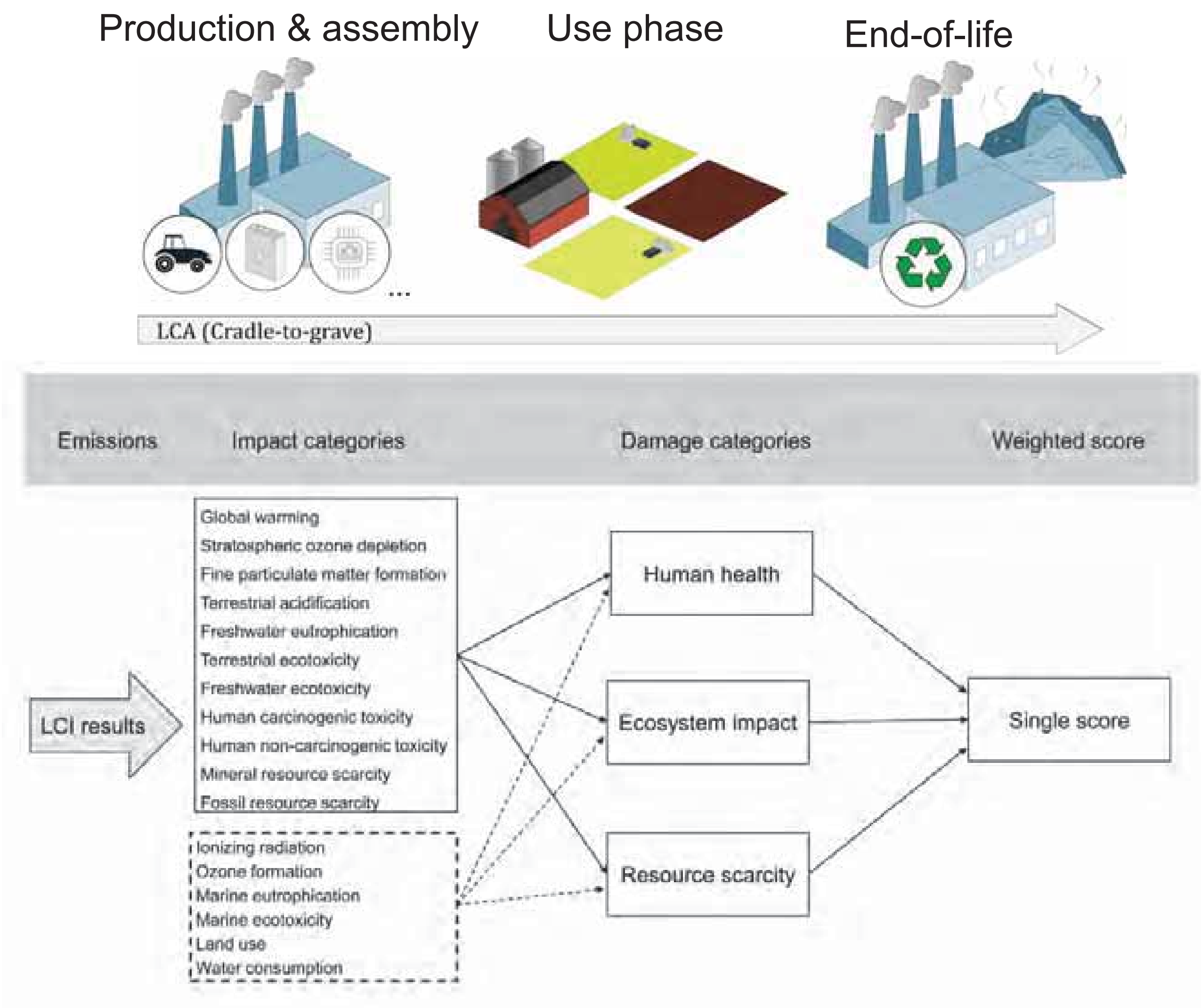
- Energy use
- Number of refuelings
- Time required
- Operational cost
- Environmental impacts
- …and much more

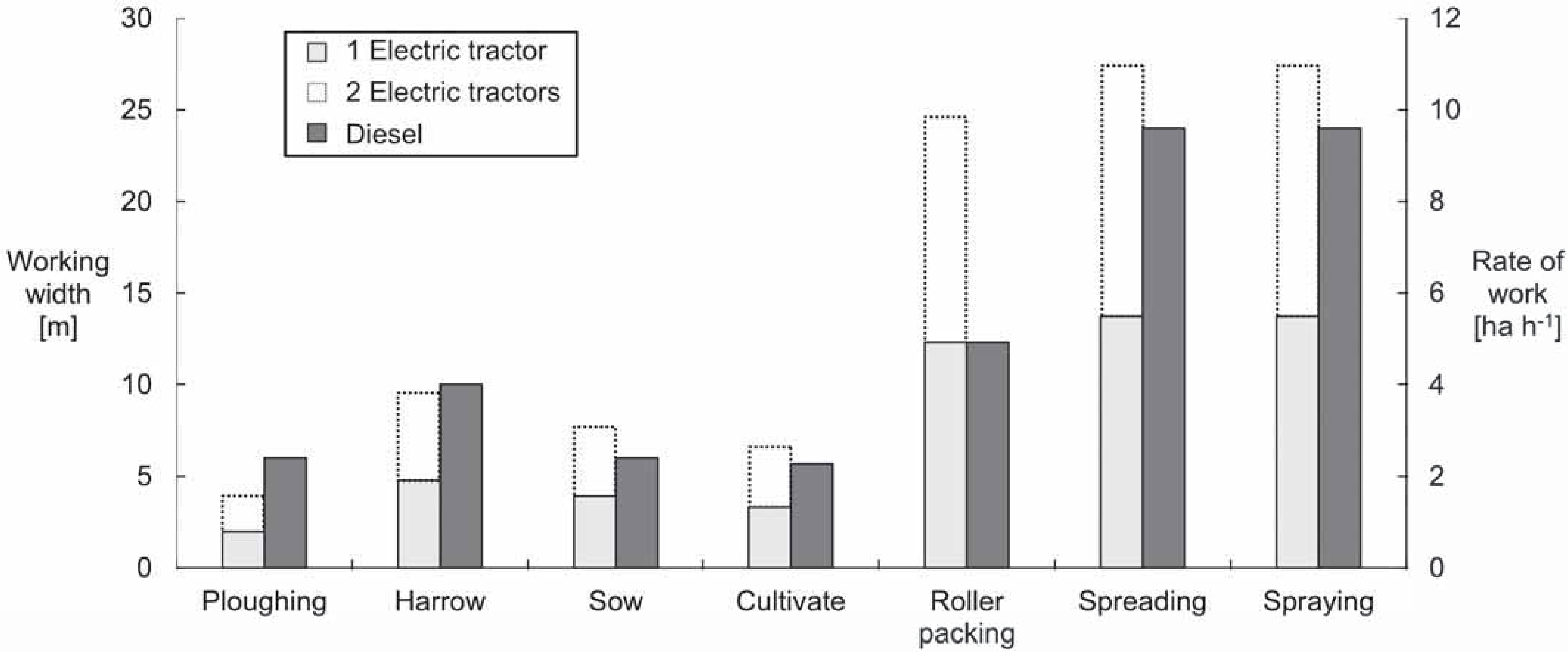
Inputs


Uppsala, Sweden
Refueling infrastructure
10-30 years
d=1-6 km
ΣA=200 ha
A=6-28 ha
Barley
Oats
Winter wheat
Spring wheat
30 cm soil
12 x
40-60% clay


250 kW
10t
50 kW
3t

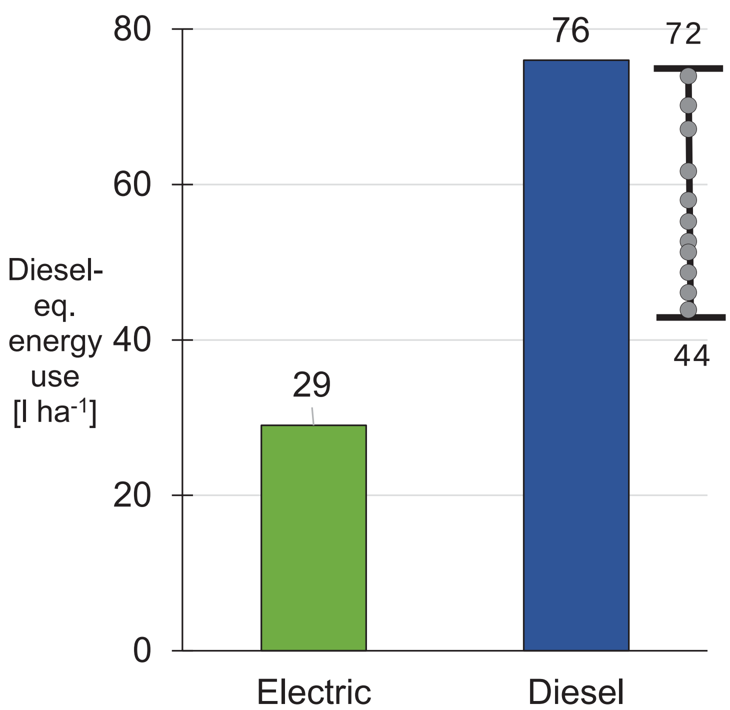
LCA

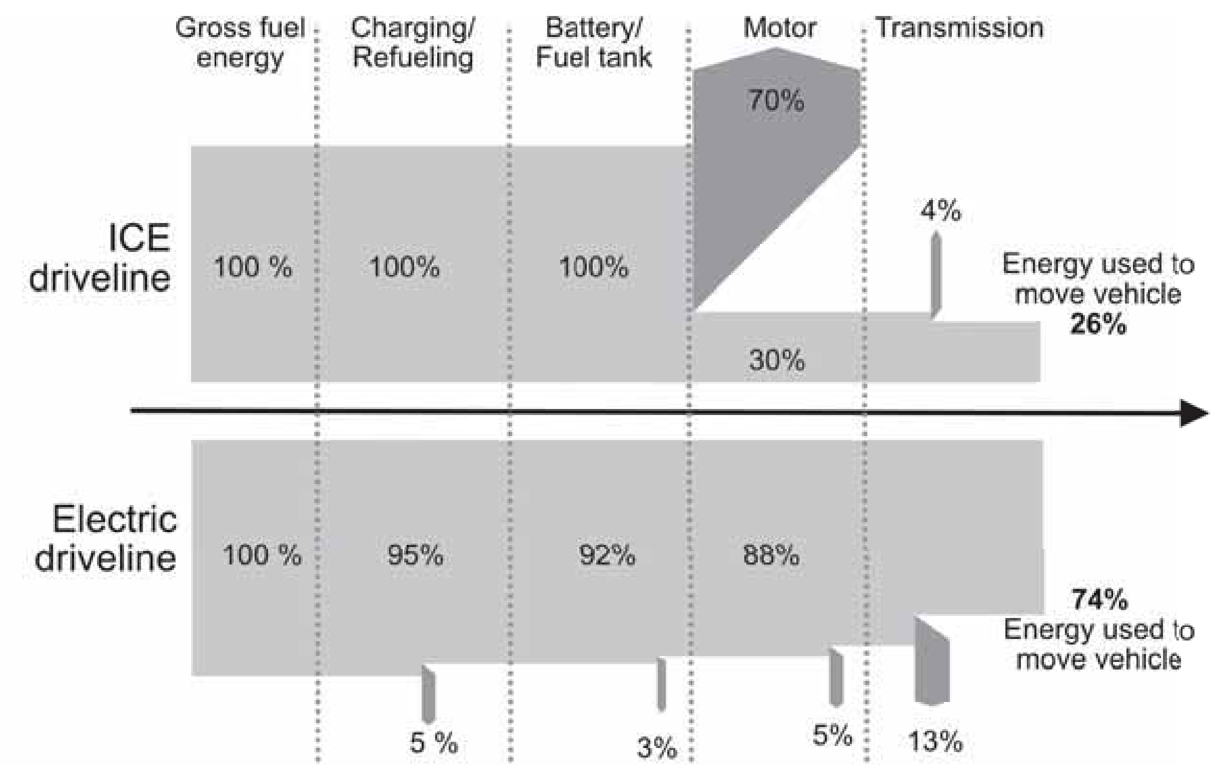

Production & assembly
Use phase
End-of-life
...
LCA (Cradle-to-grave)
Emissions
Impact categories
Damage categories
Weighted score
LCI results
Global warming
Stratospheric ozone depletion
Fine particulate matter formation
Terrestrial acidification
Freshwater eutrophication
Terrestrial ecotoxicity
Freshwater ecotoxicity
Human carcinogenic toxicity
Human non-carcinogenic toxicity
Mineral resource scarcity
Fossil resource scarcity
Ionizing radiation
Ozone formation
Marine eutrophication
Marine ecotoxicity
Land use
Water consumption
Human health
Ecosystem impact
Resource scarcity
Single score



Working width [m]
Rate of work [ha h-1]
1 Electric tractor
2 Electric tractors
Diesel
30
25
20
15
10
5
0
12
10
8
6
4
2
0
Ploughing
Harrow
Sow
Cultivate
Roller packing
Spreading
Spraying

Energy use

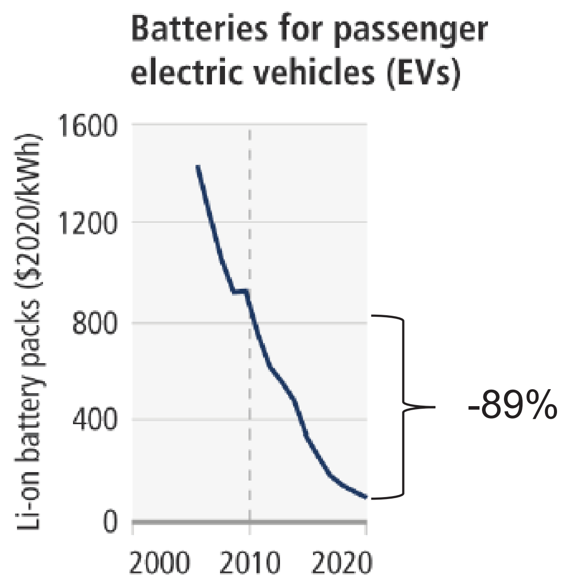

Diesel-eq. energy use [l ha-1]
80
60
40
20
0
76
72
44
29
Electric
Diesel


Gross fuel energy
Charging/ Refueling
Battery/ Fuel tank
Motor
Transmission
ICE driveline
100 %
100%
100%
70%
4%
30%
Energy used to move vehicle
26%
Electric driveline
100 %
95%
92%
88%
74%
Energy used to move vehicle
5 %
3%
5%
13%

Economy

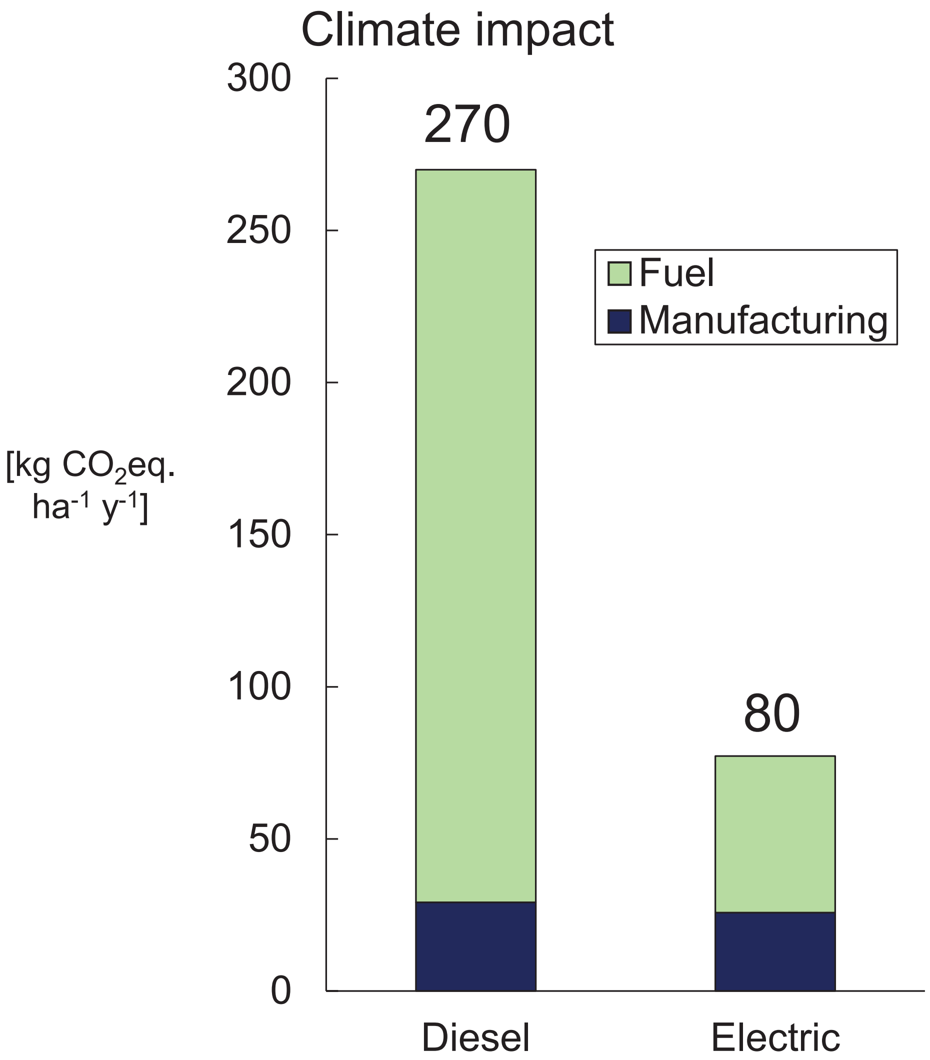
- Higher investment costs
  - Batteries
  - Infrastructure
  - Autonomous drive – costs uncertain
- Lower operational costs
  - Operator
  - Fuel
- 32-37% reduction in total annual cost
  - Compared to conventional tractor

Operator	↓
Fuel	↓
Maintenance	↓
Battery cost	↑
Timeliness	↓↑
Investment	↑
Yearly cost	↓



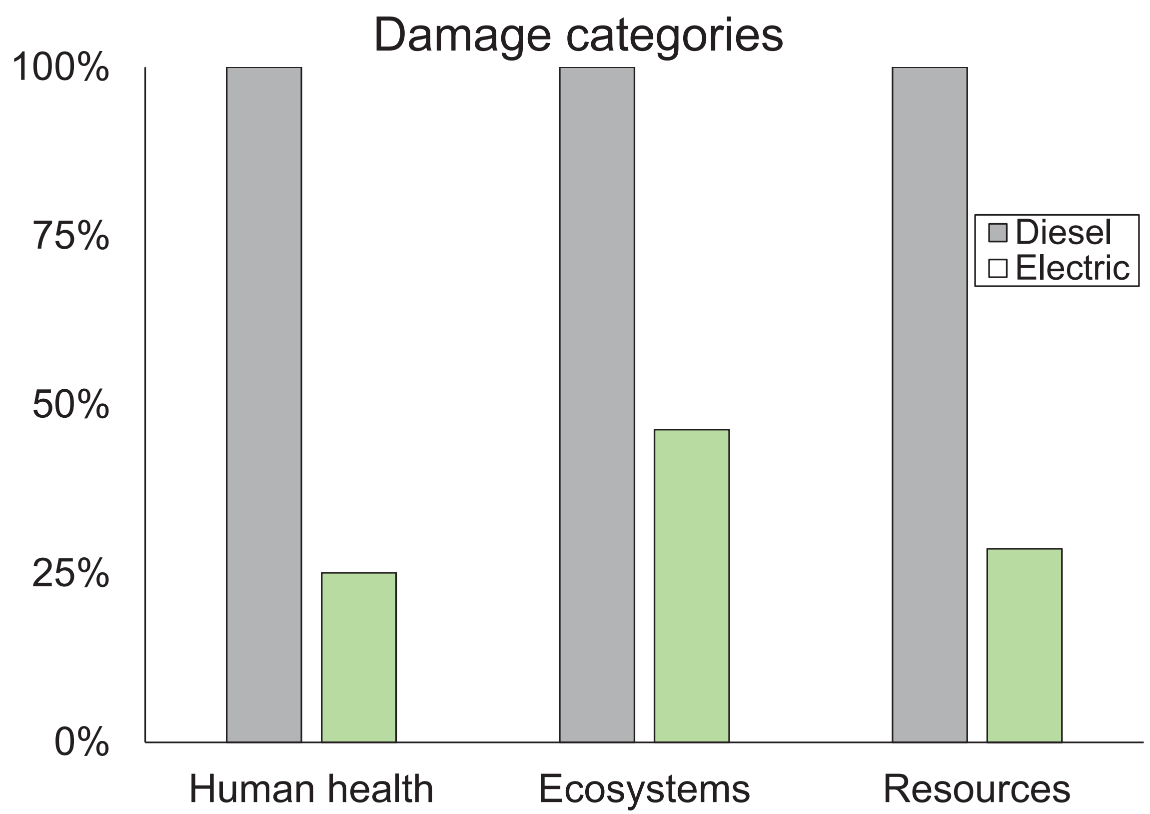
Climate impact

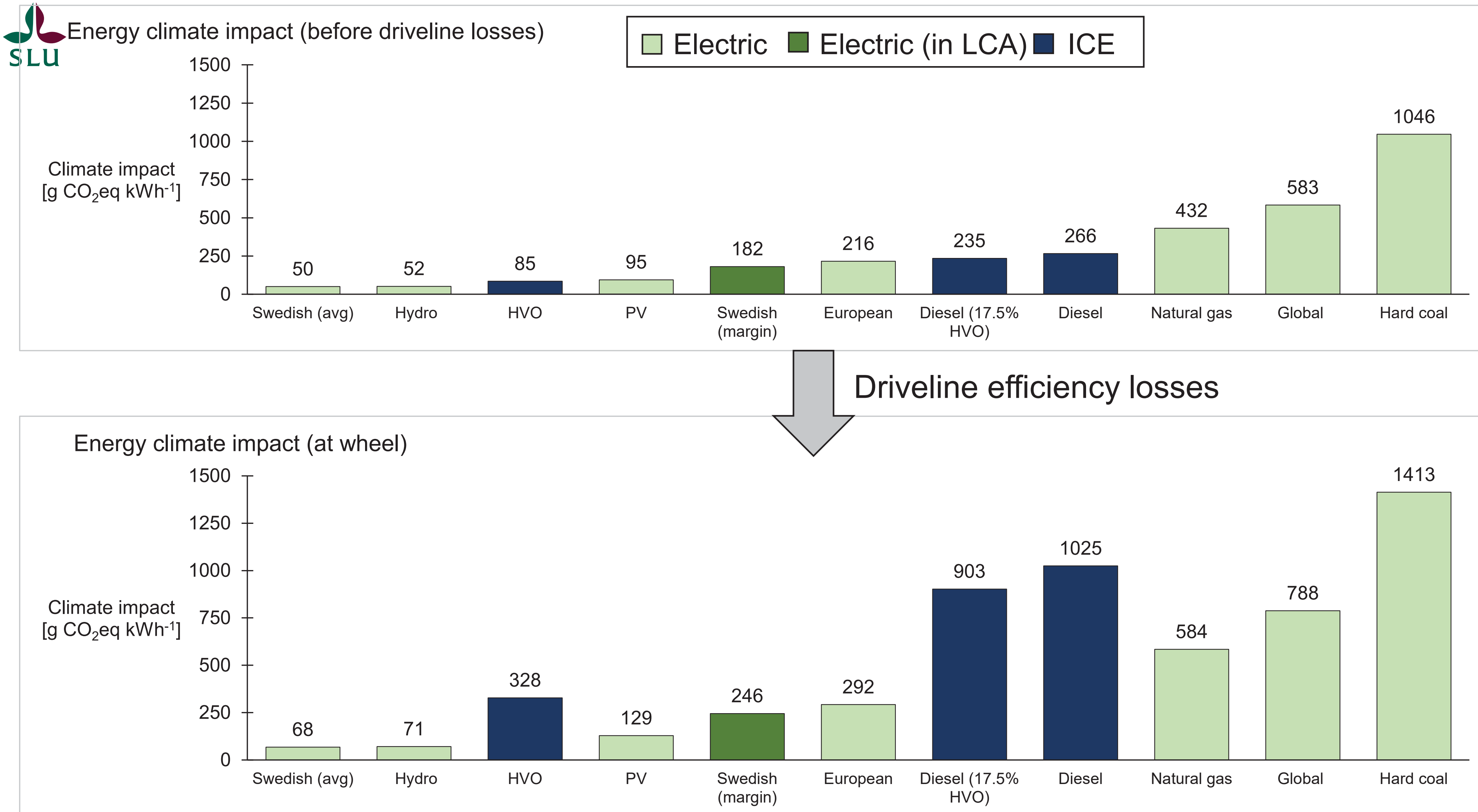
- The electrc tractor had 71% lower impact
- Battery production had a strong impact.
  – As did heavy vehicles
- Fuel choice was the most important factor
  – Diesel 100% (no mix-in)
  – Swedish marginal electricity mix
  – 41 % natural gas,
    35 % wind,
    24 % biomass



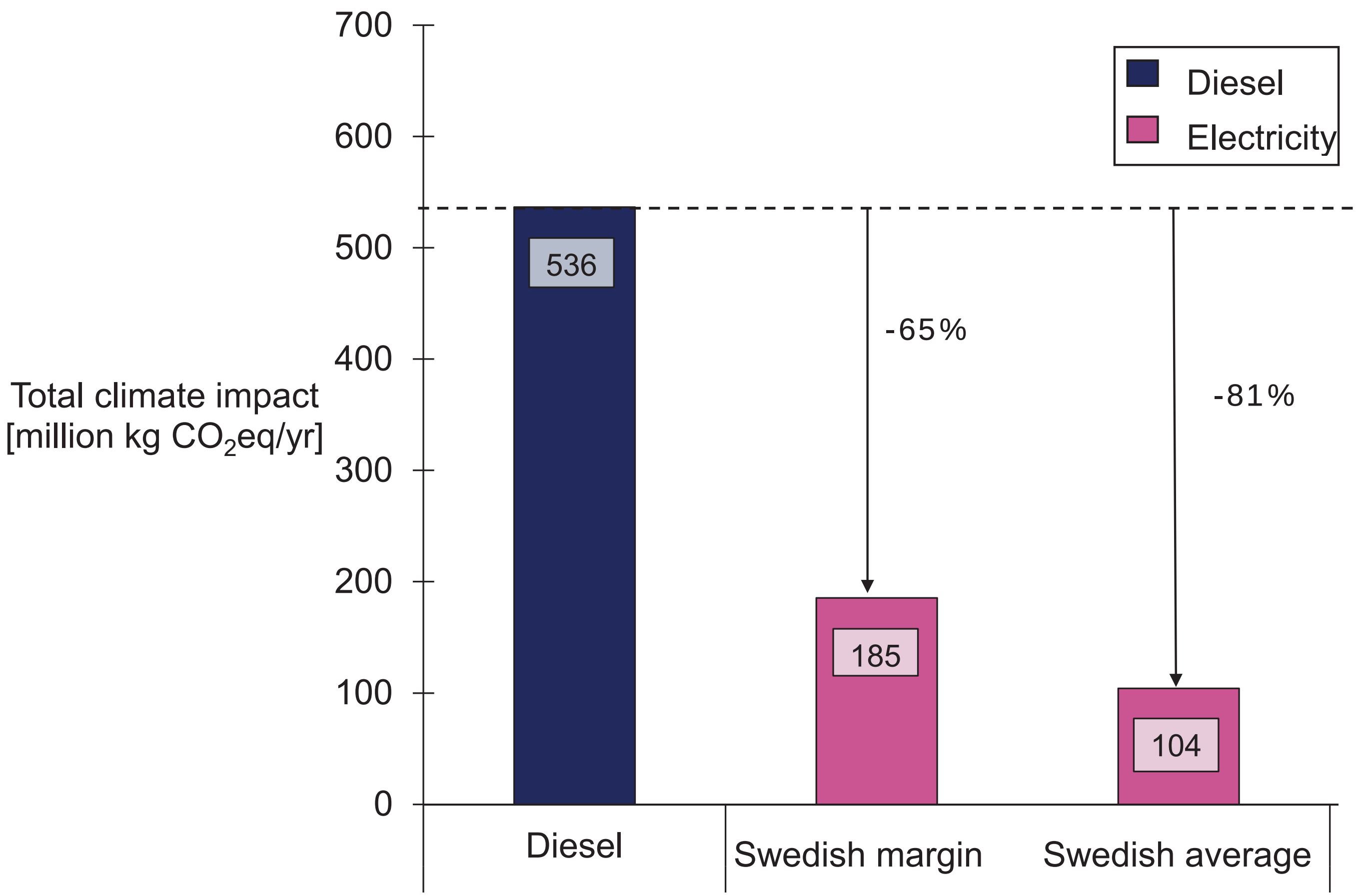
Damage impact

- Electric tractors showed big reductions in all categories
- Fuel very impactful
- The same reduction was seen in the single point score




SLU
Energy climate impact (before driveline losses)
Electric
Electric (in LCA)
ICE
Climate impact
[g CO_2eq kWh^{-1}]
1500
1250
1000
750
500
250
0
50
52
85
95
182
216
235
266
432
583
1046
Swedish (avg)
Hydro
HVO
PV
Swedish (margin)
European
Diesel (17.5% HVO)
Diesel
Natural gas
Global
Hard coal
Driveline efficiency losses
Energy climate impact (at wheel)
Climate impact
[g CO_2eq kWh^{-1}]
1500
1250
1000
750
500
250
0
68
71
328
129
246
292
903
1025
584
788
1413
Swedish (avg)
Hydro
HVO
PV
Swedish (margin)
European
Diesel (17.5% HVO)
Diesel
Natural gas
Global
Hard coal

National potential



- Results scaled up
  - Ley, grains & other
  - Clay and sand soils
- 2-3% of Swedens transport GHG emissions

Conclusions

- Electric tractors requires larger investments, but have lower operational cost
  - Economically (-1/3) & environmentally (-2/3)
- Fuel is the largest climate factor for both diesel and electric tractors
  - ”Cleaner” fuel & redcued energy use possible
- Battery optimizations are important factors
  - Not one size fits all
- Autonomy is a key driver, but electric tractors can compete and provide benefits.
  - Many ”hidden” benefits

SLU

Thank you for you attention!

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SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE


SLU
SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

A low-cost robot platform for swarm applications in agriculture

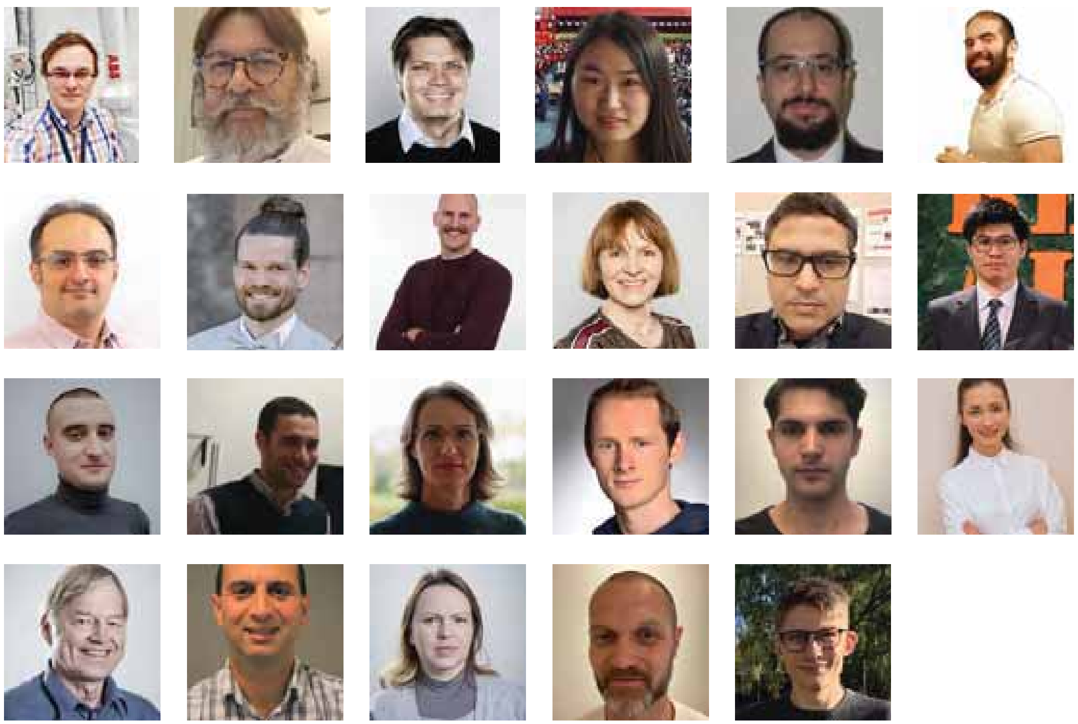
Robert Braunschweig

29.11.2022

Agenda

1. NMBU Robotics Group
2. Background and Motivation
3. Swarm Robot Platform
4. Future Research

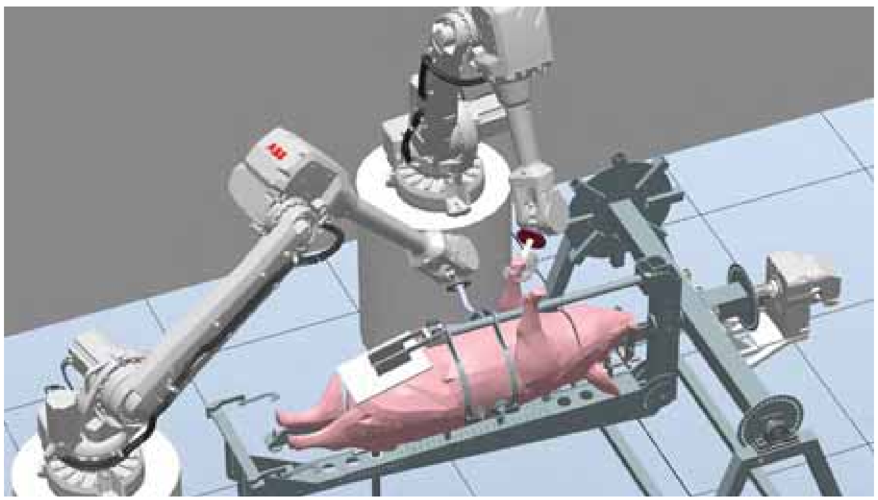
1. NMBU Robotics Group



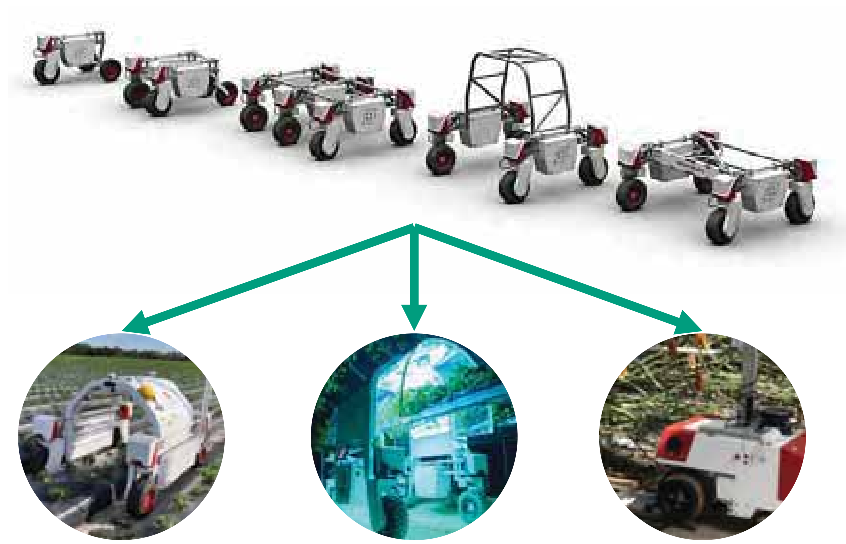
- 2 main themes in the agrifood value chain *on farm* and *food rocessin*
- Currently ca. 25 members including academic staff, PhD students and administrative/technical support
- Research underpins NMBU's 5-year master programme in *lied obotics*

1. NMBU Robotics Group

RoBUTCHER – A Robust, Flexible and Scalable Cognitive Robotics Platform



Thorvald – Modular Robot Platform for Agriculture



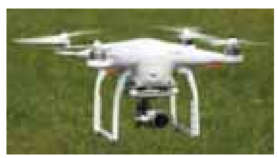
Open Fields Polytunnels Greenhouses

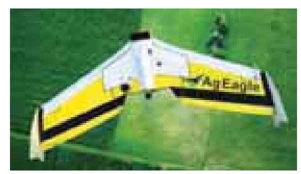
2. Background and Motivation

Robots in Agriculture

- UGV
- UAV
- Special

Fendt





Panasonic

NMBU

2. Background and Motivation

Small:

EarthSense TerraSentia

- Commercial sensiing and phenotyping platform
- RTK GPS, Camera, IMU, Encoder, 2D/3D Lidar
- Light, low-cost, easy to use

Medium:

Saga Robotics Thorvald

- Robust, commercially avaiable products
- Weight: ca 200 kg, Payload: ca 150-250 kg
- RTK GPS, Camera, -IMU, Encoder, 2D/3D Lidar

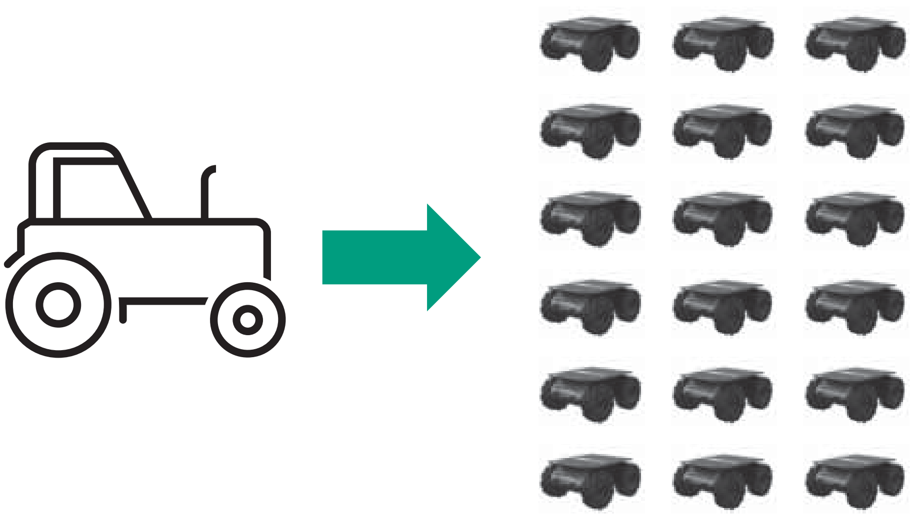
Large:

AutoAgri IC Series

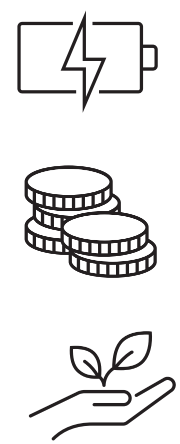
- Pilot and research platform
- Weight: ca. 2500kg, Payload: ca. 2000 kg
- RTK GPS, Cameras, Flexible mounting of own equipment (tractor replacement)

2. Background and Motivation

Can a swarm of small robots
replace a tractor or bigger robot?



Improvements in costs,
reliability, sustainability?



2. Background and Motiviation

- Inspiration for project:
  - MARS/XAVER project led by Fendt
  - Research since 2015, now commercializing
  - Focus on precision seeding
  - <40 kg, ca. 50x40 cm

Copyright: Agco GmbH

3. Swarm Robot Platform

Pros

- **Costs:**
  - Low HW costs, scalability
  - Low energy costs, lightweight
  - Less human labour
- **Sustainability:**
  - No soil compaction
  - Fully electrified
  - Site-specific operation
  - Redundant system
- **Safety:**
  - Low weight and power

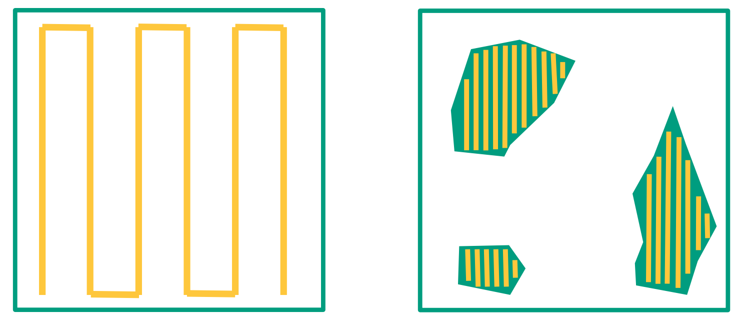
Cons

- Software complexity
- Limited number of applications
- No standard equipment

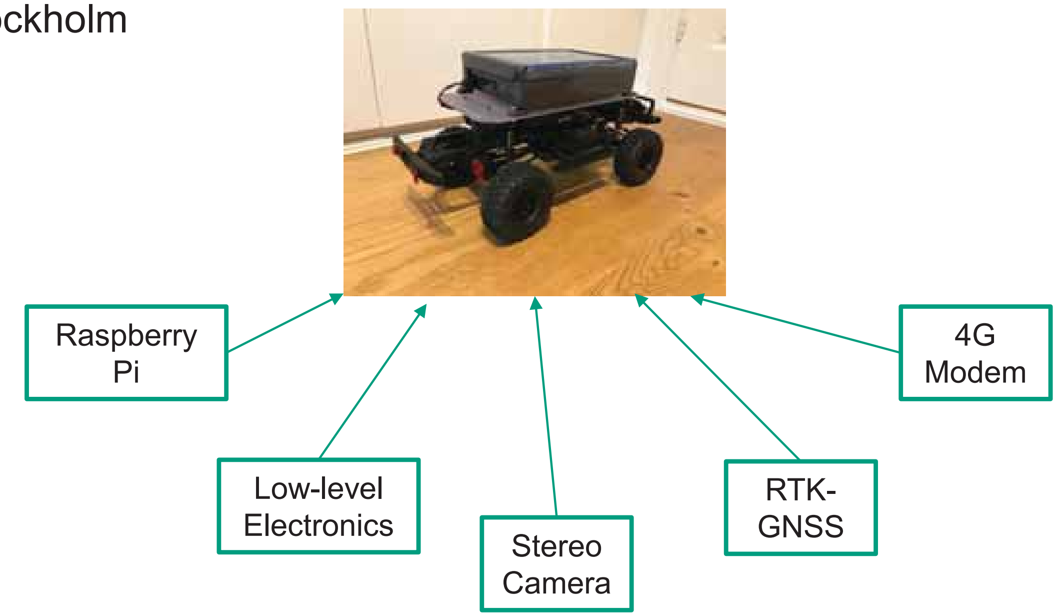
3. Swarm Robot Platform

Applications

- Precision seeding (time/space dependent)
- Mechanical weeding
- Sensing/phenotyping
- Site-specific treatment



3. Swarm Robot Platform



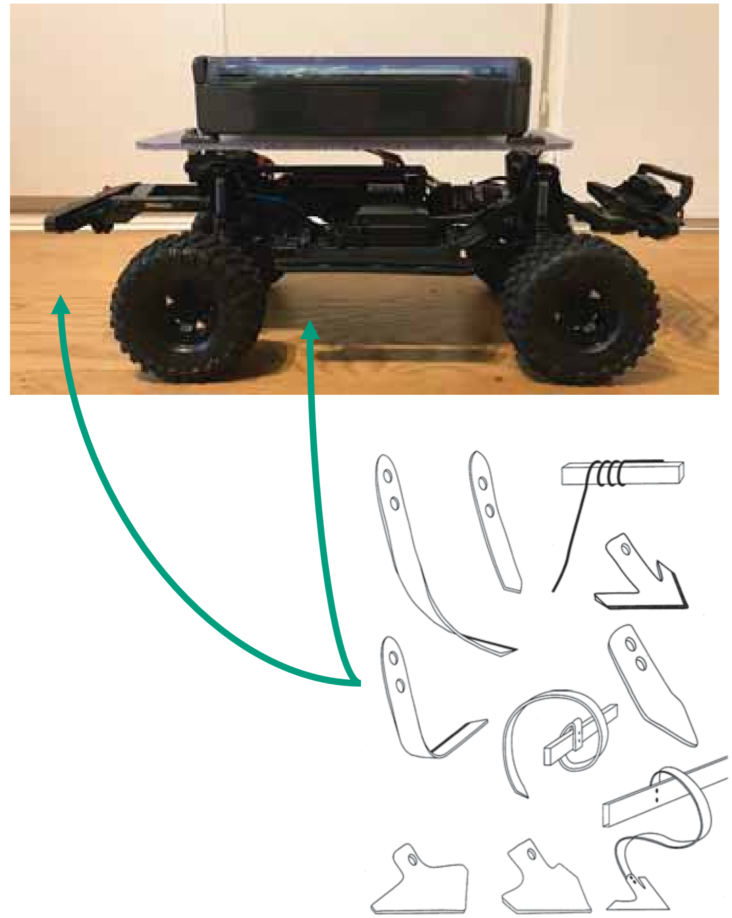
- Mobile ground robot based on Traxxas RC car:

  Small **Ve**hicles for **A**utonomy (SVEA), KTH Stockholm
- Adapted for outdoor application
- Pros:
  - Cheap and robust mechanics
  - Off-the shelve components
  - ROS compatible

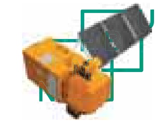
Size (LxWxH)	55 x 25 x 24 cm
Weight	3.5 kg
Price	~ 1500 €

3. Swarm Robot Platform

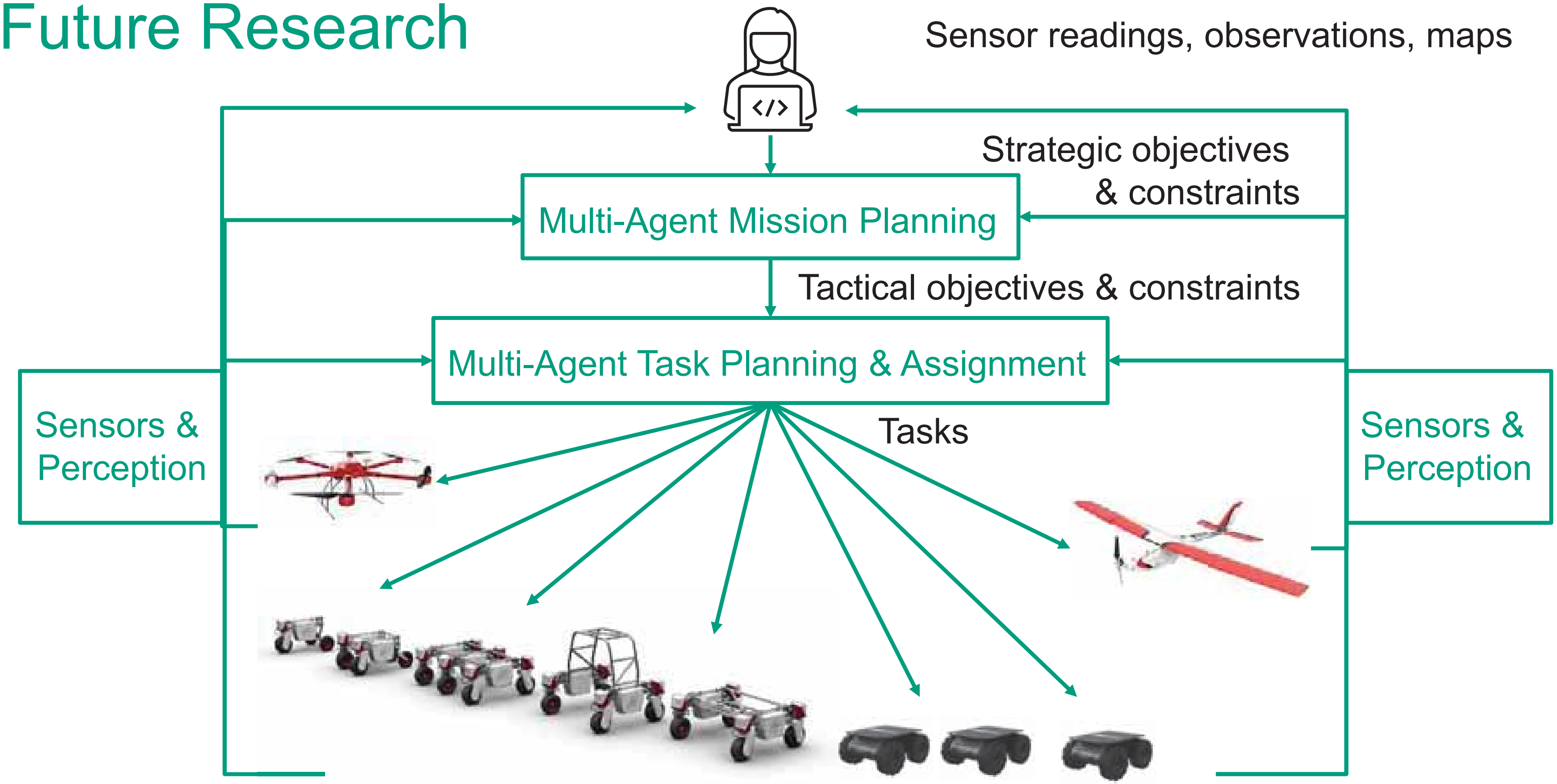
Ongoing work



- Robust design
- Mounting option for weeding tools
- Traction, speed, endurance tests
- Energy monitoring
- Navigation by GPS and camera



4. Future Research



Thank you for your attention

Smart   arming and   reen Innovation
- a plattform for sustainable agriculture

Nils Bjugstad
REALTEK NMBU

Outline

The objectives of the plattform

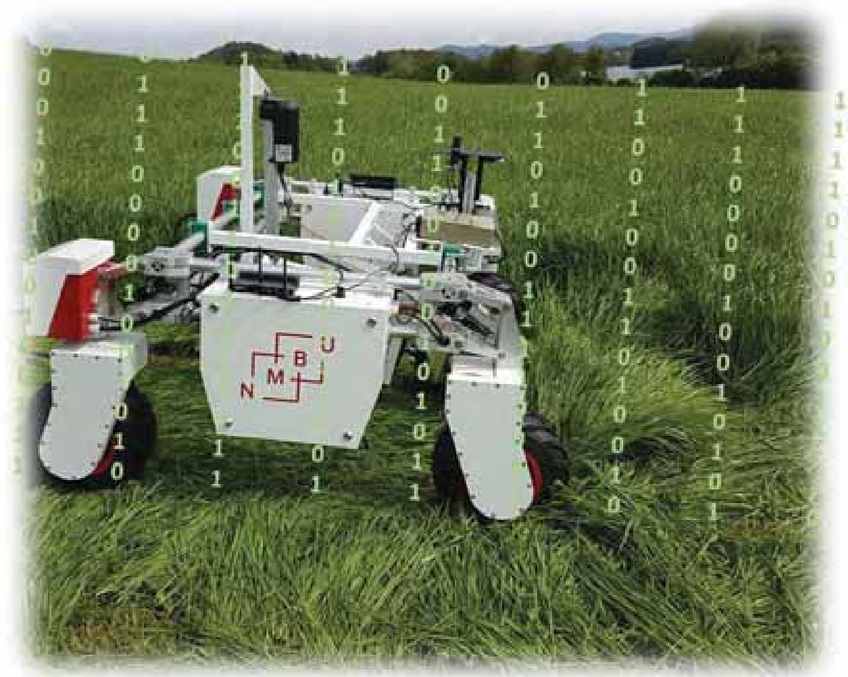
Interdisplinerary topics within education and research

Field robotics in Norway

Green Innovation Student LAB

GrasRobotics

Introduction to other projects within Smart Farming




2 ZERO HUNGER
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND

Funding– «Smart farming and green innovation»

ear				
NOK	700.000	700.000	700.000	2.800.000

Research groups within, robotics, drones, precision agriculture, GIS and GNSS, sensors, image analysis, computer science, phenotyping, plant sciences, fertilizer sciences and soil sciences are included in the group, which can also be expanded as needed.

Goals within «Smart farming and green innovation»

Main goals:
Develop a strong and complementary professional environment within "Smart Farming and Green Innovation" at NMBU. The academic community at NMBU will be a national leader with interdisciplinary knowledge and have well-developed networks with top international environments. An active and targeted collaboration will be developed with the business sector to increase the use of "Smart Farming", increased innovation and strengthened training of students and candidates. NMBU as a sustainability university will be strengthened.

Research:
Over a four-year period, the group will have initiated several strong research projects. The goal is to develop an SFI (Centre for Research-based Innovation), or equivalent a larger long-term research programme, together with user organisations and other related academic communities in Norway.

Education:
The goal is to develop the **Green Innovation Student Lab** (GISL) where interdisciplinary students and researchers at NMBU together with the business community create new innovative solutions for sustainable agriculture. GISL holds both demo/experimental fields, access to sensors and other research infrastructure. Students will participate in research early in their studies.

Master's theses, internships etc. are linked to innovative solutions and Smart Farming in cooperation with the business community. Relevant master's and PhD students come from robotics, image analysis and physics, computer science, geomatics, plant, soil and economics sciences.

Innovation:
The aim is to strengthen innovation activities for students and employees both by having outstanding research and teaching, but also through systematic development of cooperation with business and external actors. New knowledge and research-based ideas will be developed and commercialised through a strengthened culture of entrepreneurship for the benefit of business and society.

DEVELOPMENT OF AGRICULTURE

TECHNOLOGICAL REVOLUTIONS

1.0 WORK-INTENSIVE

- Work intensive
- Low productivity
- 1/3rd of population involved-required

2.0 GREEN REVOLUTION

- Artificial fertilizers
- pesticides
- More efficient equipment
- Productivity dramatically increased

3.0 PRECISION AGRICULTURE

- Precision operations within crops
- Individual treatment of animals vs total flock
- Automatic steering with 10mm precision
- Sensors and controls

4.0 SMART FARMING

- Internal and external network integration of agricultural operations
- Cloud service usage, large data sets processed
- Cheap and advanced sensors
- Big data analytics
- New algorhythms that transform raw data into insight

5.0 ROBOT FARMING

- Operations without human presence
- Artificial intelligence, self-learning systems
- Production systems adapted to plant/animal needs
- Food production, consumer needs fulfilled
- Controls of ingredients/ internal components

Science and Technology master studies at NMBU related to SF

Geomatics

Applied robotics

Engineering, processing and product developement

Data science

Physics (especially imaging and energy technology)

Plant science

Soil science

Others

Research groups and topics

REALTEK	BIOVIT and MINA

SKP – Centre for Plant Research in Controlled Climate (senter forklimaregulert planteforskning)
SHF – The lifestock Production Research Centre (senter for husdyrforsøk)

What is **reen Innovation Student LAB**?


Bærekraftsarena
Smart Farming
Grønn Innovasjon
Student LAB

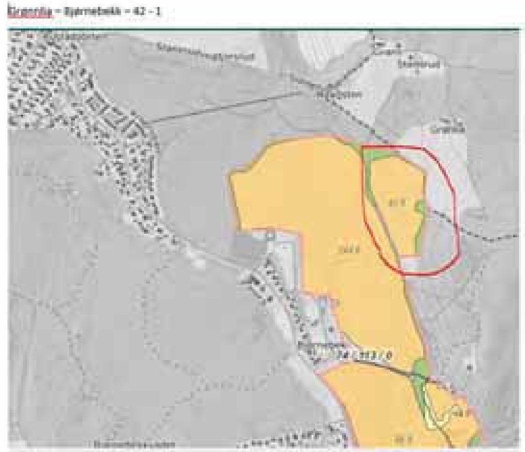

Bærekraftsarena
Smart Farming
Smart Farming | Grønn Innovasjon
Green Innovation Student LAB

Pilot areas for education and research at NMBU

20 daa Kjærringjordet

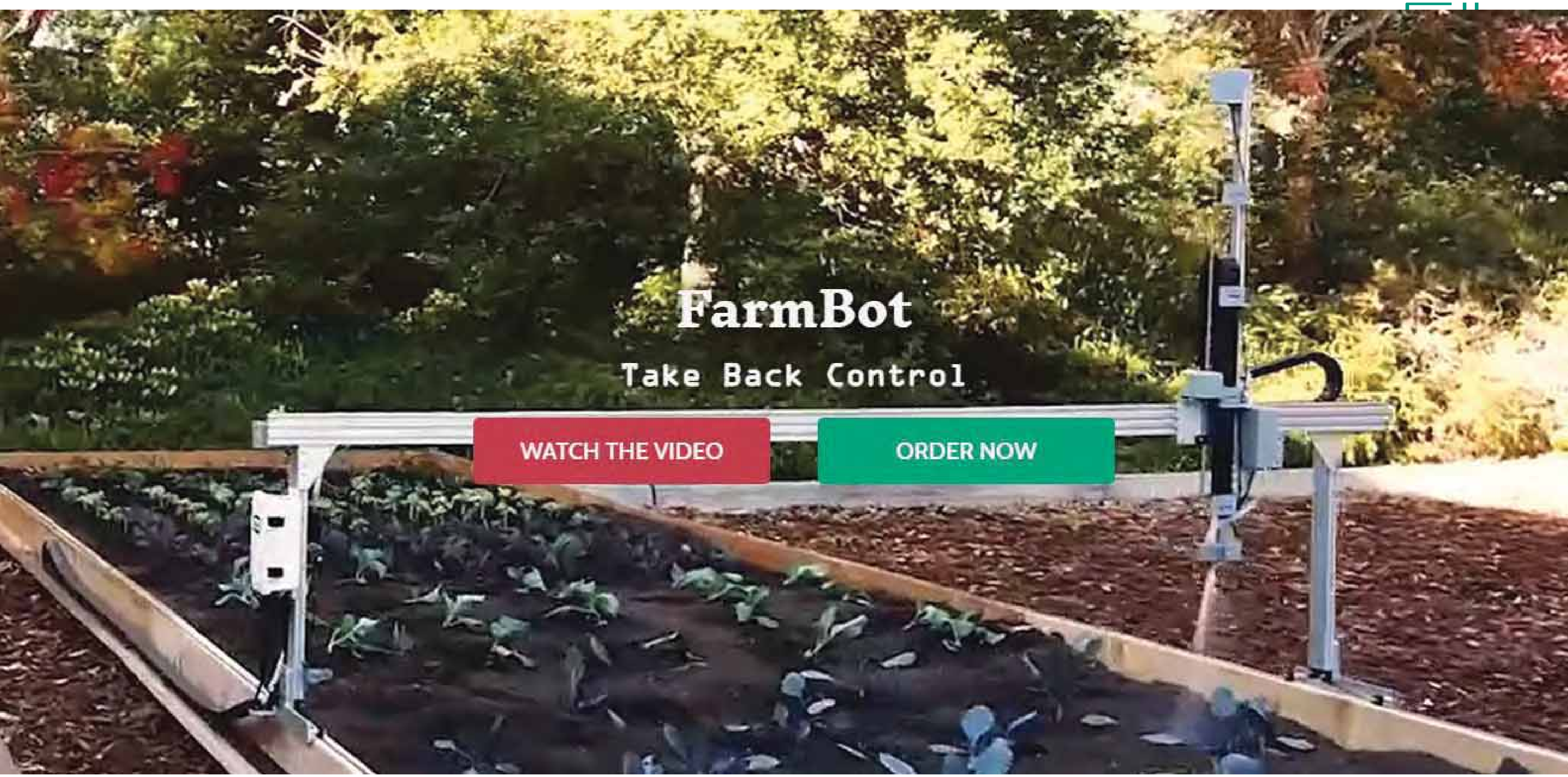
14 daa Vollebekk

Grønnlia – Bjørnebekk – 42 - 1



Grønnlia – 42 daa
Høybråtan – 20 daa

Høybråtan – Sørås – 42 - 1


FarmBot
Take Back Control
WATCH THE VIDEO
ORDER NOW


naio


autoagri


vocativ


THORVALD II

DAT

DAT

HOME HOW IT WORKS BENEFITS ABOUT DAT CONTACT

Benefits of precision spraying

Conserve herbicide

Experiments have shown that a typical barley or oats farm can reduce its herbicide consumption by 50%.

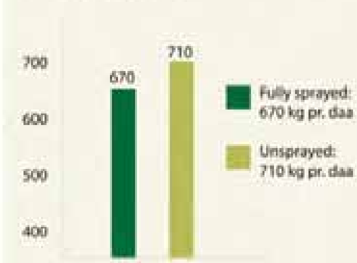
Provided a herbicide cost of NOK 300 / EUR 30 per ha, a 500 ha farm will save NOK 150 000 / EUR 15 000 per season.

Increase yields

We have observed that non-sprayed areas of barley and oats have a yield increase of 6-7%.

This will result in increased sales value of NOK 500 / EUR 20 per ha. For a 500 ha farm: NOK 250 000 / EUR 10 000.

Field trials in barley and oats indicates 6-7 % yield increase.



Harvest quantities registered by

Projects within smart farming to be presented at this seminar

Presentations Smart Farming Sustainable Plattform NMBU	**Speakers**
A low-cost robot platform for swarm applications in agriculture	Robert Braunschweig, NMBU, N
Impact of Sun Elevation Angle and Type of Sensor on Multispectral UAV Imagery Data	Sahameh Shafiee, NMBU, N
Spectral Imaging in Crop Fields – Research Activities at NMBU	Ingunn Burud, NMBU, N
Sensor technology for optimal strawberry harvesting	Siv Fagertun Remberg, NMBU, N
Prevention of subsoil compaction: Technologies and strategic planning	Mathieu Lamandé, NMBU/AU, DK

Impact of Sun Elevation Angle and Type of Sensor on Multispectral UAV Imagery Data

Sahameh Shafiee

Ingunn Burud

Morten Lillemo

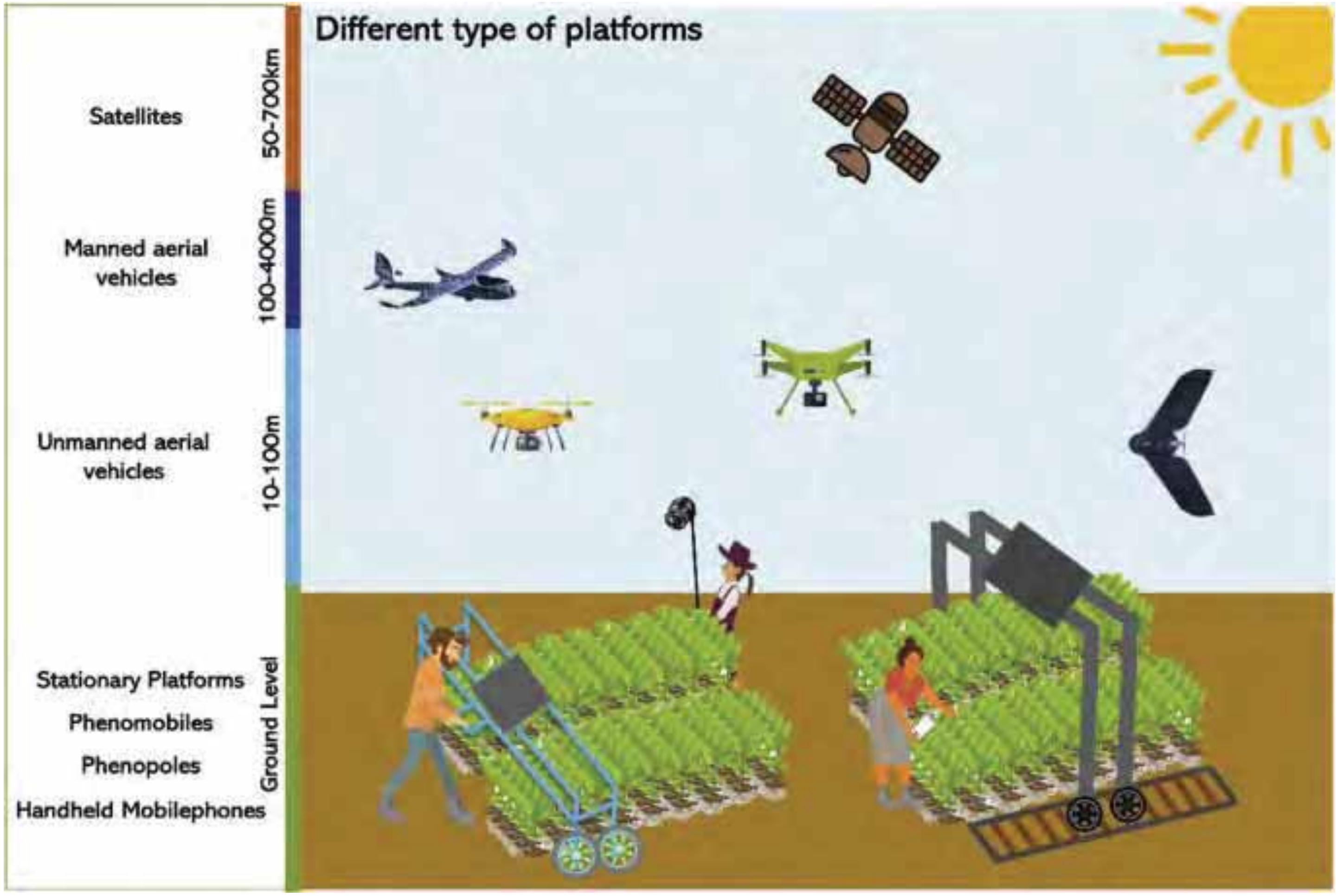
Norwegian University of Life Sciences

NJF Conference, Herning. 29.11.2022

UAV Applications in Agricultural

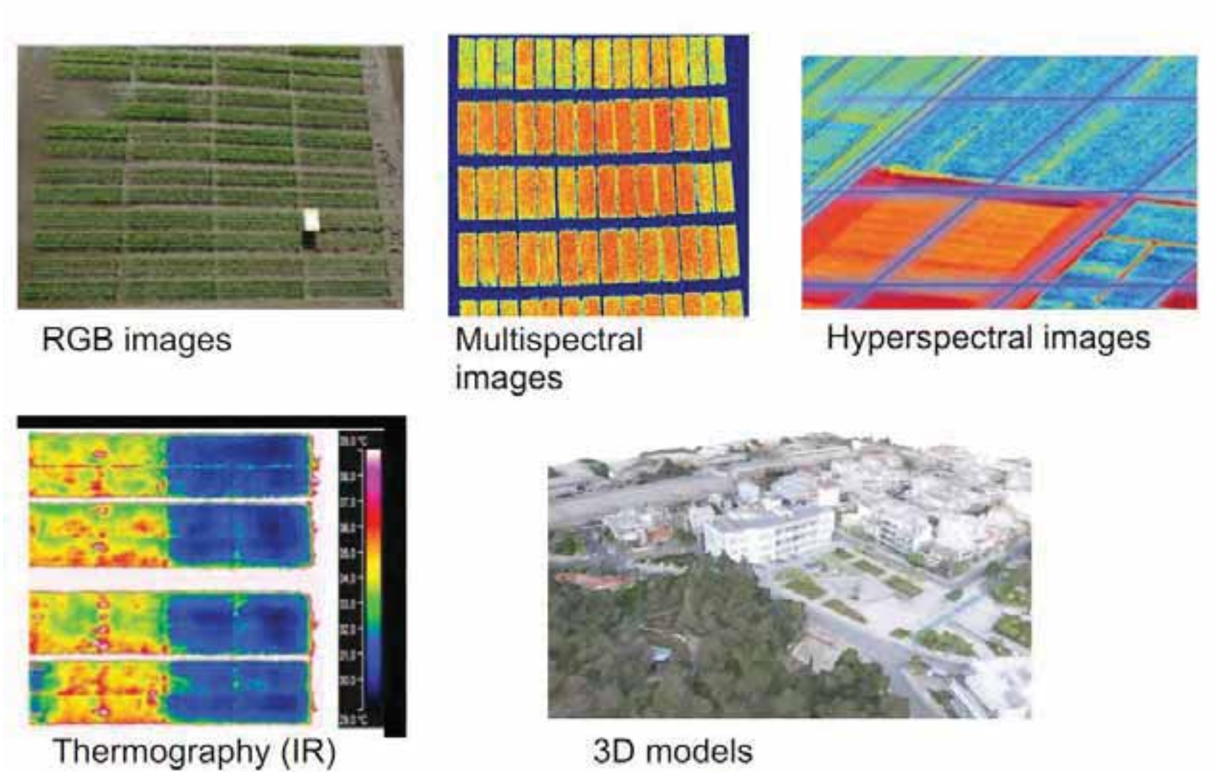
- Plant Phenotyping
- Planting seeds
- Field Monitoring
- Disease control
- Pest and herbs control
- Crop damage assessment (lodging)
- Planting seeds
- Livestock management
- And lastly pollination drones



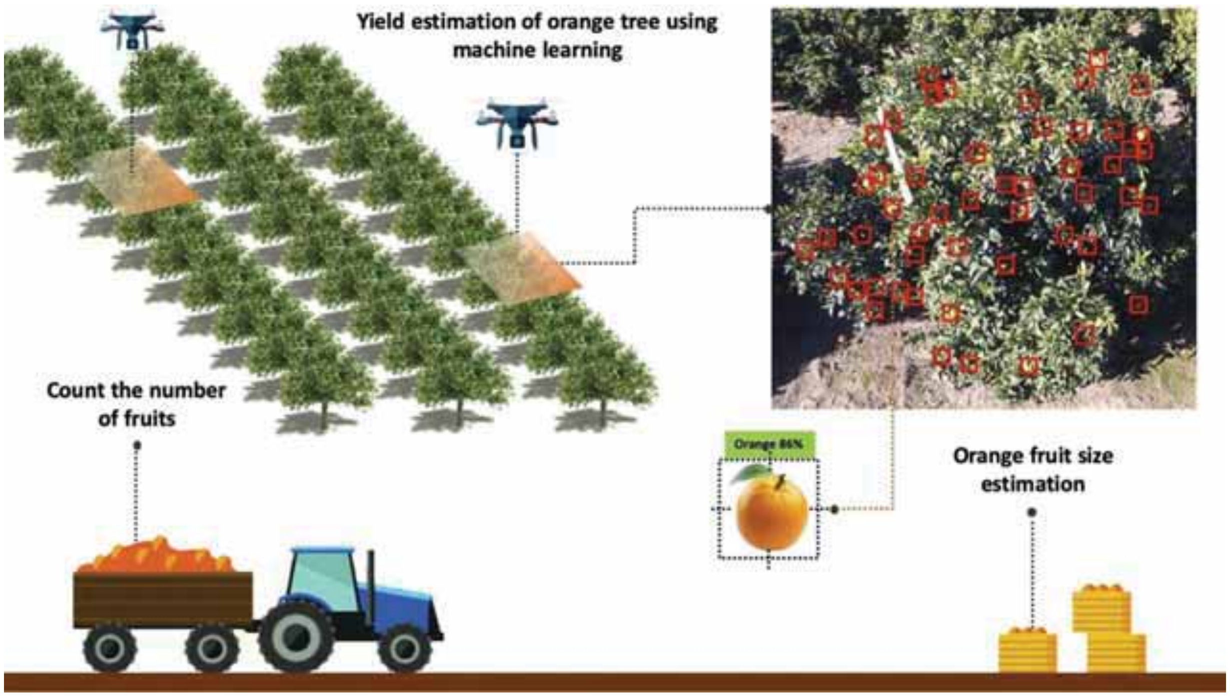



Field Based High Throughput Phenotyping Rapidly Identifies Genomic - gn.racesociety.com

What we can do with a UAV?

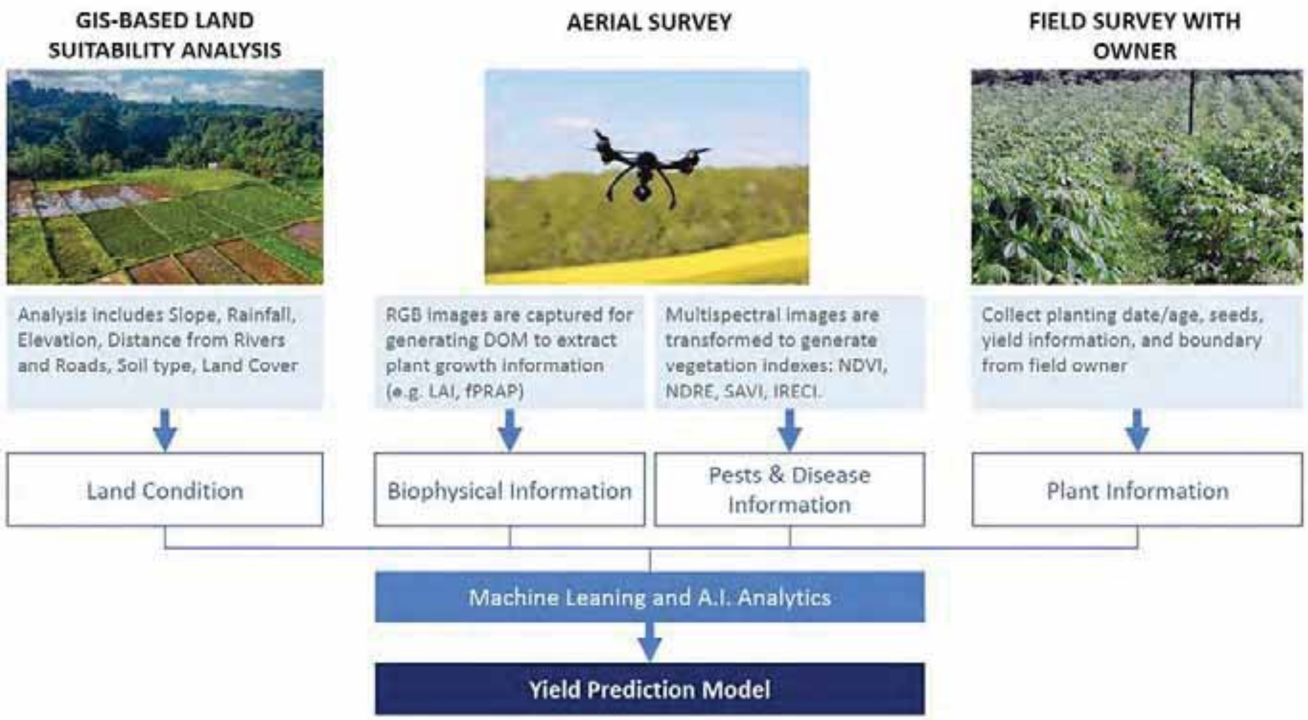


Yield Estimation



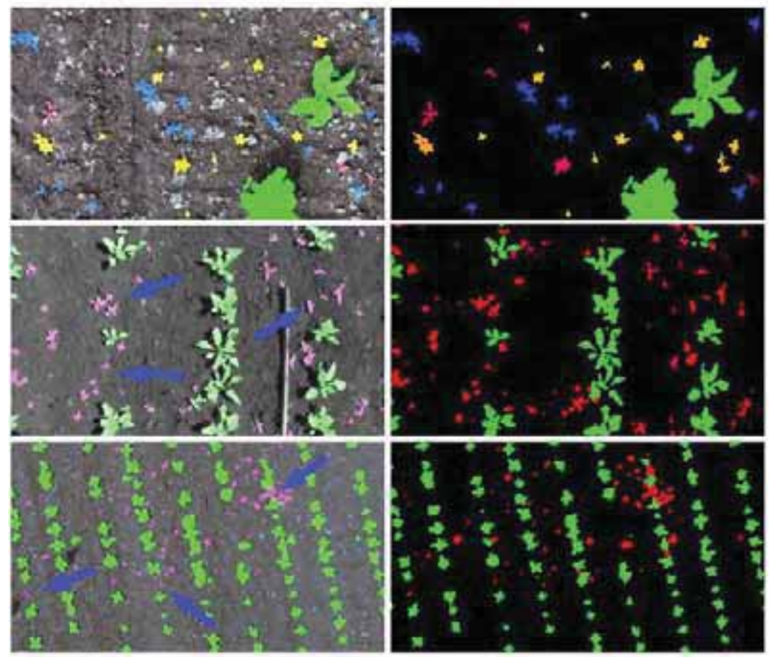
https://www.sciencedirect.com/science/article/pii/S1161030120300381#fig0055

Development of Cassava Yield Prediction Model



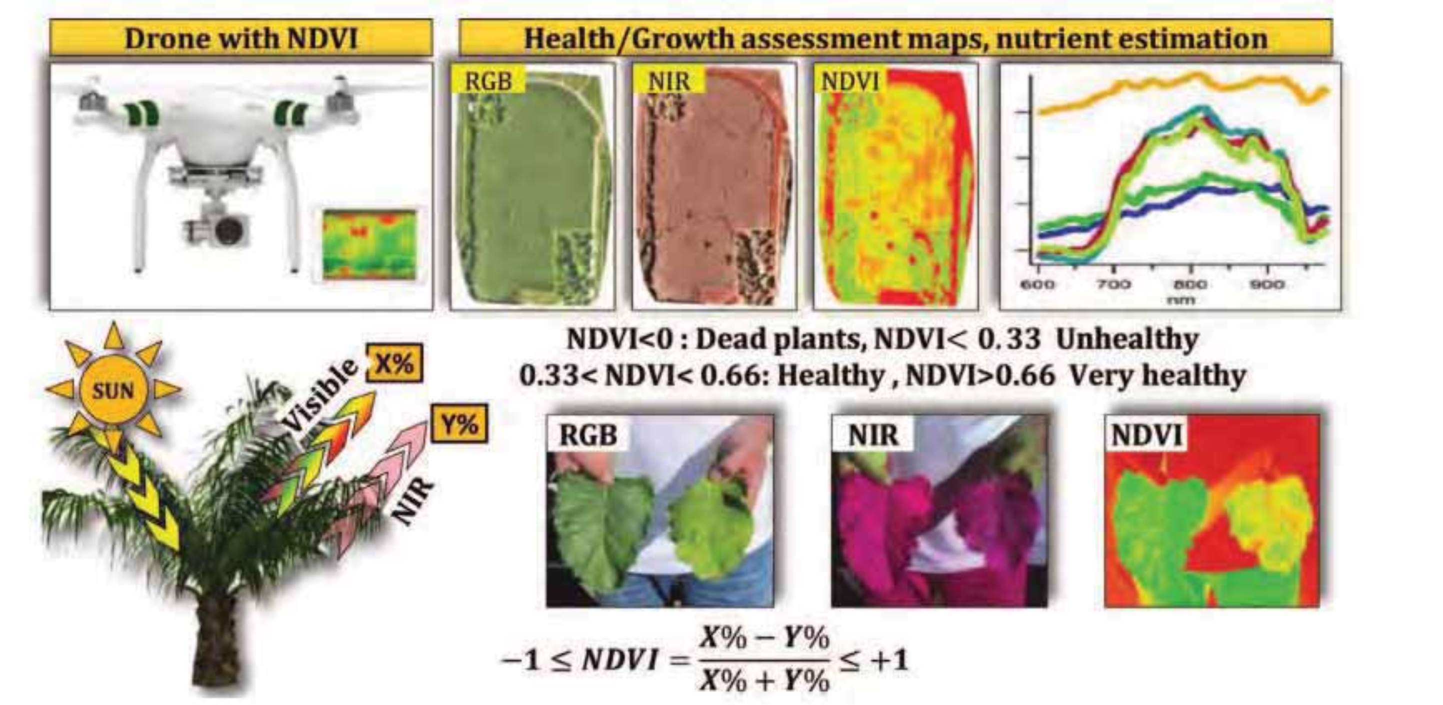
https://anavision.com/blog/cassava-yield-prediction/

Weed Detection



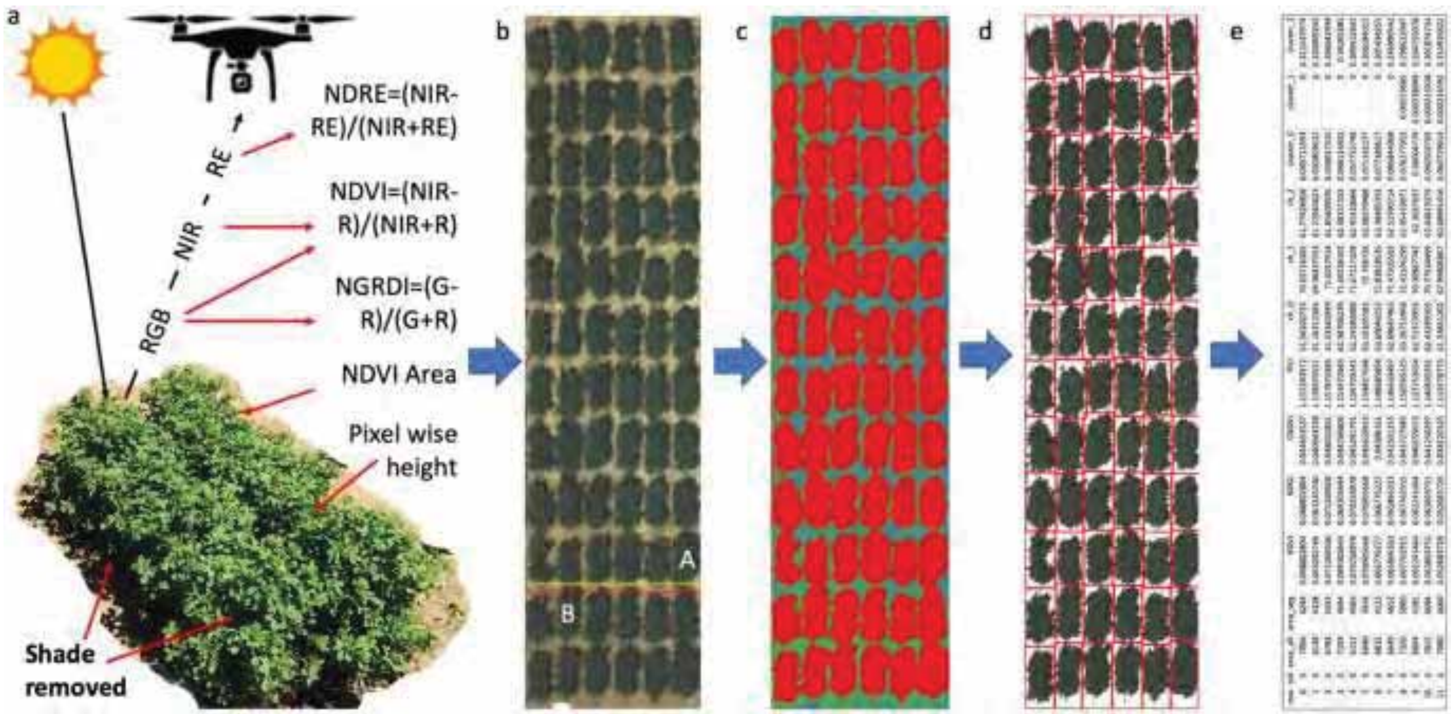
https://robohub.org/uav-based-crop-and-weed-classification-for-future-farming/

Disease detection



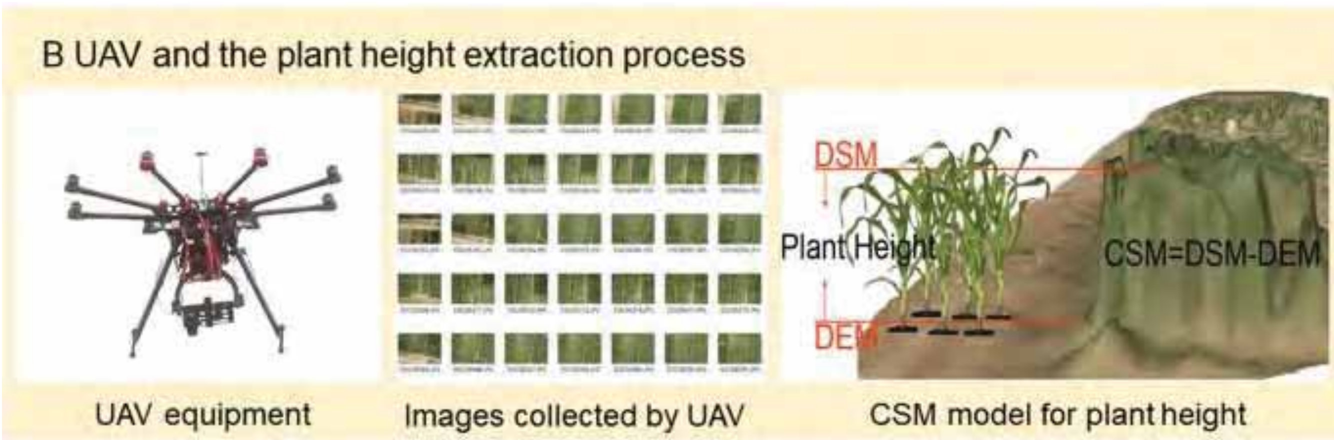
UAV sample NDVI mapping for health assessment and disease UAV sample NDVI mapping for health assessment and disease detection (Shamshiri et al., 2018).

Biomass Estimation



[Validation of UAV-based alfalfa biomass predictability using photogrammetry with fully automatic plot segmentation | Scientific Reports (nature.com)]

Plant Height Measurement



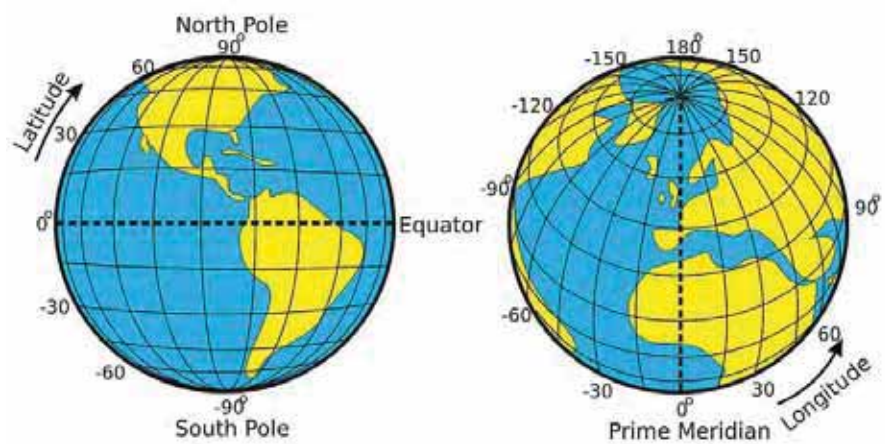
[Dynamic plant height QTL revealed in maize through remote sensing phenotyping using a high-throughput unmanned aerial vehicle (UAV) | Scientific Reports (nature.com)]

Is it possible to use the same protocol for UAVs?
Case study: UAVs in high latitudes

1) How does the time of flight or sun elevation angle affect data gathering flexibility and quality by UAVs?

2) Does the sun elevation angle have a significant effect on trait prediction using UAV data?

3) How does the type of sensor could affect data quality and model prediction performance?

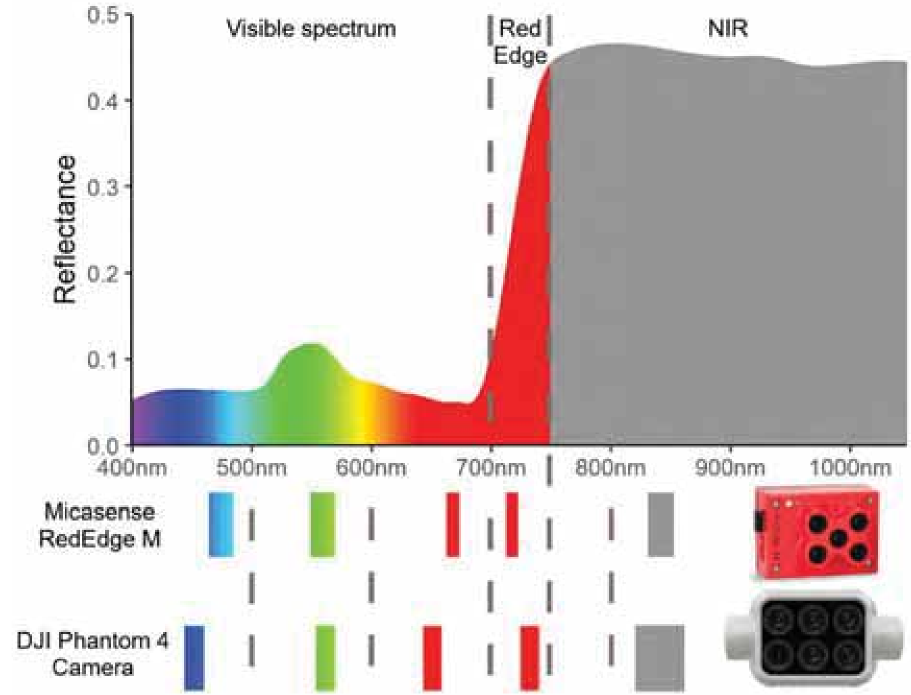


The Distance Between Degrees of Latitude and Longitude (thoughtco.com)

What types of sensors?

Phantom 4
Multispectral
(P4M)

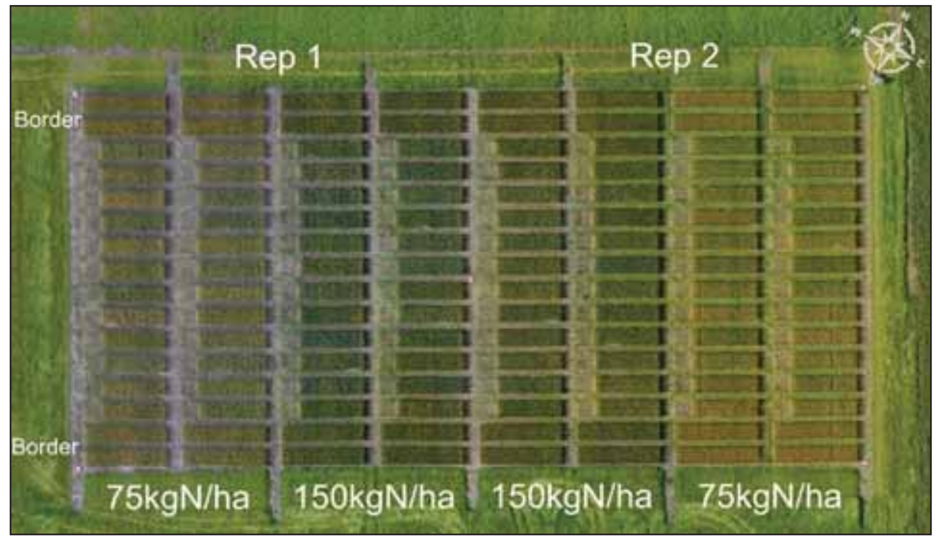
Micasense
RedEdge-M



	P4 Multispectral	Micasense RedEdge M
Red	650 ± 16 nm	668 ± 5 nm
Green	560 ± 16 nm	560 ± 10 nm
Blue	450 ± 16 nm	475 ± 10 nm
Red Edge	730 ± 16 nm	717 ± 5 nm
NIR	840 ± 26 nm	840 ± 20 nm

Trials and flights

- A collection of 24 historical and modern spring wheat cultivars planted in Ås, south-eastern Norway, 59º39’N, 10º45’E, in 2020 and 2021.
- 5 parallel mission flights:
  - Beginning of June – tillering stage
  - Last week of June – stem elongation
  - Beginning of July – heading stage
  - End of July – the onset of maturity
  - End of July – maturing progress

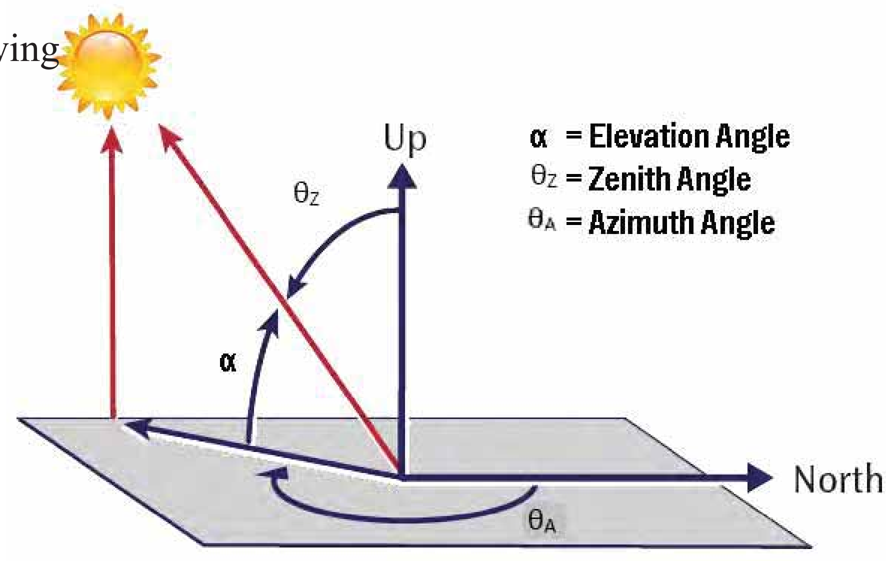


Field Overview

What is the impact of the sun's elevation angle?

To study the sun elevation angle effect:
Seven flights were conducted by both cameras at the following time points and corresponding solar elevation angles:

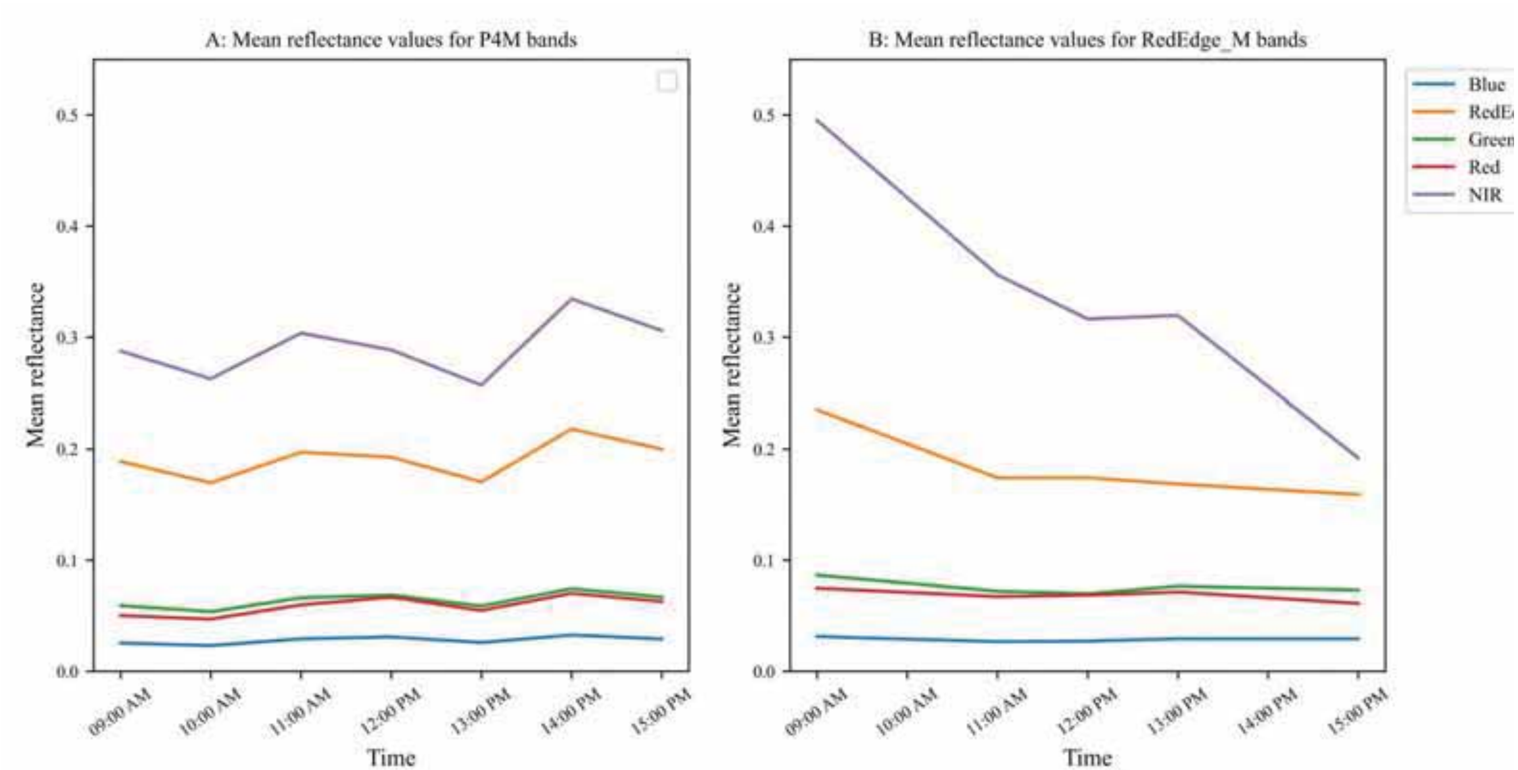
- 09:00 (28.59°),
- 10:00 (37.75°),
- 11:00 (42.04°),
- 12:00 (46.78°),
- 13:00 (49.23°),
- 14 (48.92°),
- 15 (45.89°)



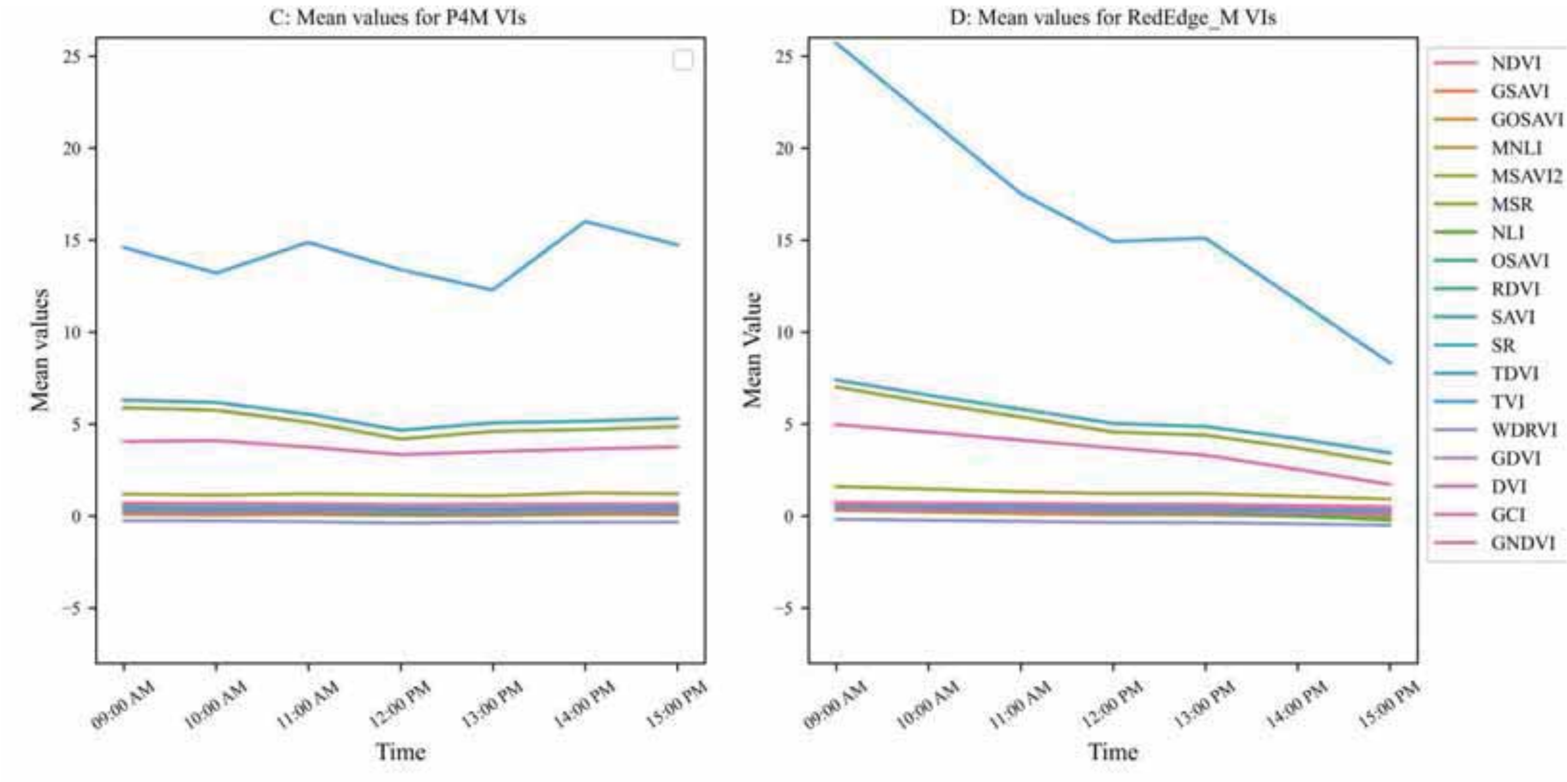
Trait prediction using two models
The overall between-camera differences for the corresponding variables were estimated using the mean difference (MD).

$$MD_i = \frac{\sum_1^j \left(Var_{ij}^{S1} - Var_{ij}^{S2}\right)}{j}$$

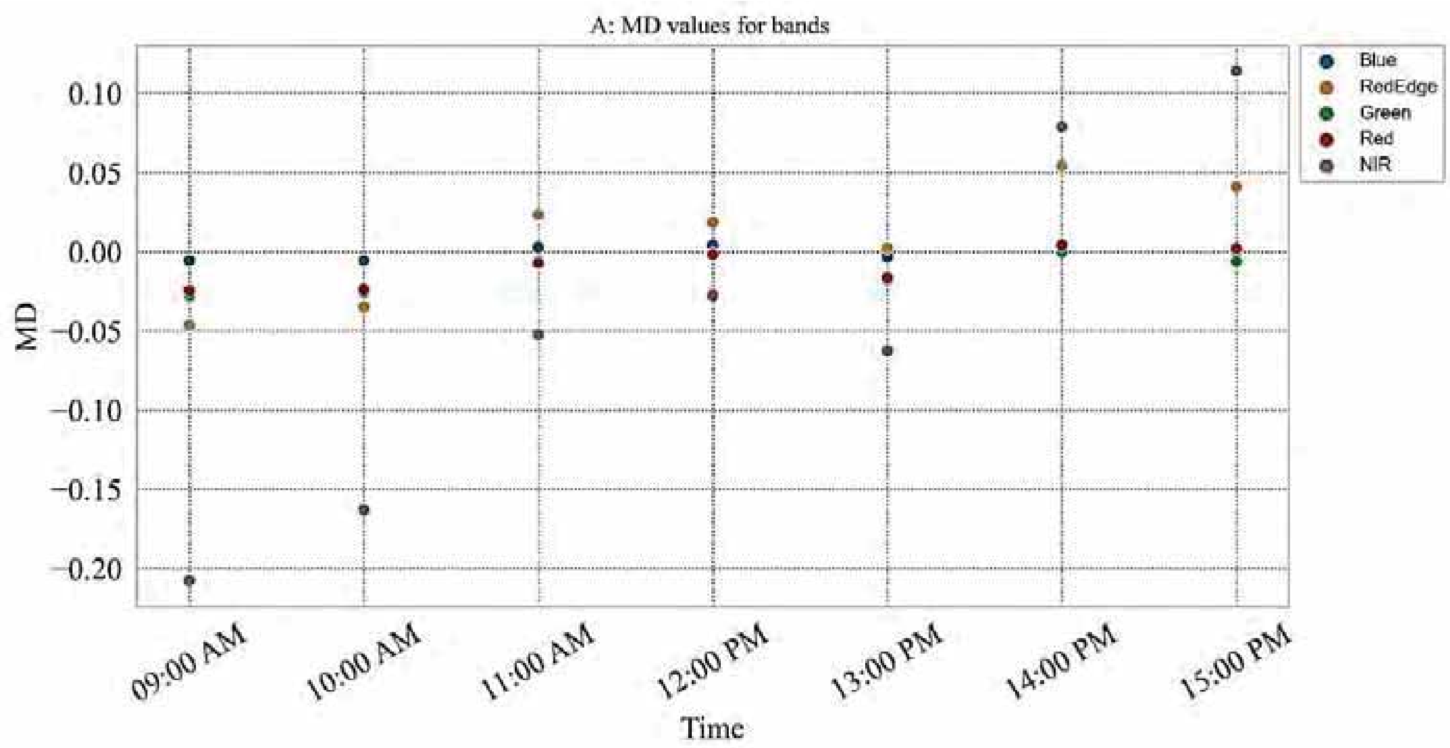
Where Var_{ij}^{S1} and Var_{ij}^{S2} are corresponding values of sample j (j=1,2, 3, …, n) for the variable i for cameras S1 and S2 respectively.



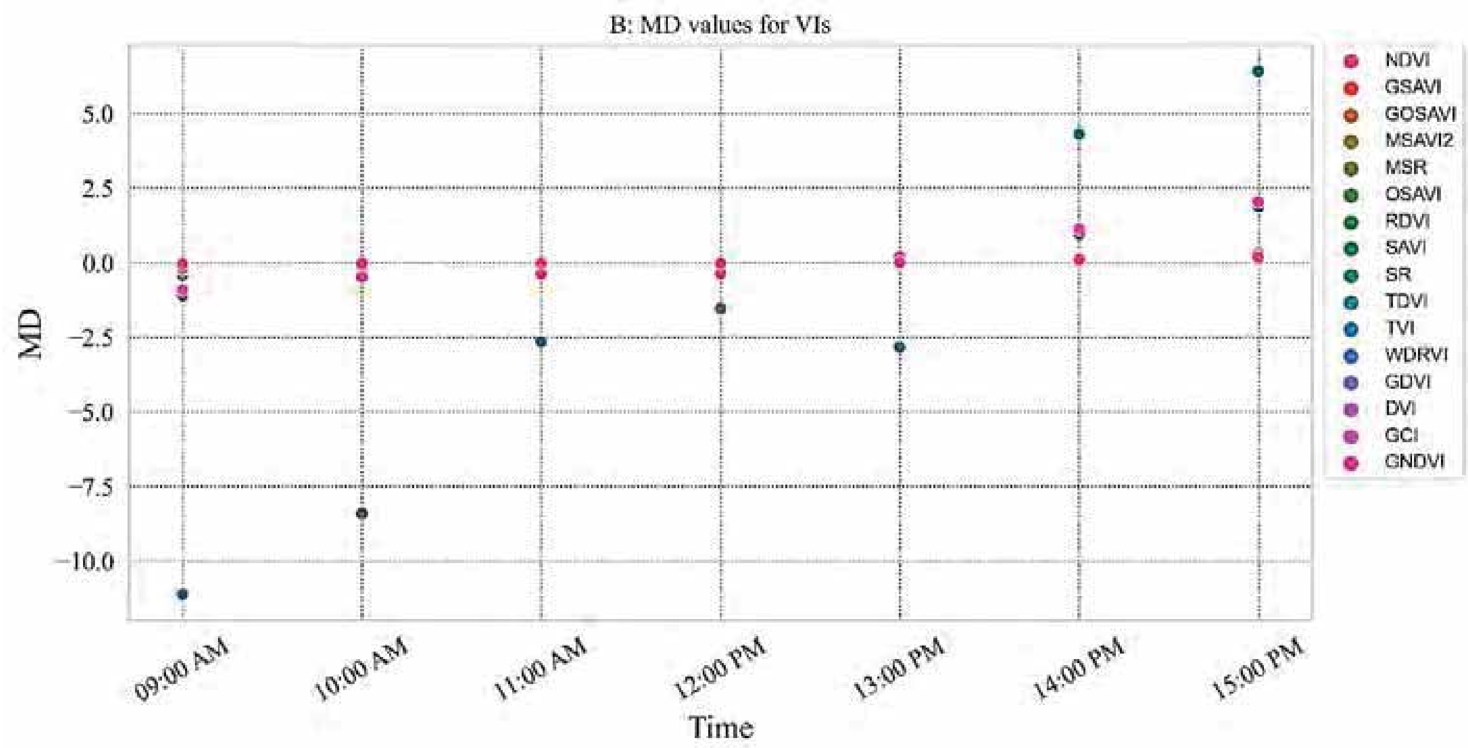
Average band reflectance (A, B) values during the day generated from both cameras



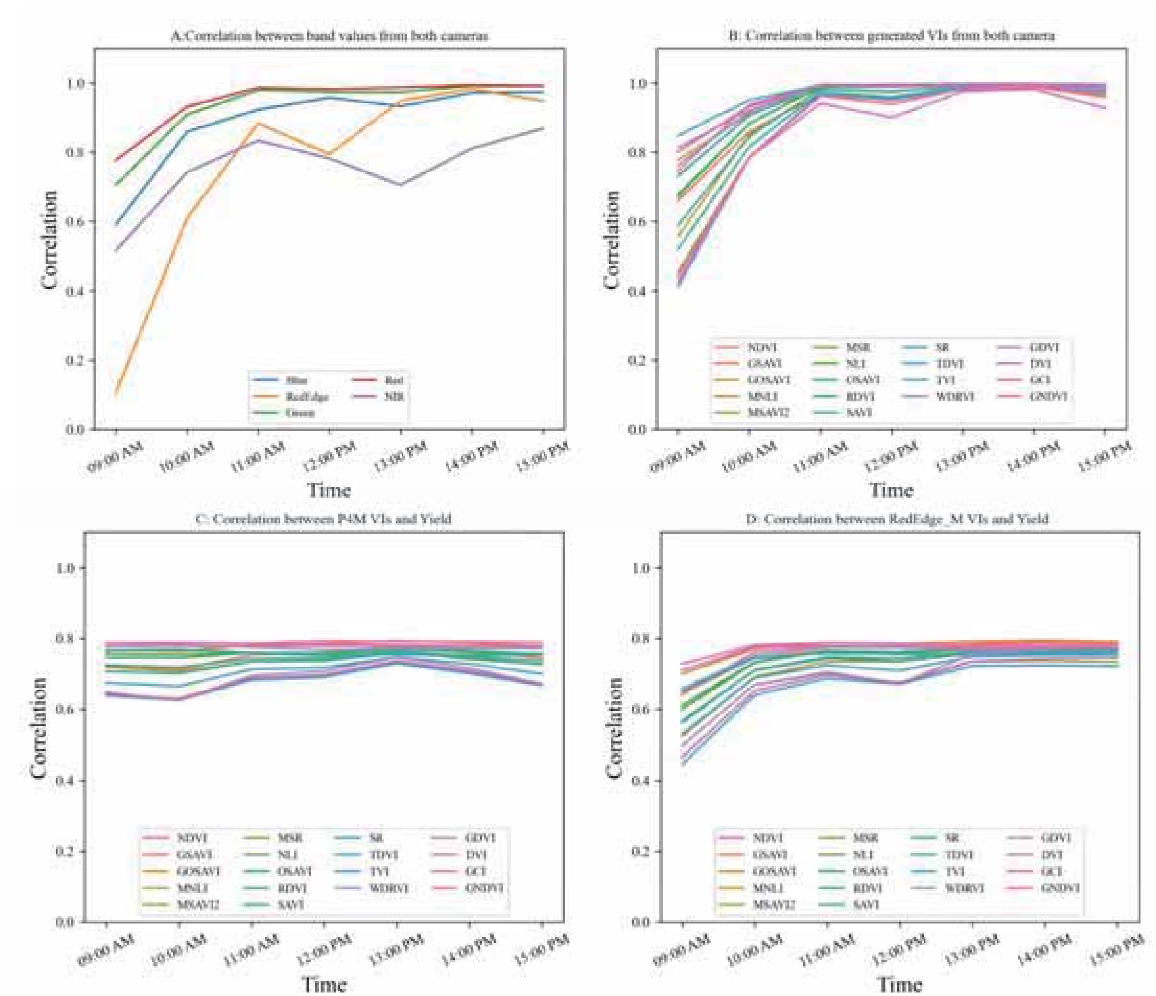
Average band reflectance VIs (C, D) values during the day generated from both cameras



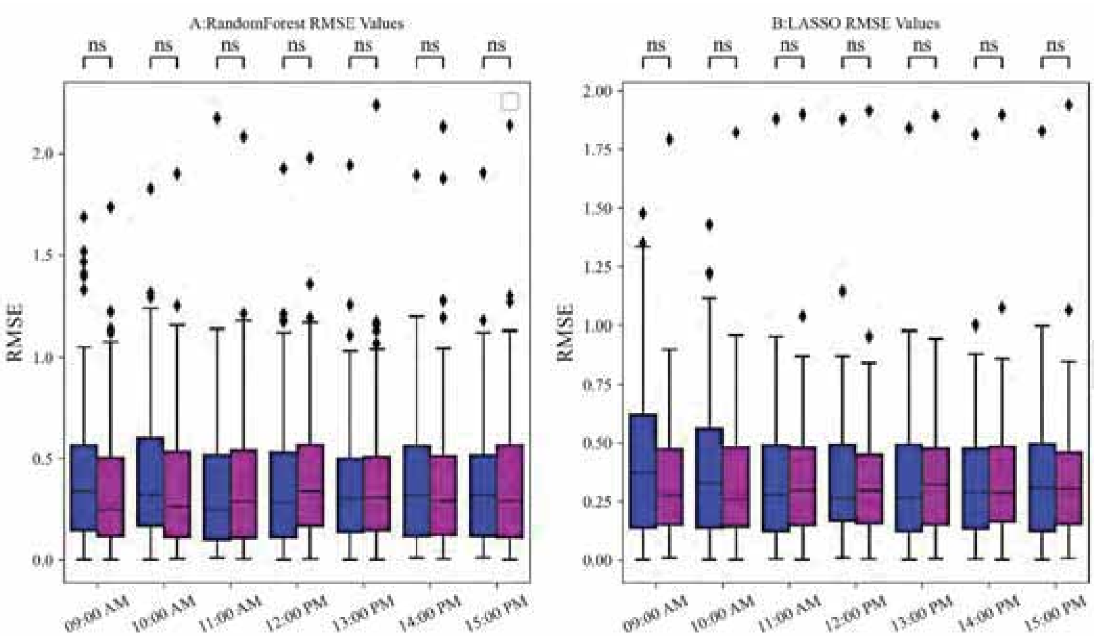
Mean difference (MD) values of captured bands by both cameras A) Bands B)VIs



Mean difference (MD) values of captured bands by both cameras VIs

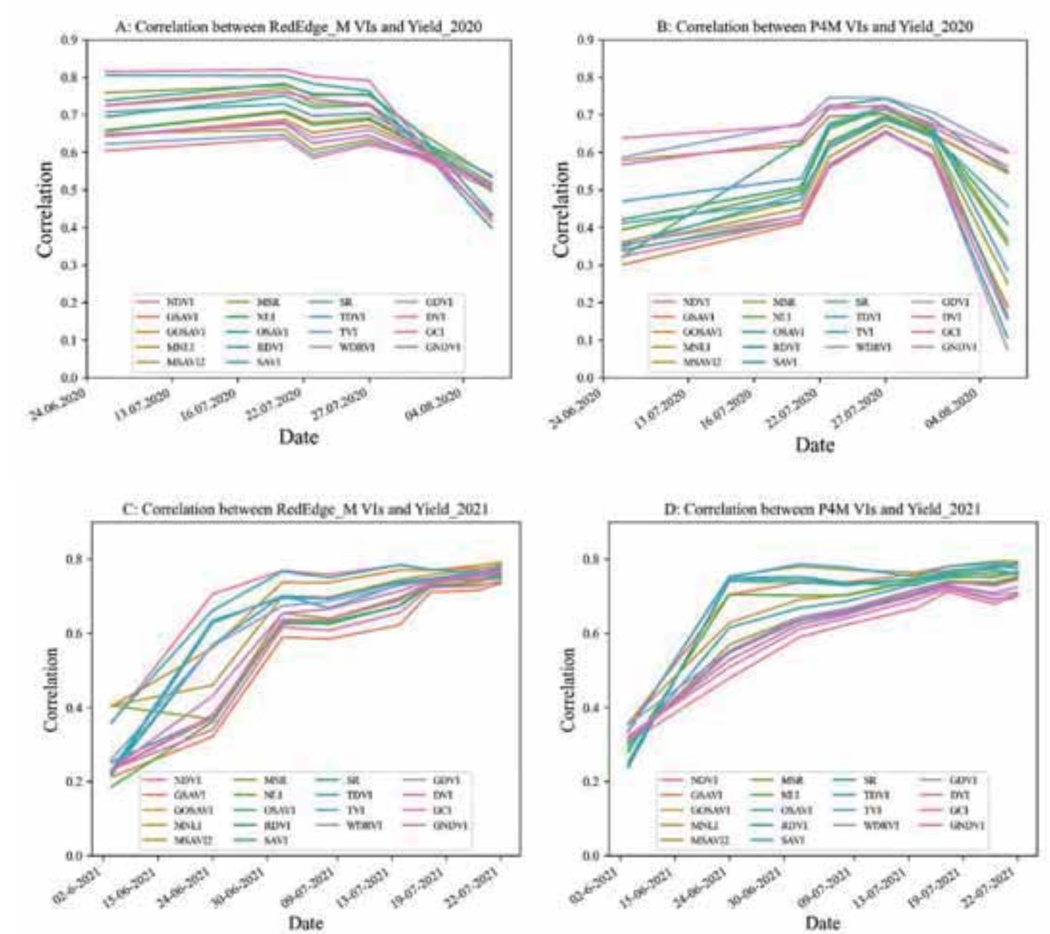


Correlation between band values and VIs generated from both cameras (A, B), the correlation between VIs by both cameras, and yield (C, D).

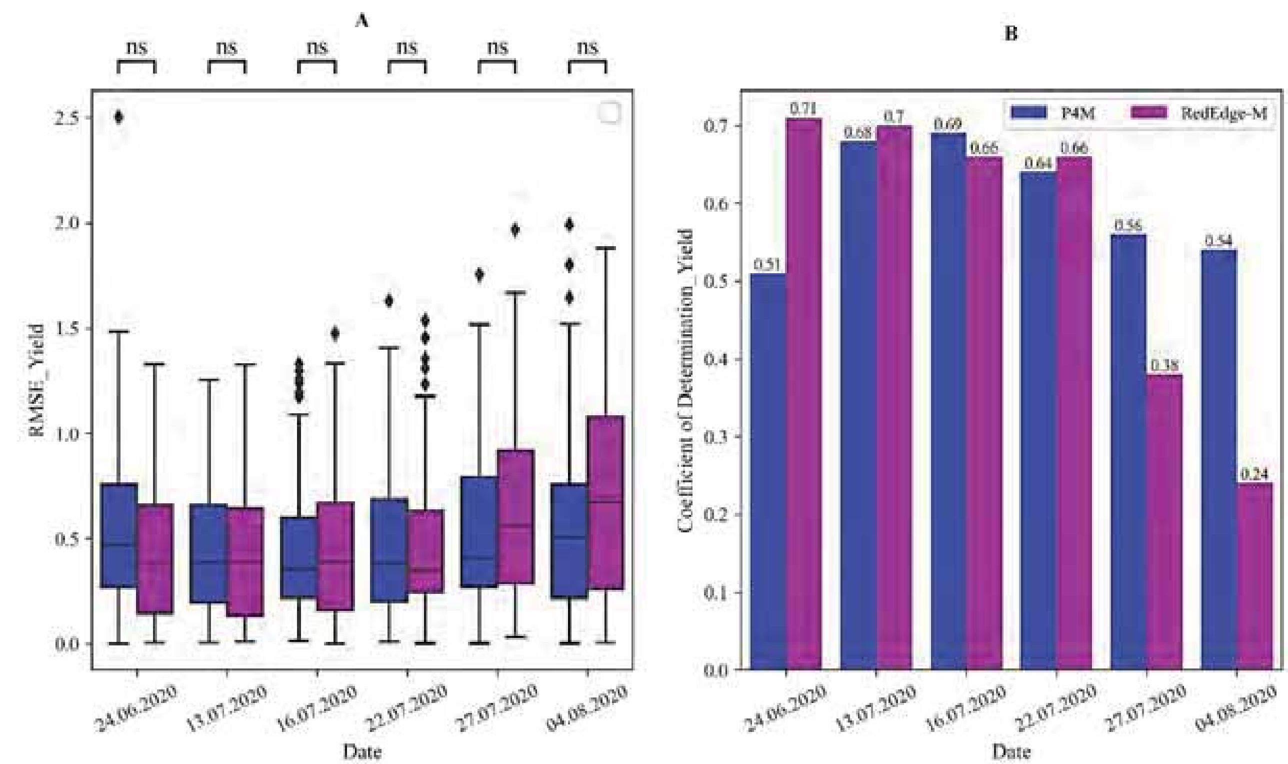


Time	LASSO		RF	
	P4M	RedEdge-M	P4M	RedEdge-M
09:00 AM	0.63	0.45	0.59	0.44
10:00 AM	0.66	0.54	0.57	0.47
11:00 AM	0.64	0.65	0.57	0.56
12:00 PM	0.64	0.65	0.51	0.52
13:00 PM	0.65	0.65	0.53	0.56
14:00 PM	0.65	0.65	0.51	0.56
15:00 PM	0.64	0.65	0.52	0.56

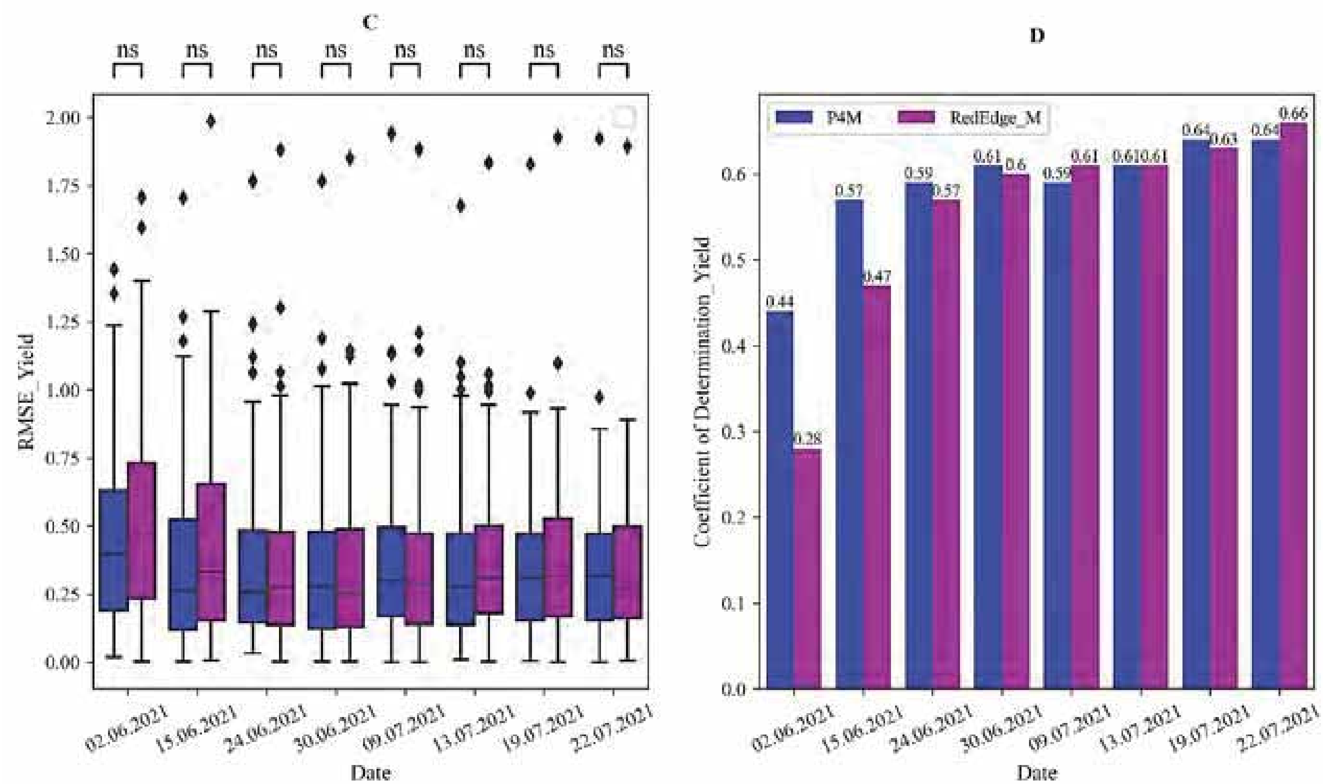
Models' performance and t-test results to compare the two cameras during the course of the day



Pearson correlation between yield and generated VIs by both cameras A, B (2020), C, D (2021)



Model performance and t-test results to compare the two cameras during the 2020 season



Model performance and t-test results to compare the two cameras during the 2021 season

Conclusion:

- The reflectance values changed with changes in the sun elevation angle.
- The reflectance values measured by both cameras are most correlated around local noon when the sun angle is highest.
- Some vegetation indices measured by P4M multispectral camera can compensate for the sun elevation angle effect and generate more consistent values during the day.
- The research results showed that the P4M camera has a better performance and consistency to generate different vegetation indices for application in plant phenotyping and precision agriculture.
- In overall, the difference between both sensors wasn’t significant for trait prediction.

Thank you

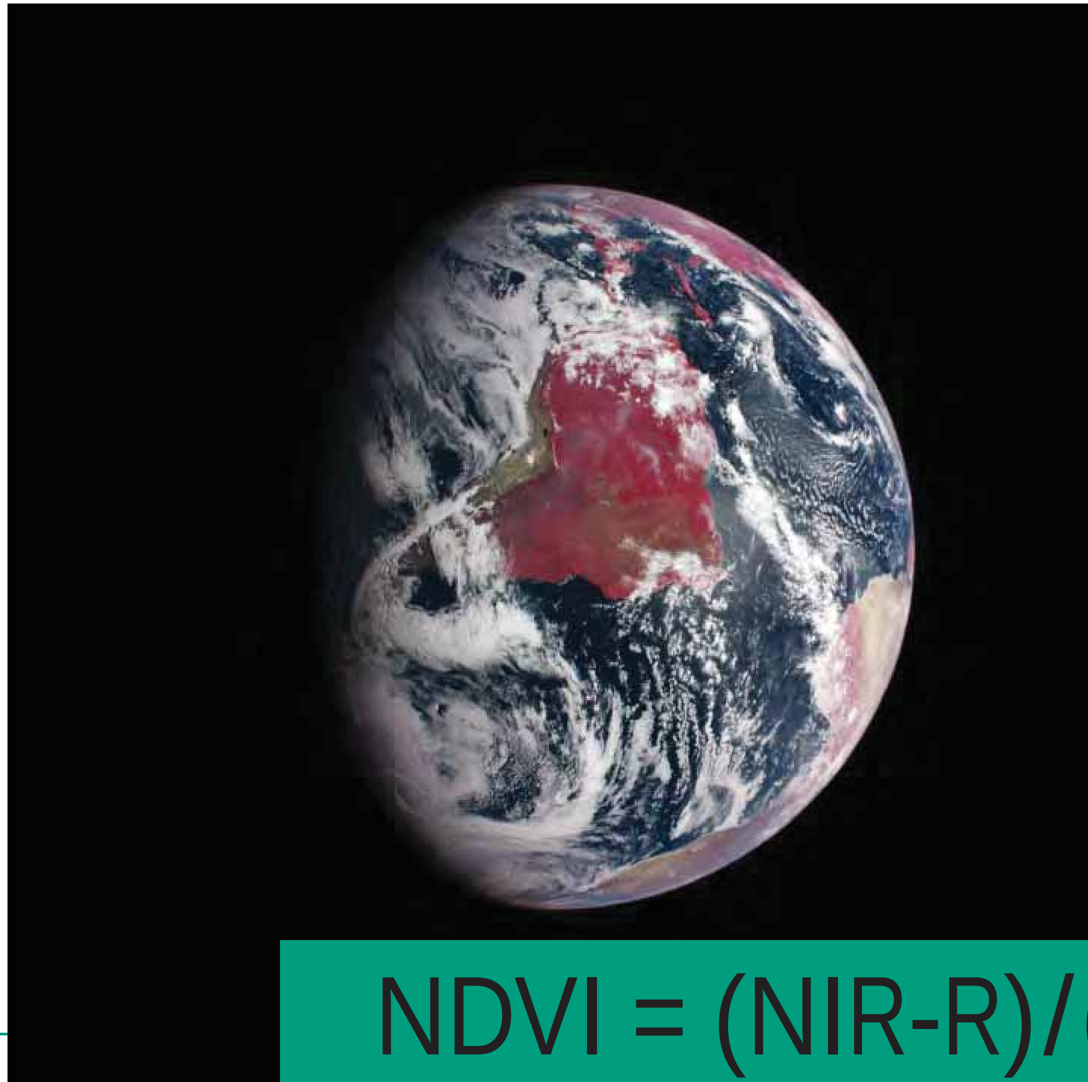
sahameh.shafiee@nmbu.no

SPECTRAL IMAGING IN CROP FIELDS – RESEARCH ACTIVITIES AT NMBU

Ingunn Burud, Sahameh Shafiee, Tomasz Mroz, Morten Lillemo
Norwegian University of Life Sciences


SMART
FARMING

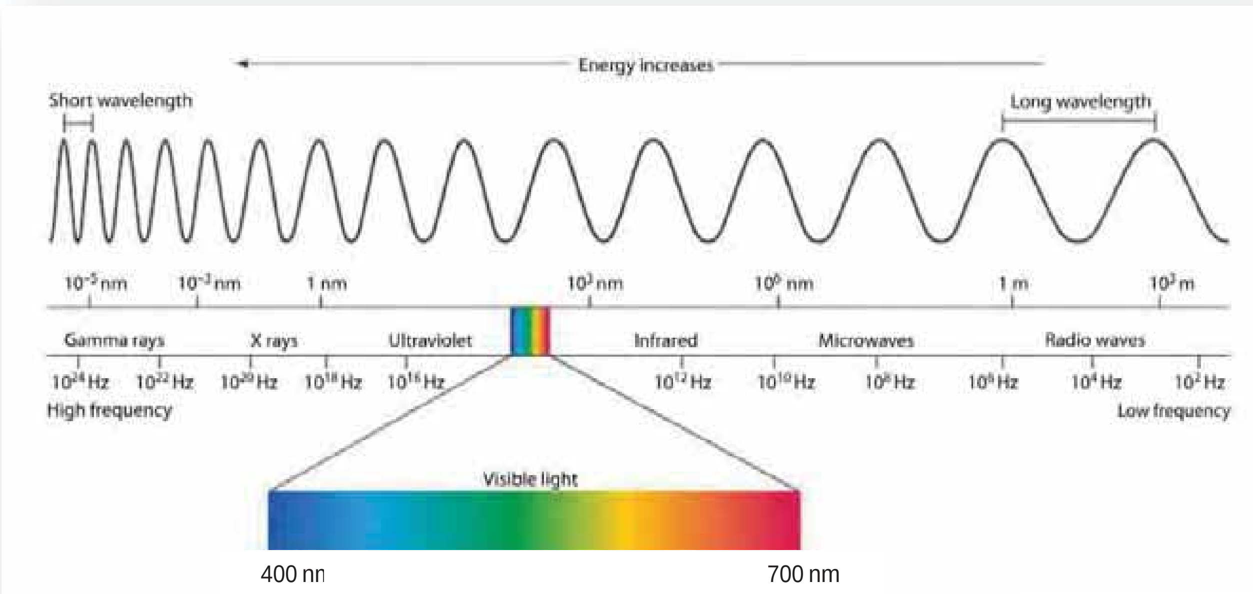
NIR imaging of the Earth

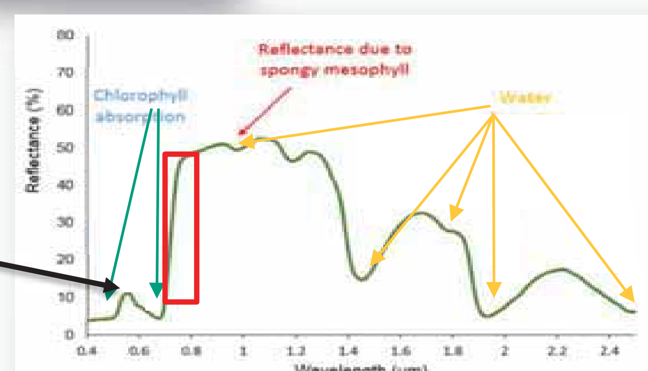


Nasa

$$NDVI = (NIR-R)/(NIR+R)$$

The electromagnetic spectrum

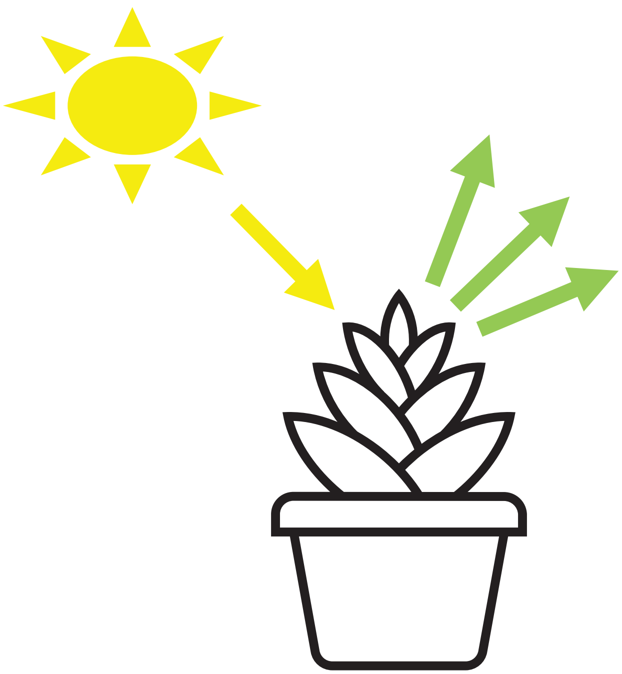


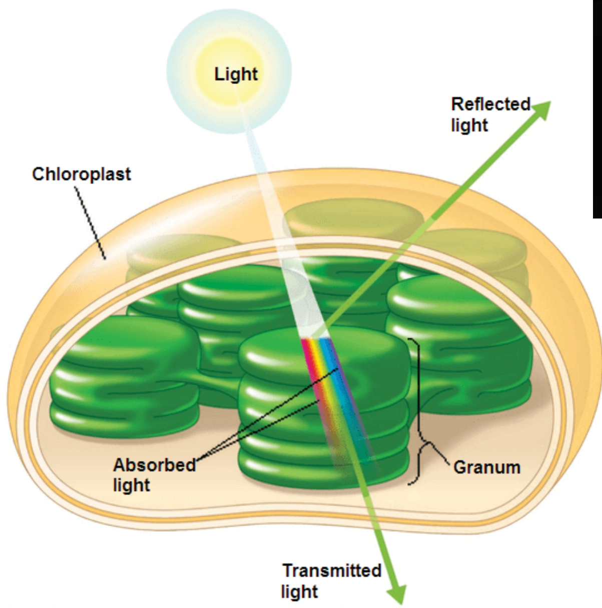


green peak

Red edge:
scattering due to leaf internal structure in the NIR region

Plant Reaction to Stress





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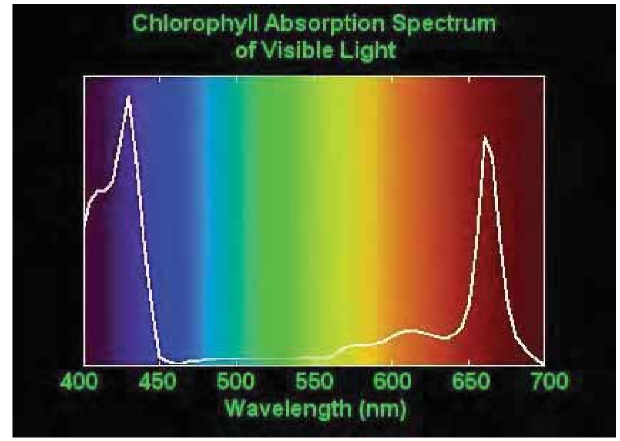
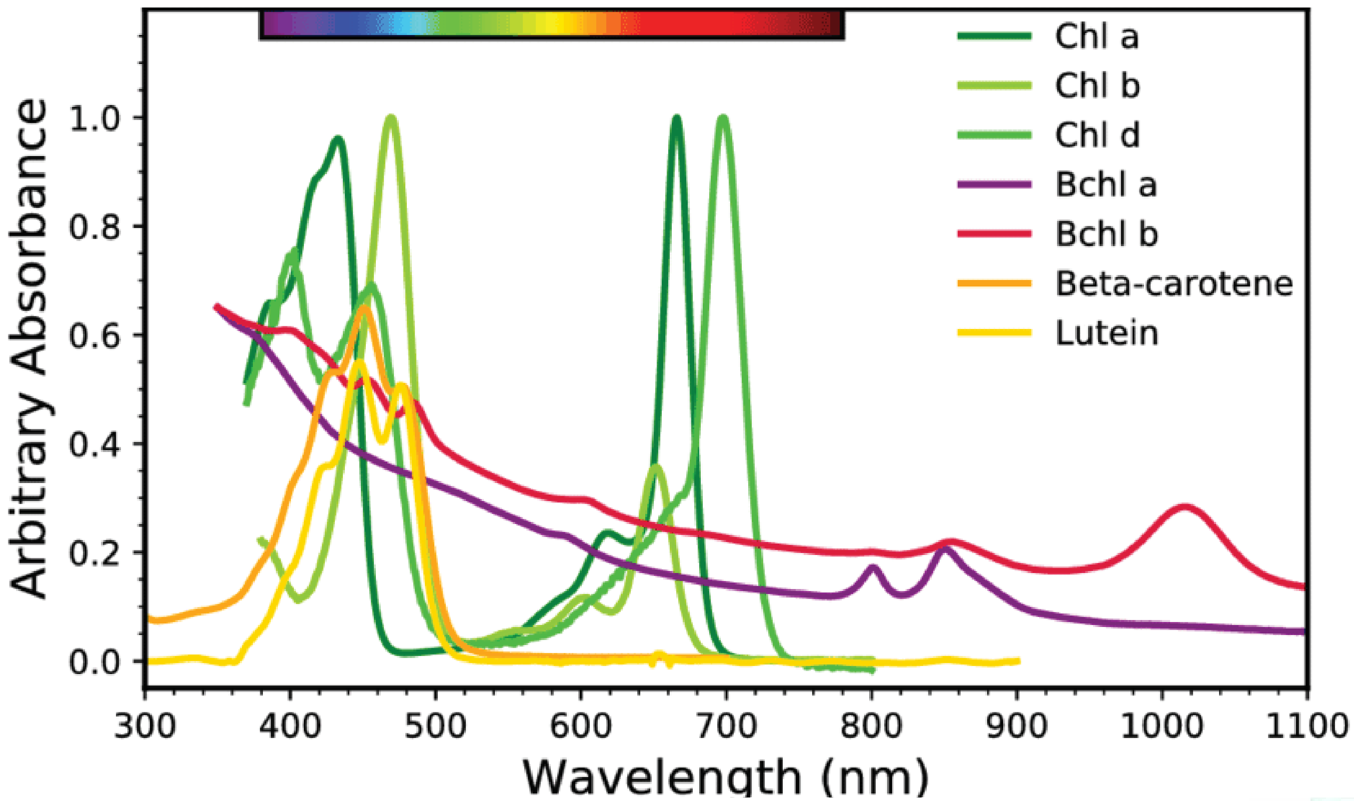


Norwegian University of Life Sciences

Leaf Spectra



Norwegian University of Life Sciences

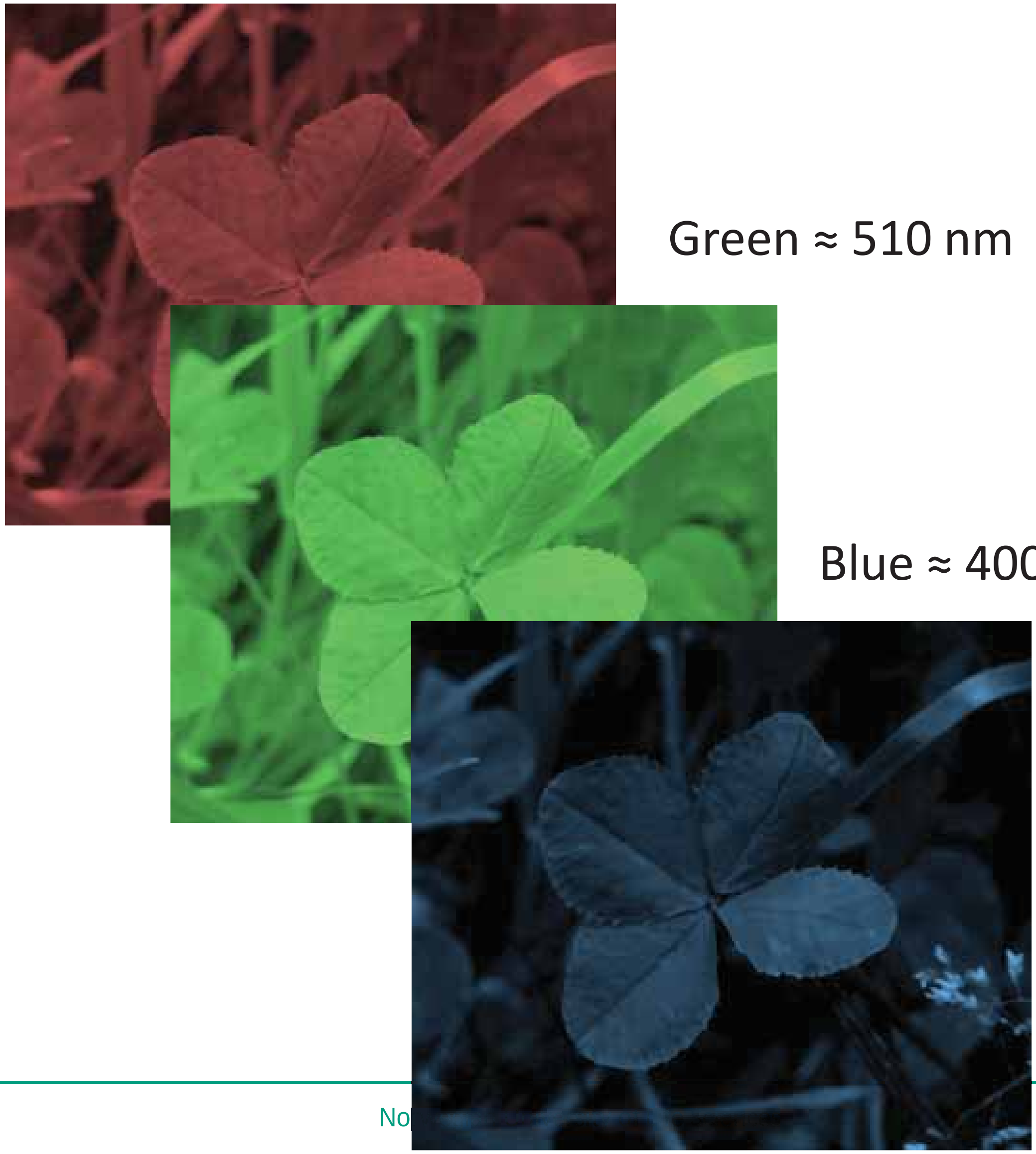
Schwieterman, Edward. (2018). Surface and Temporal Biosignatures

RGB images

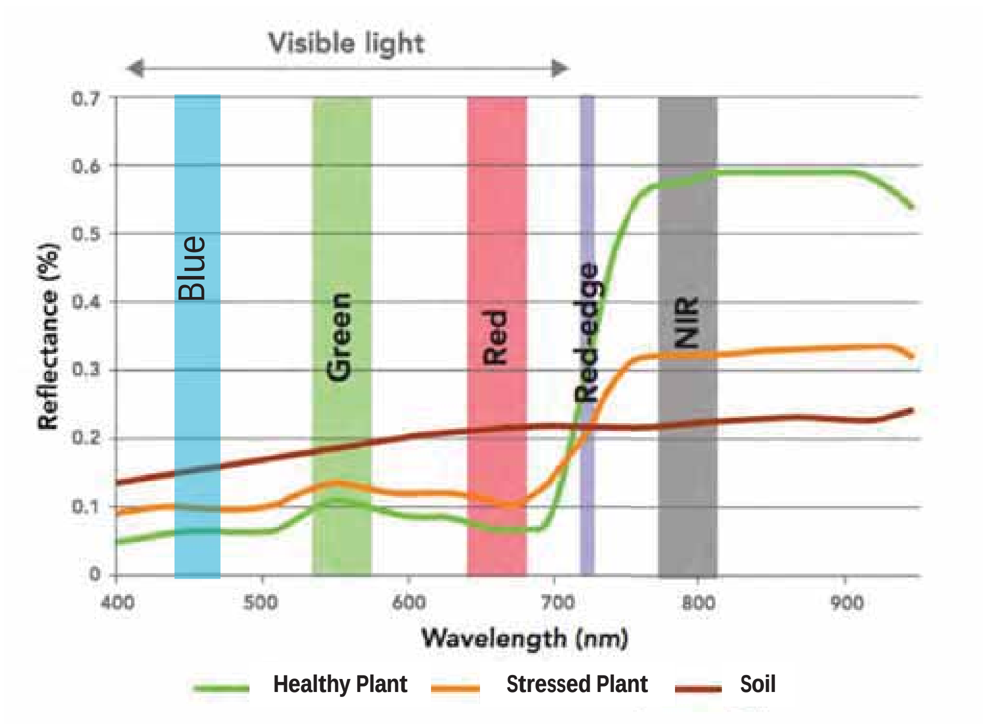
Red ≈ 645 nm

Green ≈ 510 nm

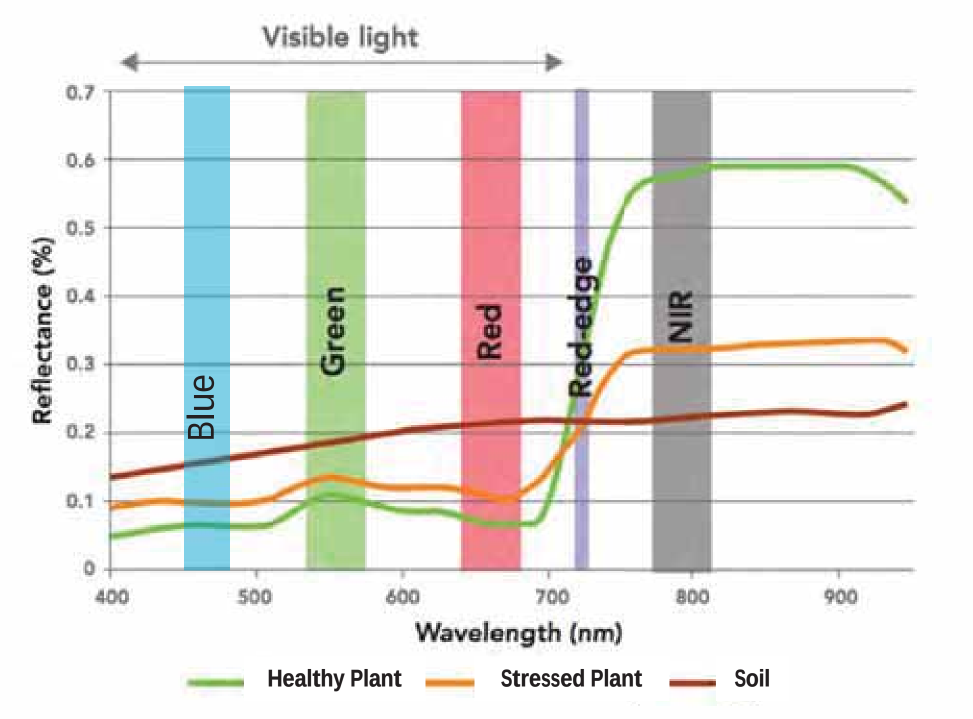
Blue ≈ 400 nm



Multispectral images



Vegetation indices

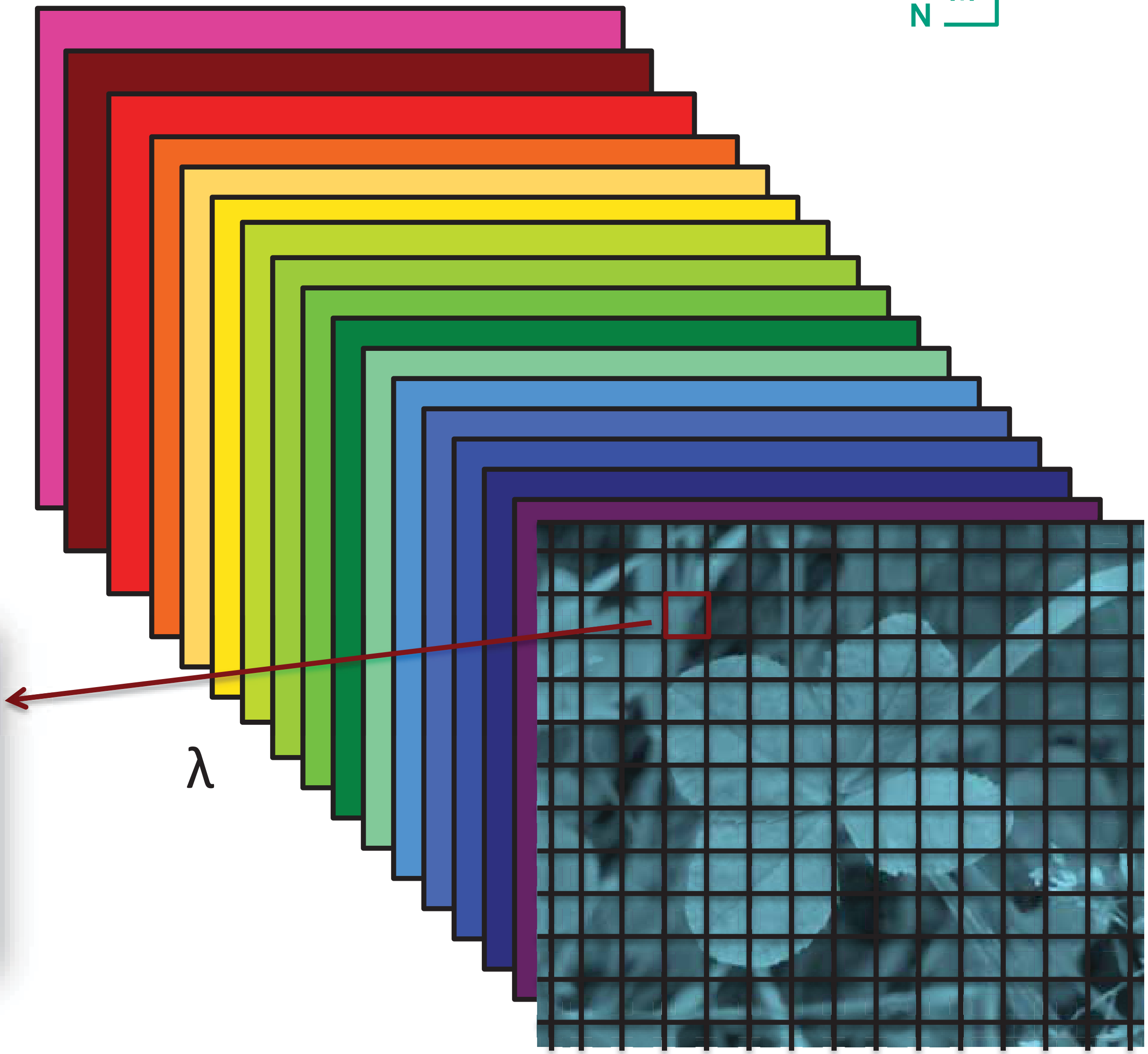


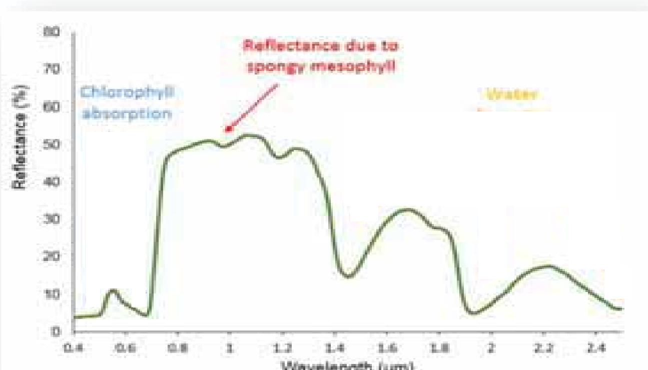
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$MTCI = \frac{NIR - Rededge}{Redege - Red}$$

$$EVI = 2.5 * \frac{(NIR - Rededge)}{(NIR + 6 * Red - 7.5 * Blue + 1)}$$

Hyperspectral imaging

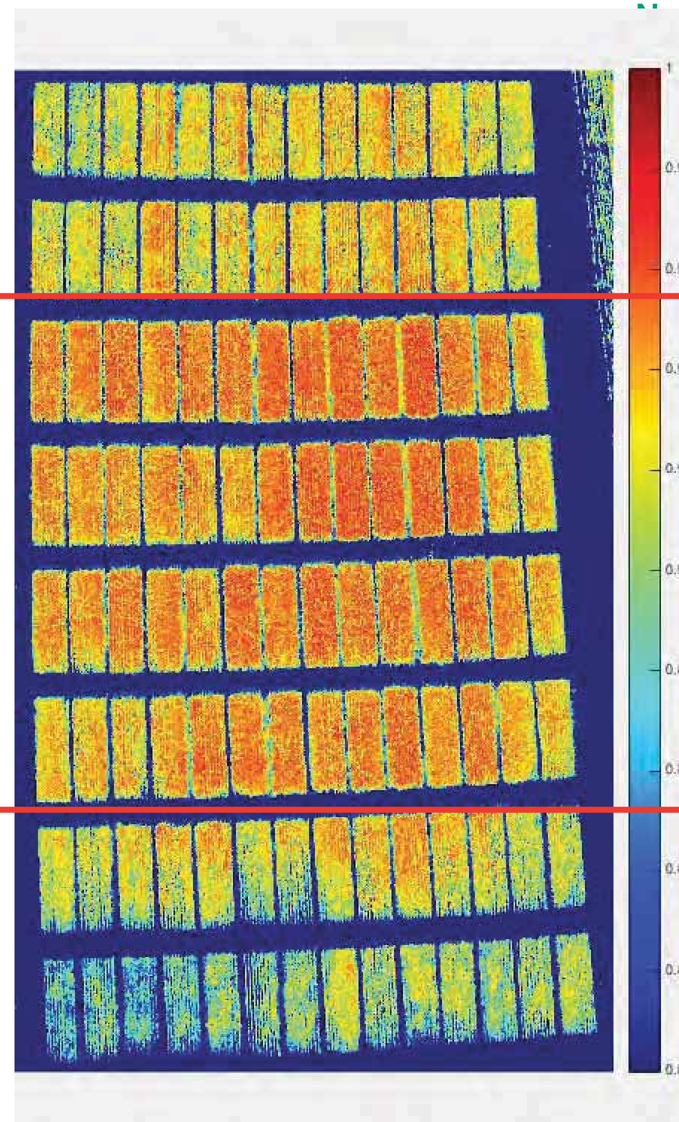




Full spectrum in each pixel

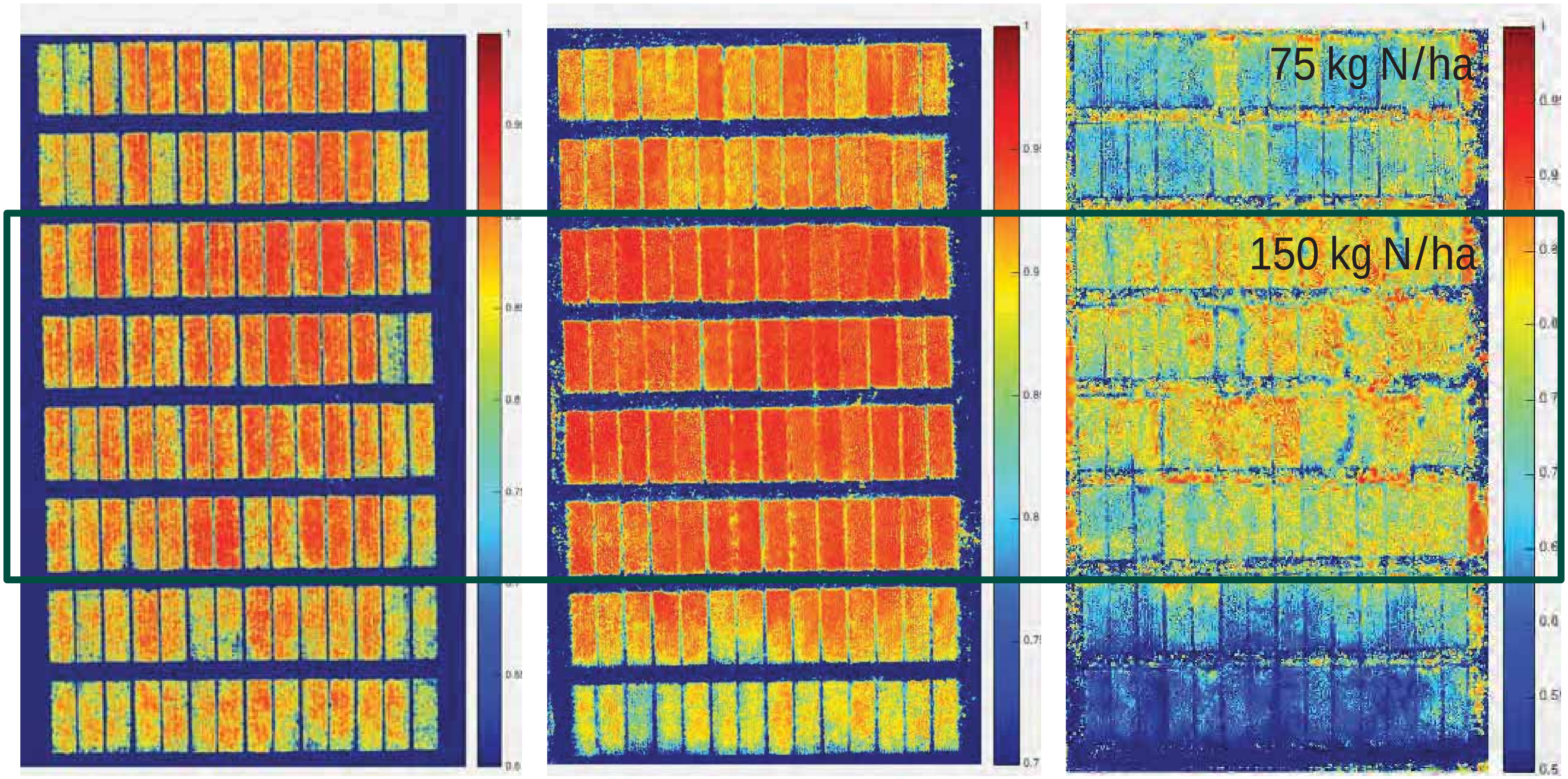
Phenotyping of wheat

Chlorophyll production



- Plant cover
- Stress
- Diseases
- Fertilizers

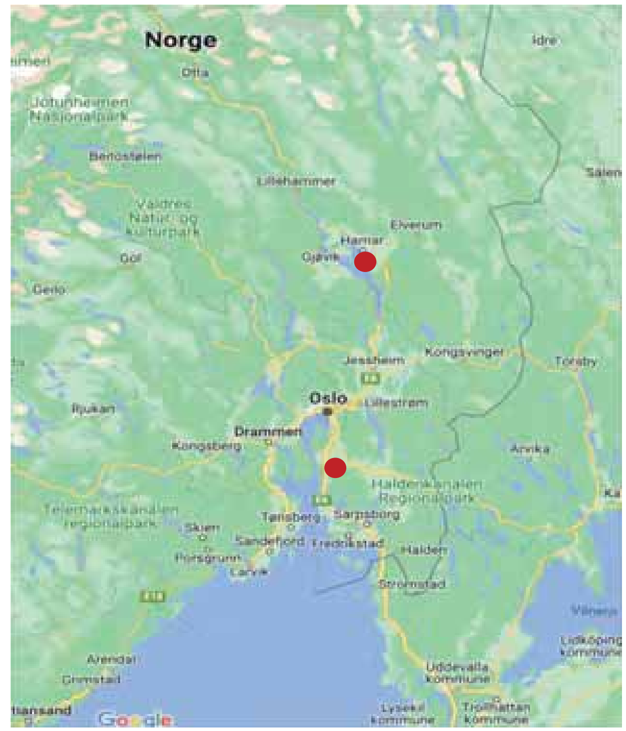
NDVI maps

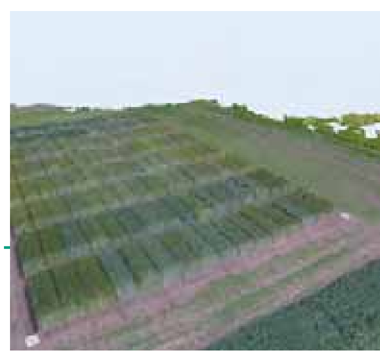


17/06 18/07 10/08

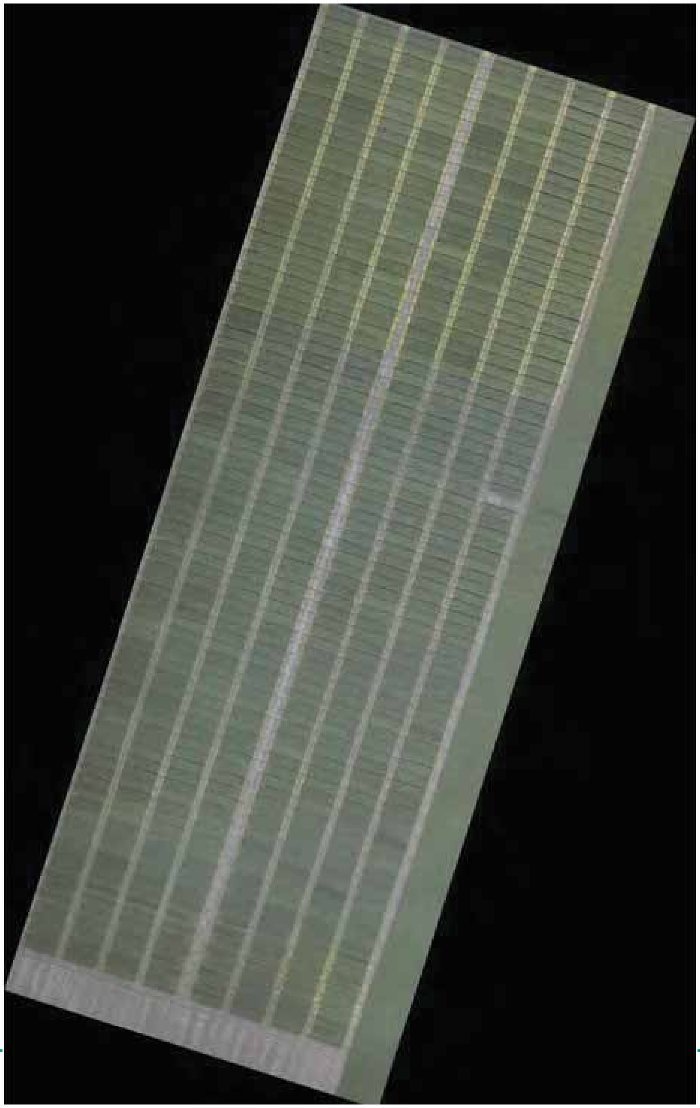
Phenotyping experiment

- Field trials at two locations in Norway:
  Ås and Stange
- 300 spring wheat lines, 396 cultivars
- Measurements of agronomic traits and grain yield
- Multispectral images from UAV



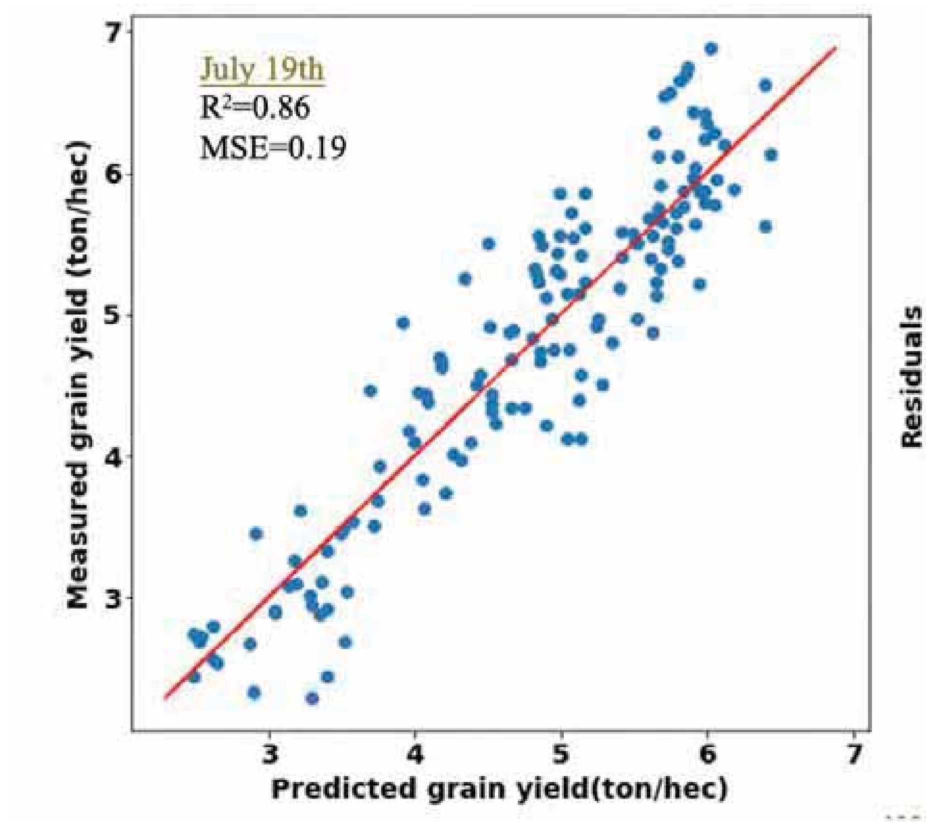


Phenotyping experiment



Yield prediction

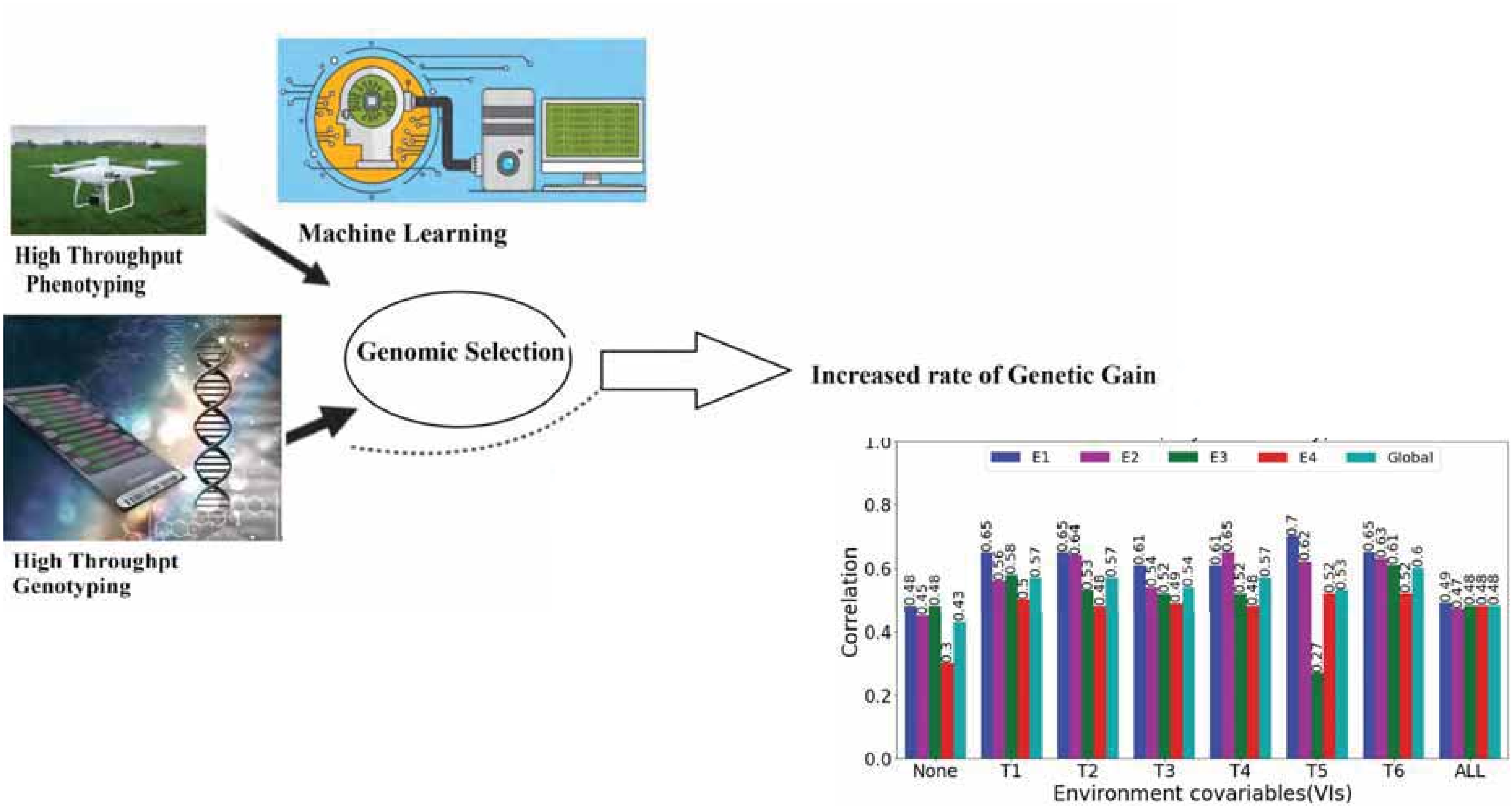
- Machine learning was applied for yield prediction (Sequential Forward Selection and LASSO)
- NDVI showed good prediction ability of grain yield in final grain filling stages.
- MTCI and EVI are more important grain yield predictors during early grain filling
- Best predictions resulted from combining vegetation indices from multitemporal data



Computers and Electronics in Agriculture

Sequential forward selection and support vector regression in comparison to LASSO regression for spring wheat yield prediction based on UAV imagery

Genomic prediction



Comparison of multispectral cameras

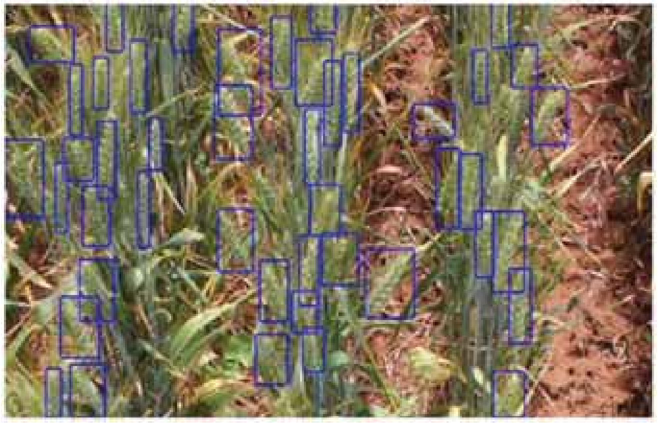
- In 2020 and 2021 we performed weekly parallel testing of the P4M and the Micasence camera
- P4M camera was more stable than Micasence for the derived vegetation indices and less sensitive to sun angles
- P4M seems particularly well suited for phenotyping

P4 Multispectral DJI

Micasense RedEdge-M

Robot images

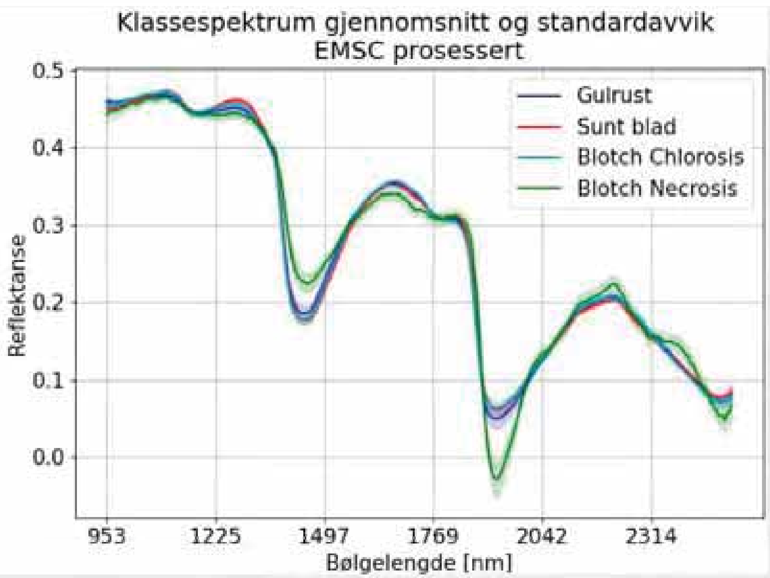
- Number of spikes is related to yield
- Automatic spike detection from robot images
- Deep learning: annotating, annotating, annotating,…
- Kaggle competition (https://www.kaggle.com/c/global-wheat-detection)

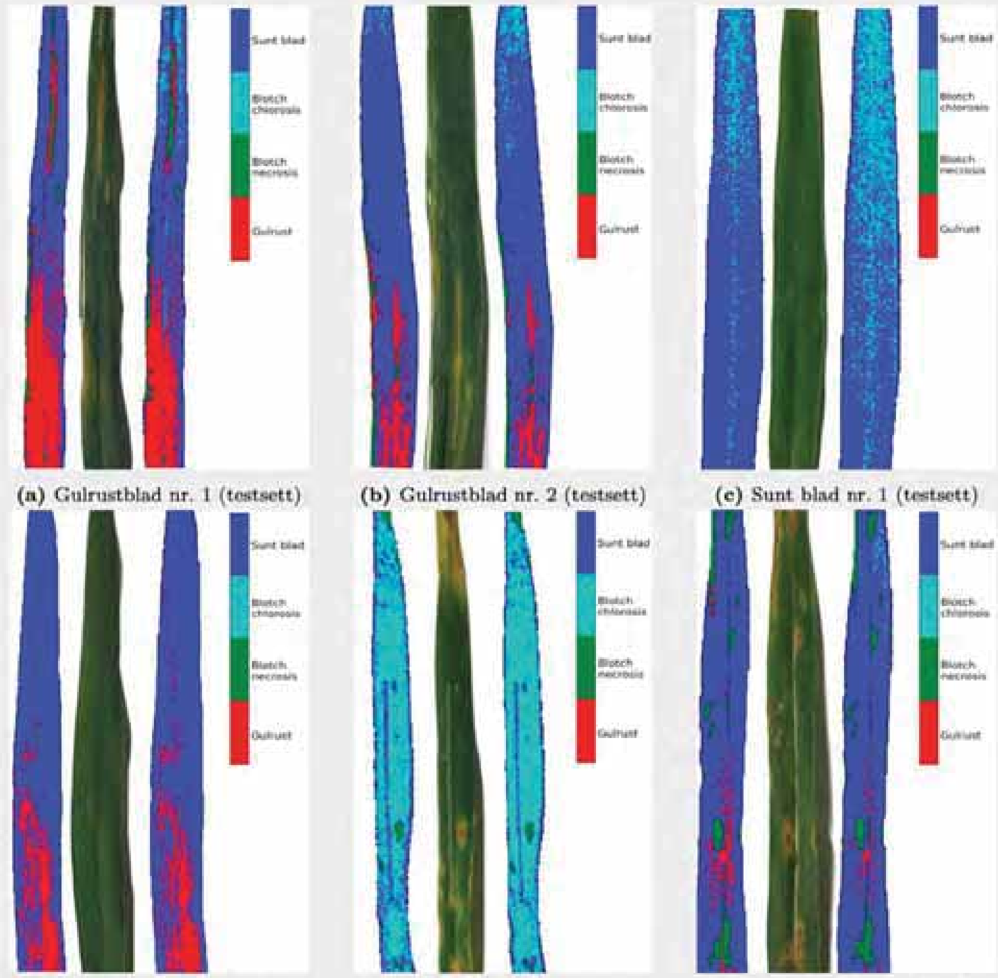


Hyperspectral imaging – wheat rust

(a) Sunne blad. (b) Blad infisert med gulrust. (c) Blad infisert med blotch.

Figur 2: RGB-bilder av utvalg av bladene før hyperspektral bildetaking.





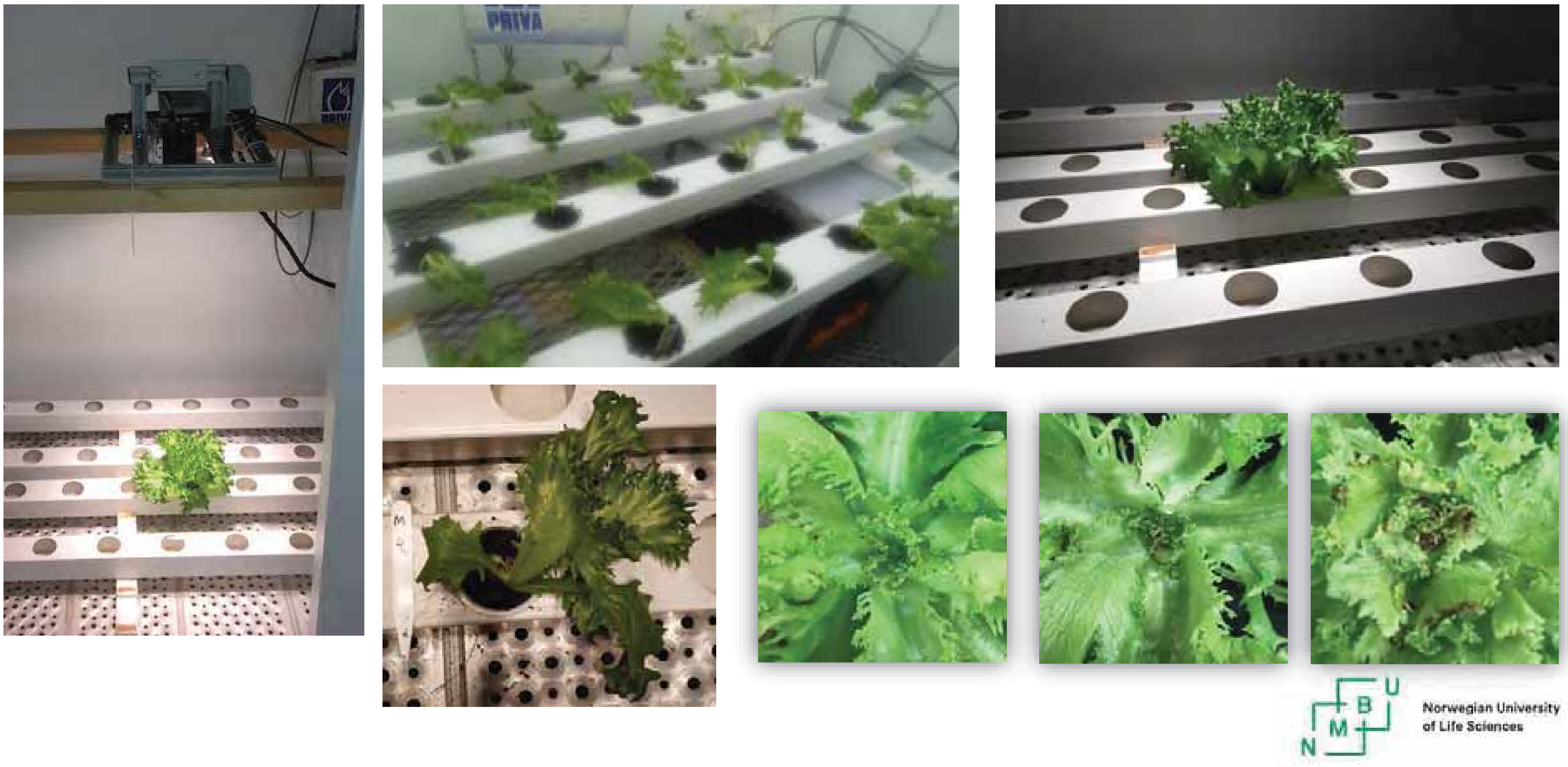
(a) Gulrustblad nr. 1 (testsett) (b) Gulrustblad nr. 2 (testsett) (c) Sunt blad nr. 1 (testsett)

(d) Sunt blad nr. 2 (testsett) (e) blotch-blad nr. 1 (testsett) (f) blotch-blad nr. 2 (testsett)

Figur 13: Bildeklassifisering av testsett med SVC og RFC. Figurene a-f viser klassifisering av bladene gulrust 1 og 2, sunt blad 1 og 2 og blotch-blad 1 og 2 fra testsettet. På hver figur er bladets RGB-bilde i midten, til venstre er pikselklassifiseringen til SVC trent på EMSC og til høyre er den til RFC trent på 10 sensitive bølgelengder fra sett 3.

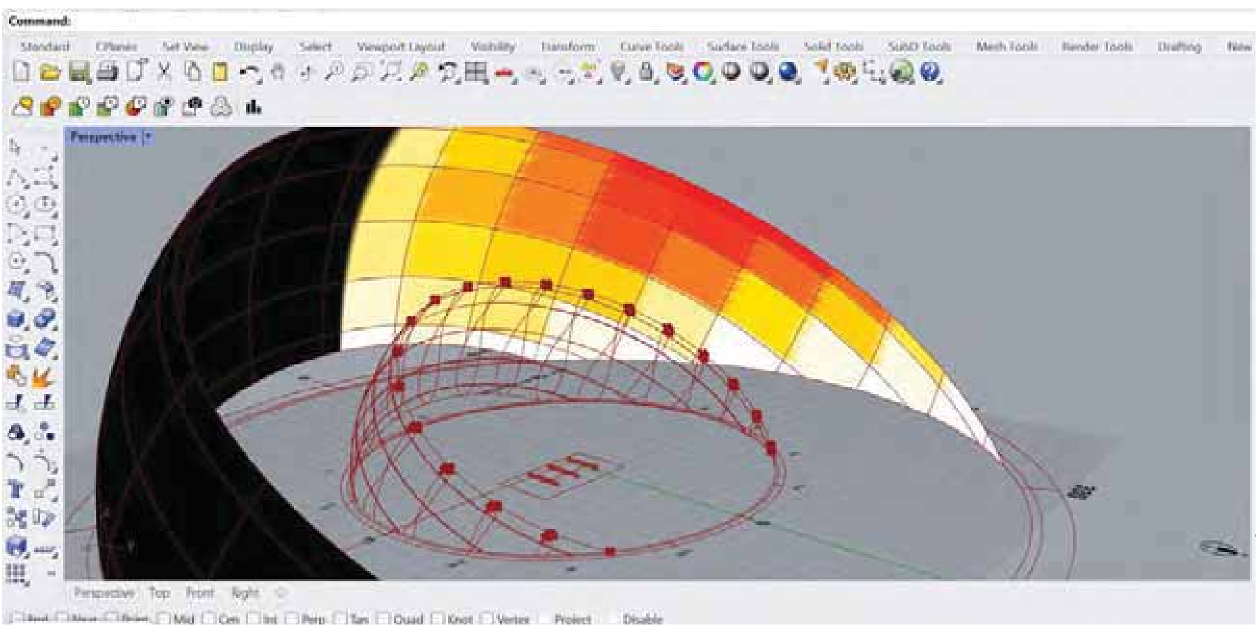
Hyperspectral imaging

Detecting tipburn in lettuce



AgriPV – combining agriculture and solar energy production

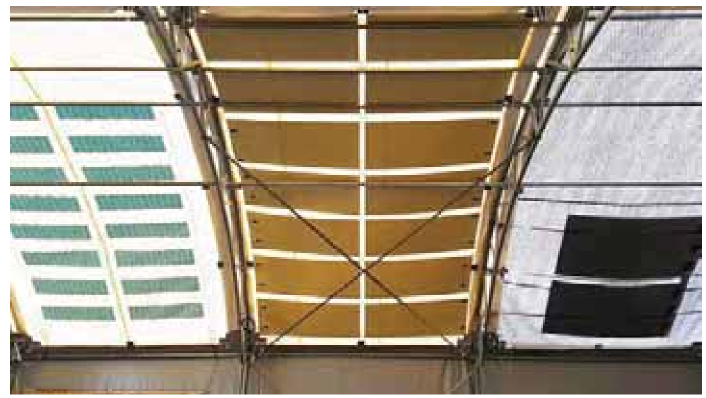
AgriPV – SunFarming at NMBU



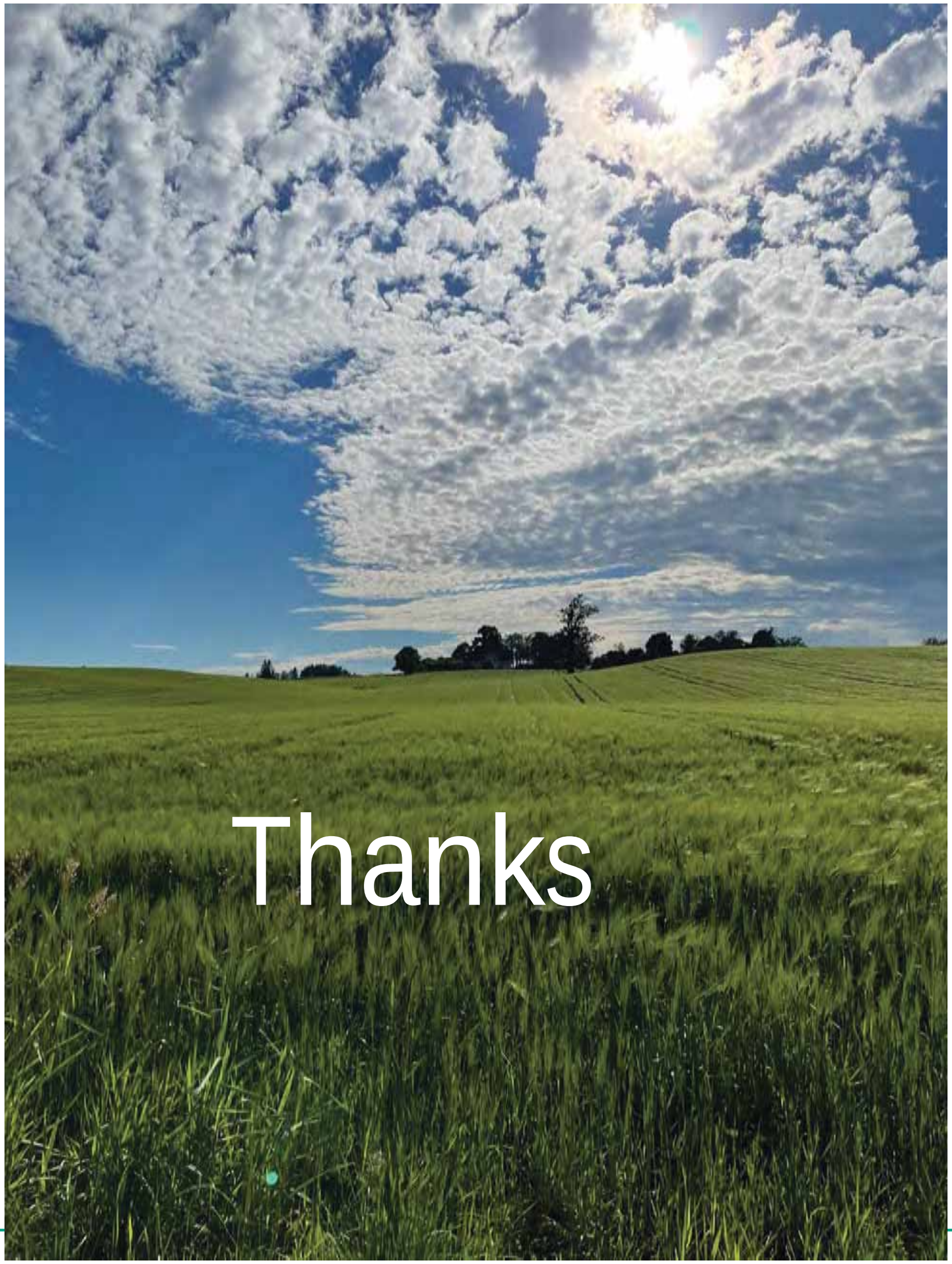
Next 2 Sun

DEUTSCHER SOLARPREIS GEWINNER 2020

AgriPV – SunFarming at NMBU



TARPON
SOLAR


Thanks

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NORSK INSTITUTT FOR
BIOØKONOMI

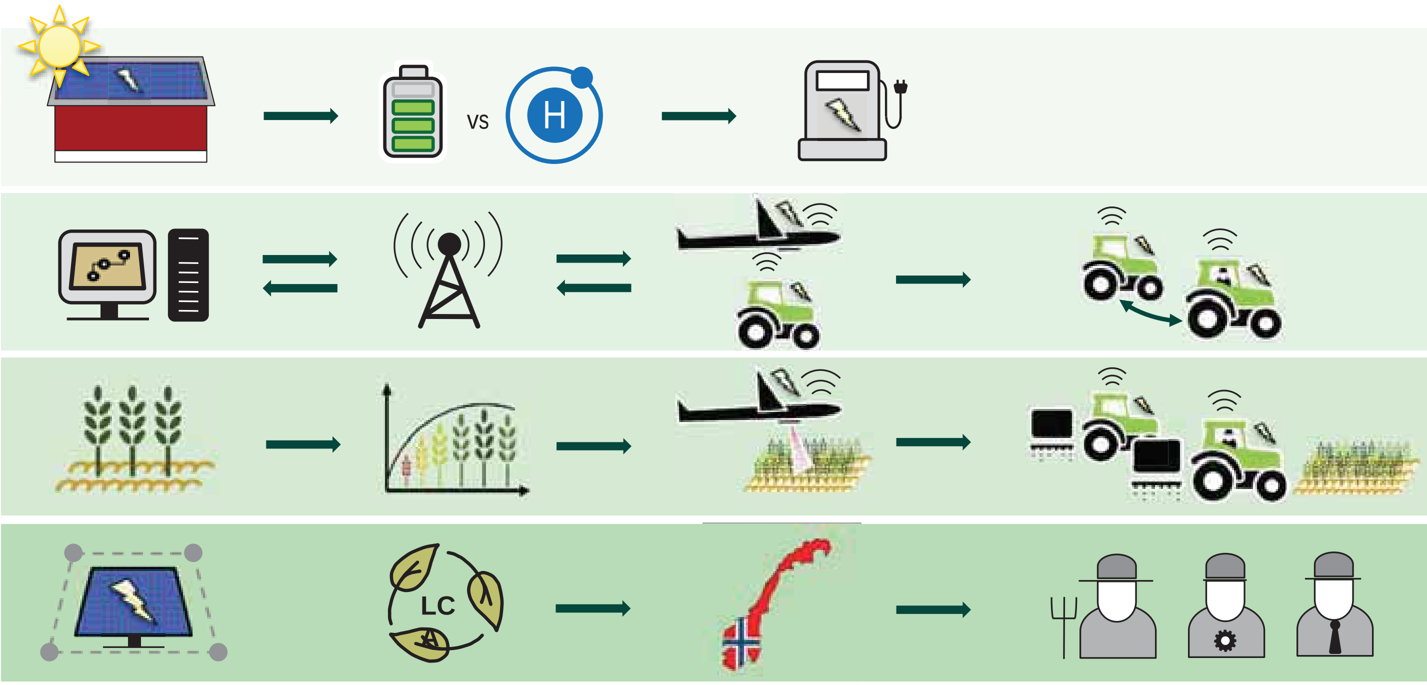
Exploring solar energy combined with a fleet of electrical vehicles and precision agriculture for reduced GHG-emissions (SolarFarm)

Advances and Innovations in Agriculture. The 4th NJF –EurAgEng – Agromek Joint seminar

November 29th , 2022

El Houssein Chouaib Harik / NIBIO

SolarFarm – at a glance



Solar energy production system

Electrical vehicle fleet management

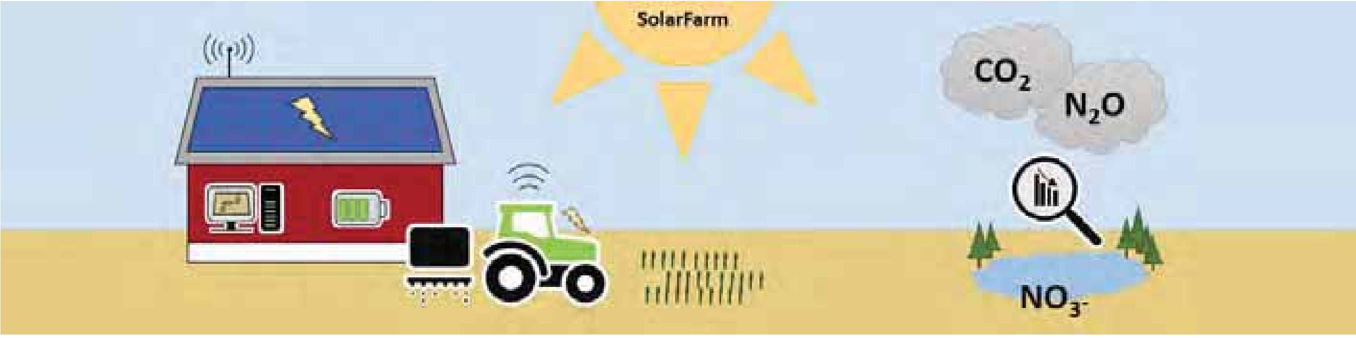
Precision fertilization

System analysis

“The low hanging fruits”

1. Develop a fleet of electrically powered machinery as a **non-fossil based alternative.**

2. Improve nitrogen use efficiency to **reduce nitrogen losses to the environment.**

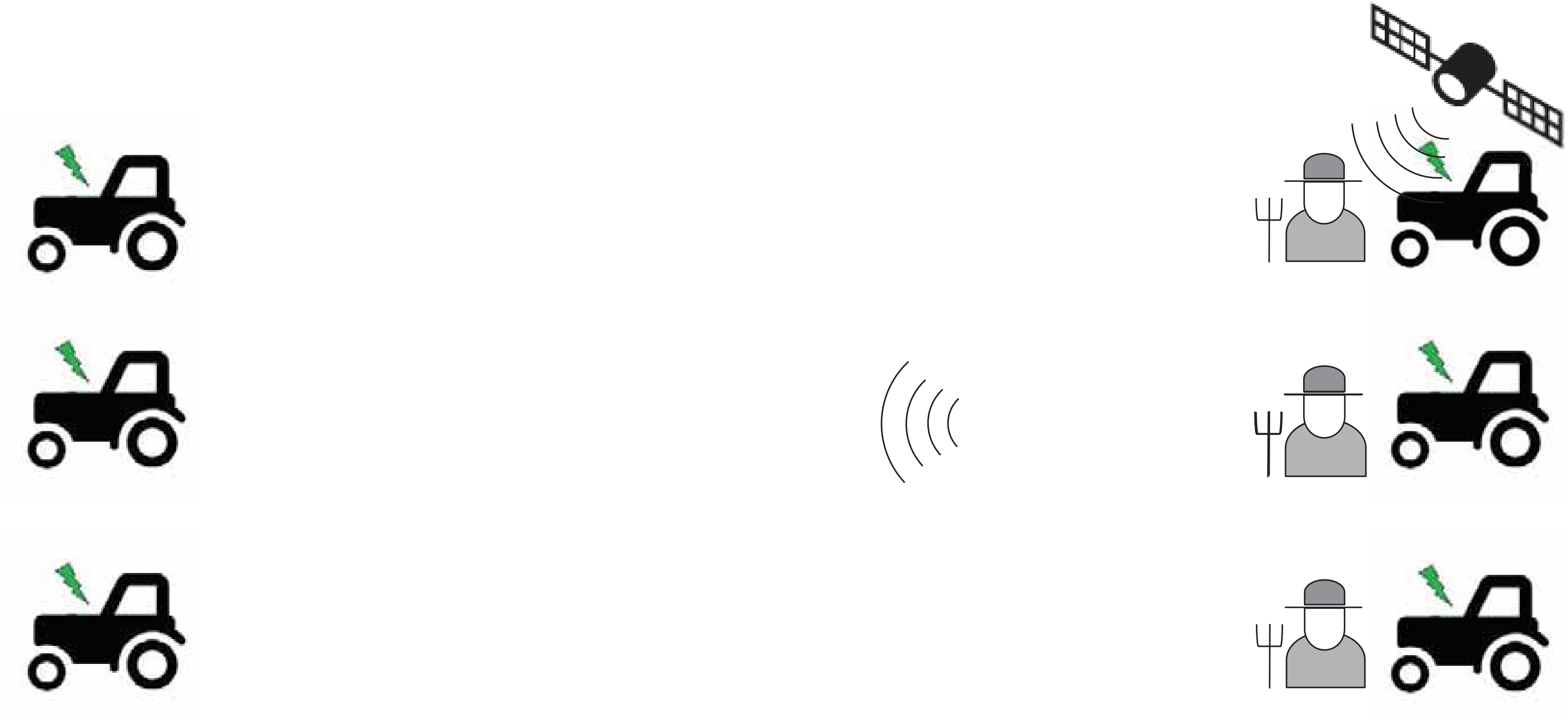


Reduce the emissions from tractor related activities on the farm

Replace diesel tractors with electrical tractors

150 HP Diesel tractor

3 x 50 HP Electric tractor



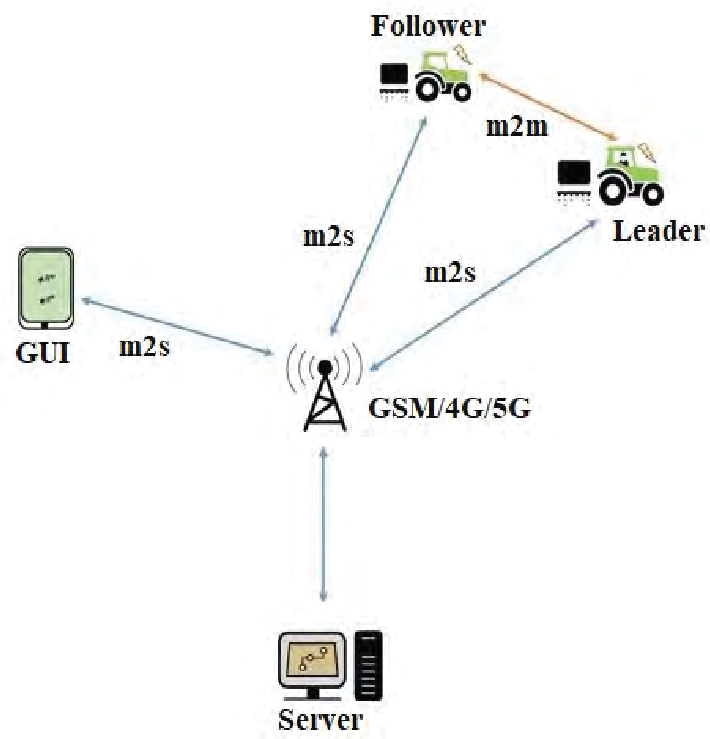
How to drive 3 tractors at the same time?

Solution 2

To reach this:

We want to “*Design a control and communication system for semi-autonomous on-farm fleet management*.”

Communication scheme



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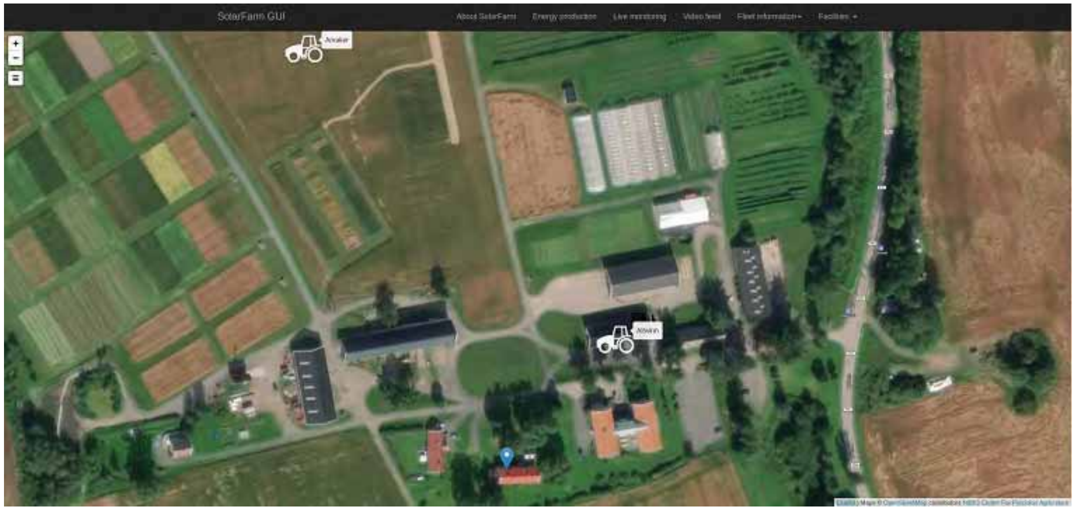
The user interface



The GUI

Contextual menu of the robot

Task allocation example

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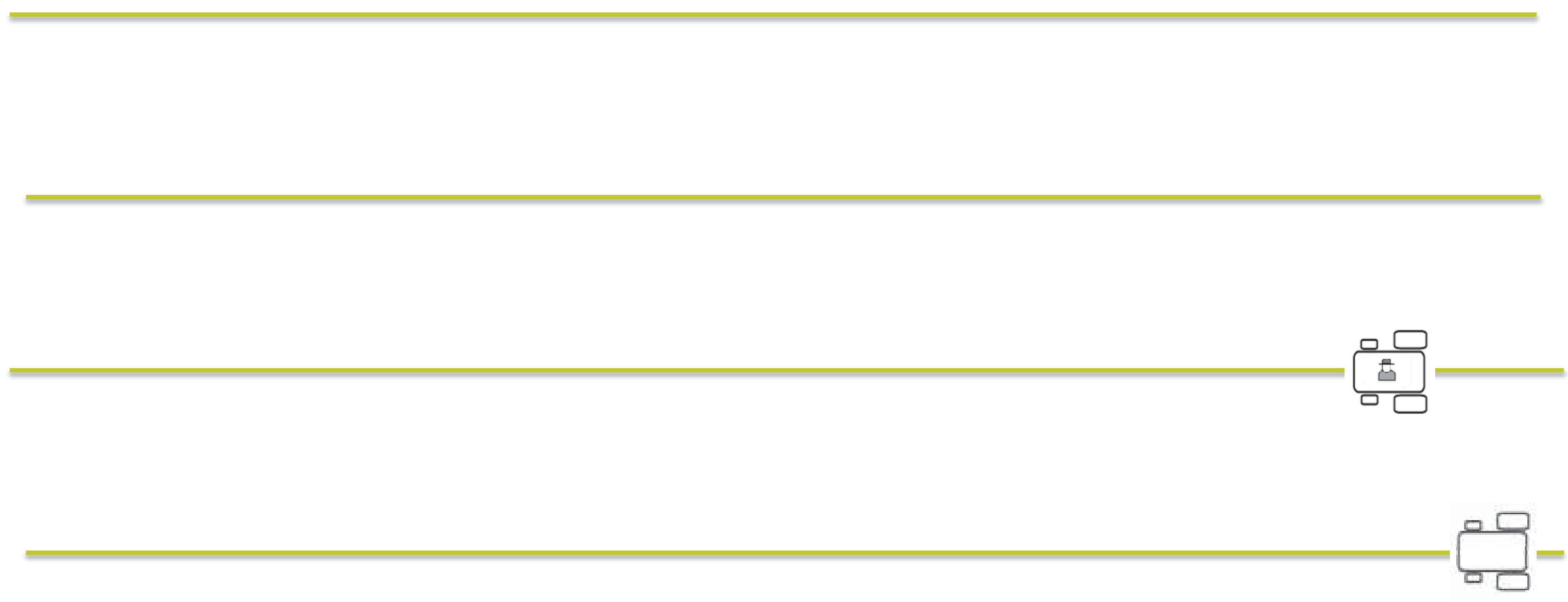
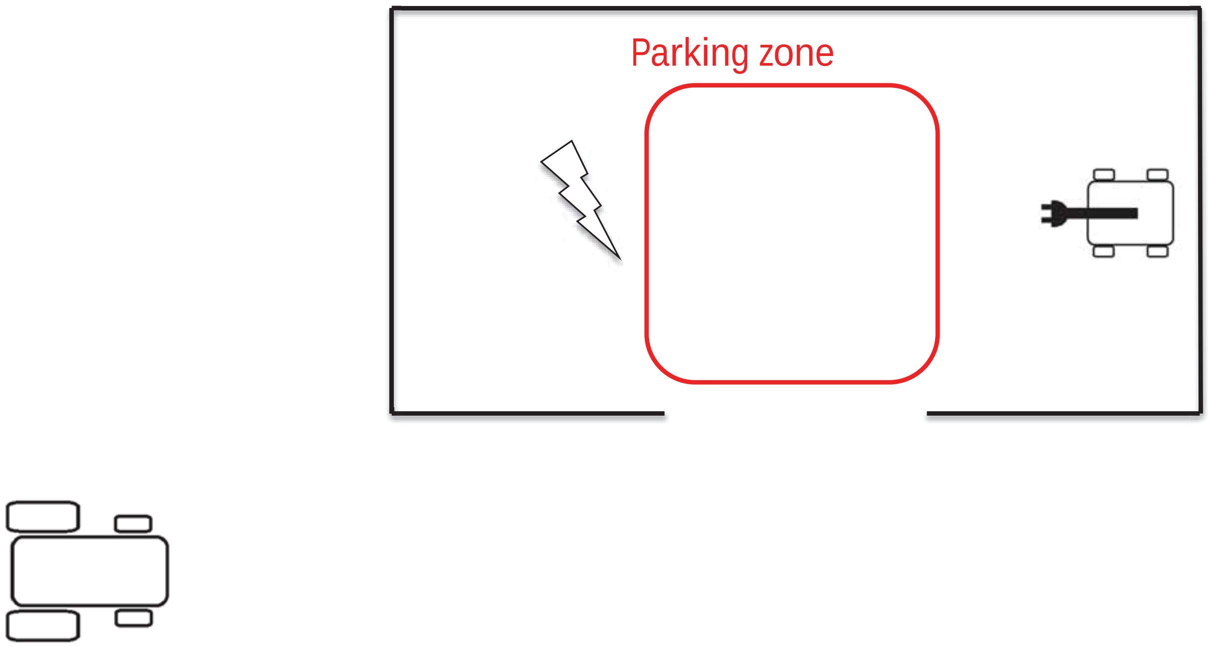
Operation of vehicles in a small team



The Charging station

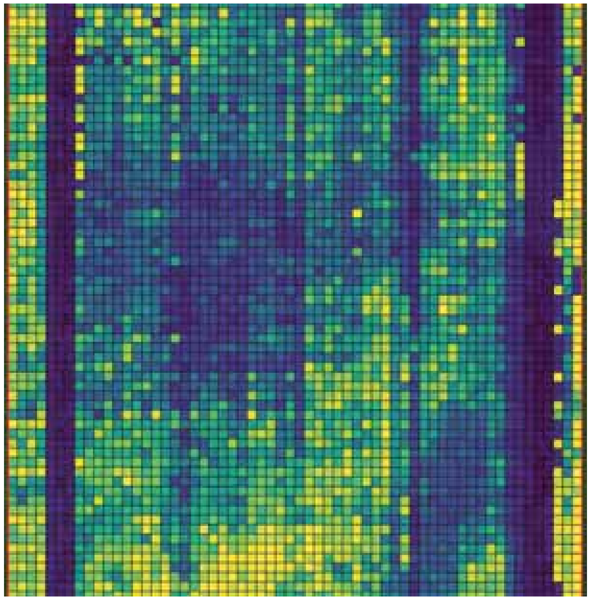


Reduce the emissions related to sub-optimized use of inorganic nitrogen fertilizers

The path from drone measurement to the field application

An UAV equipped with an RGB and a hyperspectral camera

A UAV taken image (BBCH49)



Prediction of the N uptake (BBCH49)

(blue = low, green = middle, yellow = high)

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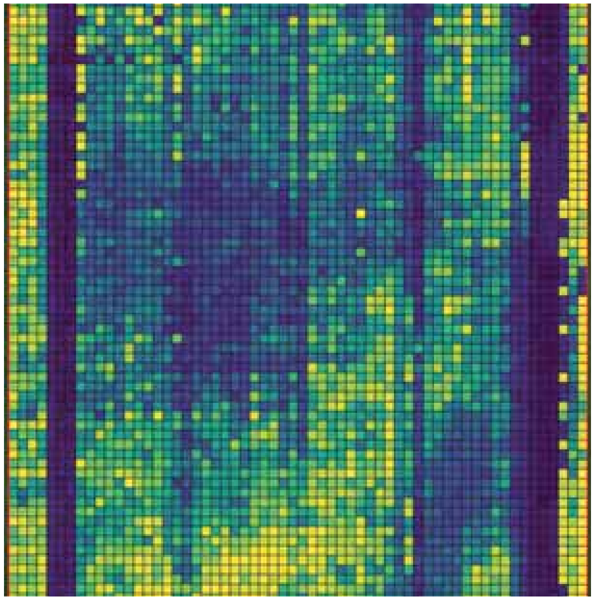
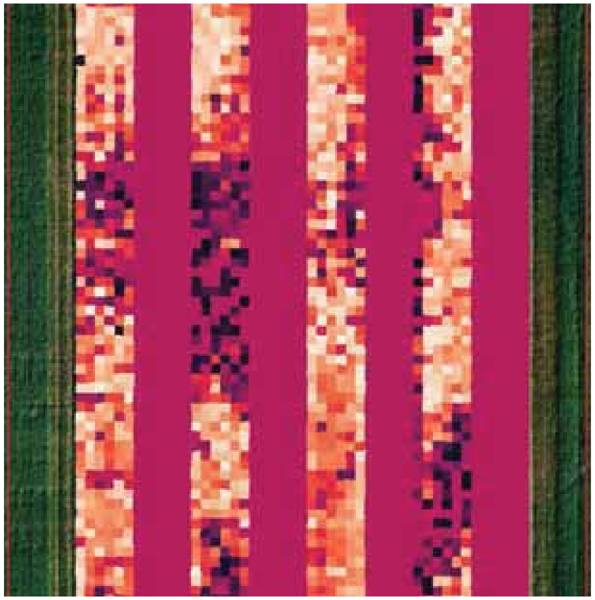
The path from drone measurement to the field application



Prediction of the N uptake (BBCH49)

(blue = low, green = middle, yellow = high)



Recommendations for variable N application (BBCH49)

(dark = low, rose = middle, light = high)

Precision application of liquid mineral N fertilizer using the developed prototype

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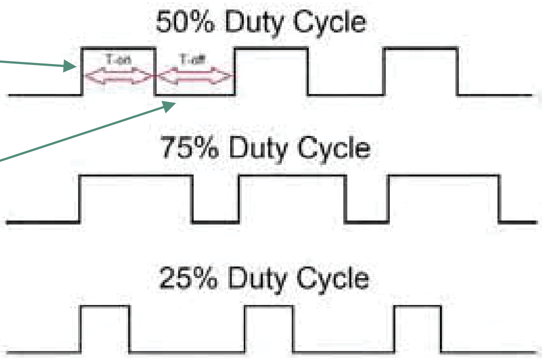
Development of a high spatial resolution liquid fertilizer applicator

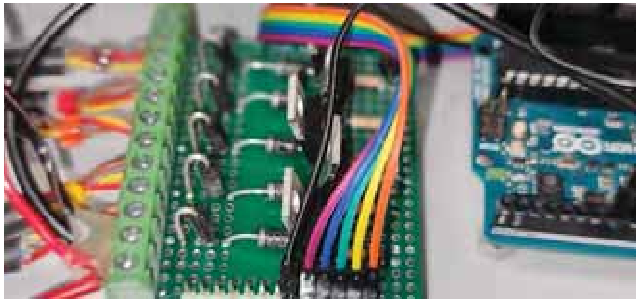
Test bench to analyze the performance of the valves and controllers and calibrate the PWM signal with the weight/volume of the liquid discharged at each nozzle.

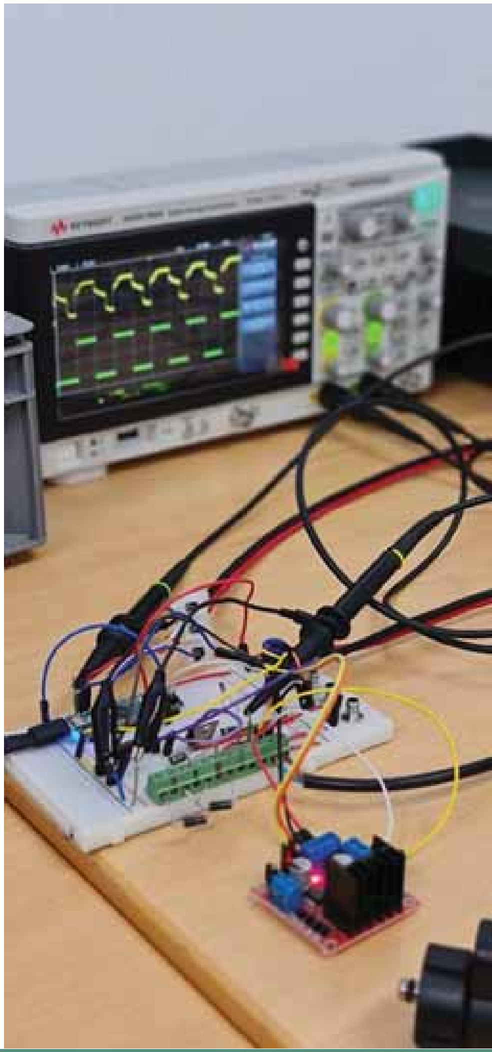
Driver development

spraying

not spraying







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The first functioning prototype of the precision spreader based on a Hardi sprayer.

NIBIO

Thank you for your attention

El Houssein Chouaib Harik
chouaib.harik@nibio.no
www.precisionag.no

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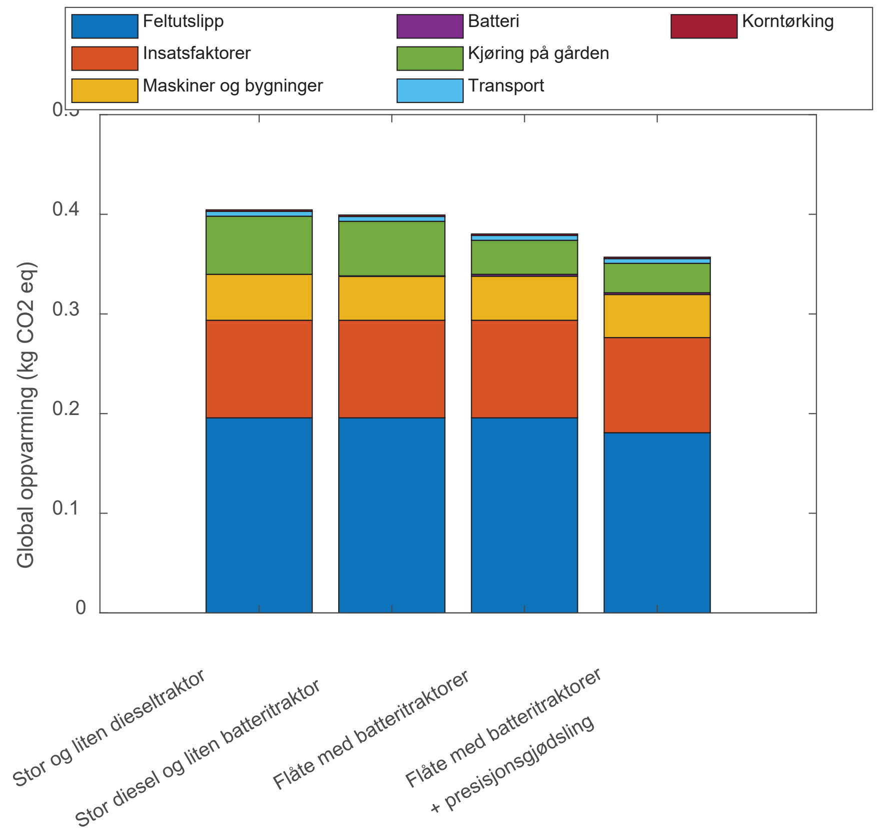
NIBIO_no
NIBIO.no
NIBIO_no
www.nibio.no

Some numbers…

Lokalitet: S r st orge	Stor korng rd		Stort melkebruk		Stor kombinas onsg rd gris og korn	
Totalt forbruk	Diesel	Elektrisitet	Diesel	Elektrisitet	Diesel	Elektrisitet
Stor og liten dieseltraktor	4 910 l	-	8 250 l	-	4 380 l	-
Stor diesel- og liten batteritraktor	4 250 l	2 500 kWh (18 m^2)	8 080 l	600 kWh (5 m^2)	3 900 l	1 800 kWh (13 m^2)
Stor hydrogen- og liten batteritraktor	-	50 500 kWh (376 m^2)	-	94 200 kWh (702 m^2)	-	46 500 kWh (346 m^2)
Stor og liten hydrogen traktor	-	55 700 kWh (415 m^2)	-	95 600 kWh (712 m^2)	-	50 300 kWh (374 m^2)
Flåte med små batteritraktorer	-	10 200 kWh (76 m^2)	-	-	-	-

Areal med solcellepanel

- Stor korngård lokalisert i Sørøst-Norge
- Funksjonell enhet: 1 kg (85% tørrstoff) med bygg, vårhvete og høsthvete ved gårdsgrinda
- Klimagassutslippene synker med omkring 6% pr kg produsert korn ved å bytte fra dieseltraktorer til batteritraktorer som lades med solenergi fra gården.



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Avlingsregistrering

- 96 høsteruter satt ut i de forskjellige blokker/striper i feltet
- Kornprøver tatt med Haldrup forsøkstresker og registrert med samme rutiner som vanlige feltforsøk
- Avling og kvalitet analysert på Apelsvoll med samme rutiner som vanlige feltforsøk. Relativt lav avling med omtrent 600 kg daa-1.
- Jordvariasjon påvirket avlingsresultat og var ikke fullstendig eliminert av variabel N-tildeling basert på drone og regressiv agronomisk tildelingsmodell

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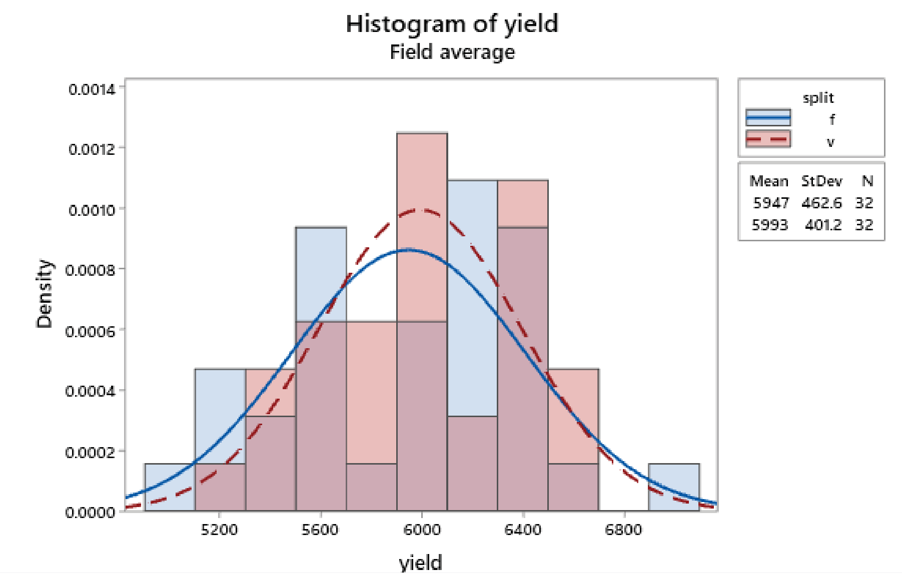
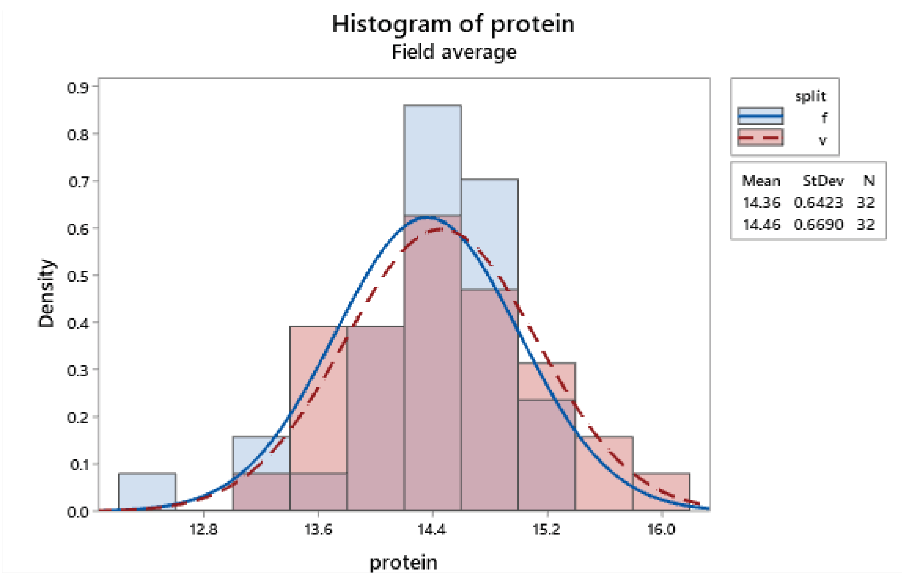
Avlingsresultat





Relativt lav avling men forbedret homogenitet med variabel tildeling (v) sammenlignet med konvensjonell tildeling (f)

Forbedret protein-innhold men litt redusert homogenitet med variabel tildeling (v) sammenlignet med konvensjonell tildeling (f)

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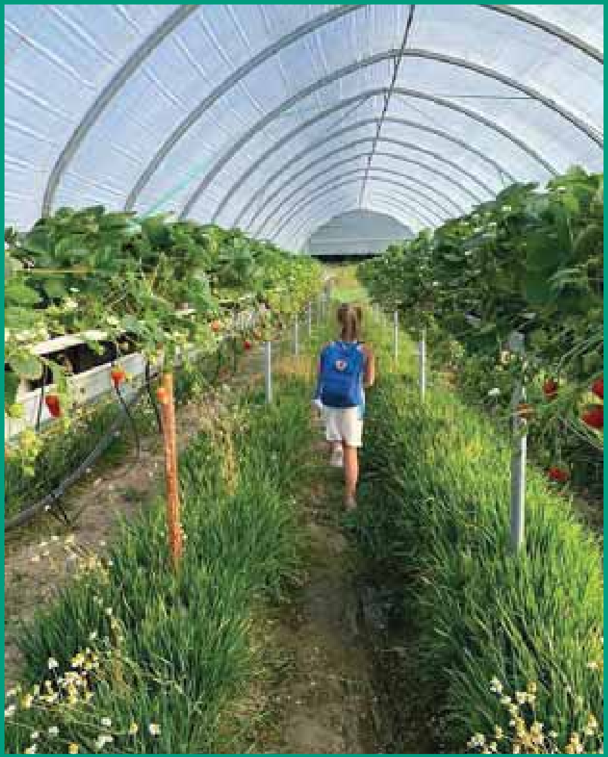
Sensor technology for optimal harvest in strawberry



Siv Fagertun Remberg
Associate professor
Norwegian University of Life Sciences (NMBU)

Advances and Innovations in Agricultural Engineering

The 4th NJF – EurAgEng – Agromek Joint Seminar, Herning, Denmark, 29.-30. November 2022

Strawberryproduction (in Norway and many other countries)

- Open fields
- Greenhouses
- Tunnels
  1) Tunnel cultivation with plants on soil ridges
  2) Tunnel cultivation (high tunnels) with plants on table-tops

A changed production results in changed production methods -but give new opportunities!

- The climatic conditions are changed!
  - Temperature, light (?), precipitation/moisture
- Plants out of the ground and up in the air!
  - Require more adapted equipment (irrigation, fertilization..)
  - A production adapted to all kind of plants and cultivars?

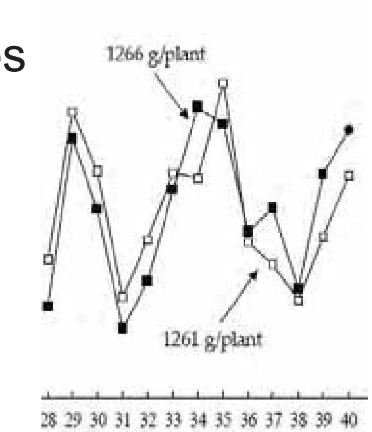
A changed production results in changed production methods -but give new opportunities!

- Extended growing and production season
  - Both ‘pre- and post’ ordinary season (seasonal flowering cvs.)
- Produce (straw)berries in novel areas
  - Geographically
  - Growing technique not dependent on growing in the ground

Strawberries – plant types and type of cultivation

- Field production:
  - Seasonal flowering cultivars
    - = short days are needed for flowerbud induction
  - Flowering the following year
  - Harvesting for 4 weeks
  - Different cultivars mature at different times
  - In Norway: strawberry fruit harvest June-August

- Tunnel:
  - Everbearing cultivars
  - Flower induction in long days
  - Yield (on the same plants) the whole growing season
    - Usually 3 crop tops in Norway



Rivero et al., Horticulturae 2022, 8, 504. https://doi.org/10.3390/horticulturae8060504

Strawberry cultivation

- All strawberry cultivars are different!
  - Growth and development, fruit shape, taste and flavour, chemical content, susceptibility to insects and diseases, frost tolerance etc.

- There are certain requirements for strawberry cultivars used in commercial production (which is not decided by the producer!)
- Different requirements and regulations for production in open fields compared to greenhouse/tunnel

- Possible changes due to cultivation practice:
  - Pests and diseases, berry quality, pollination etc.


‘Favori’ June 27 2022


‘Murano’ July 5 2022

Case from NMBU: strawberry tabletop tunnel cultivation

- Coorporation: Faculty of Science and Technology (Realtek) and Biosciences (Biovit) and Centre for Plant Research in Controlled Climate (SKP), NMBU

- Funding from NMBU, FORREGION Vestfold and Saga Robotics at an early stage

- Tunnel (Haygrove, UK (Myhrene AS) and tabletop built in 2019, automatic irrigation and fertigation system (Elceta), technical help from SKP and Realtek


NMBU

Innovation project (SAGA Robotics, RCN/NFR):

Sensors for automatic strawberry precision picking
Sensorer for automatisk presisjonsplukking av jordbær

MålBær

- Aims to develop sensors for estimating:
  - Size and shape
  - Ripeness
  - Chemical indicators
  - Diseases?

- With the use of an autonomous (strawberry-picking) robot

MålBær

- The value potential of a strawberry-picking robot will be realized when:
  - The sensors will give reliable information on berry quality at harvest
- Destructive measurements are used to measure various quality attributes
- Correlated to non-destructive measurements (different sensors)

Technology can help to solve
the food production in the future!

Thorvald – the robot!

Photo: nmbu.no

Thorvald – the famous robot!

Royal visit to NMBU in March 2017

Photo: Håkon Sparre, NMBU

Thorvald as a platform –and different technical solutions on various challenges

- Powdery mildew in strawberries

- Efficient, autonomous, sustainable and cost-effective treatment

- UV-C light treatments every night
  - Exposing the plants to shortwave light weekly at night
  - A substitute for conventional (chemical) fungicide application
  - Controls powdery mildew
  - Autonomous application
  - Environmental benefits

https://sagarobotics.com/crops/strawberries/

https://sagarobotics.com/

Strawberry picker

- A unit attached on Thorvald platform
- This unit can track and seek out single berries
  - Can identify red colour
    - This does not mean berries of the correct ripening stage!
  - Succession rate of 70-90%, with a low rate of picking unripe berries
- It can also follow and register berry development

https://sagarobotics.com/crops/strawberries/

Strawberry picker

- It has a potential for including several sensors
- Sensordata can optimalize production and harvest and will provide yield predictability valuable for the market

- To develop this picking unit further:
  - Distinguish between unripe berries, and berries of various ripening stages
  - Identify berries with different symptoms
    - Diseases, deformed berries
  - In the end: sort the different qualities to ensure berries of good quality in the punnets

https://sagarobotics.com/crops/strawberries/

Strawberry picker

- Tested in UK and Norway in 2020
- In traditional strawberry production, labor-costs are estimated to approx. 40% of the production costs
- In Europe, shortage of labor is a problem
  - Automatization will then play an important role for this industry
- Customers are willing to pay good money for berries of good quality
- The sensors developed in this project can also be used on other crops, e.g. apples

https://sagarobotics.com/crops/strawberries/

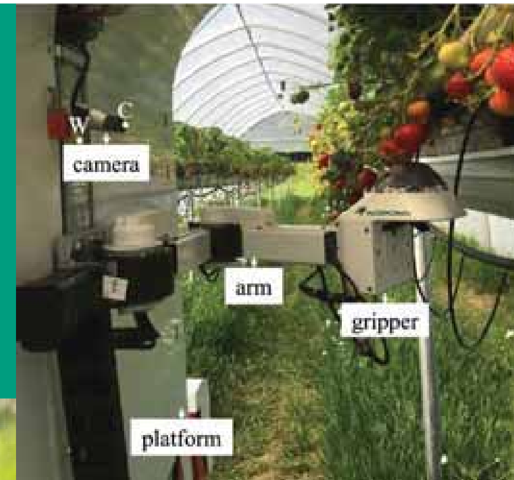
Project 2021&2022

- 2021:
  - Growing strawberries in NMBU-tunnel in a table-top system
  - Berry quality analyses
    - “traditional” destructive analyses
  - Develop and test sensors in lab
    - Outdoor and indoor measurements with multiple sensors
  - Sensory panel (human taste/flavour perception)

- 2022: Further testing of the robot
- 2023: Develop sensors on Thorvald, further and final testing!

https://sagarobotics.com/crops/strawberries/

Promising preliminary results!




Thank you for listening!