Reliable and efficient high-throughput phenotyping to accelerate genetic gains in Norwegian plant breeding

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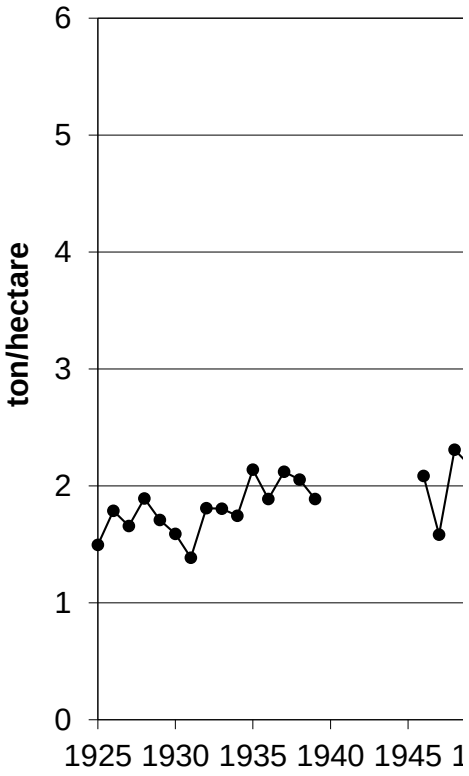
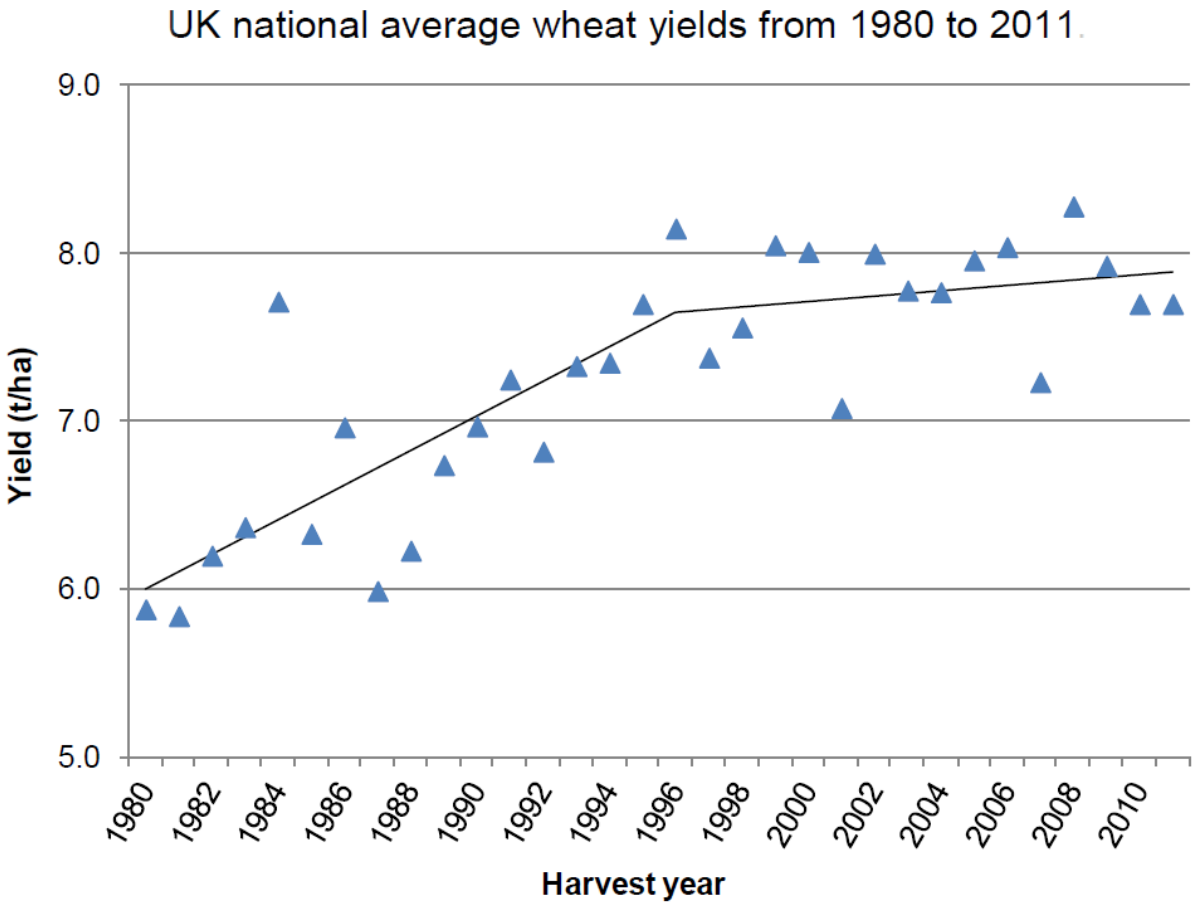
The grand challenge

"In the next 50 years we will need to produce as much food as has been consumed over our entire human history."

Megan Clark
CEO of the Commonwealth Scientific and Industrial Research Organization (CSIRO)
Australia

Yields have stagnated



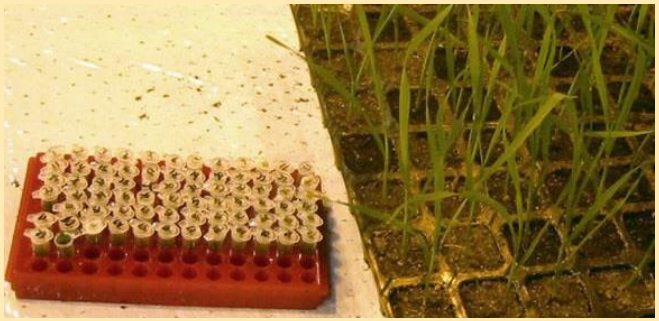


How to produce more food with limited resources?

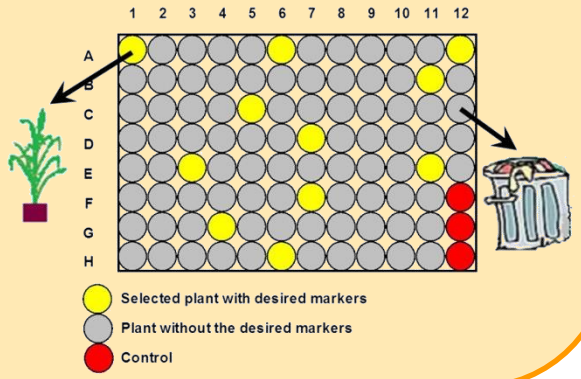
- Improved agronomy

Precision agriculture

- Improved varieties – plant breeding



Precision genetics



New 4-year project: Virtual phenomics

May 2017 – April 2021, Budget: 10.1 mill. NOK (≈1.1 mill EUR)

Graminor

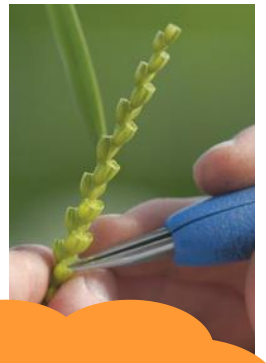
MAKING VIEW

BOSTON UNIVERSITY

CIMMYT
International Maize and Wheat Improvement Center

Forskningsmidlene for jordbruk og matindustri

Classical wheat breeding



Year 1	Parent 1 x Parent 2	Crossing
Year 2	F_1	Bulk seed
Year 2	F_2	Space pla
Year 3	F_3	Head rows
Year 5	F_4	Small plots, s
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Year 8	F_7	Head rows, select the best lines
Year 9	F_8	Unreplicated yield trial
Year 10-11	F_9-F_{10}	Replicated yield trials
Year 12-14	F_{11}-F_{13}	Official variety testing
Year 15		Cultivar release

Can we do this more effectively?

Plant selection tools

Visual selection

Sensors

Genetic markers

NMBU strategic alliance

- Faculty of Biosciences

- Faculty of Mathematical Sciences and Technology

Plant breeding and virtual reality

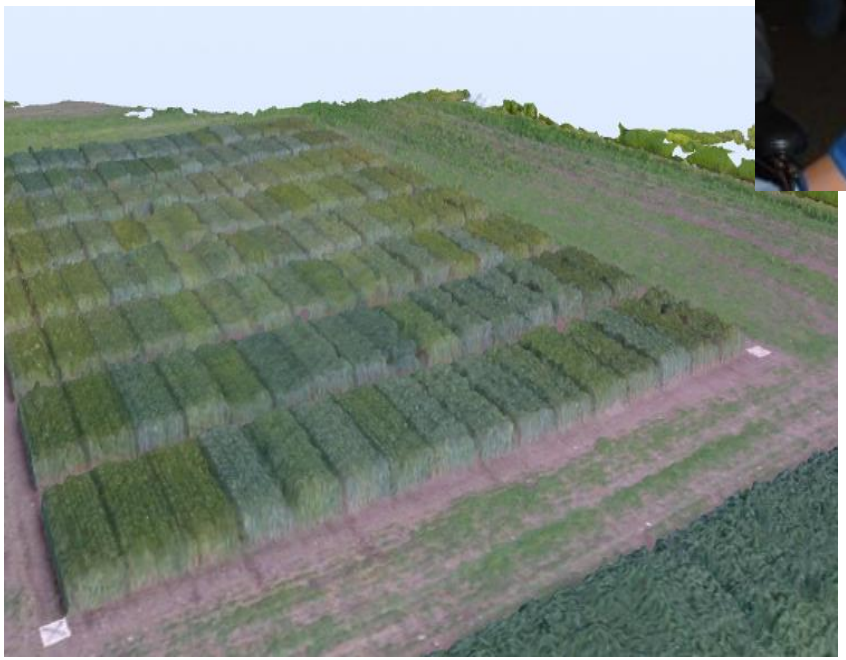
Graminor

MAKING VIEW

Genomic prediction and data management

$$y_{ij} = \mu + E_i + L_j + g_j + a_j + Eg_{ij} + Ea_{ij} + e_{ij}$$

BOSTON UNIVERSITY

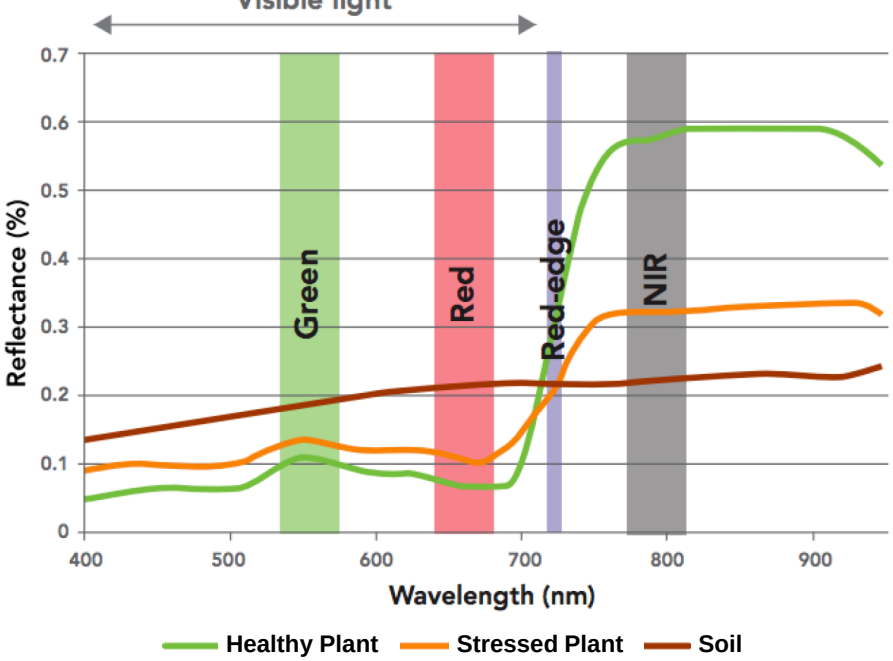


CIMMYT
International Maize and Wheat Improvement Center

Multispectral imaging

Parrot Sequoia

DJI Phantom 3



Thorvald II

Research objectives

- Comparison of platforms:
  - Ground cover/early vigour
  - Heading date
  - Biomass (VIs)
  - Plant height
  - Maturity date

- Can we predict yield from these measurements?
- How can HTP data improve genomic prediction models?
- Can we use VR to take the field to the breeder?

Fun in the field

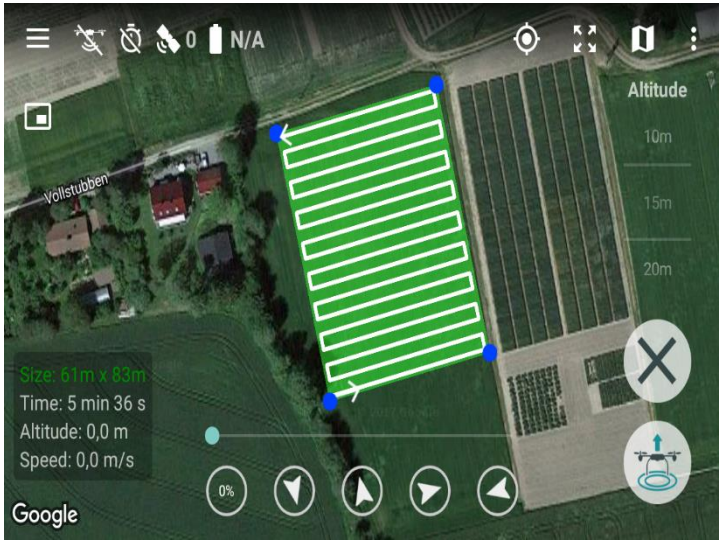
Silje Larsen & Kristine Skattum

UAV operators and pilots 2017

Upgrade from Thorvald I to Thorvald II (Kristine)

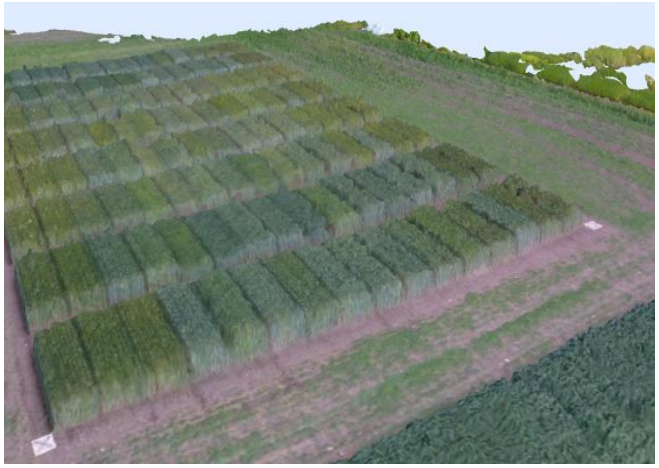
Phenotyping with drone

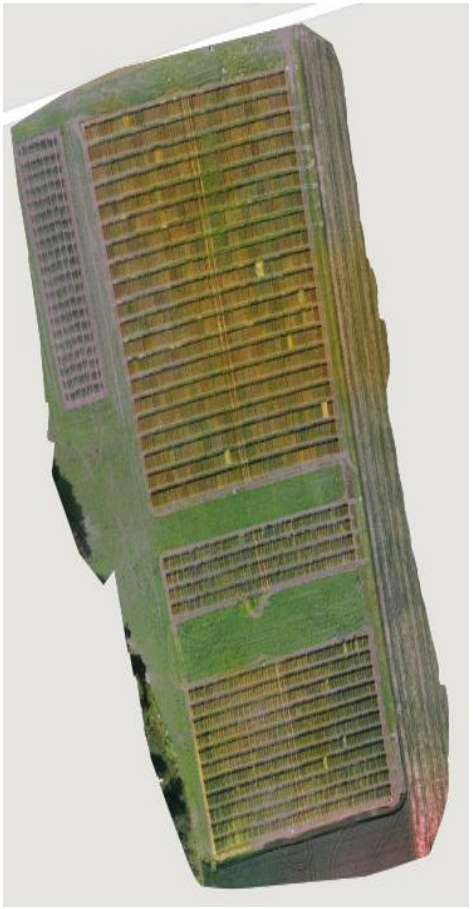
- Better overview over the field
- DJI Phantom 4
- Regular camera
- Multispectral camera
- Altizure
- Automatically capturing

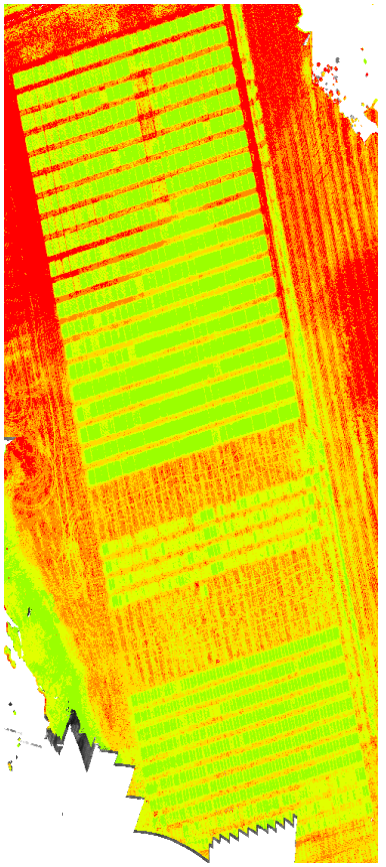


Analyzing the images

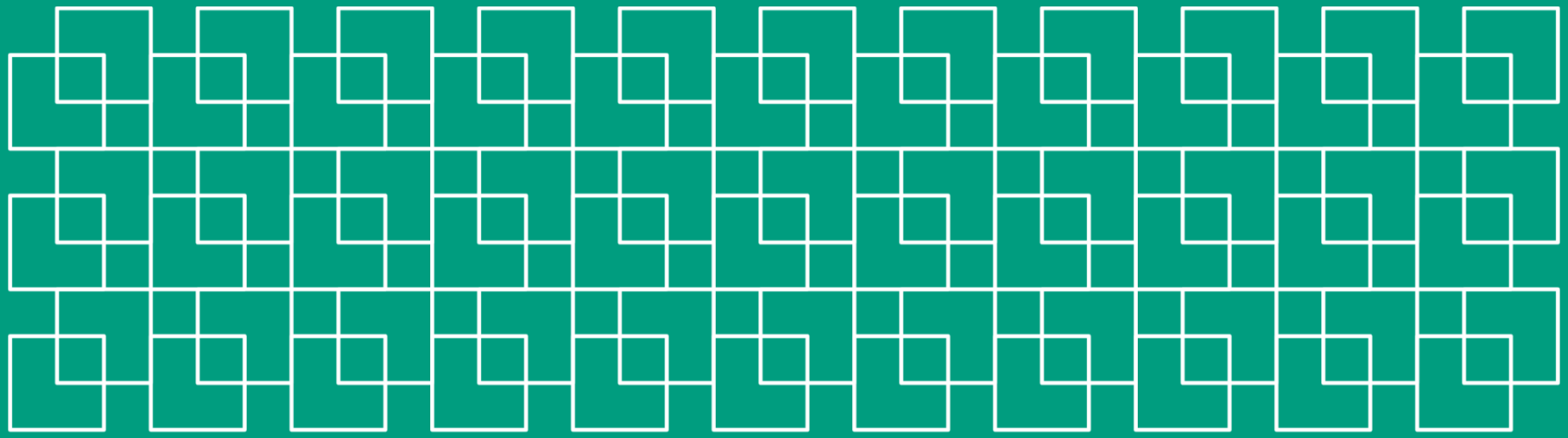
- Using Pix4d
- Stitching the images together
- Generating index map
- Generating 2D and 3D maps



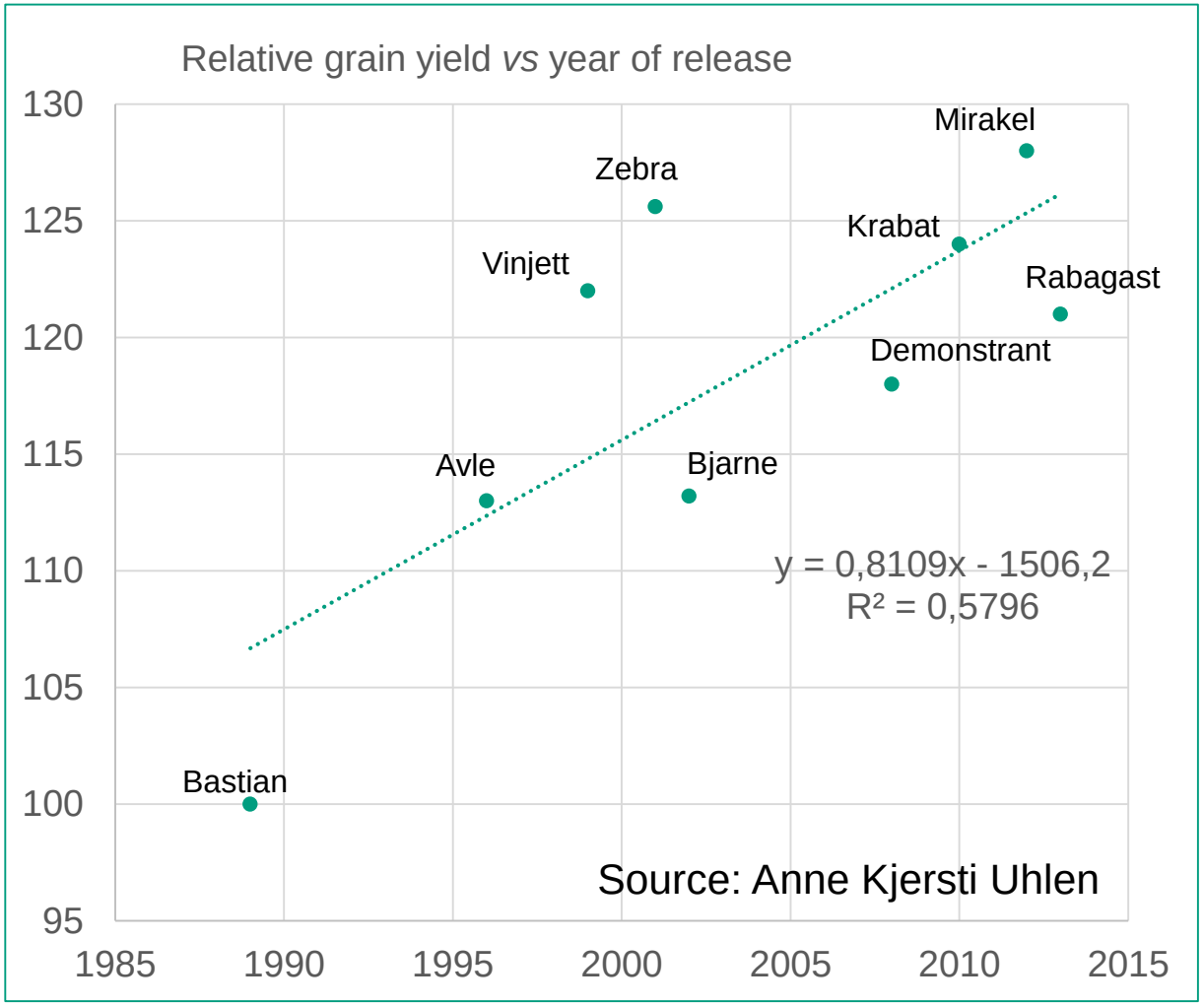




Preliminary results from analysing yield increase in Norwegian spring wheat



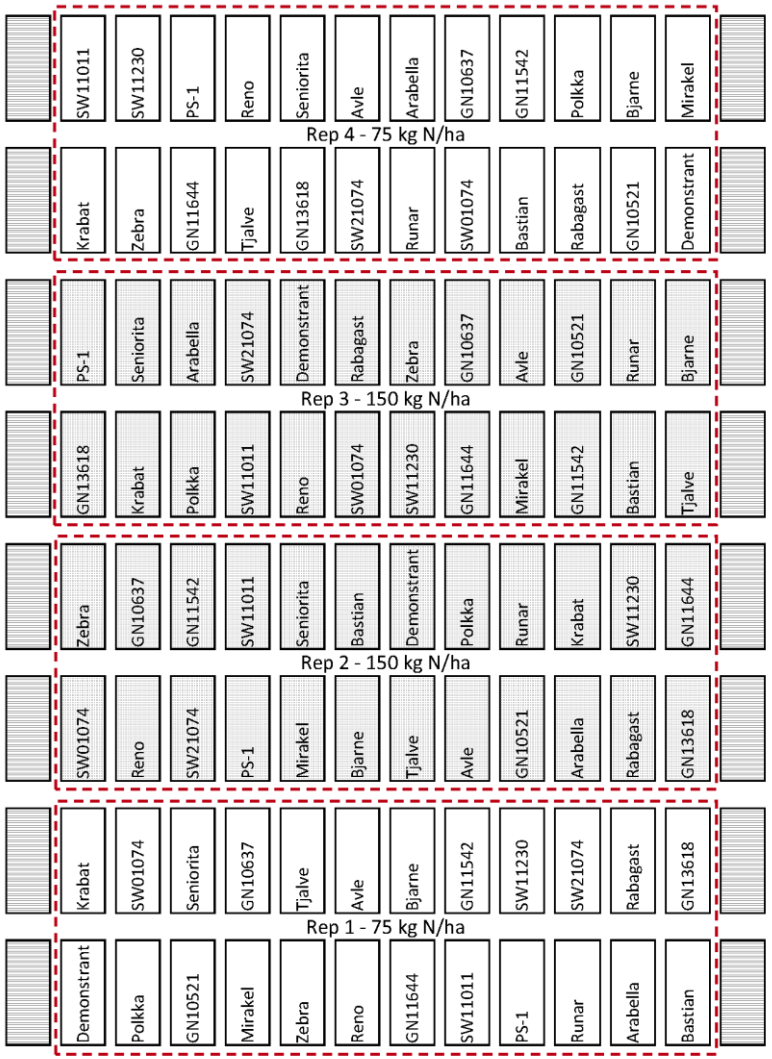
Breeding has increased yield



- What is the physiological basis of this yield increase?

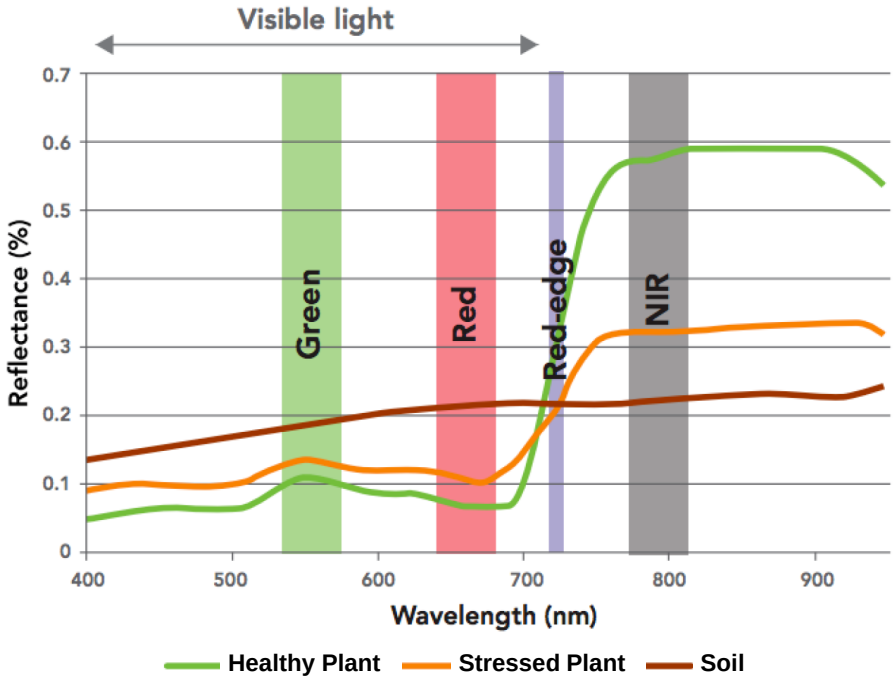
Wheat yield trial

- 24 spring wheat cultivars and breeding lines
  - 1972 - today
- Two Nitrogen levels
  - 75 kg N/ha
  - 150 kg N/ha
- Yield and grain quality
- Multispectral imaging
  - Robot
  - Drone



Eivind Bleken MSc thesis field trial work 2016

Estimation of healthy biomass



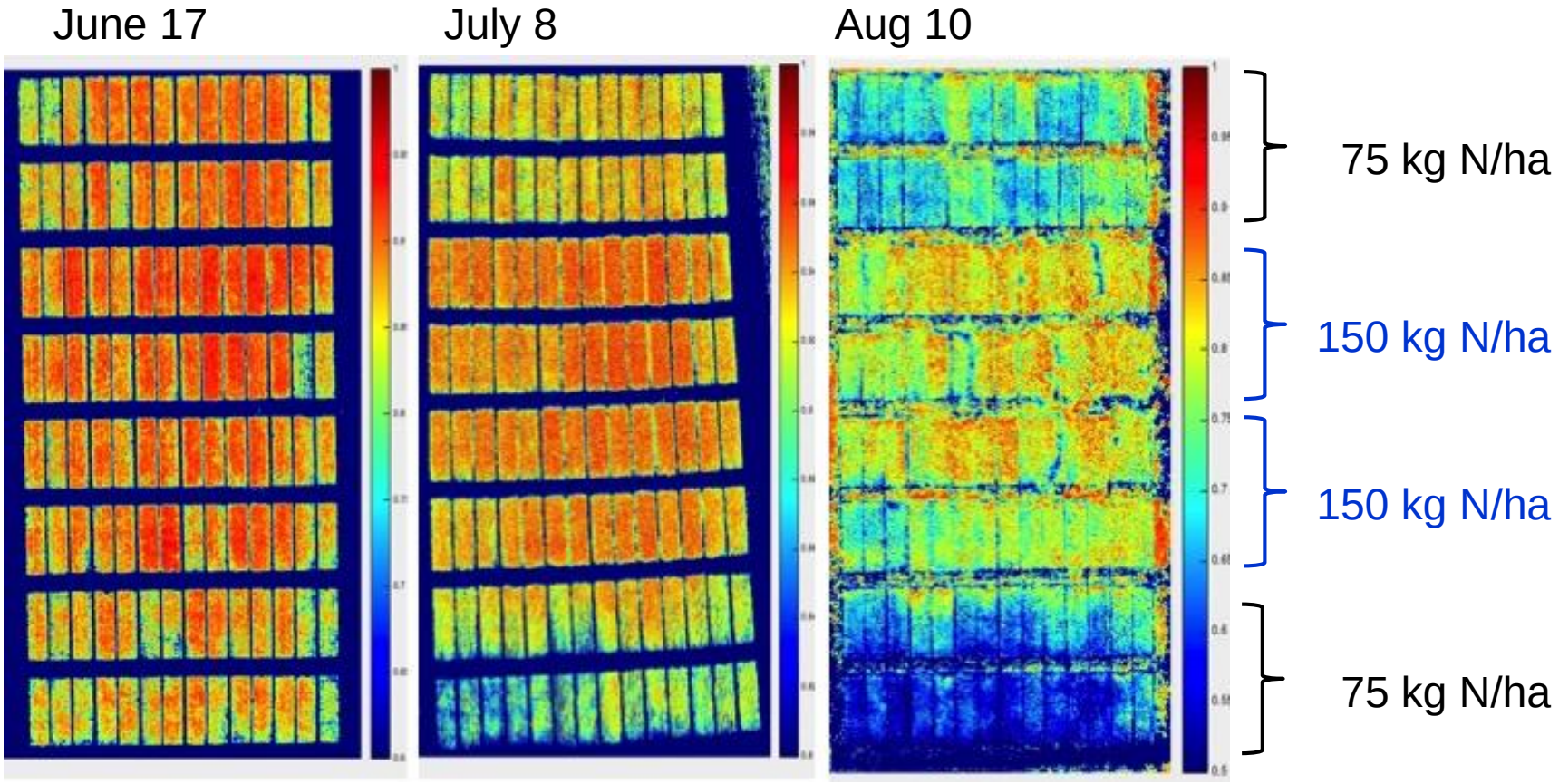
- Normalized Difference Vegetation Index (NDVI):

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

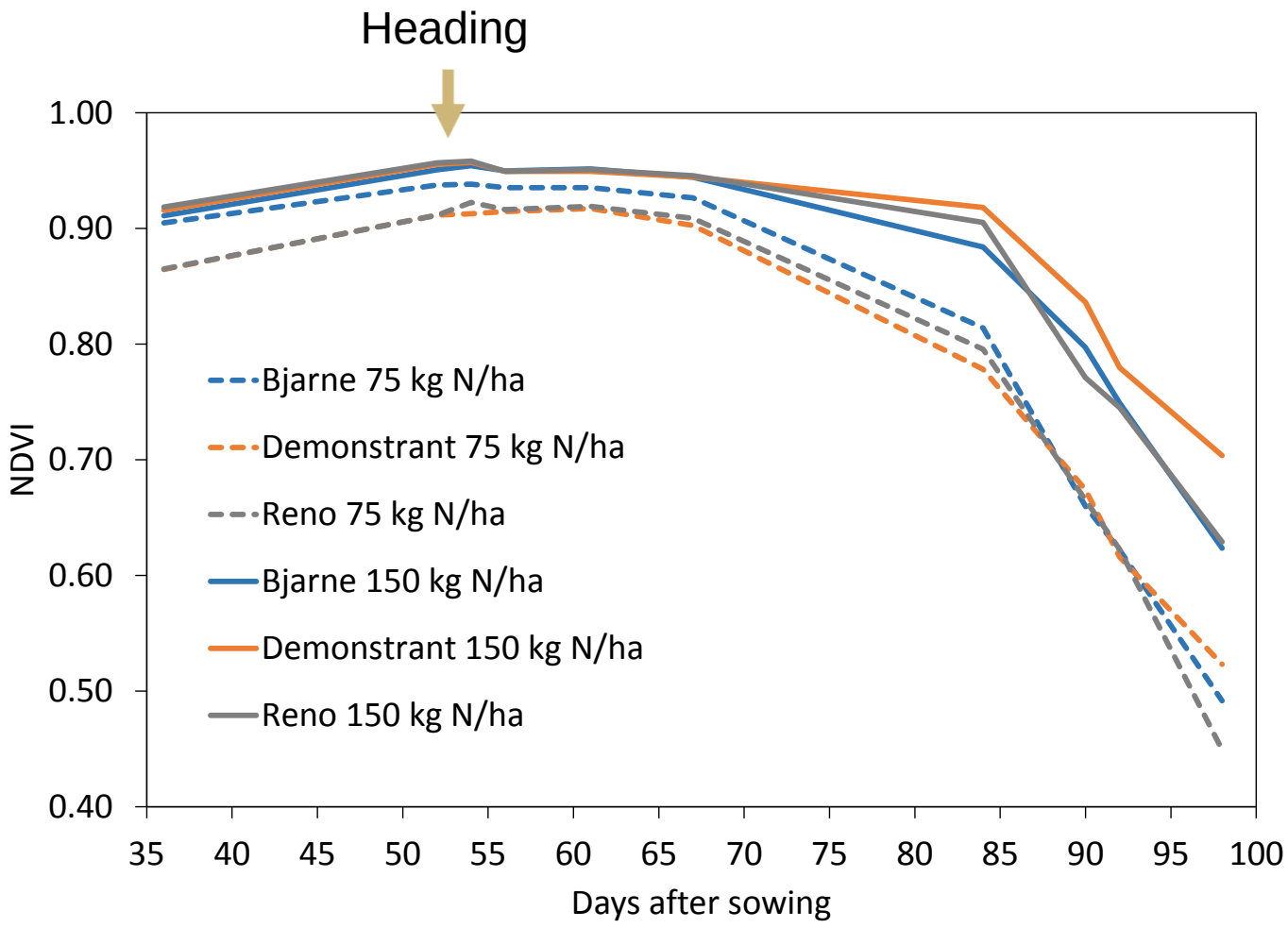
- MERIS Terrestrial Chlorophyll Index (MTCI):

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

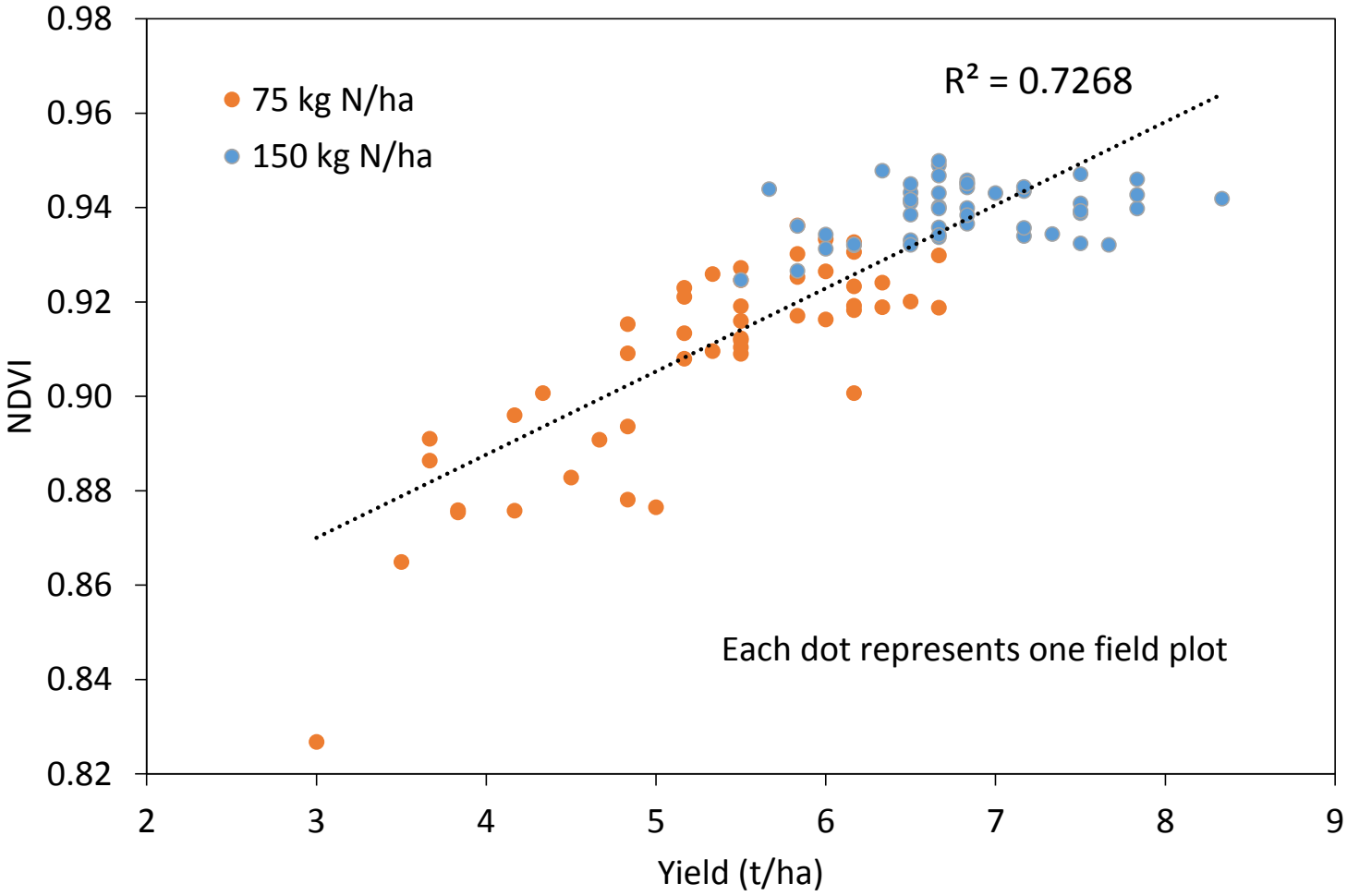
NDVI maps based on drone images



NDVI throughout the season



NDVI just after heading correlates with yield

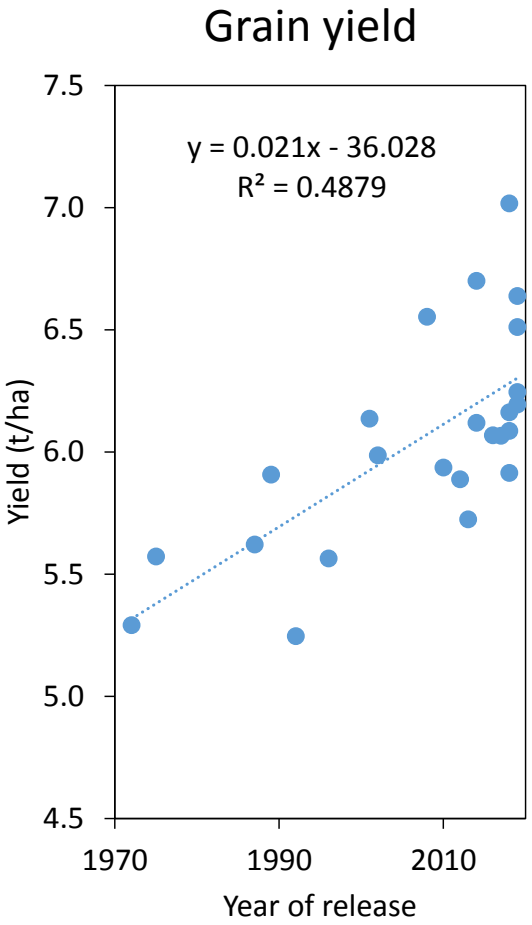


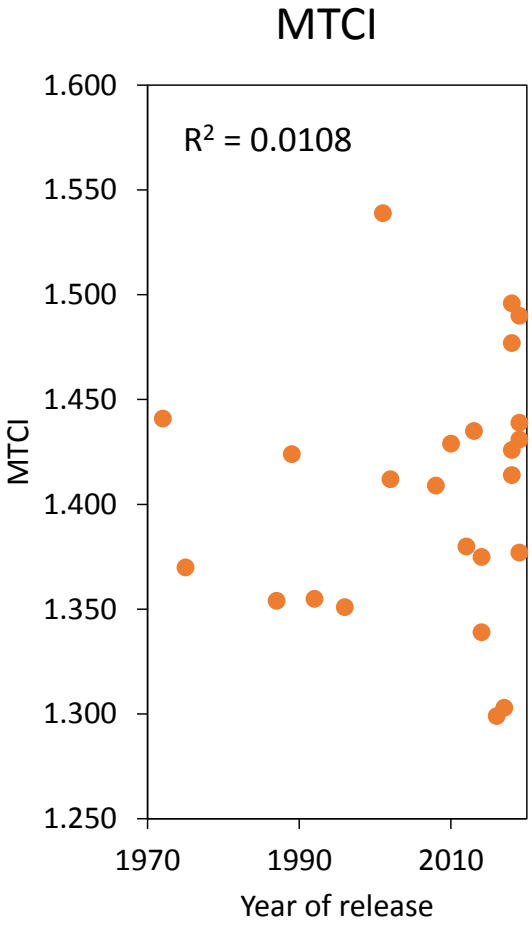
Can vegetation indices explain cultivar differences in yield?

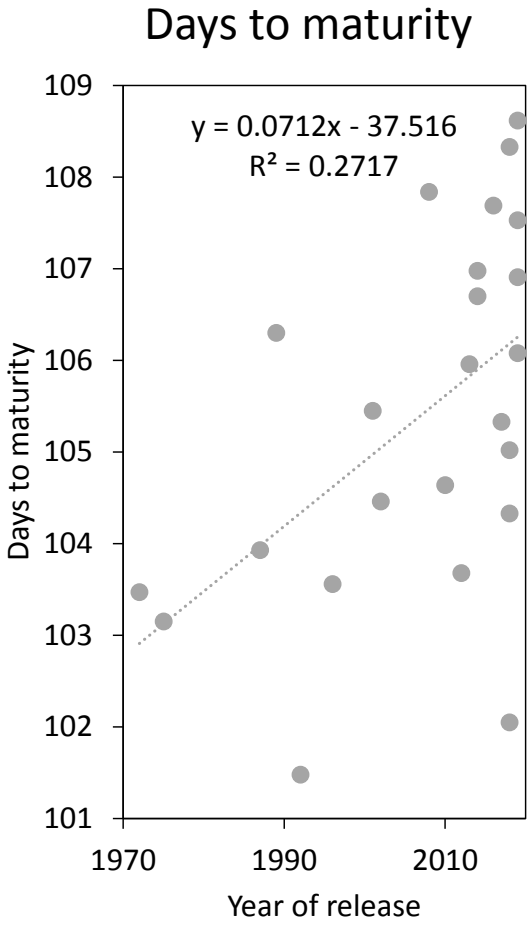
- Correlations between cultivar means for vegetation indices and cultivar means for grain yield:

	NDVI	**MTCI**
75 kg N/ha	0.37	0.39
150 kg N/ha	0.08	0.20

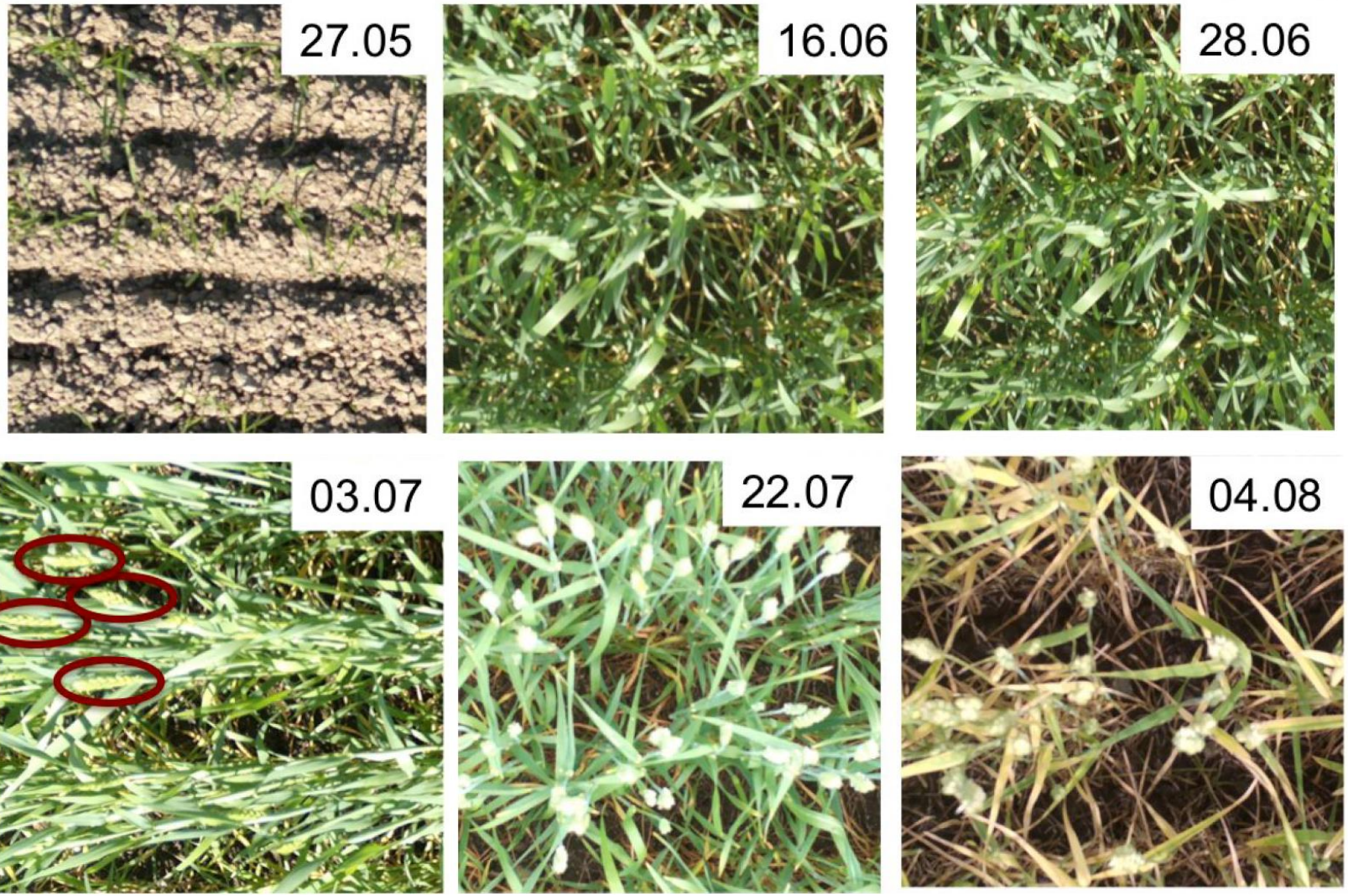
Cultivars by year of release







Close-up images from robot



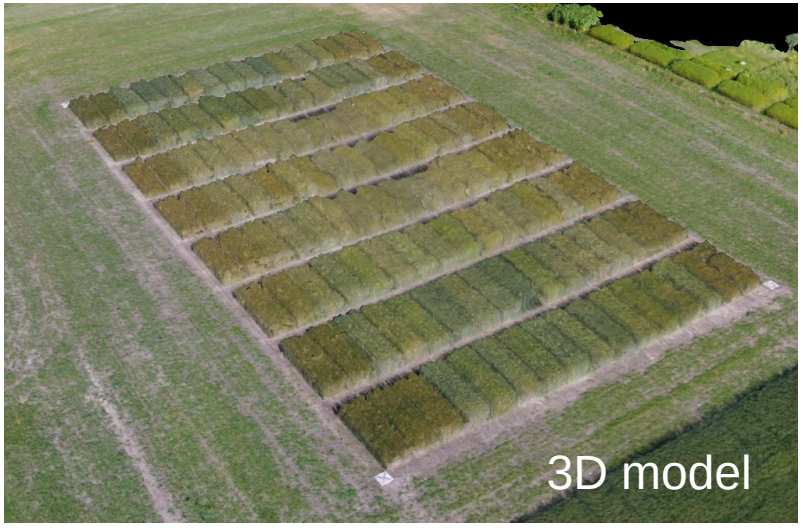
Bless Kufoalor MSc thesis field trial work 2017

Light interception

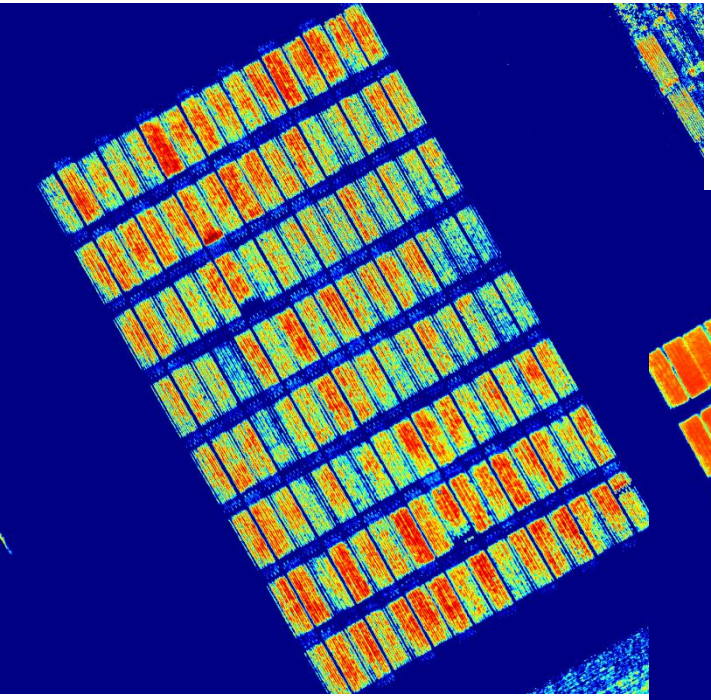
Chlorophyll content


20 july

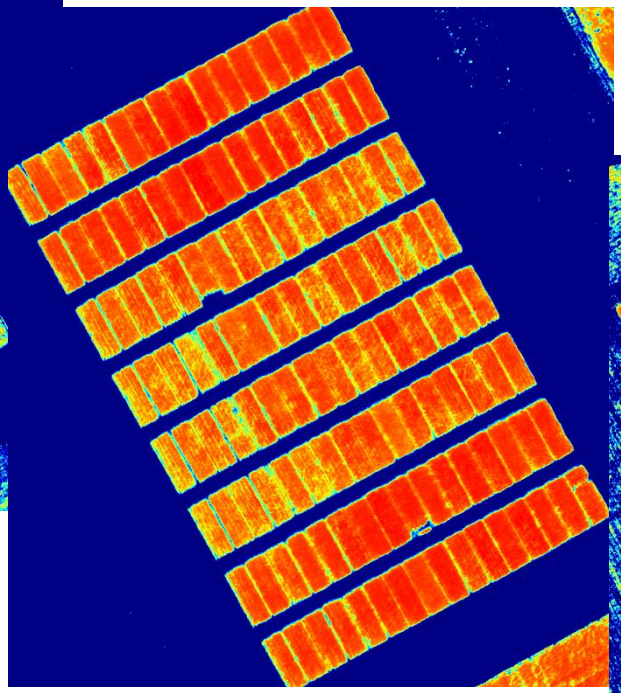

14 aug


3D model

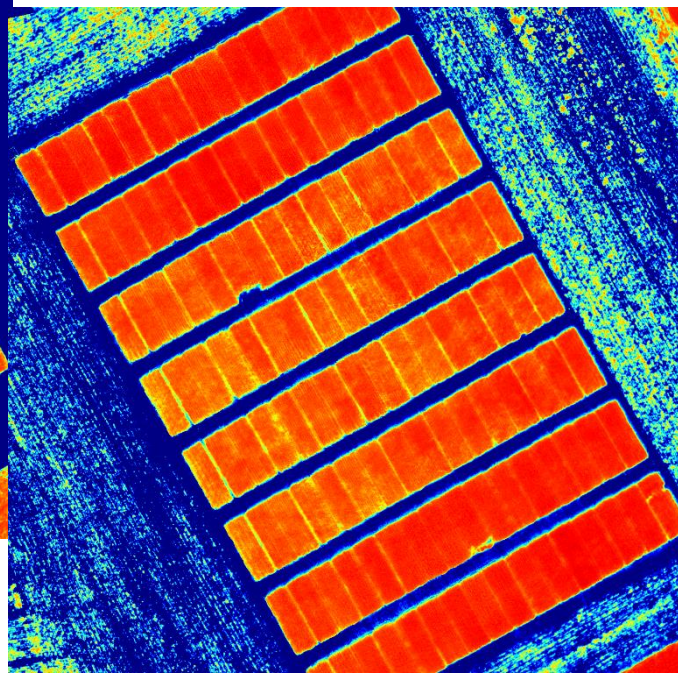
NDVI images



19 june

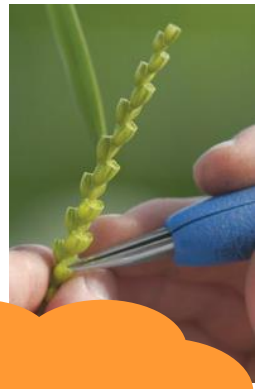


3 july



17 july

Classical plant breeding



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Year 15		Cultivar release

Genomic selection
+
Multispectral
image analyses

Can we do this more effectively?

vPheno project group

<u>NMBU – Biovit</u>

Morten Lillemo

Bless Kufoalor

Postdoc (maybe you)

++

<u>NMBU – RealTek</u>

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Erik Solberg

Pål Johan From

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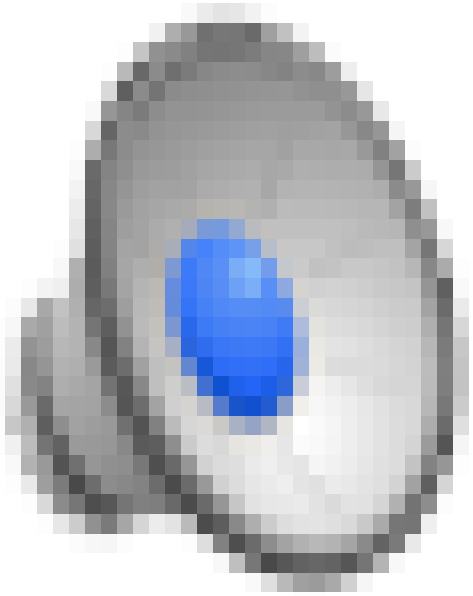

http://www.clipartkid.com/