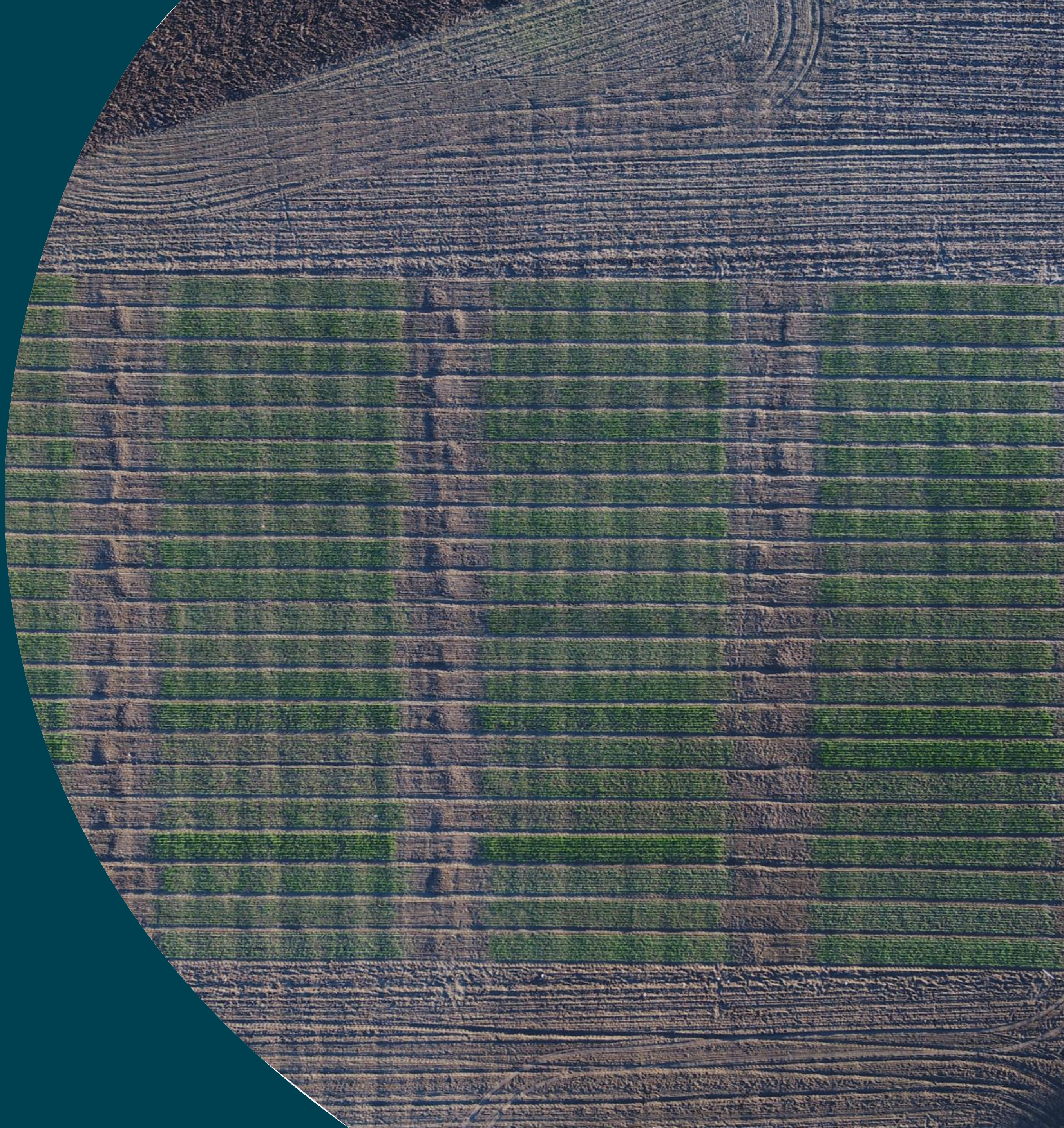
Experiences from appliance of drones in practical research projects at Natural resources institute Finland

21.11.2024

Juho Hautsalo, Panu Korhonen, Kalle Ohralahti, Alma Lehti, Pentti Ruuttunen, Jere Kaivosoja

Luke



Outline of presentation

- Luke
- General info about drones in Luke
- Case studies from drone applications at Luke

Luke

Luke in brief

85
M€
State budget funding

66
M€
External funding

22
Locations
head office in Helsinki, Viikki

1334
employees

648 **Scientists**
639 **Experts***
47 **Research professors**

Luke

*Employees in service groups and research infrastructure servicesas well as directors

Figures updated: 31 December 2023

Scientific activity

We have **650** ongoing research projects, including **80** EU projects. We coordinate **15** of these.

646

Scientific peer-reviewed articles in 2023

We promote the achievement of the United Nations Sustainable Development Goals with our research

Luke

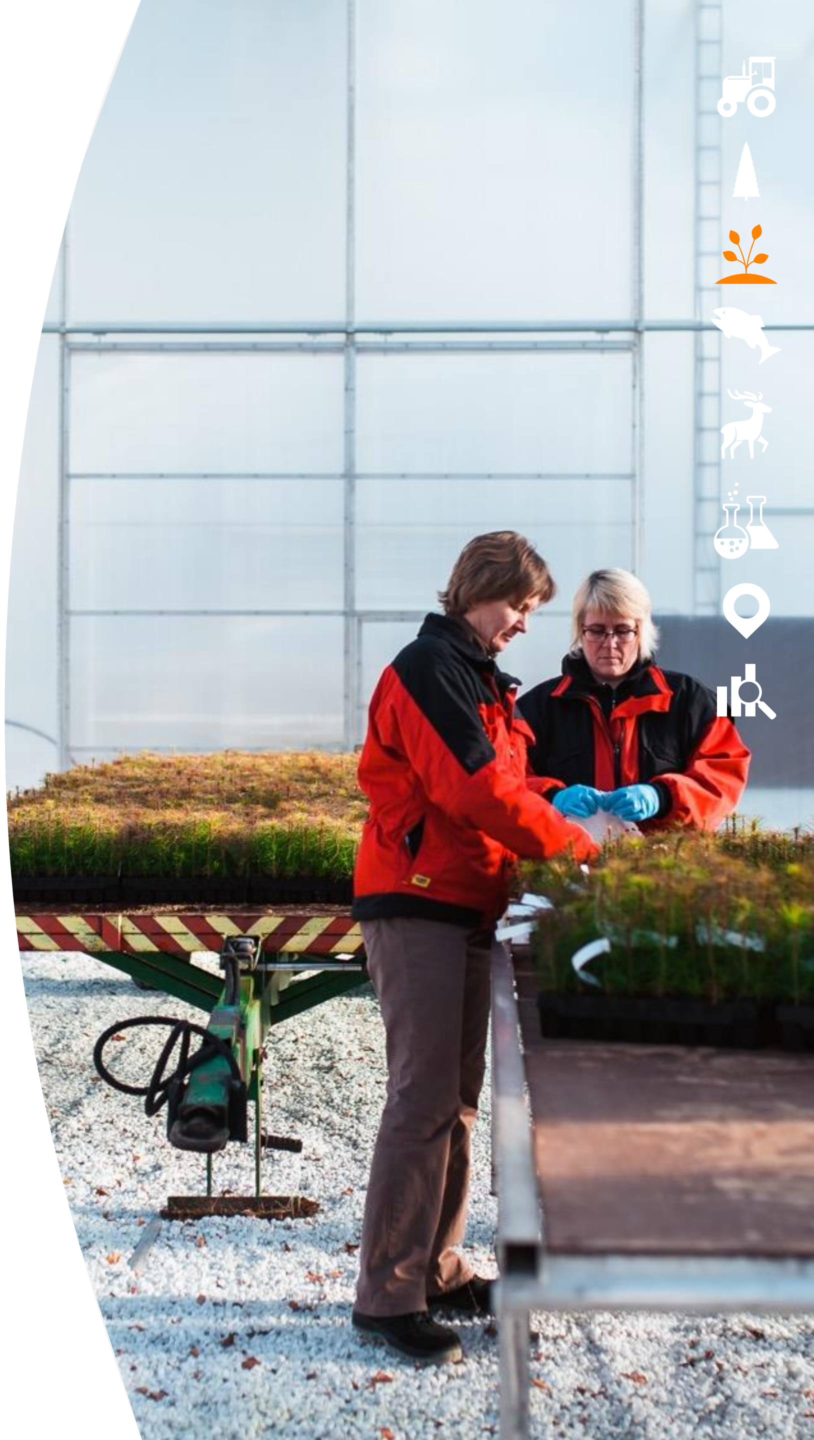
Figures updated: 31 December 2023

Agriculture

- Research platforms and multi-purpose research facilities for studying the milk and feed production chain, as well as other livestock research.
- Research platforms for field water and nutrient management, load, and environmental condition simulations.
- Experimental fields for crop cultivation and plant production.
- Research platforms for carbon fluxes.
- Research platforms for bioeconomy and food system.
- Biogas plants and new energy solutions.
- **Smart agriculture and agricultural technologies.**
- Organic and biodiversity plots.
- Research on environmental impacts of agriculture, cultivation, and peatlands.

Crop and horticulture production

- Research, development, and breeding of garden plants, berries, fruits, vegetables, crops, ornamental plants, green building plants, tree species, and forest seedlings.
  - Greenhouses and their energy efficiency
  - Field research areas for open field cultivation: fields, container trial areas, growth tunnels
  - A fully closed-loop unit for vertical farming
  - **Mobile plant phenotyping platform, imaging device for measuring plant activity during growth**
  - Study of soil biota
  - Testing plant climate resilience
- Long-term conservation collections of horticultural plant genetic resources.



Luke

Phenotyping at Luke

Imaging

CI-710
Specim IQ
Phantom 4 RGB RTK
Phantom 4 multispectral
Micasense Altum
Specim AFX10
Sentinel-1, Sentinel-2

DroneDeploy
Agisoft Metashape Pro
DJI Terra
Caligeo Pro
Others

DroneDeploy
Agisoft Metashape Pro
DJI Terra
ENVI
OpenDroneMap
Others

Dronedeploy
Matlab
ArcGIS
QGIS
TNTGIS
Excel
Others

FMIS
ArcGIS
QGIS
TNTGIS
Excel
Others

Trait of interest

- Spectrical/ spatial
- Temporal
- shapes, image angles

Method

- Spektrometer
- Hyperspektral images
- Drone-RGB
- Drone-multispectral
- Drone-hyperspectral
- Angles, distance
- Mapping/imaging
- setup
- circumstances
- legislation

Pre-processing

- Calibrations
- Georeferencing
- Fixing

Image processing

- Projections
- Target points
- Point clouds
- Altitude- and surface models
- Orthomosaic

Aim

- Why are we imaging?
- What needs to be found?
- What is the application?

Classification

- Measurement & reference
- Machine learning
- Image interpretation & classification

Application

- Link to aim
- Storaging

Environmental properties

- Spectrical/ spatial
- Temporal
- shapes, image angles
- Plants, soil

Reference method

- Classification method
- Vector –insitu
- Digitation from images /from map
- images
- geolocation
- sampling
- Souces of uncertaunty

Pre treatments

- cutting, drying
- Tagging to place
- Meta, storaging
- Cross checing the tables

Reference analyses

- Lab analyses
- Measurements
- Image classification
- Labelling

- Clean Reference data

Reference

Imaging

Analysis

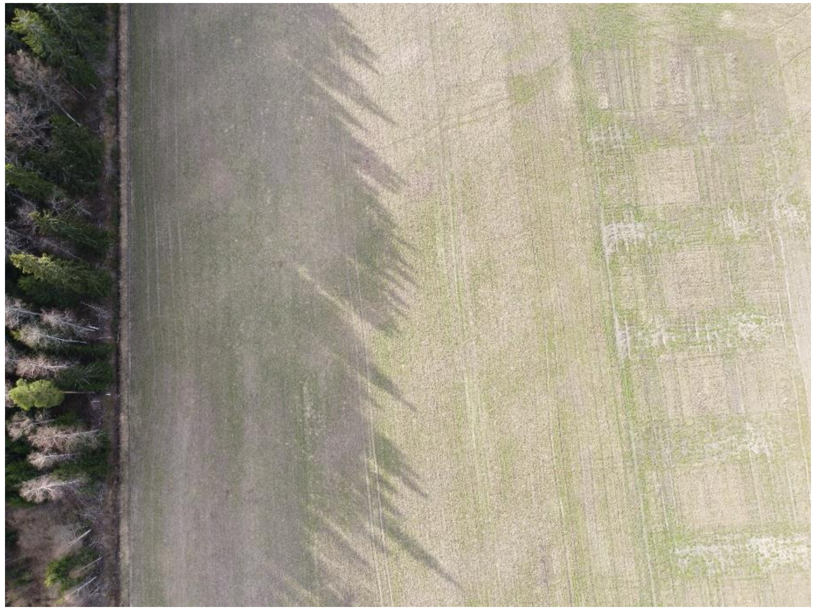
Figure by Jere Kaivosoja

Case studies

Using drones to spot a good place for trials, spring time:

Alma Lehti, PhD student at Plant health group

- Things you can see from the air:



Shadows

Deer precense

Weeds (thistle in this case)

Using drones to spot a good place for trials, autumn time

- Things you can see from the air:

Grass growth & condition, underground drainage

Wet areas

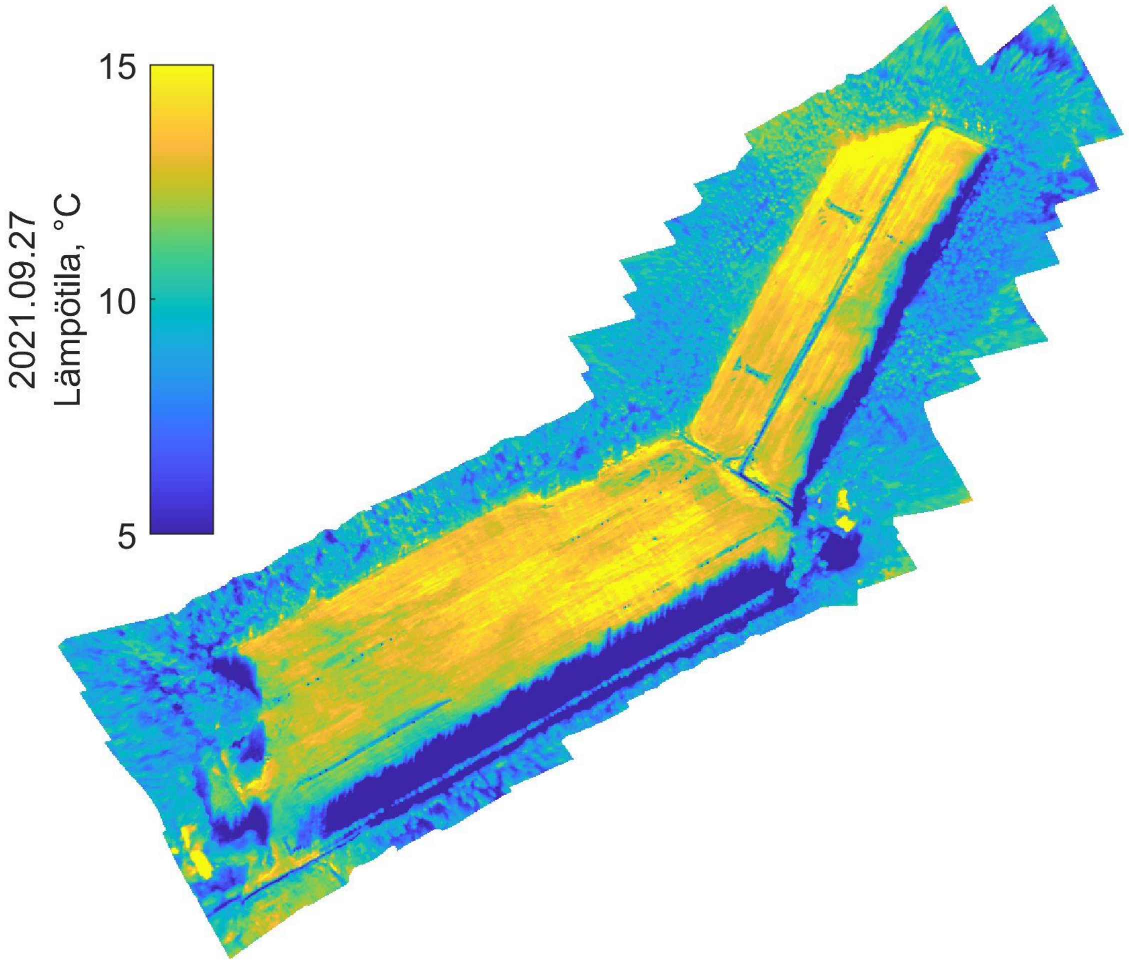
Weeds

Success is not quaranteed

Looks "homogenous" in May

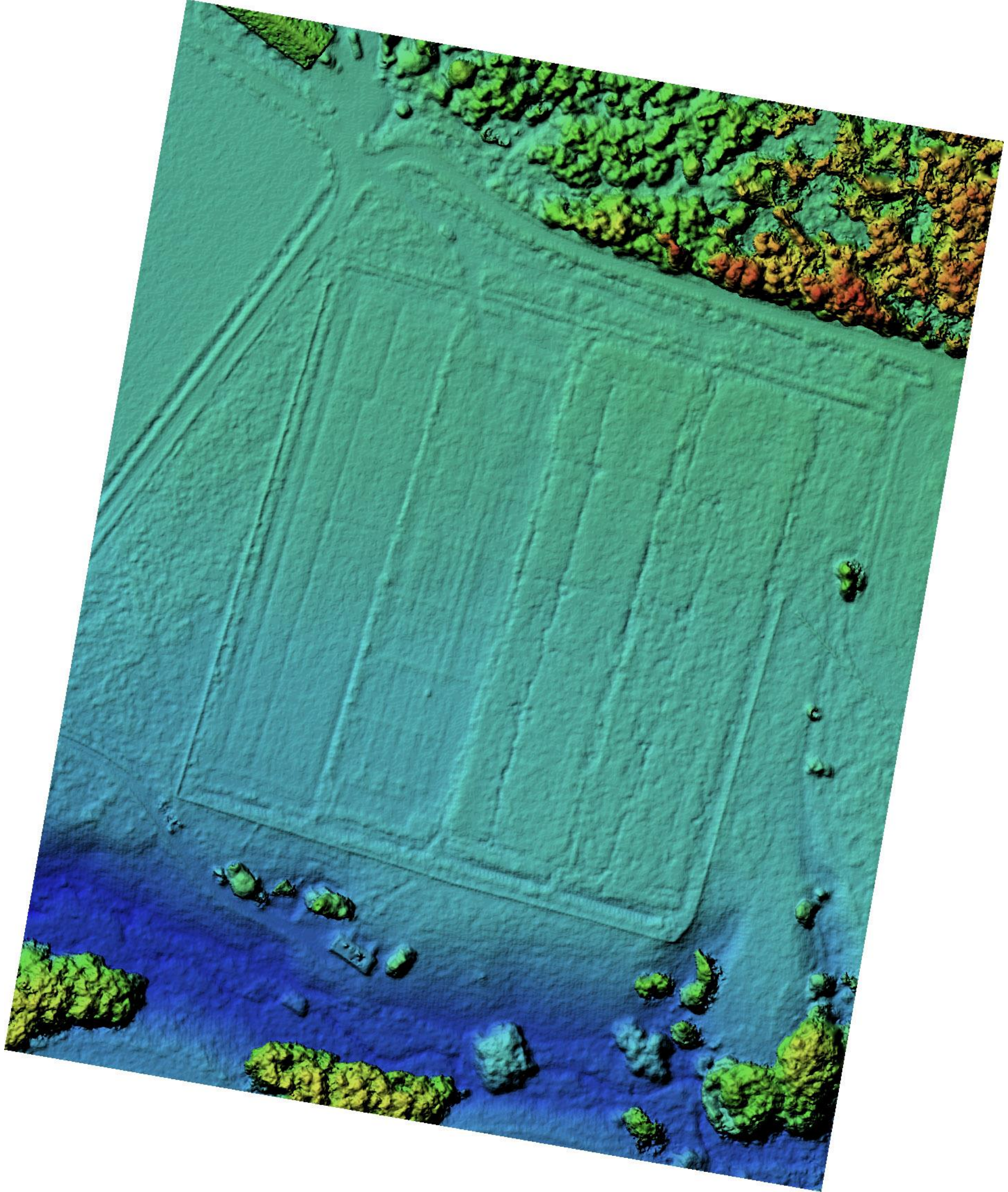
... but not in July...

Soil moisture and ground water surface level determination with heat camera



Jaakko Heikkinen,
Luke

Luke



Snowmold and calculations of living plants

Juho Hautsalo, **Kalle Ohralahti**,
Sanna Kulmala, Marja Jalli

Kuva: Lantmännen Agro https://www.lantmannenagro.fi/palvelut-ja-innovaatiot/viljely/kasvitautien-ja-rikkakasvien-tunnistuskuvat/lumihome/

Snowmold

- *M. nivale* causes yield reductions in grasses and winter cereals by killing overwintering plants
- Spreads through infested seed and crop residue
- Routine observation in VCU trials and also in some fungicide testing
- We also calculate the number of overwintered plants from plots to check the winter survival

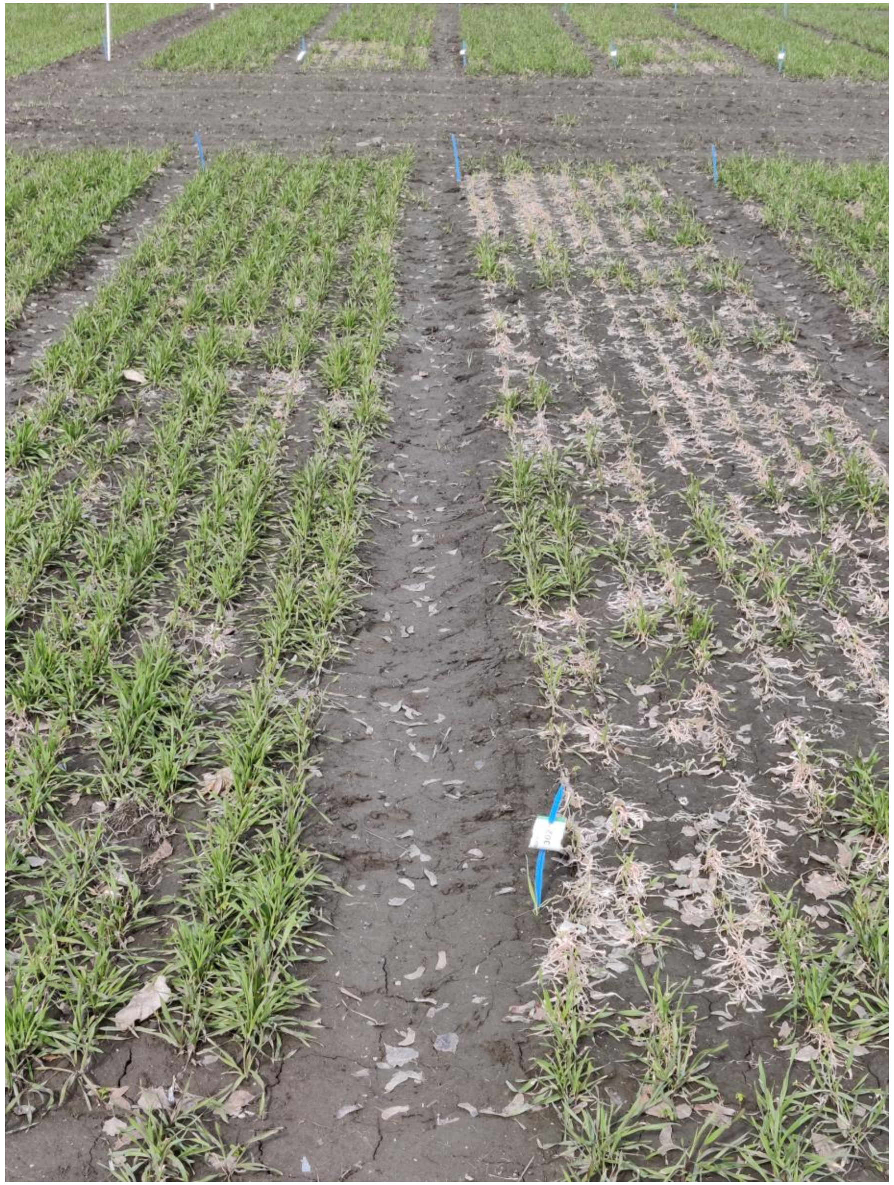


Photo by kalle

Data and reference data

- Five experiments phenotyped for snowmold
- Three of these had also plant number per meter determined
  - 4 rye experiments
  - 1 winter wheat

- Drone flights over the experiments (Matrice 200 V2, camera zenmuse X5S 15mm, altitude 12-15m)
- Ortomosaic by drone deploy, isolation of plot data with **plot cut.**
- Data processing with excel

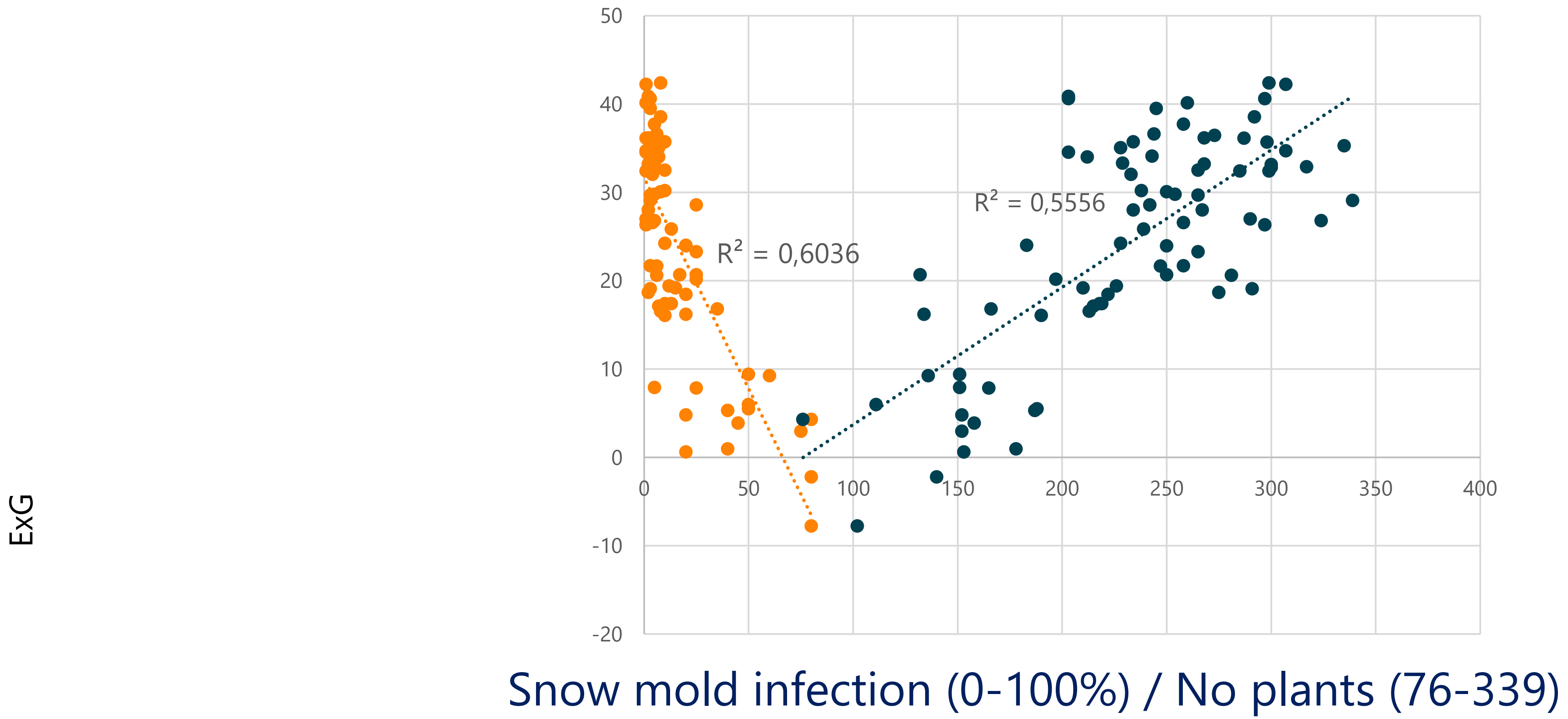
Thanks Jesper!

Different indices to compare with drone image data

Index	Name	Formulation	References
VARI	Visible Atmospherically Resistant Index	$\mathrm{VARI} = \frac{g-r}{g+r-b}$	Gitelson et al. [46]
ExG	Excess Green Index	ExG = 2 * $g - r - b$	Woebbecke et al. [47]
ExR	Excess Red Vegetation Index	$\mathrm{ExR} = \frac{1.4R-G}{G+R+B}$	Meyer et al. [48]
ExB	Excess Blue Vegetation Index	$\mathrm{ExB} = \frac{1.4*B-G}{G+R+B}$	Mao et al. [49]
ExGR	Excess Green minus Excess Red	ExGR = ExG–ExR	Neto et al. [50]
GRVI	Green Red Vegetation Index	$\mathrm{GRVI} = \frac{G-R}{G+R}$	Tucker et al. [51]
MGRVI	Modified Green Red Vegetation Index	$\mathrm{MGRVI} = \frac{G^2-R^2}{G^2+R^2}$	Bendig et al. [6]
GLI	Green Leaf Index	$\mathrm{GLI} = \frac{2*g-r-b}{-r-b}$	Louhaichi et al. [52]
RGBVI	Red Green Blue Vegetation Index	$\mathrm{RGBVI} = \frac{G^2-B*R}{G^2+B*R}$	Bendig et al. [6]
IKAW	Kawashima Index	$\mathrm{IKAW} = \frac{R-B}{R+B}$	Kawashima et al. [53]

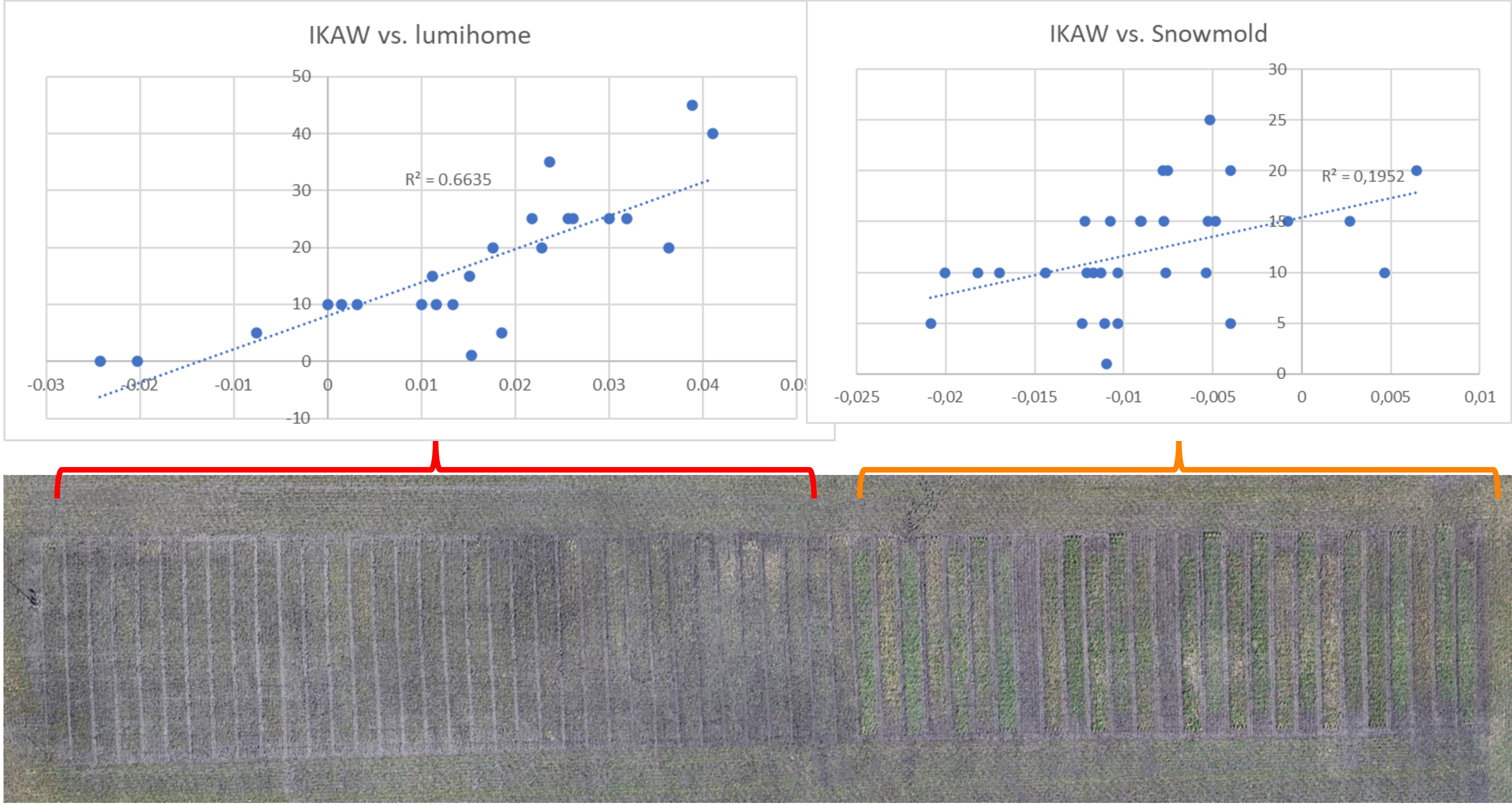
https://plantmethods.biomedcentral.com/articles/10.1186/s13007-019-0402-3/tables/6

Rye 2023,
excess green index vs snowmold, %
excess green index vs. plant number



Rye

Winter wheat



Autumn 2021 (correlation 0.3-0.4)

VARI (Gilteson et al.)

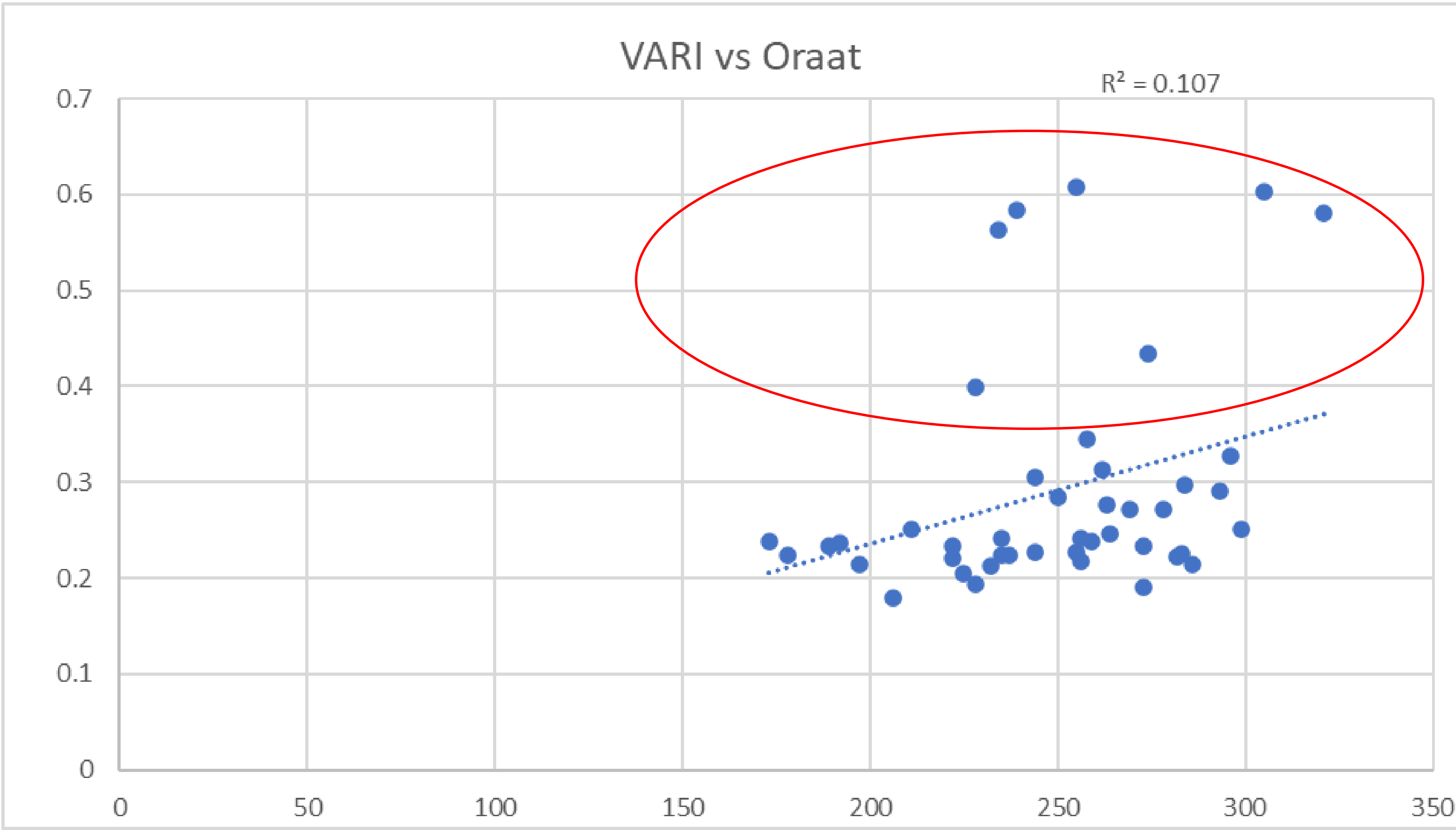


Table 2. Pearson correlations ($p<0.05$). na=not observed, ns=not significant. Indices taken from: Lu, N., Zhou, J., Han, Z. et al. Improved estimation of aboveground biomass in wheat from RGB imagery and point cloud data acquired with a low-cost unmanned aerial vehicle system. Plant Methods 15, 17 (2019). https://doi.org/10.1186/s13007-019-0402-3

Index	Name	Reference	winter wheat trial 2021	rye trial 2021	rye trial 2022	rye trial 1 2023	rye trial 2 2023
VARI	Visible Atmospherically Resistant Index	Gitelson et al. (2002)	ns	ns	-0,87	-0,78	-0,81
ExG	Excess Green Index	Woebbecke et al. (1995)	ns	ns	-0,86	-0,76	-0,81
ExR	Excess Red Vegetation Index	Meyer et al. (2008)	ns	0,49	0,87	0,76	0,78
ExB	Excess Blue Vegetation Index	Mao et al. (2003)	-0,38	ns	0,72	0,71	0,78
ExGR	Excess Green minus Excess Red	Neto et al. (2004)	ns	ns	-0,85	ns	-0,79
GRVI	Green Red Vegetation Index	Tucker et al. (1979)	ns	-0,41	-0,87	-0,76	-0,79
MGRVI	Modified Green Red Vegetation Index	Bendig et al. (2015)	-0,37	ns	0,76	0,72	0,79
GLI	Green Leaf Index	Louhaichi et al. (2001)	ns	ns	0,83	0,73	0,78
RGBVI	Red Green Blue Vegetation Index	Bendig et al. (2015)	ns	0,47	0,62	-0,35	ns
IKAW	Kawashima Index	Kawashima et al. (1998)	0,44	0,81	0,54	-0,6	-0,63
No plants /m2			na	na	-0,81	-0,74	-0,76
normExG			ns	ns	-0,84	0,42	ns

Conclusion snowmold & emergence

- Drones could be used to make things faster with large experiments
- But you need to be carefull with the conditions and timing of imaging
- Make also visual observation at least for the part of the field

JUOTVAI –project 2021 – 2023:
Alternative management options of couch grass and insect pests of oilseed crops

- Funders: Ministry of Agriculture and Forestry (Makera funding), Luke, Nylands Svenska Lantbrukssällskap, Maatalouskoneiden tutkimussäätiö (Finnish Research Foundation for Agricultural Machinery)
- Duration: 2021 – 2023
- Leader Pentti Ruuttunen (Luke, Plant health)

Luke

Objective:

- 1) To produce information applicable to practical crop production on alternative methods of control of couch grass (Elymus repens). Also, the profitability of the methods, as well as the effects of the possible removal of glyphosate on crop rotation planning and field tillage practices, are evaluated.

- Also other objectives but these are not now relevant…..

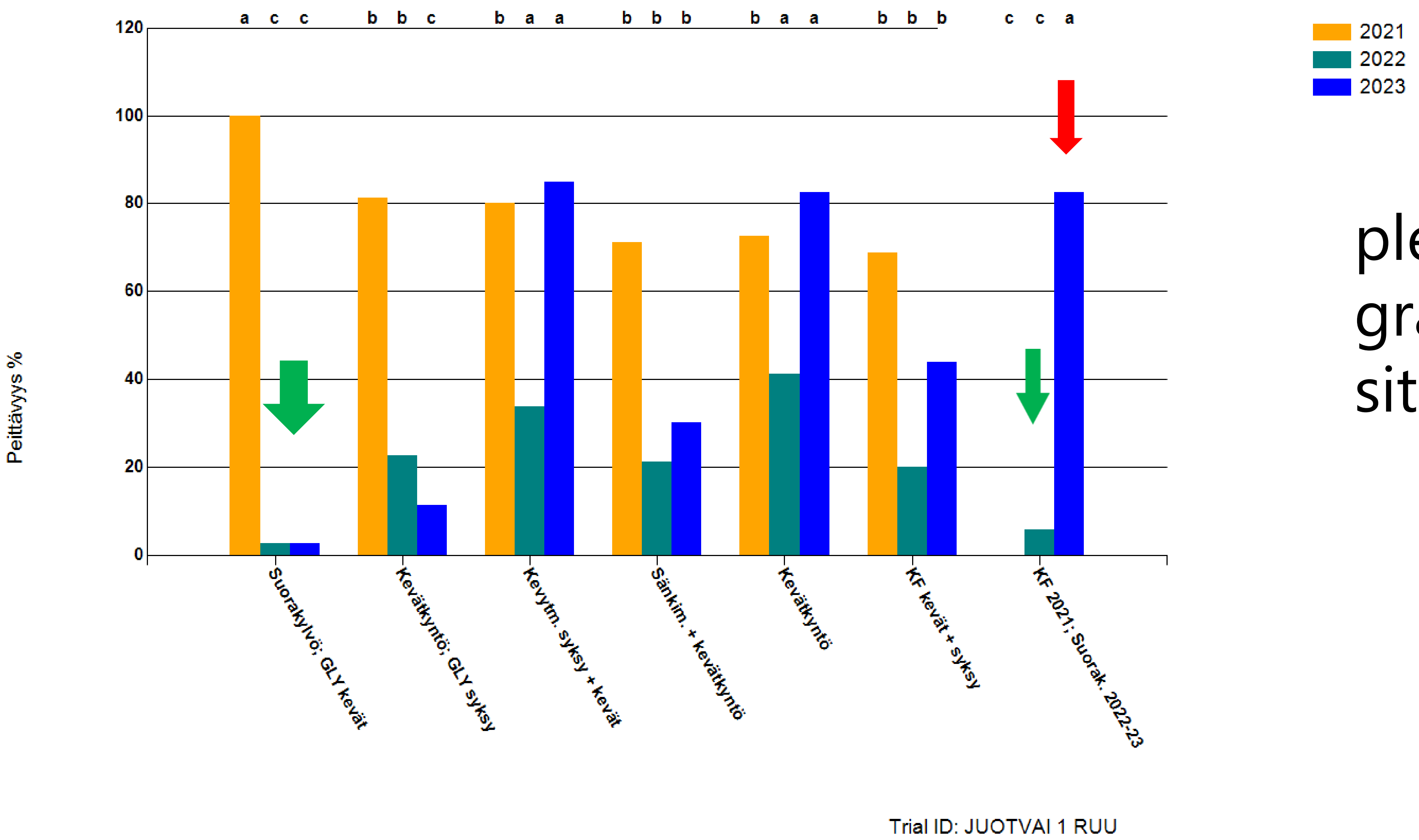
JUOTVAI 1 –experimental design 2021 – 2023
7 treatments, 4 reps, 2 locations

Treatment	2021	2022	2023
1. Direct seeding and glyphosate when needed	Barley	Oats	Barley
2. Glyphosate after harvest and plowing	Barley	Oats	Barley
3. Lighter cultivation practices	Barley	Oats	Barley
4. Lighter cultivation practices + plow	Barley	Oats	Barley
5. Plow and harrow every year	Barley	Oats	Barley
6. Kvick-Finn twice a year	Barley	Oats	Barley
7. Half-Fallow+ greenmanure 2021, direct seeding	Green manure	Oats	Barley

Ilmakuva NSL/Inkoon kokeesta 17.8.2022 (Sanna Kulmala, Luke)

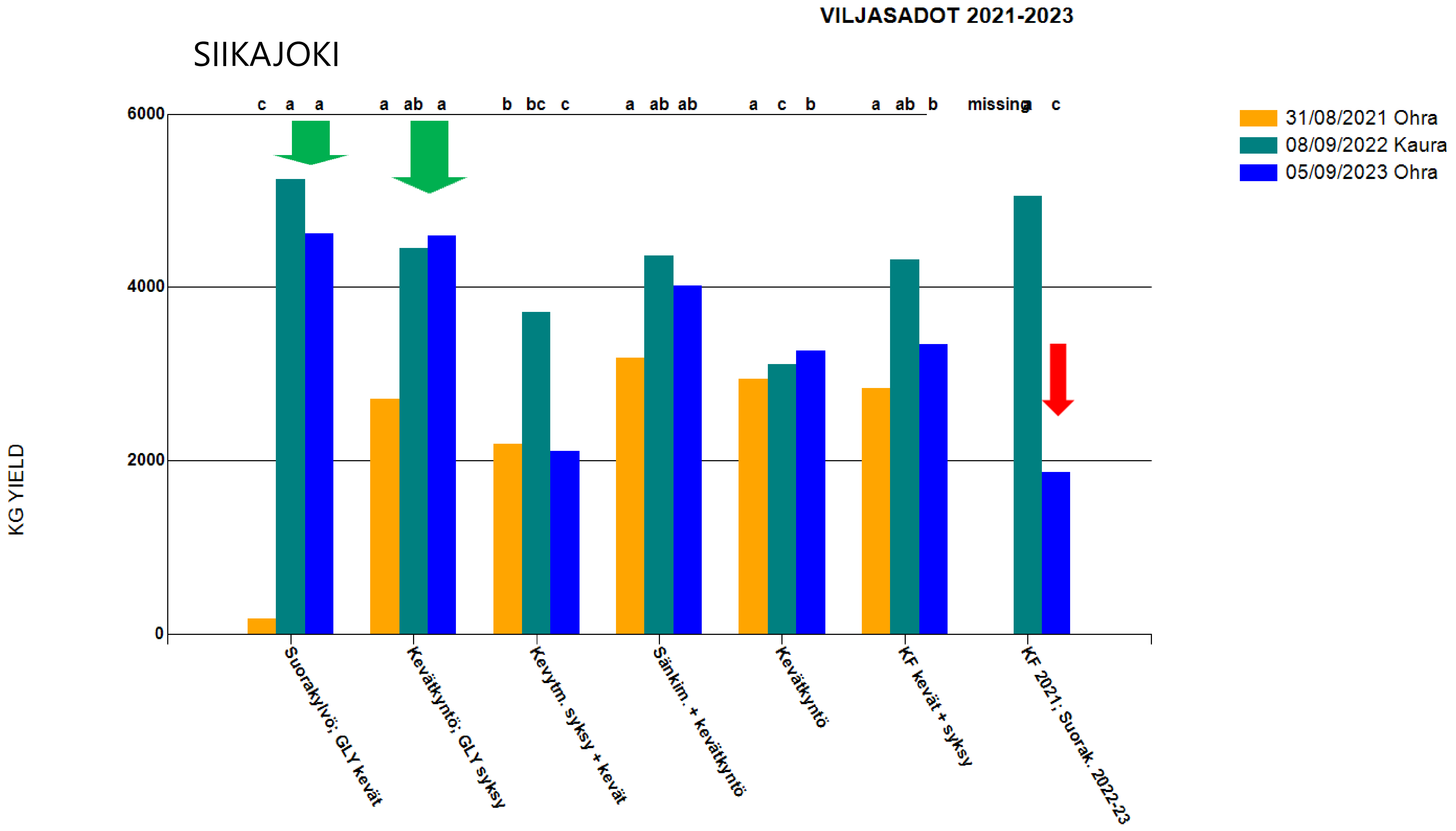
SIIKAJOKI

Crop coverage of couch grass %



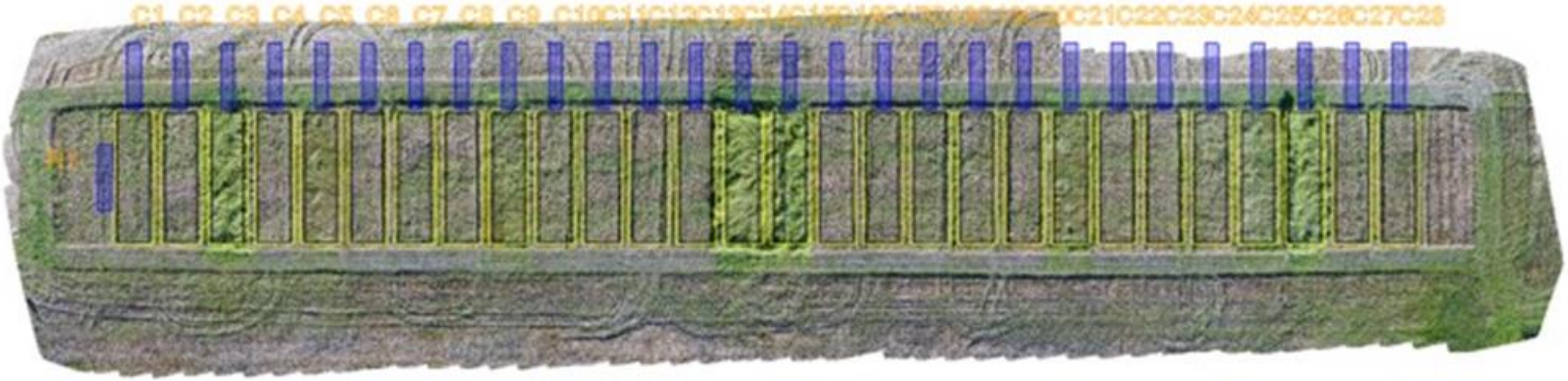
plenty of couch grass at Siikajoki site

SIIKAJOKI



Trial ID: JUOTVAI 1 RUU

Drones can supplement the results(Siikajoki) 30.8.2021. barley

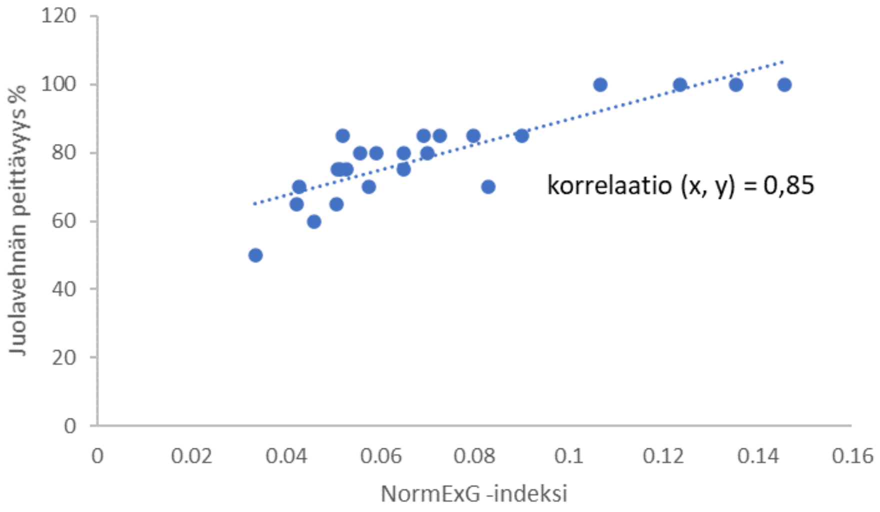


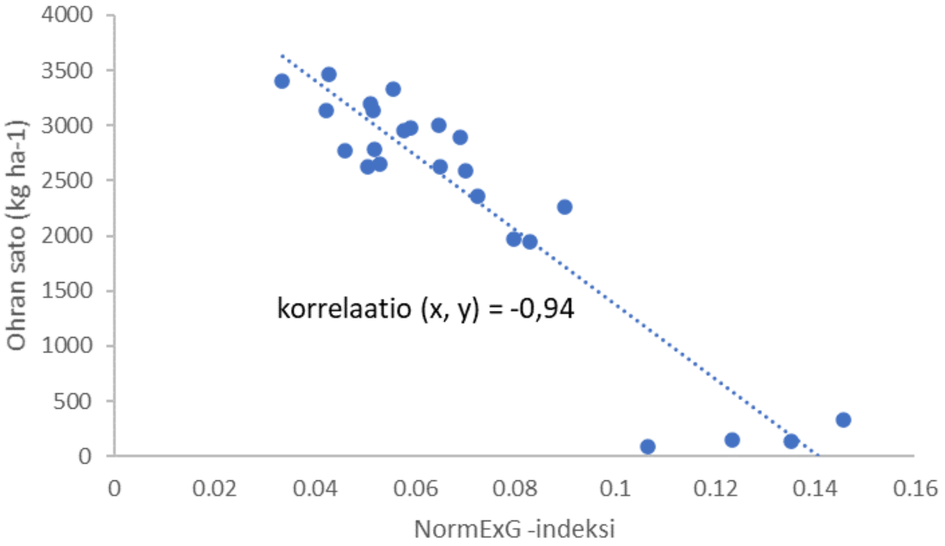
6m

15m	Suojaruutu	101	102	103	104	105	106	107	201	202	203	204	205	206	207	301	302	303	304	305	306	307	401	402	403	404	405	406	407	Suojaruutu
Liittymä		3	6	7	4	1	5	2	6	1	3	5	4	2	7	7	6	5	2	3	4	1	5	2	3	1	7	6	4	
Juolavehnän peittävyys-% 30.8.2021		70	65	0	65	100	60	80	75	100	85	75	80	85	0	0	50	75	85	80	70	100	80	75	85	100	0	85	70	

Havainnot: Timo Lötjönen & Timo Keränen

Good correlations with ground references





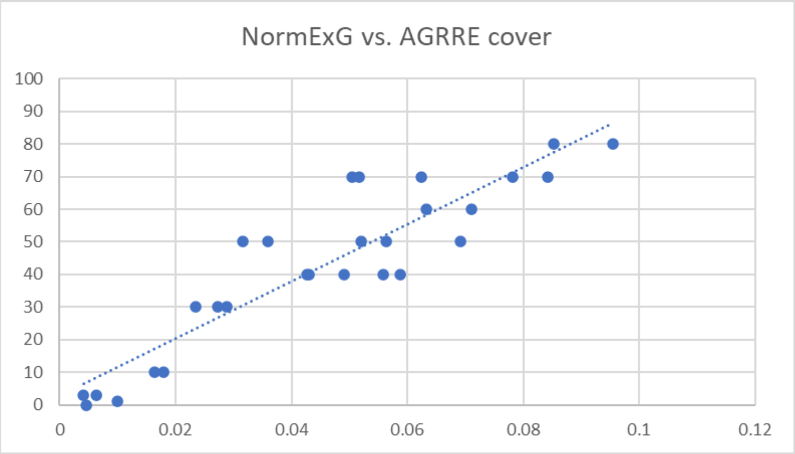
- Couch grass coverage vs. NormExG   Barley yield vs. NormExG

Oats 2022

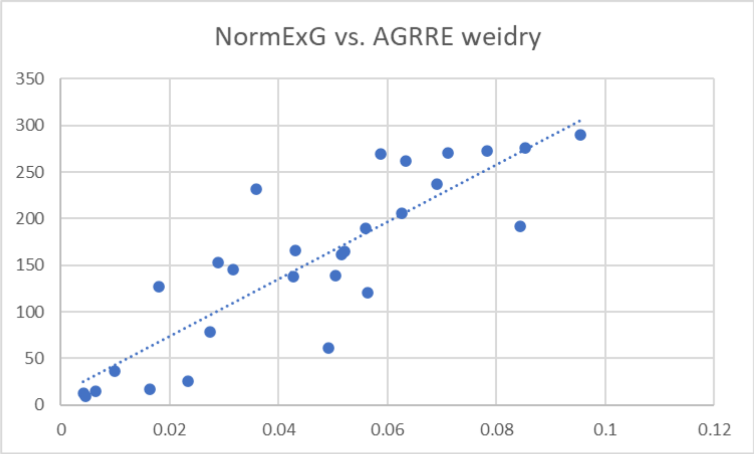
Sunshine and lodging did not spoil the utilization of this orthomosaic

2022 data

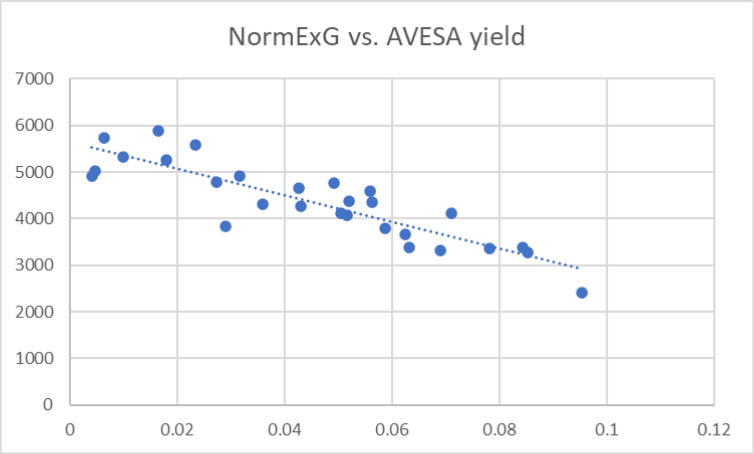
NormExG = ExG / R + G + B



correlation 0.91



correlation 0.86



correlation -0.87

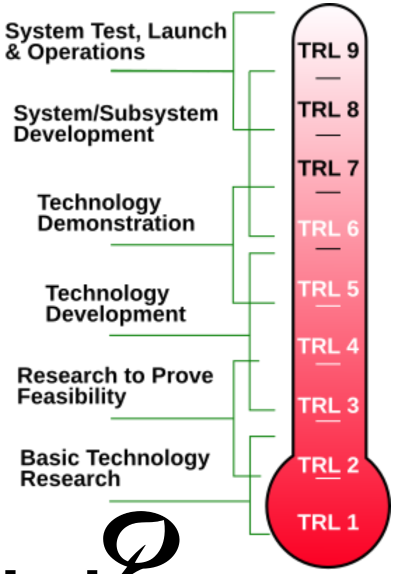
Drones in grassland research – case Luke Maaninka

Panu Korhonen
Research Scientist at
Grasslands and sustainable farming group at
Luke Maaninka

Luke

What are drones good for in grassland production?

Drone services assessed for their applicability, required instrumentation and highest estimated technology readiness levels (TRL; EU) for cattle farms in Finland.

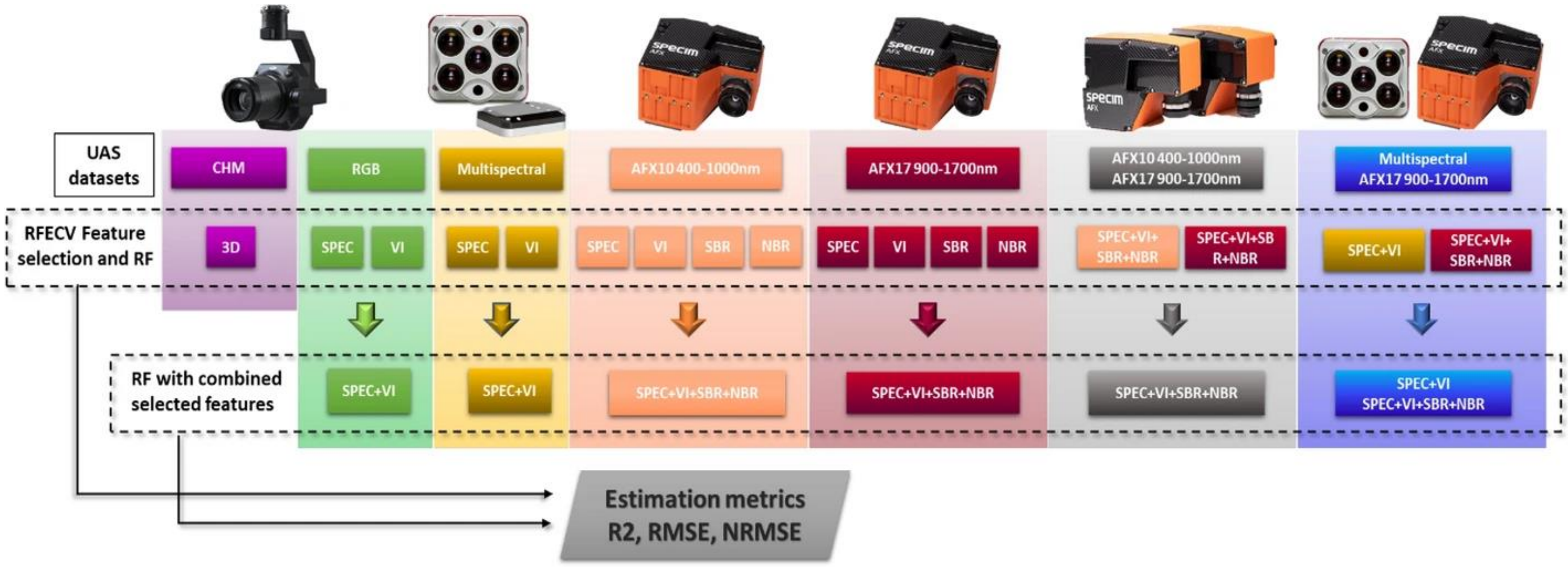


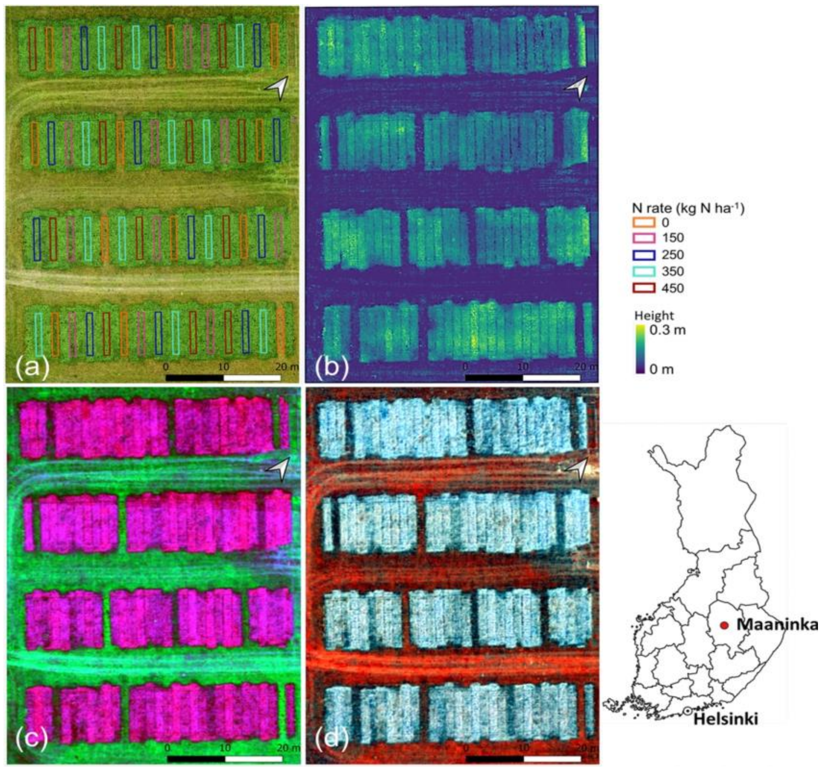
Service type	Service product	Required instrumentation	TRL (1-9)
Aerial canopy imaging	Plant biomass map	MS[1], RGB[2], LiDAR[3]	7
	Forage quality map	(RGB), MS, (HS[4])	5
	Plant density map (overwintering)	RGB	6
	Canopy water stress map	MS, (HS)	6
	Continuous plant development monitoring	RGB, MS (autonomous drone-system)	3
	Nitrogen uptake map	MS, HS	6
3d-mapping	Canopy height map	LiDAR, RGB	8
	Feed volume estimation (e.g. silos)	RGB, LiDAR	7
Canopy close-up imaging	Legume proportion estimation	RGB (high-resolution)	6
	Information for weed protection	RGB (high-resolution)	6
Large area mapping	Field parcel rating	RGB, MS, BVLOS[5] drone	7
Aerial soil imaging	Soil moisture map, drainage monitoring	Thermal camera, RGB, MS	6
Pasture monitoring	Nutrient dispersion map (manure, urine)	RGB, MS	6
	Animal location and movement monitoring	RGB, thermal camera	6
	Grazing pressure optimization map	MS, RGB, LiDAR	3
Environment monitoring	Plant biodiversity map	RGB, MS	3
Spreading and spraying	Oversowing, reseeding	UAV-mounted spreader	6
	Fertilizer application	UAV-mounted spreader	8
	Plant protection	Spraying system	6

[1]MS = multispectral camera, [2]RGB = red-green-blue camera (visible light), [3]LiDAR = light detection and ranging, [4]HS = hyperspectral camera, [5] BVLOS = beyond visual line of sight

Luke

Grass quantity and quality estimations using VNIR and SWIR UAS-hyperspectral cameras and machine learning



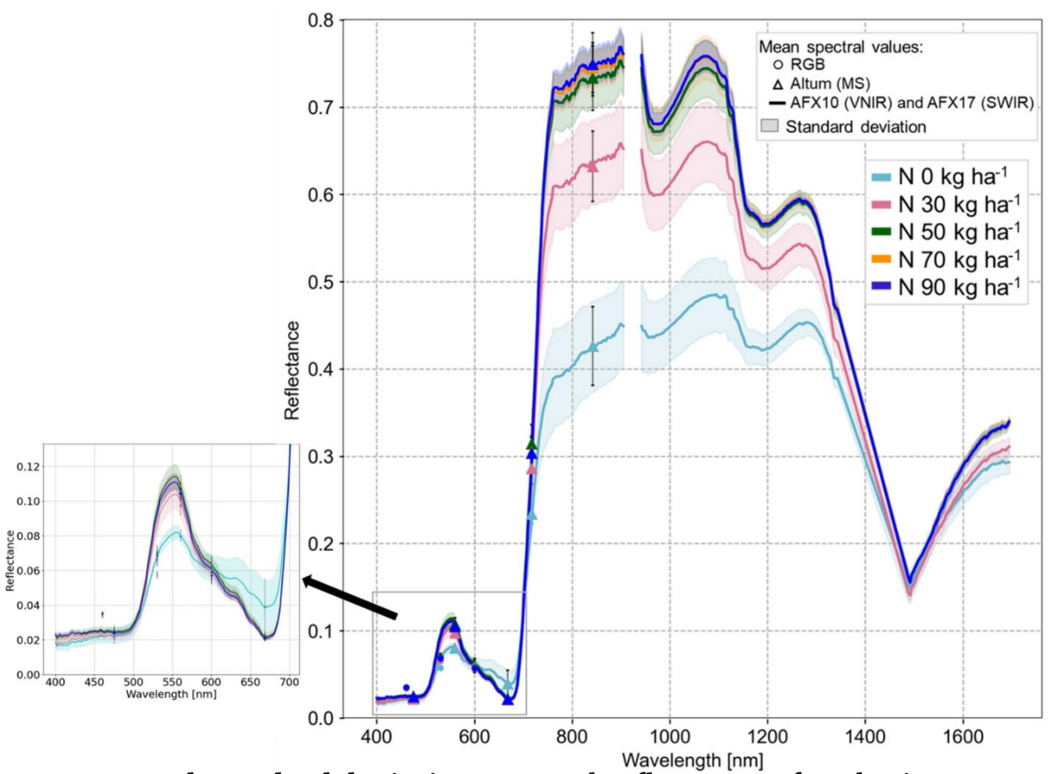


Aim was to develop remote sensing methods for estimating timothy grass yield and quality using data from an experiment with five different N fertilization levels (0-450kg N/ha/y)

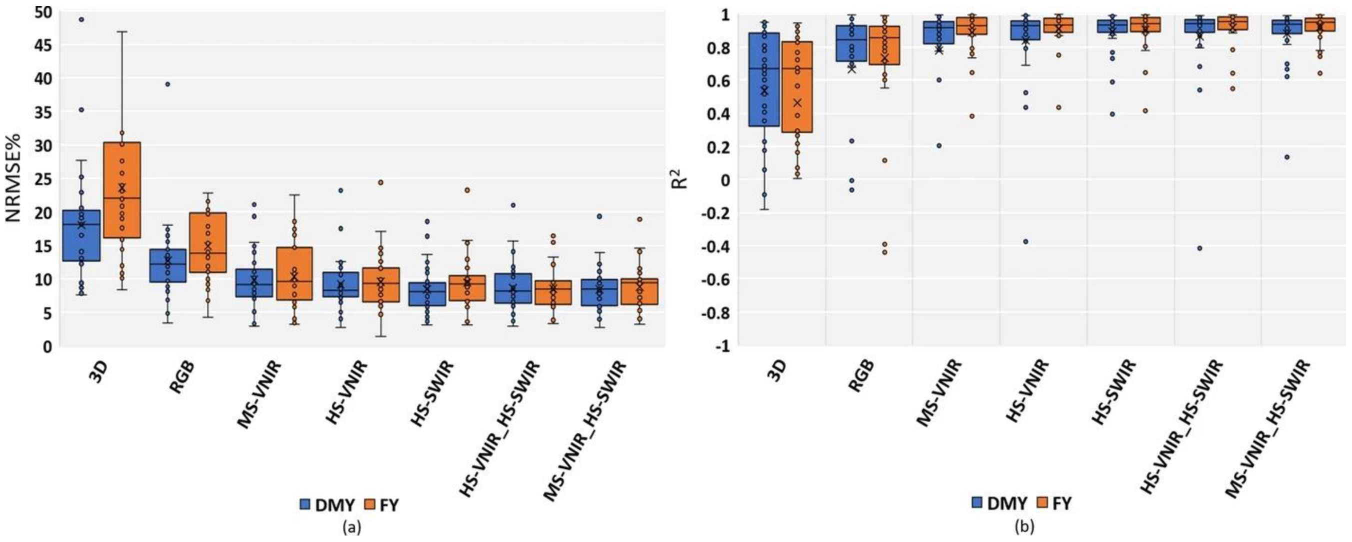
The machine-learning process included feature extraction, feature selection, and a supervised learning process.

Oliveira et al. 2024 *"High-precision estimation of grass quality and quantity using UAS-based VNIR and SWIR hyperspectral cameras and machine learning."*

Grass quantity and quality estimations using VNIR and SWIR UAS-hyperspectral cameras and machine learning



Average and standard deviation spectral reflectance of each nitrogen level sample plots for RGB, multispectral (Altum), and hyperspectral (VNIR AFX10 and SWIR AFX17) cameras



The hyperspectral sensors predicted grass quantity and quality traits more accurately than the other tested systems.

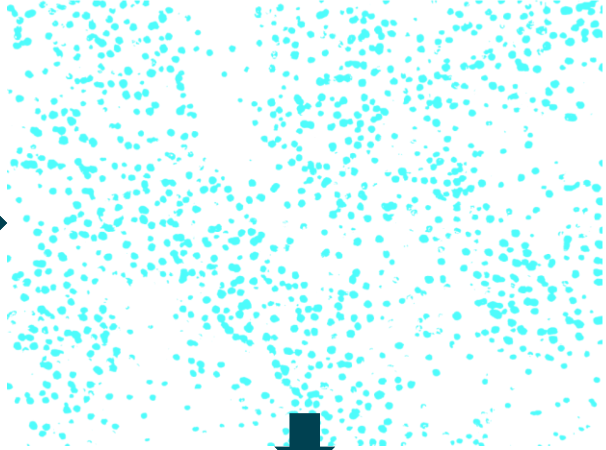
Especially SWIR-hyperspectral performed well

Oliveira et al. 2024 *"High-precision estimation of grass quality and quantity using UAS-based VNIR and SWIR hyperspectral cameras and machine learning."*

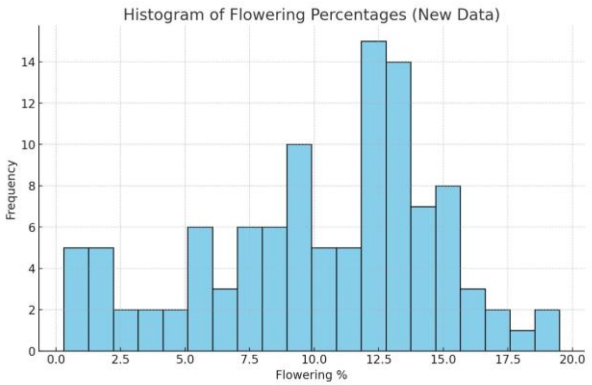
Flowering and ecotype imaging with drones for developing red clover seed production (N-fiksu project)

Work aims to recognize good practices and factors affecting the success of red clover seed cultivation – drones used as a central part of data collection

- Images collected using two cameras simultaneously (5 fields in Central Finland):
  - high zoom for flower counting ("image sampling")
  - wider lense for photogrammetric map creation
- Also field surroundings mapped with high resolution imaging to find pollinator habitats
- 2024 summer first year of observations
- Reference data includes e.g. seed yield and quality, pollinator activity (bee counts) etc.



First tests with AI segmentation models seem to estimate flower count and area with good accuracy already.



Luke

Moving towards automatic drone data collection

Semi-autonomous (remotely controlled) drone-in-a-box system implemented by Luke's collaboration partner Finnish Geospatial Institute for agronomic application in Mustiala, Finland.

Takes of and returns for charging to self-contained landing box

Data transfers automatically

- Real-time during flight
- After flight

4G/5G connectivity

Operations at Sail2 possible

Current version with multispectral camera

Luke

”Drone tractors” – drones tested for various work tasks

- DJI Agras T16 tested for oversowing and fertilization tasks and for operation as a part of robotic ecosystem
- Research on plant protection using drones has been prevented by regulations earlier, but now becoming possible!

Luke

Other recent research topics utilizing drones

Could rate of decline in quality be followed as a part of official grass variety trials using remote sensing? (N-fiksu project)

Field plots established in 2023 using 5 contrasting varieties in 4 replicates

Imaging done in 2024 using RGB imaging, multispectral drones (Phantom 4 MS) and hand-held hyperspectral camera (Specim IQ) + Zeiss corona extreme NIRS

High-resolution RGB for following head-emergence (AI-based semantic segmentation models)

With hyperspectral three types of imaging:

1) on-field canopy from top with soil as a background, natural light
2) on-field from top with plant samples on uniform background, natural light
3) in-lab with plant samples on uniform background, standardized lighting

Luke

Other recent research topics utilizing drones

How reliably clover content can be estimated using UAVs on fields and how to do the imaging? (N-fiksu project)

Data acquisition started in 2024

Data collected from normal fields and from experimental plots

High resolution imaging and image processing using AI-based models for semantic segmentation of images to ”clovers” and ”other plants”

An important question is the timing of imaging and how it affects interpretation of results (reference data of botanical composition at different stages needed for reference). Also light conditions have a big effect – high-contrast sunny conditions have been problematic.

Aim is to get objective tools for decision making in management to adjust N-levels, plant protection etc.

Luke

Conclusions & thanks for listening!

- Drone technology is a great tool for many things
- Design your work carefully and remember what you are seeking for
- Don’t hesitate to contact the people I mentioned to you

Luke