Battle of the spectral resolutions

RGB vs Multispectral

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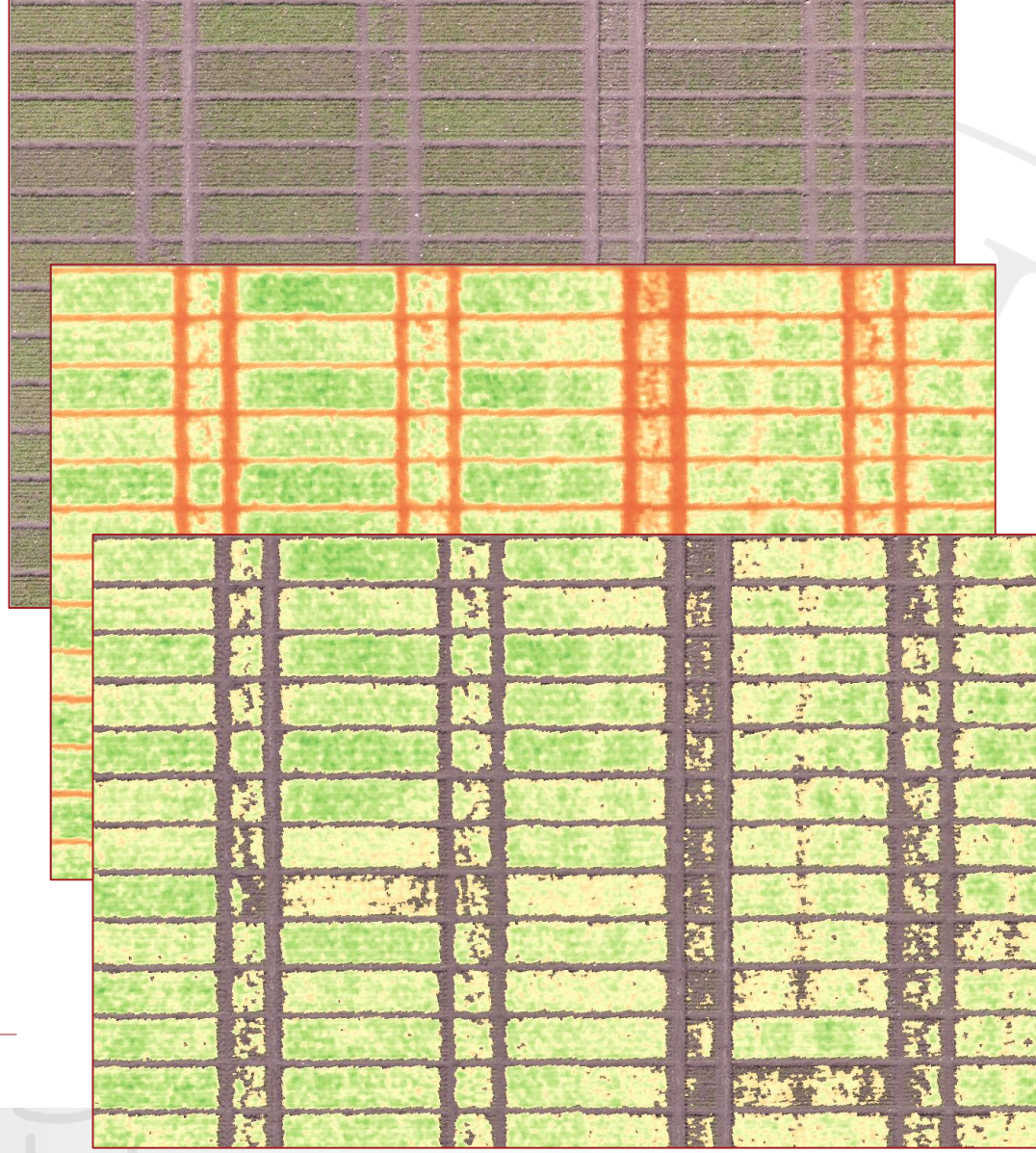


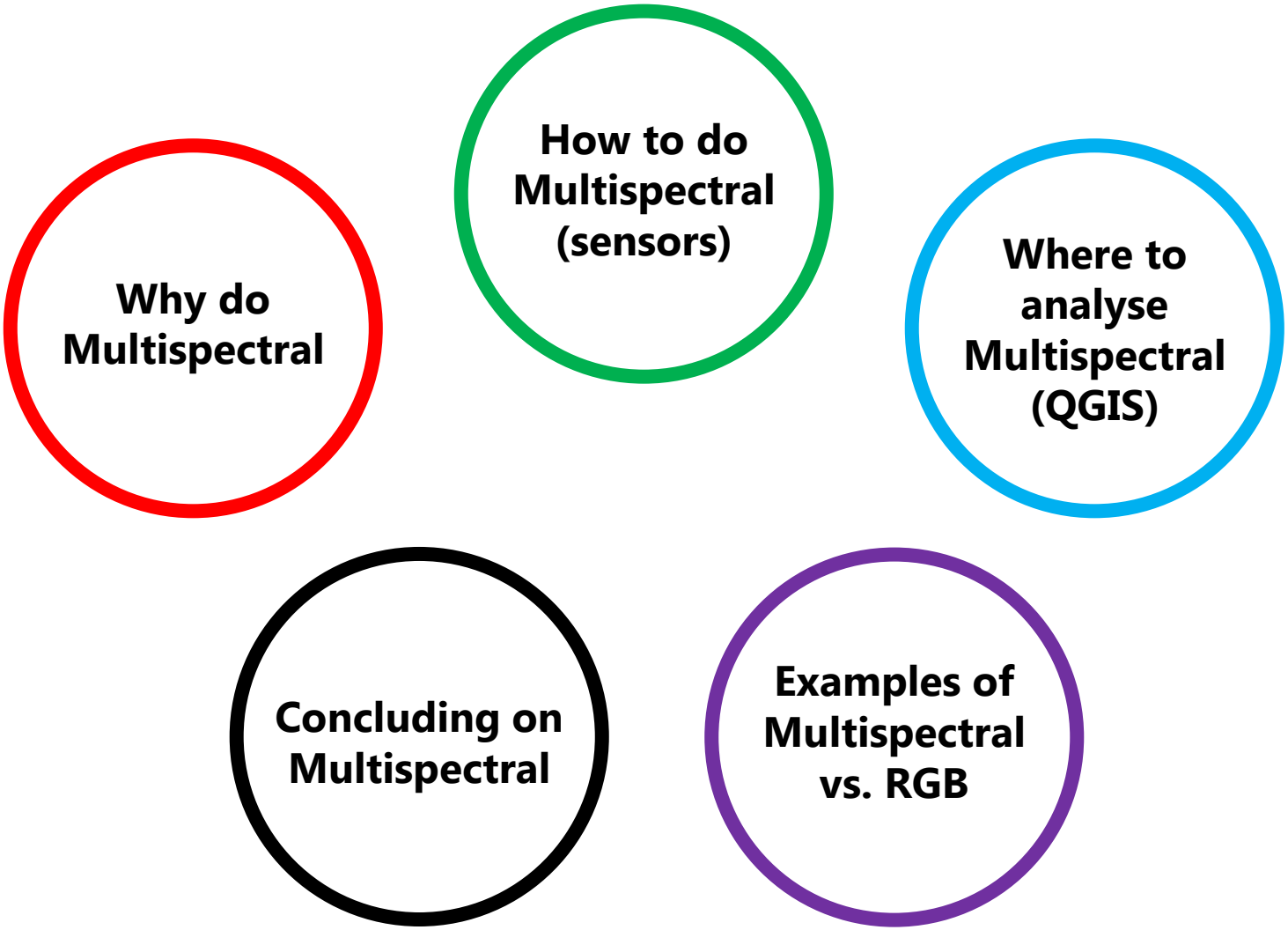
This talk

- Multispectral and RGB in 6P
- Why and how to use multispectral
- Analyse multispectral and RGB
- Few cases on multispectral vs RGB in 6P
- What's next in 6P
- Stimulate a discussion for the rest of the workshop – gains from going beyond RGB

- Inputs for those of your who consider embarking on/already using multispectral imaging and/or want to handle your plots in a more dynamic way.

Trait	Precision	Application timeline/project	Methods
Germination homogeneity, counting plants *(Potato, cereals)*	High	***/(6P-1, 6P-2)	Crop coverage (green pixels), RGB, VIS/NIR, segmentation/classification algorithms
Vigor/Early development *(cereals, grasses, potato)*	High	***/(6P-1, 6P-2)	Crop coverage (green pixels) + simple vegetation index[#], Dynamic growth curves, RGB, VIS/NIR[##]
Biomass accumulation *(cereals, grasses)*	high	***/(6P-1, 6P-2)	Crop coverage (green pixels) + simple vegetation index, Dynamic growth curves, RGB, VIS/NIR
Growth rate, Green biomass accumulation rate *(cereals, grasses)*	High	***/(6P-1, 6P-2)	Crop coverage (green pixels) + simple vegetation index, Dynamic growth curves, RGB, VIS/NIR
Winter hardiness *(cereals, grasses)*	High	***/(6P-1, 6P2)	Crop coverage (green pixels), vegetation Index, RGB, VIS/NIR
Spatial biomass homogeneity *(cereals, grasses, potato)*	High	***/(6P-1, 6P-2)	Crop coverage (green pixels) + simple vegetation index, RGB, VIS/NIR
Crop structures, number of ears, height, volume) *(cereals, grasses)*	High	***/(6P-2)	Advanced photogrammetry, RGB, VIS/NIR
Biotic/Abiotic Stress *(cereals, grasses, potato)*	Medium	**/(6P-2)	Specific vegetation indices, leaf temperature, RGB, VIS/NIR, Hyperspectral, Thermal[###]
Timing of maturity/heading *(cereals, grasses, potato)*	Medium	**(*)/(6P-2)	Specific vegetation indices, multivariate image analysis, RGB, VIS/NIR, Thermal
Nitrogen Use efficiency (NUE) (Cereals)	Medium	*/(6P-2)	Specific vegetation indices, Dynamic relative content, VIS/NIR

This talk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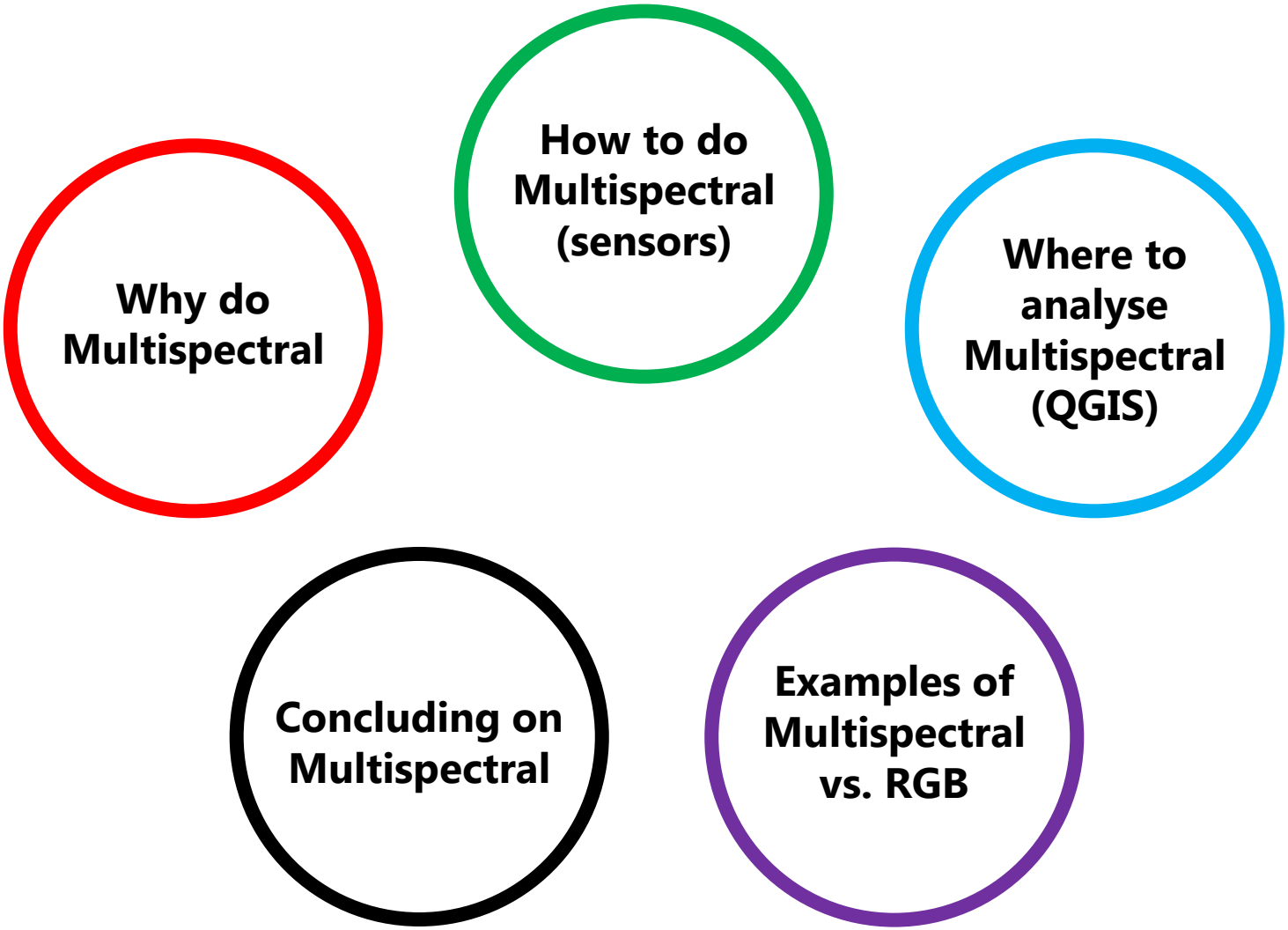
How to do Multispectral (sensors)
Where to analyse Multispectral (QGIS)
Concluding on Multispectral
Examples of Multispectral vs. RGB

Next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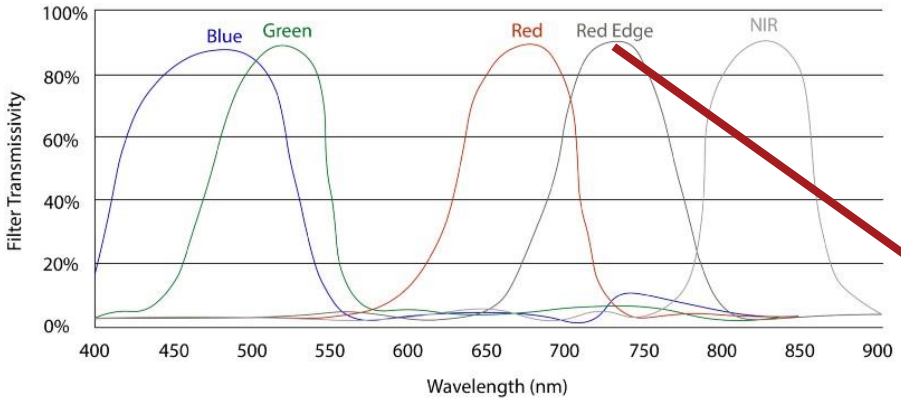
Why multispectral

Traits	RGB	Multi/hyperspectral
Plant density @ emergence		
Cover fraction		
Plant/canopy height		
Ear density		
Fruit/inflorescence size		
Grain number and size		
Leaf/plant glaucousness		
Phenology (e.g., heading, anthesis...)		
Lodging		
Weed infestation		
Diseases		
Vegetation index monitoring		
Green area index (GAI)		
Senescense		
Fraction of intercepted radiation		
Leaf orientation		
Leaf rolling		
Chlorophyll content		
Leaf/canopy temperature		
Leaf/canopy chlorophyll fluorescense		

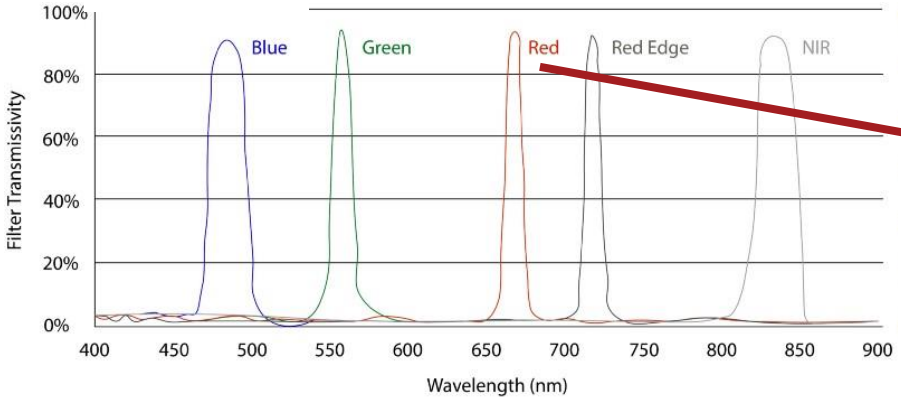
Araus, J.L., Kefauver, S.C., Zaman-Allah, M., Olsen, M.S., Cairns, J.E., 2018. Translating High-Throughput Phenotyping into Genetic Gain. Trends Plant Sci. 23, 451–466

Why multispectral (explained by MicaSense)

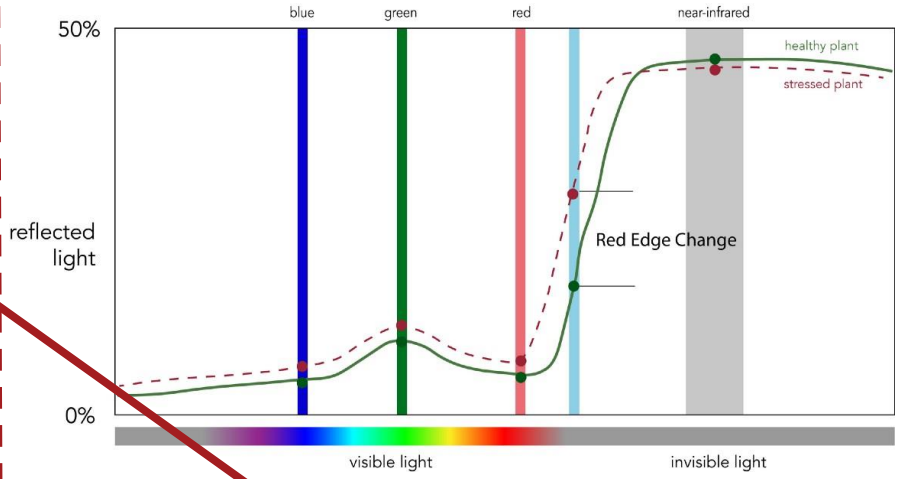
Modified RGB (color) camera

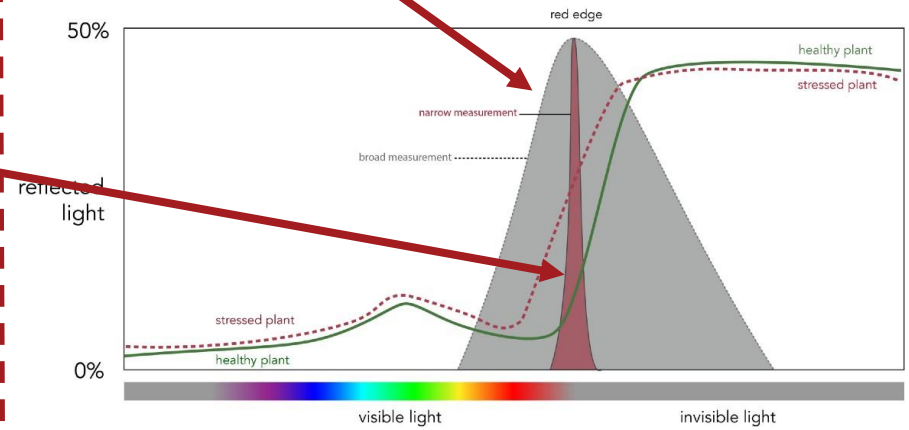


Multispectral camera



Healthy plant
Healthy plant





Vegetation indices (VI)

- **Different platforms (e.g. Solvi and Dronedeploy) offer VI from UAS imagery**
- **VI rel. estimate of plant greenes from 0 (no vegetation) to 1 (dense green crop)**
- **But how do the indices differ? Some examples (from platforms) we will use:**

VI suited for	VI	Mathematical calculation
Plant vigor/healt, relative biomass, nutrient content, canopy leaf area. At early/mid plant development	NDVI (LAI 3), GNDVI	NDVI =(nir-red)/(nir + red) GNDVI =(nir-green)/(nir + green)
Leaf chlorophyll, plant vigor, plant stress, N. Later plant development	NDRE, Red-Edge (RE)	NDRE =(NIR-RE)/(NIR+RE) RE =slope RED to NIR
In open crops, adjust for interaction between soil and canopy	SAVI, OSAVI	SAVI =1,5*(NIR-Red)/(NIR+Red+0,5) OSAVI =(NIR-Red)/(NIR+Red+0,16)
Chlorophyll concentration, canopy leaf area and canopy architecture (RGB based)	nExG (RGB) VARI (RGB)	nExG =(2*G-R-B)/(R+G+B) VARI =(Red-Green)/(Green+Red-Blue)

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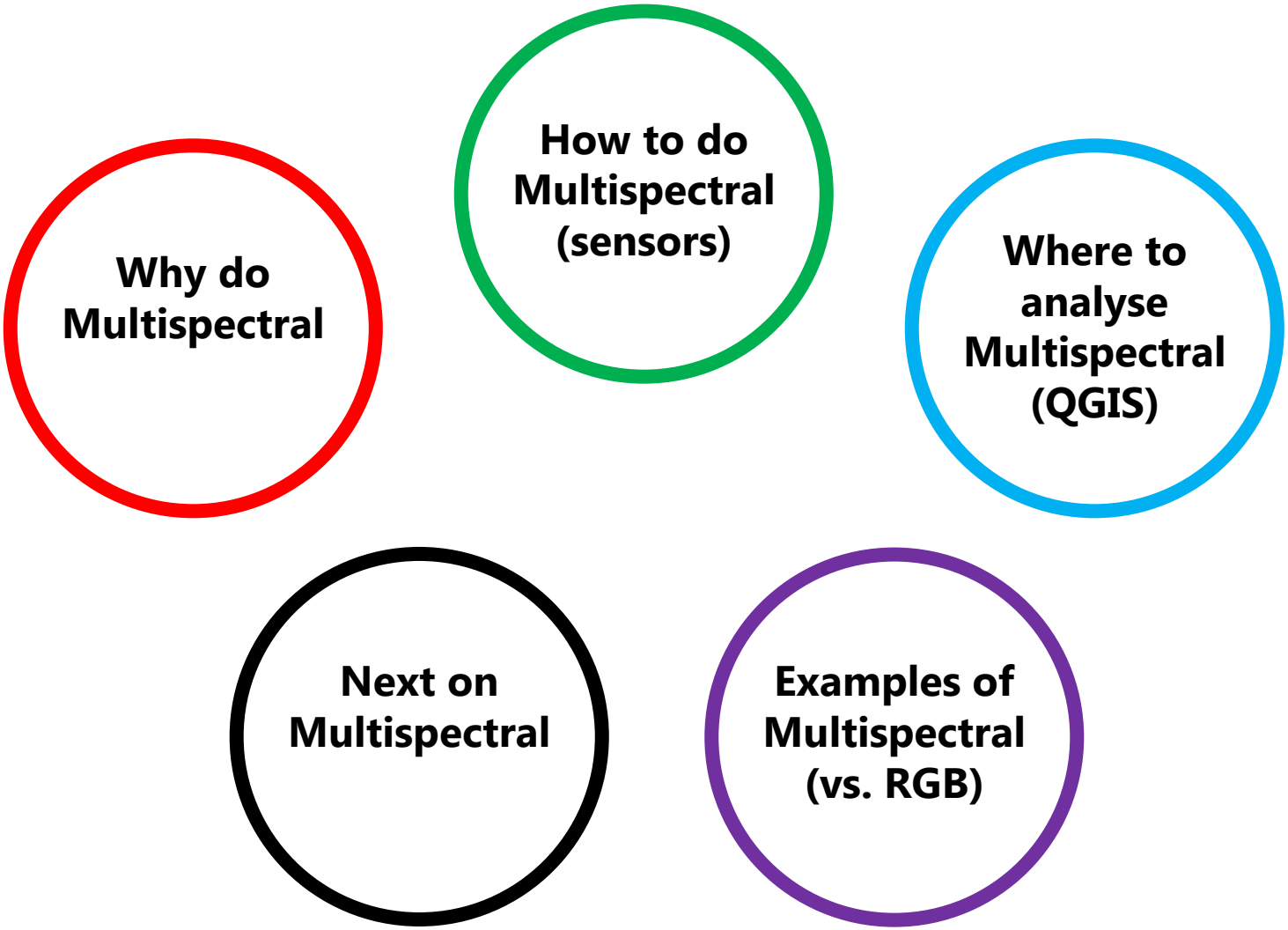
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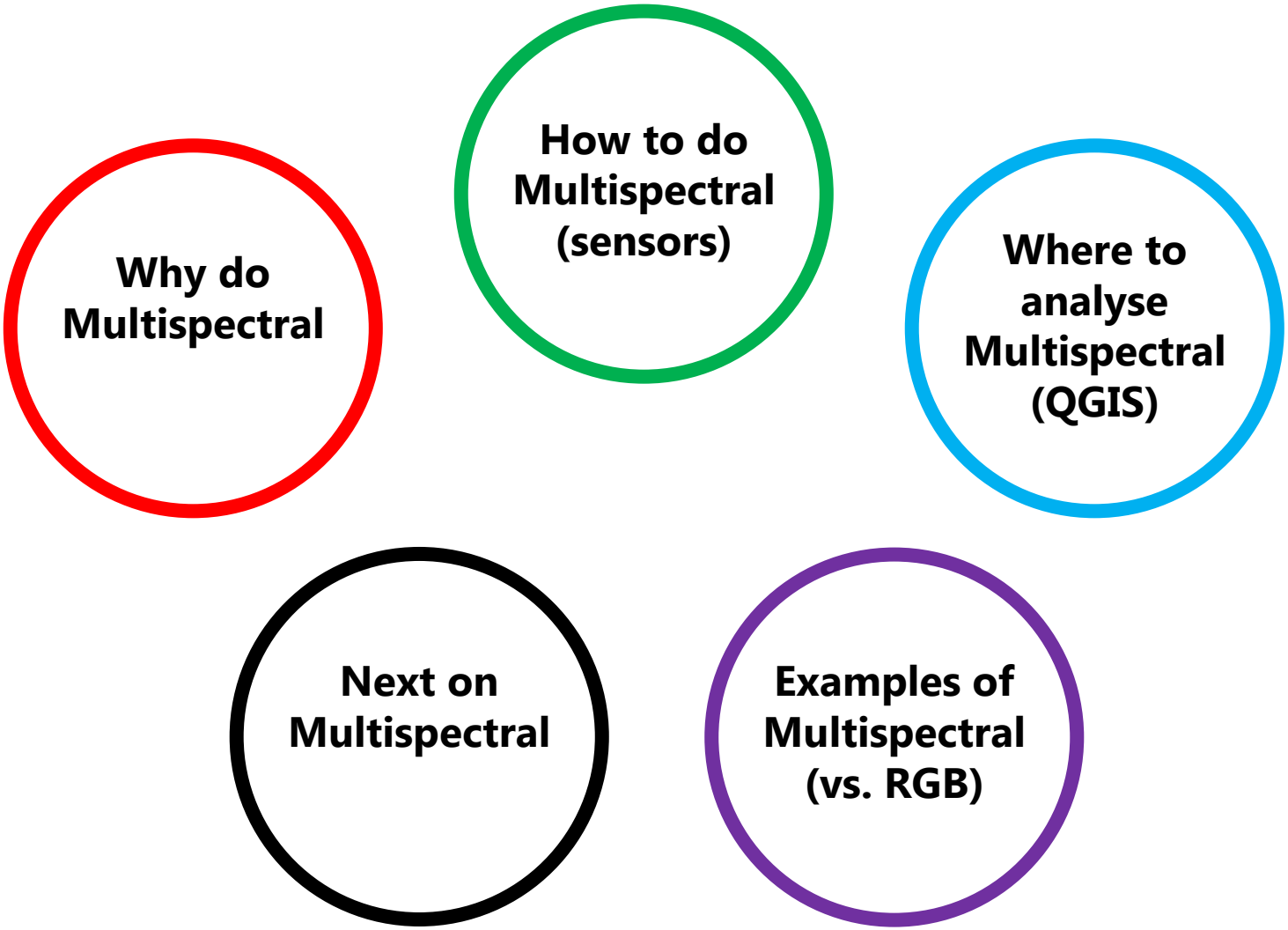
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Imaging sensors (at least some of them)

Lightsensor, RGB, multispec (R, G, B, RE, NIR; 2064*1544) and thermal

Lightsensor, RGB, multispec (R, G, RE, NIR; 1280*960)

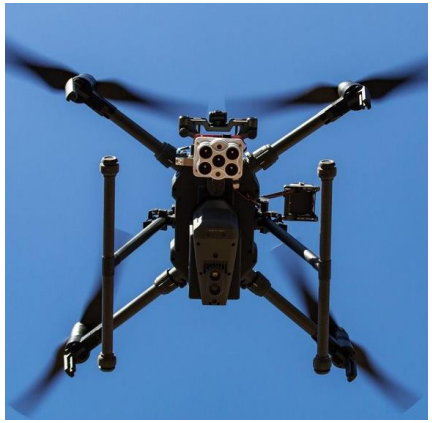
Lightsensor, multispec (R, G, B, RE, NIR; 1280*960)

Lightsensor, multispec (R, G, RE, NIR; 1280*960), different cameras and bands

Lightsensor, multispec (R, G, RE, NIR; 1280*1024), customize sensor, real time analysis

Multispec (1280*960), Customized sensing configurations, the support

Integration on a range of platforms



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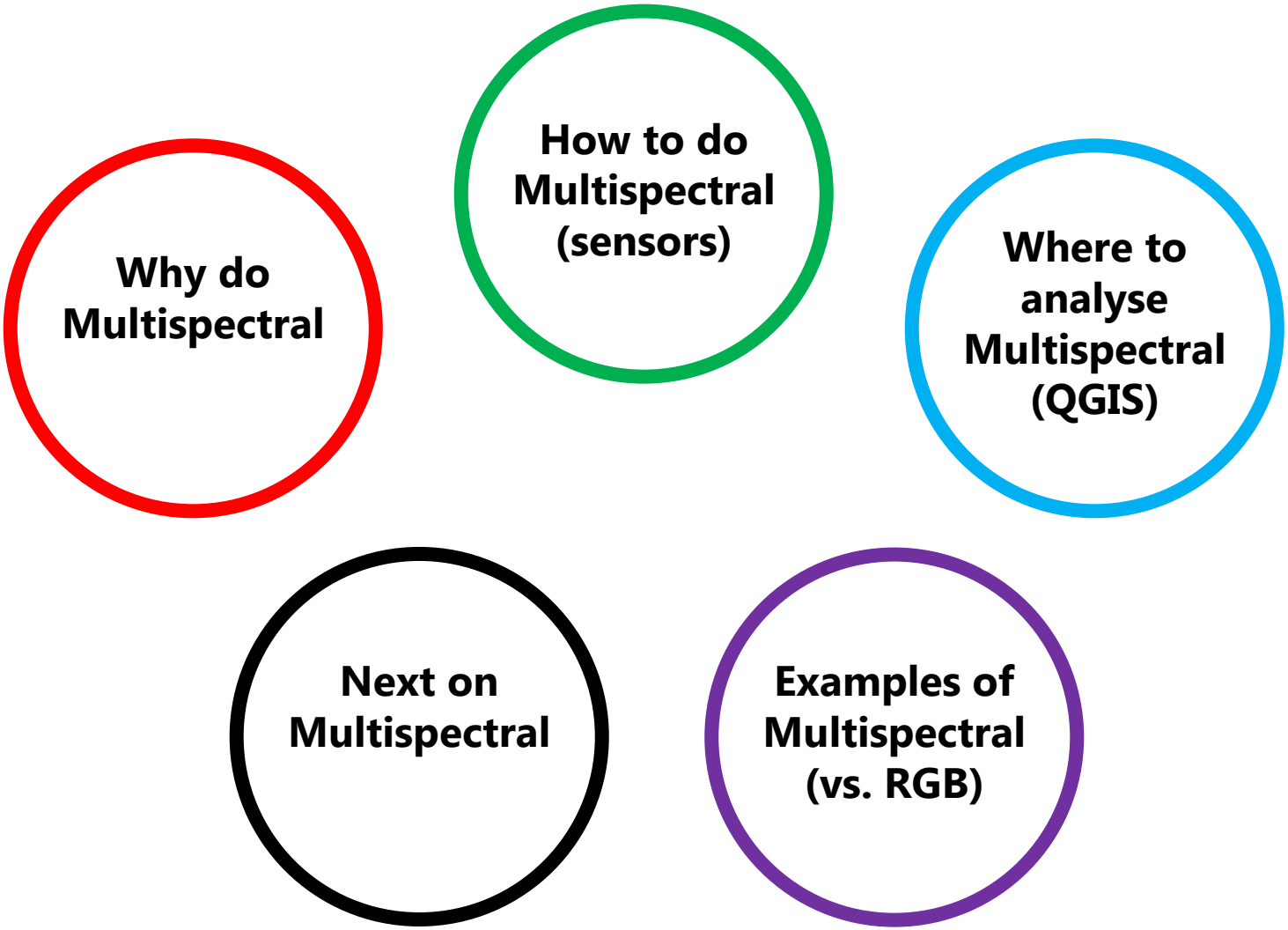
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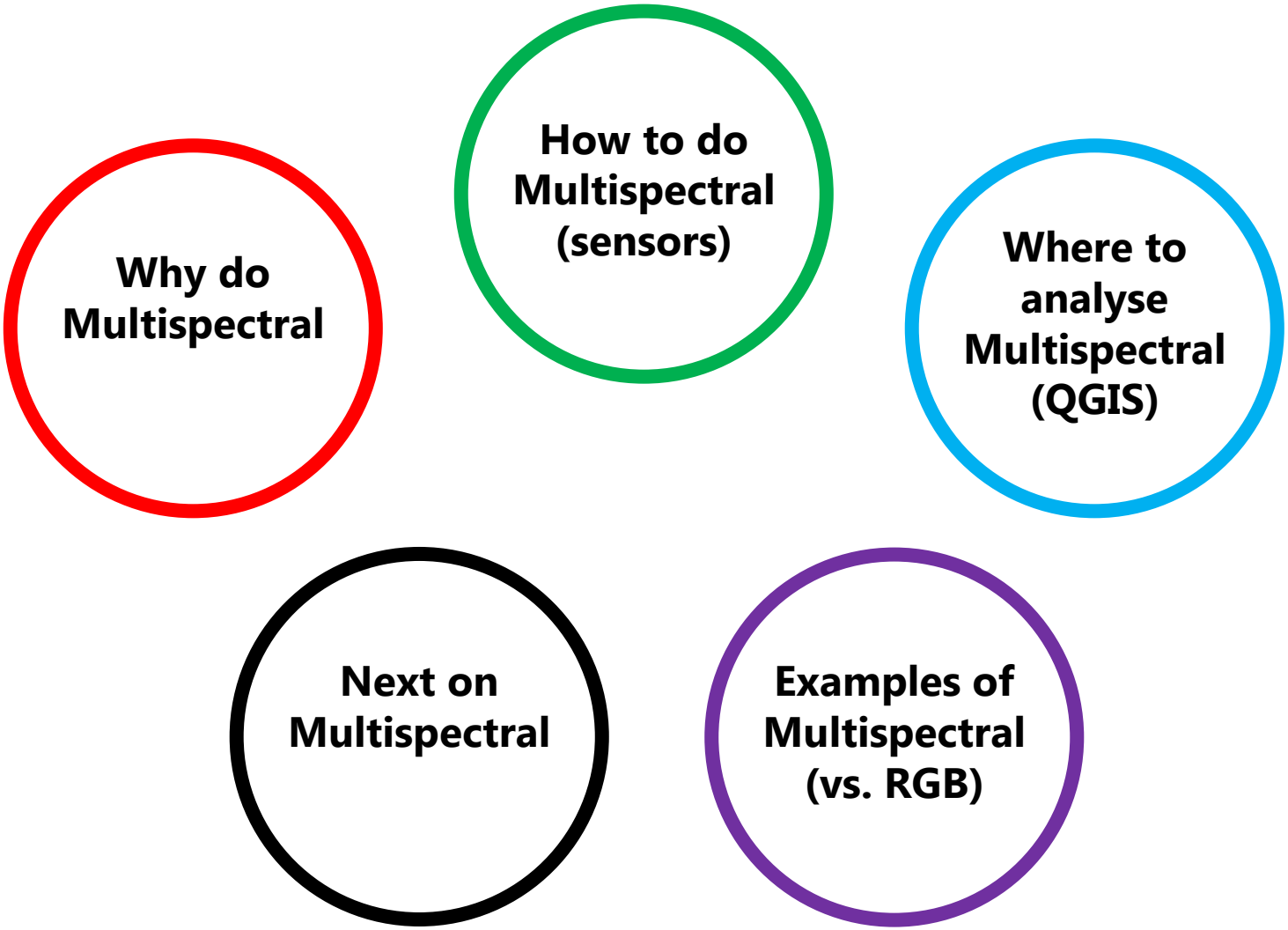
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A pipeline

RGB

Multispectral

Thermal

PhotoScan
3D Modeling and Mapping
Agisoft

PIX4D

DroneDeploy

MAPPER

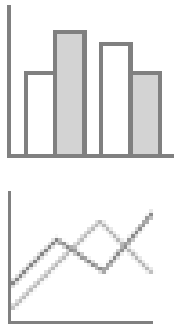
solvi

PlotCut (UCPH)

QGIS

MaizeScanner

FIJI



R

X

A pipeline

PhotoScan

RGB

Multispe

Hypersp

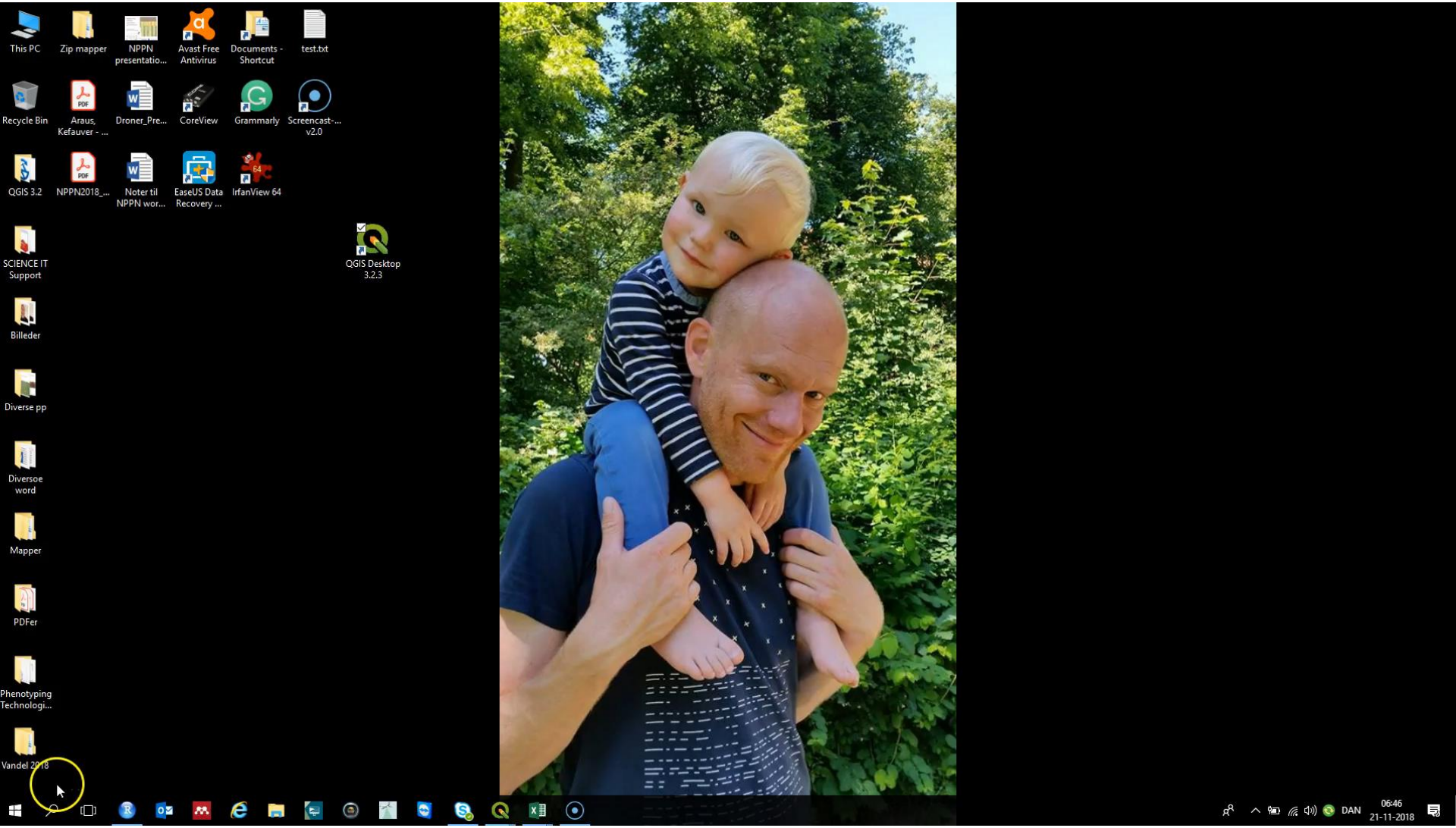
Thermal

QGIS

solvi

FIJI

One-O-One QGIS video



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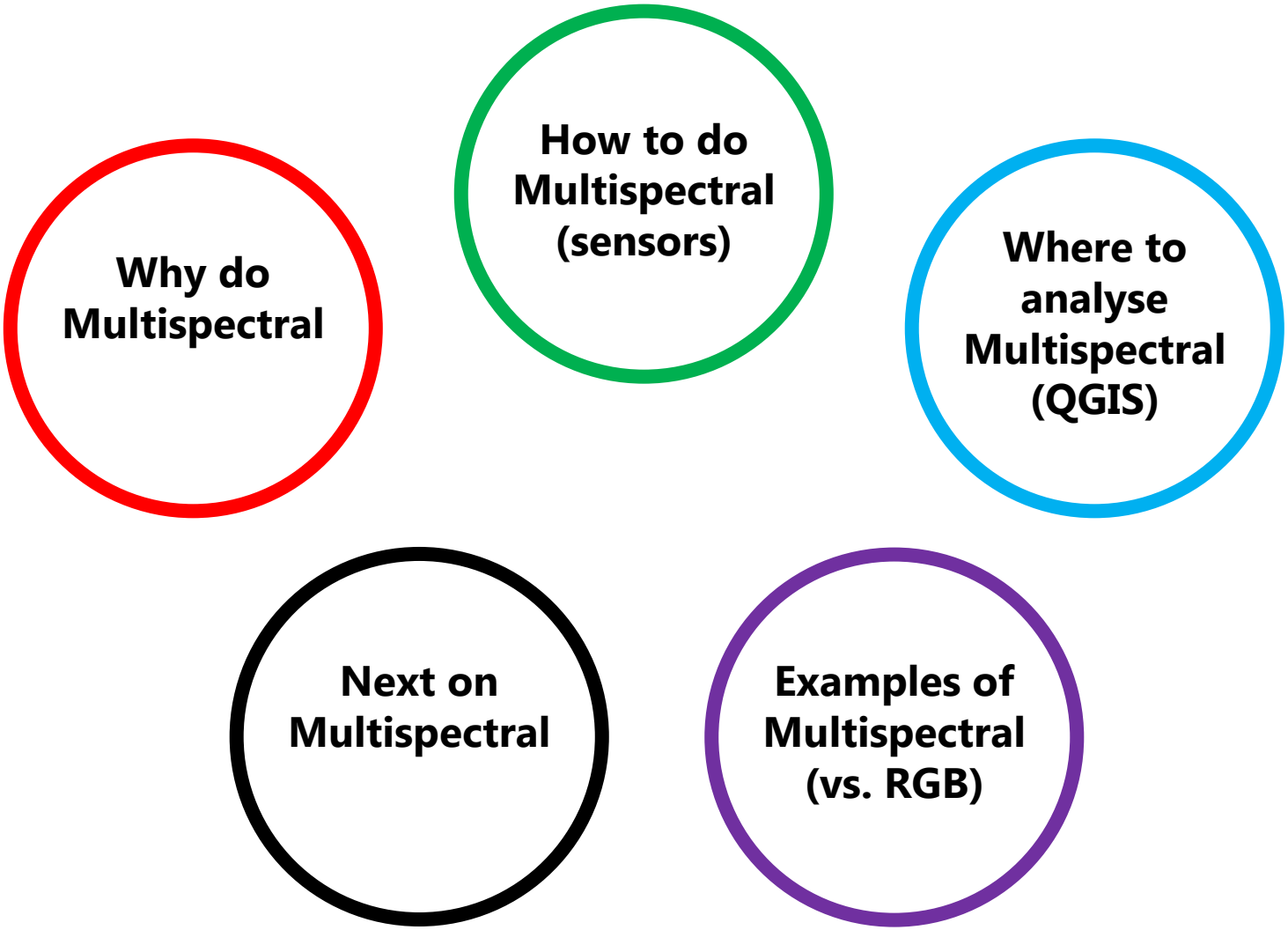
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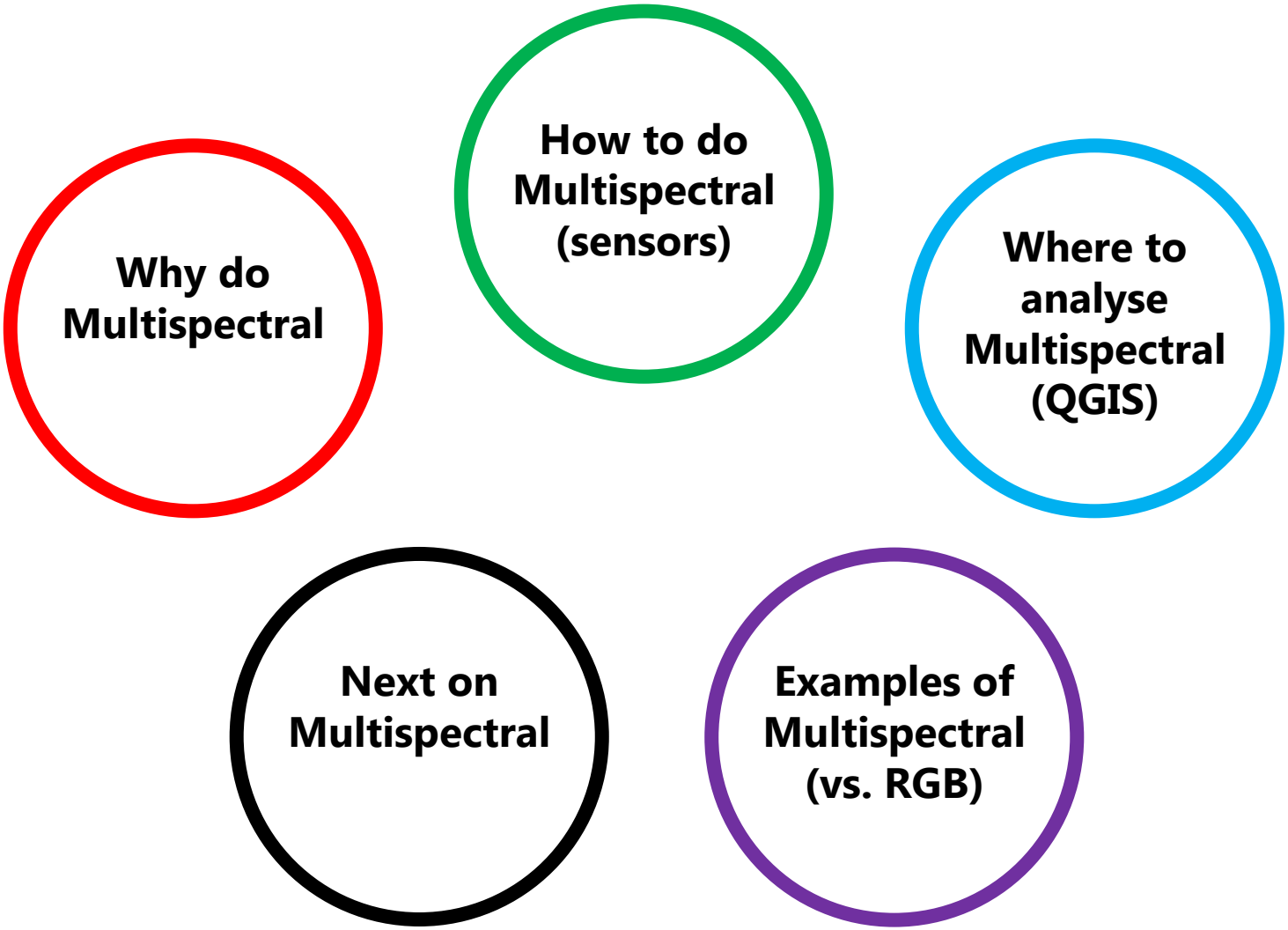
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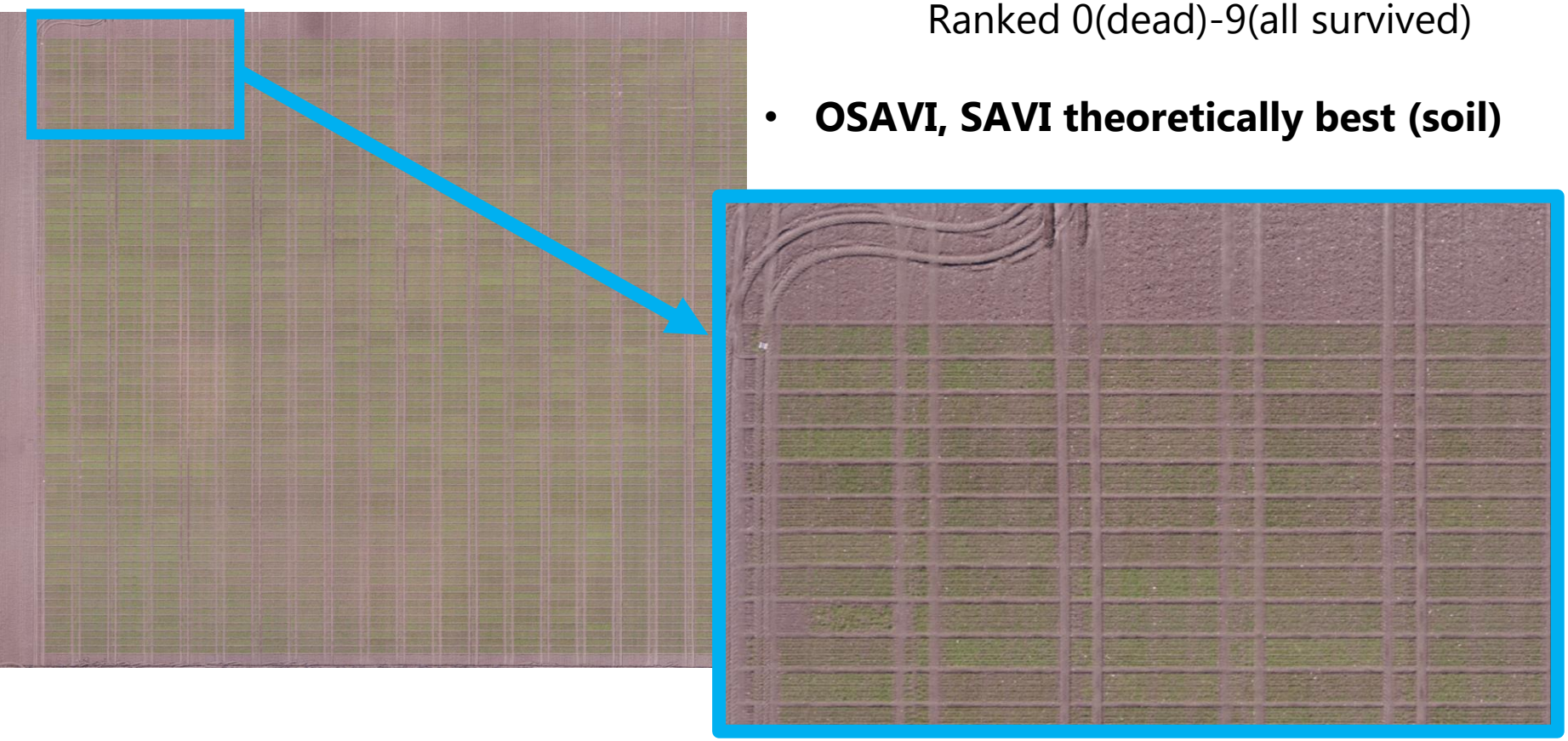
Cases of RGB vs Multispectral

- 3 cases
  - Early vigor/winter survival in winter barley (OSAVI, SAVI)
  - Maturity in potatoes (soil segmentation, NDRE)
  - Late blight in potatoes (soil segmentation, NIR indices)

- **A simple study** of the correlations matrixes when RGB/Multispectral indices are compared to ratings
- Merely looking at a few VI

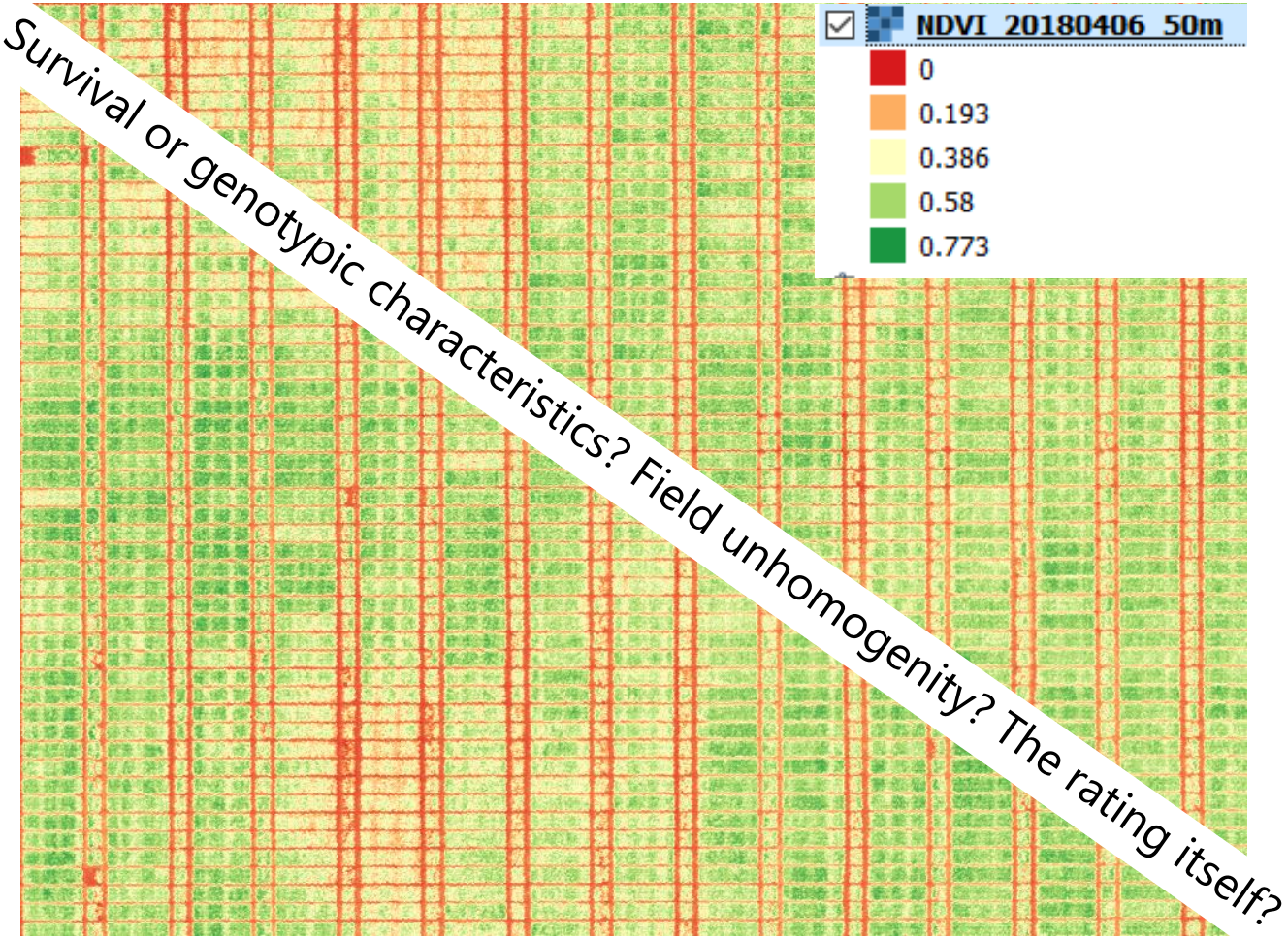
Winter barley Sejet (early open crop)

- **Multispectral** (R, G, RE, NIR) and **RGB**
- **Different genotypes**
- **Winter hardiness (6. April 2018)**
  Ranked 0(dead)-9(all survived)
- **OSAVI, SAVI theoretically best (soil)**

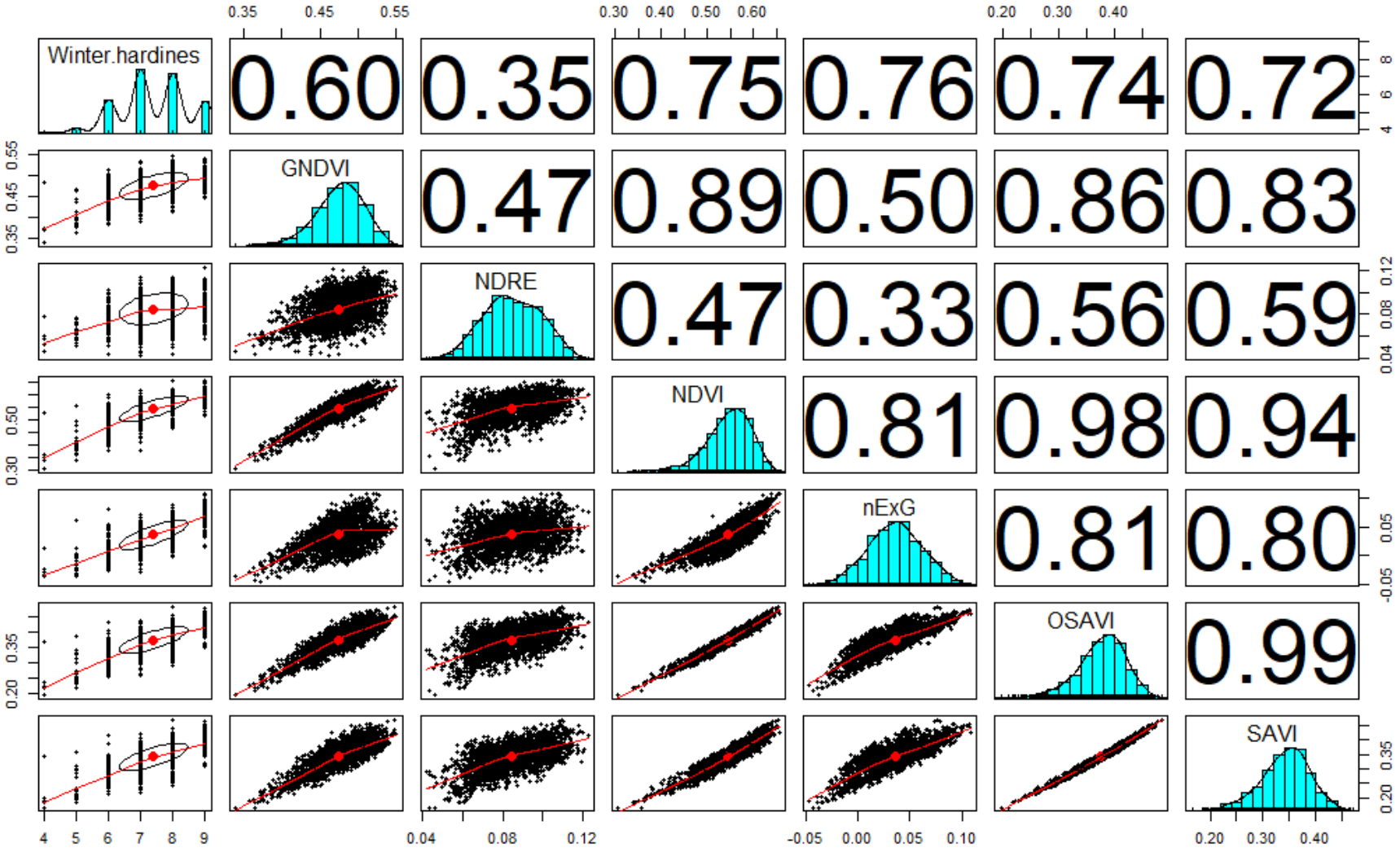


The challenge

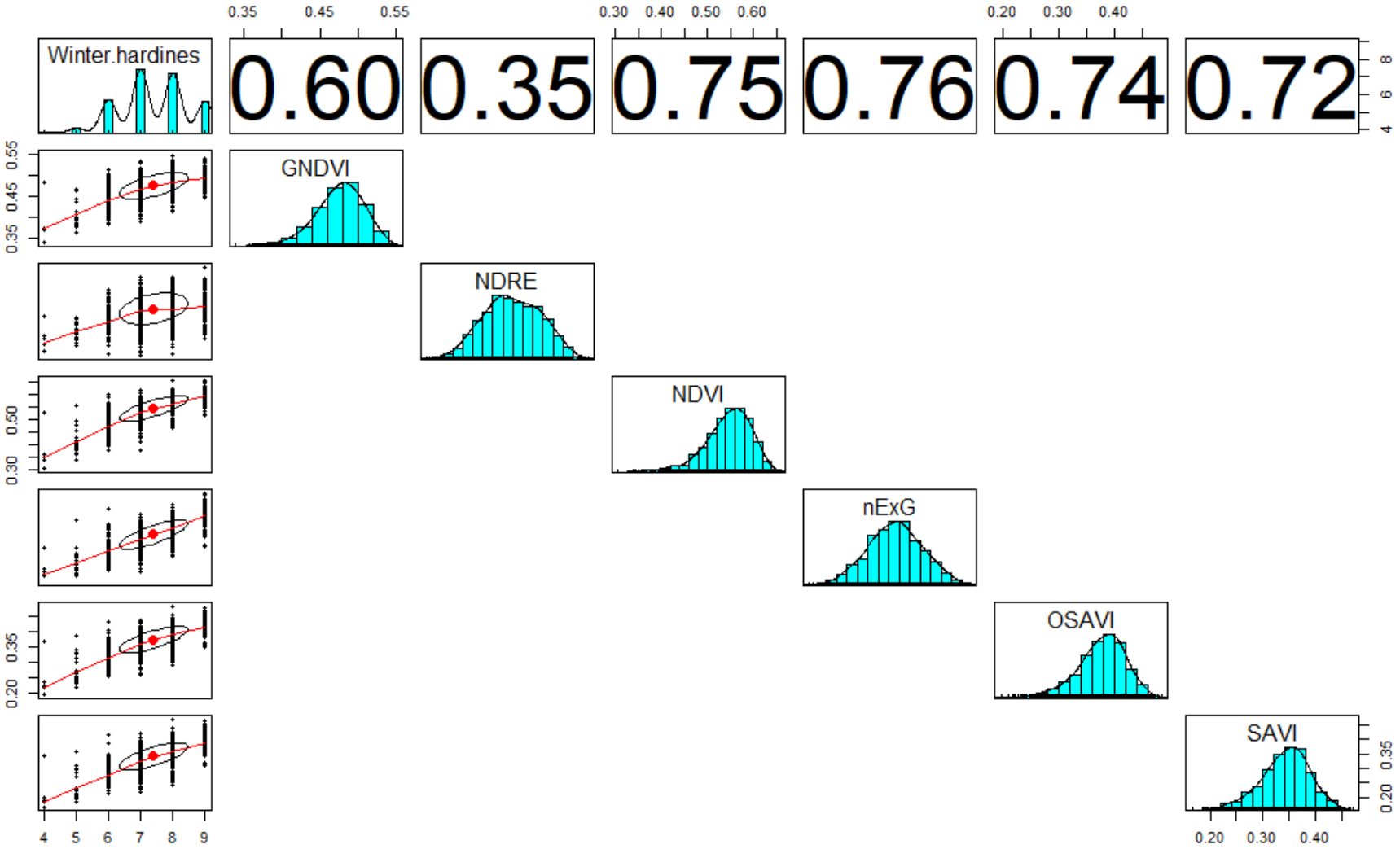
NDVI map winter barley



Look at a correlation matrix



Look at a correlation matrix



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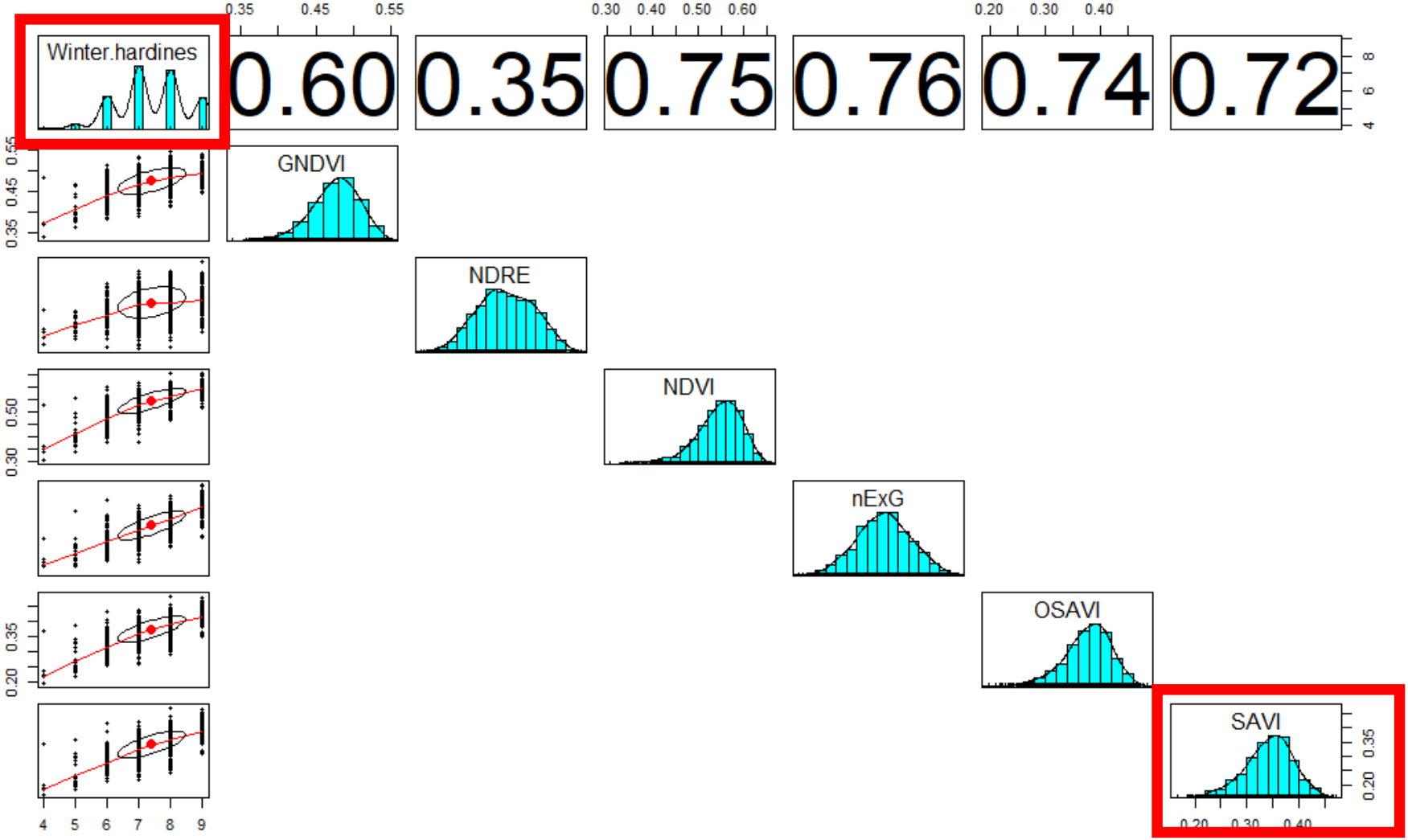
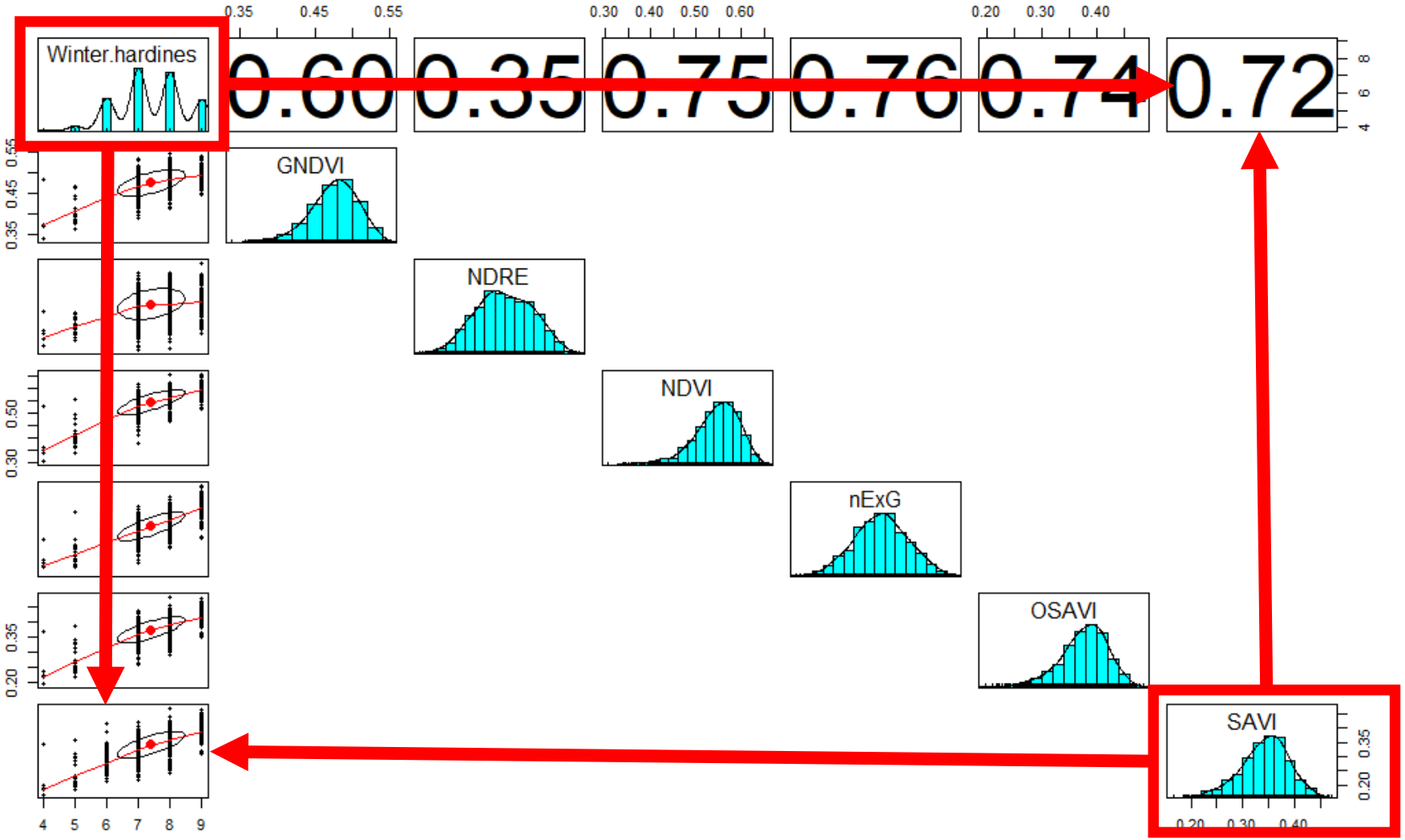
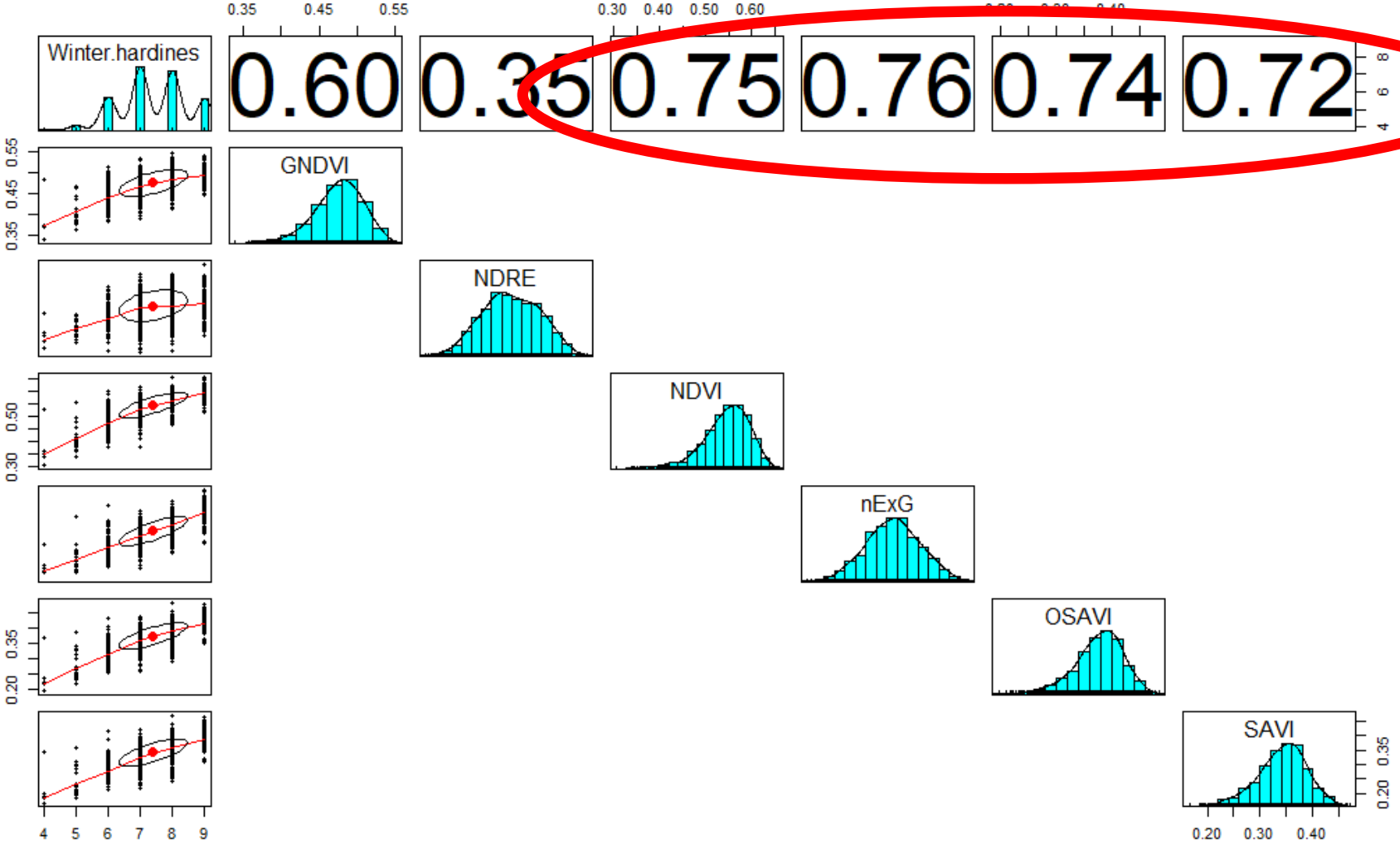


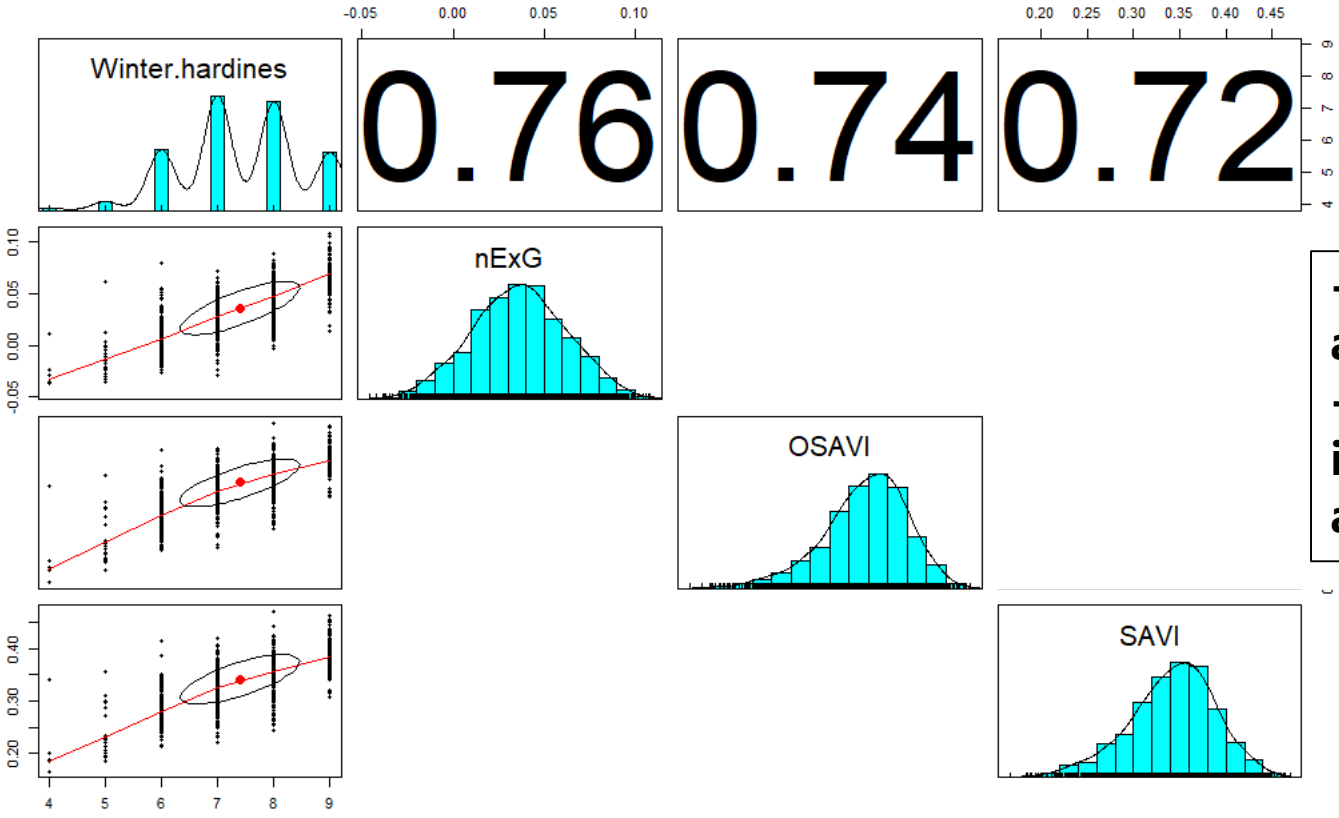
Look at a correlation matrix



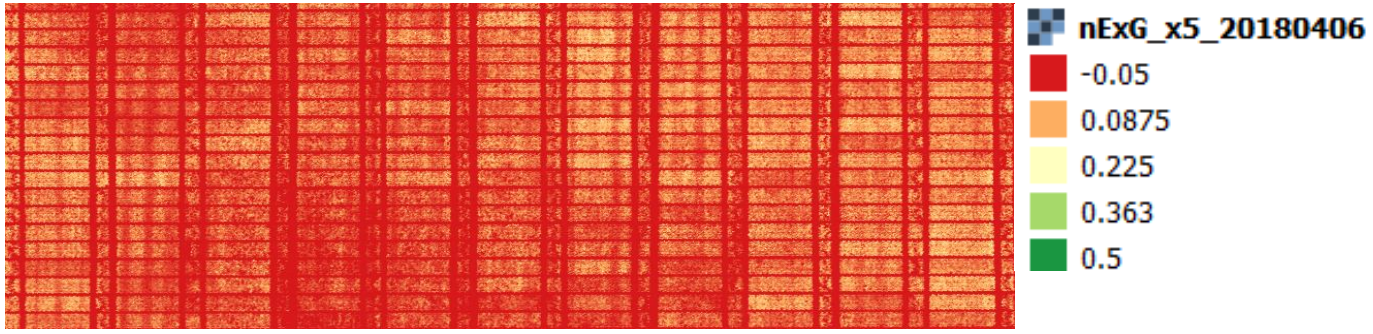
Look at a correlation matrix



Conclusions

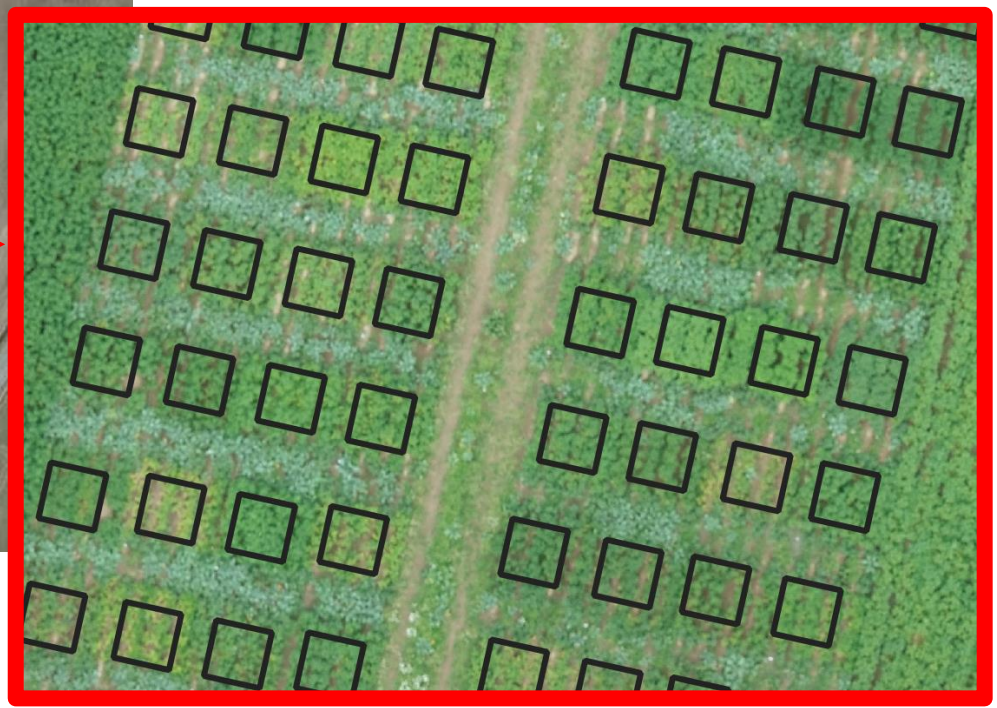


-nExG performs just as well as SAVI/OSAVI
-Perhaps coefficients in SAVI/OSAVI needs adjustment



Maturity in potatoes (senecense in late stage)

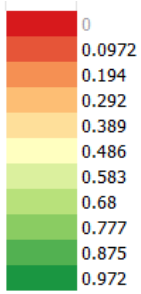
- **Multispectral** (R, G, B, RE, NIR) and **RGB**
- **186 genotypes, 1 rep.**
- **Maturity**
  Ranked 1(late)-9(very early)
- **Theoretically NDRE best**

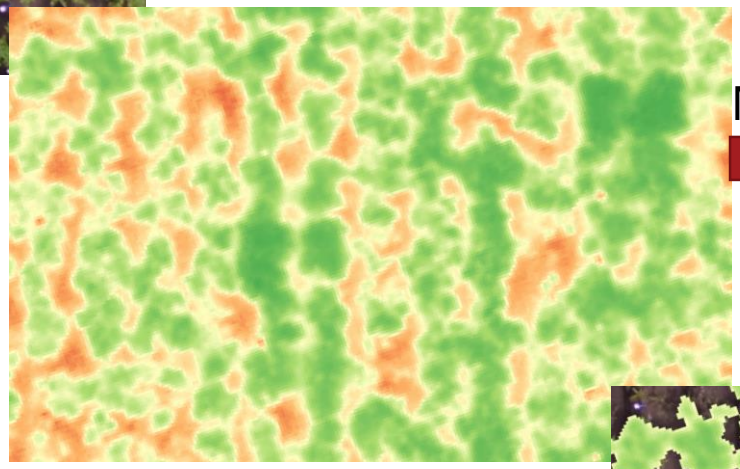


The challenge: Maturity or genotypic characteristics? Soil effects? Rating effects?

Soil segmentation

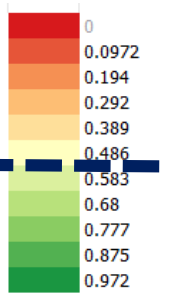
NDVI (0,0-0,972)

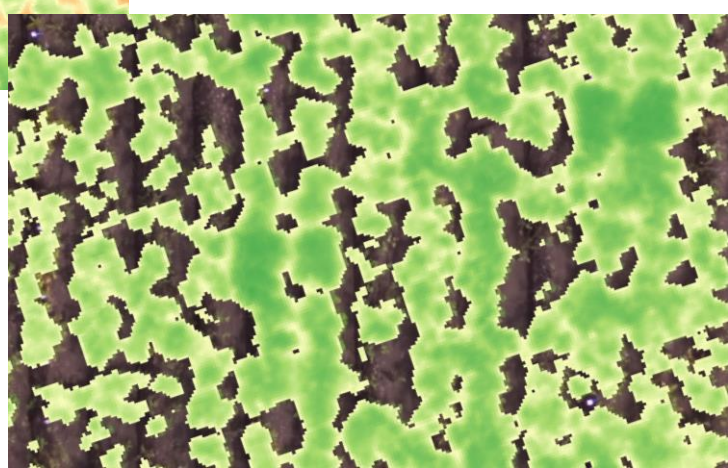




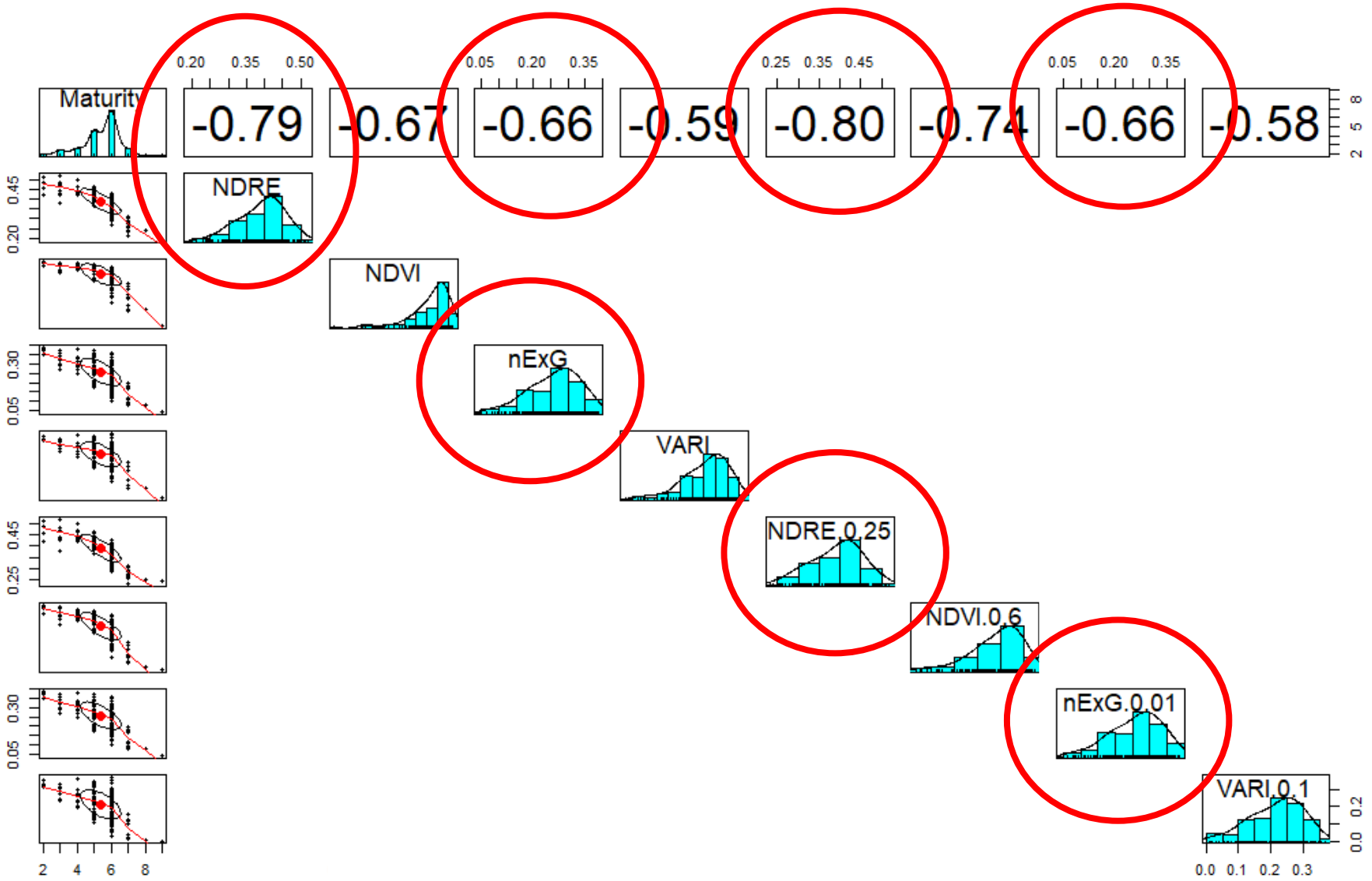
NDVI (0,0-0,972)

(0,5)





The correlation matrix



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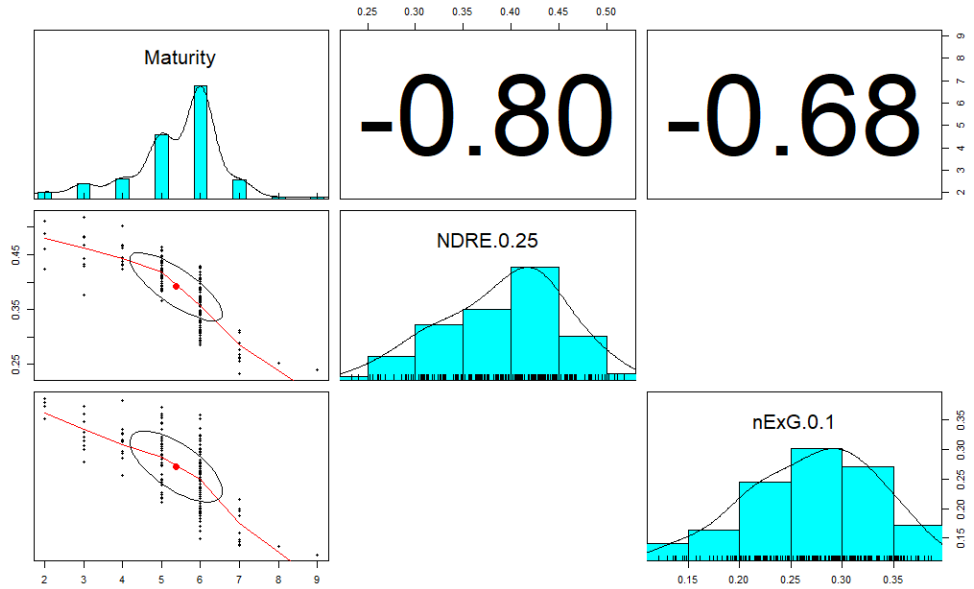
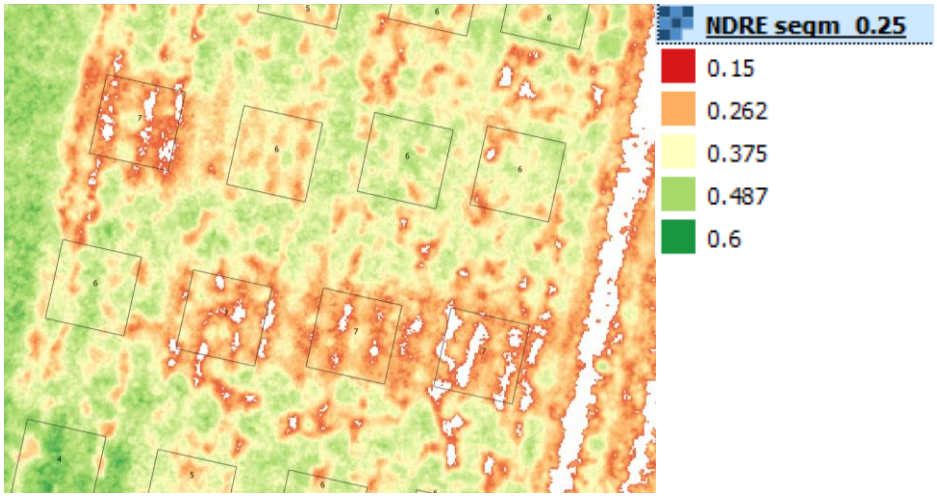
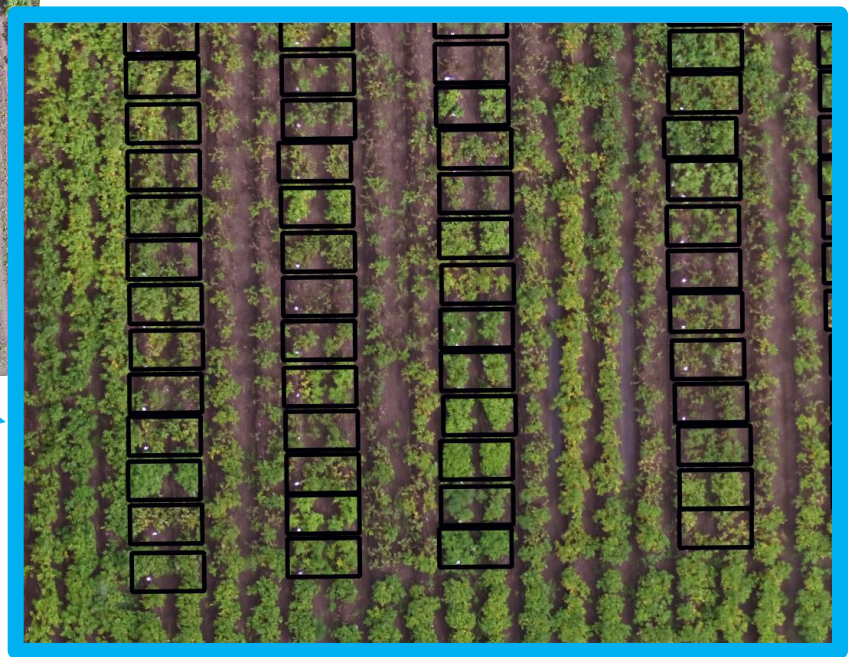


-NDRE (RE index) without soil performs best (as presented previously).
-High variation around rating



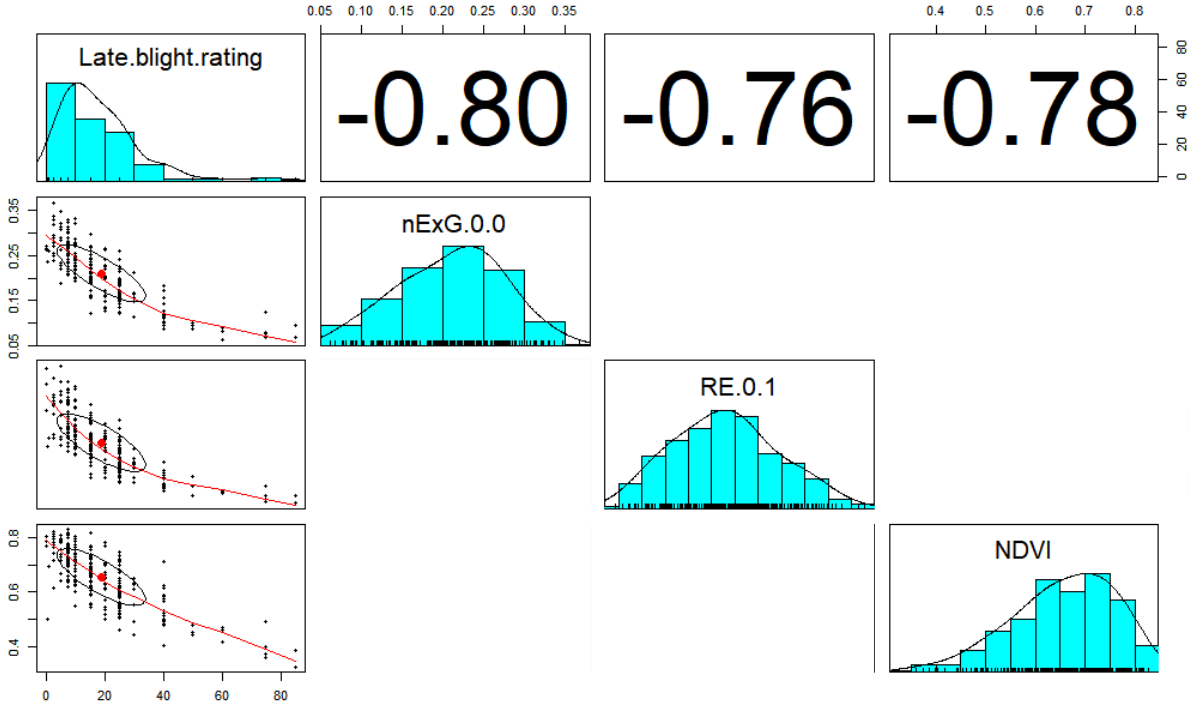
Potato Late blight (diseases in late growth stage)

- **Multispectral** (R, G, RE, NIR) and **RGB**
- **Late blight severity**
  0-100
- **Light fluctuation**

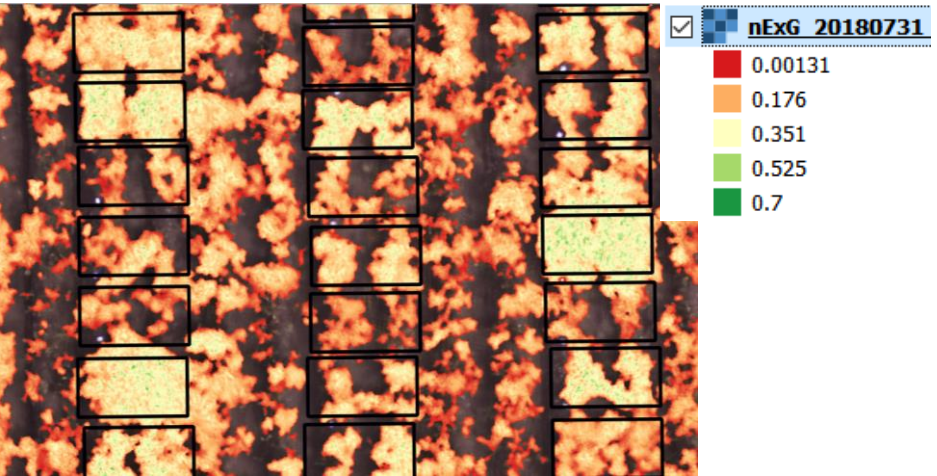


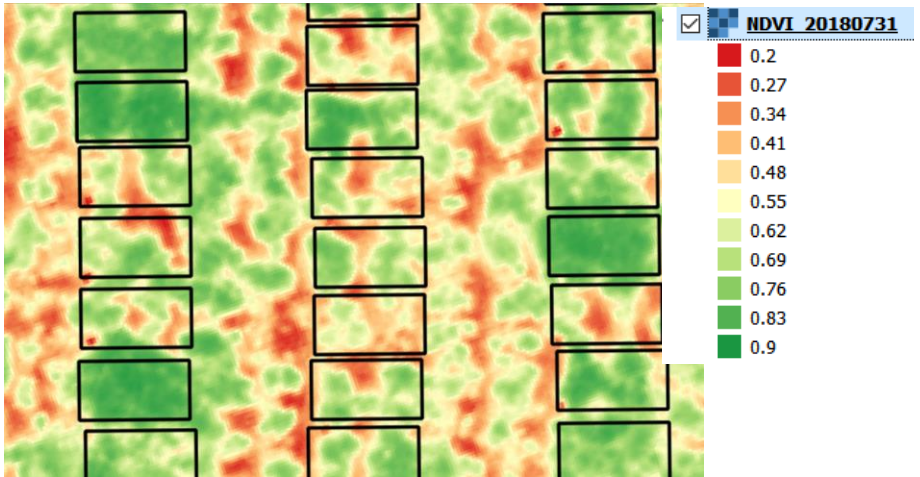
Another correlation matrix

Conclusions



-nExG without soil performs as well as NIR/RE indices (fluctuating light)
-NDVI performs well despite soil background
- Resolution and mixed pixels?

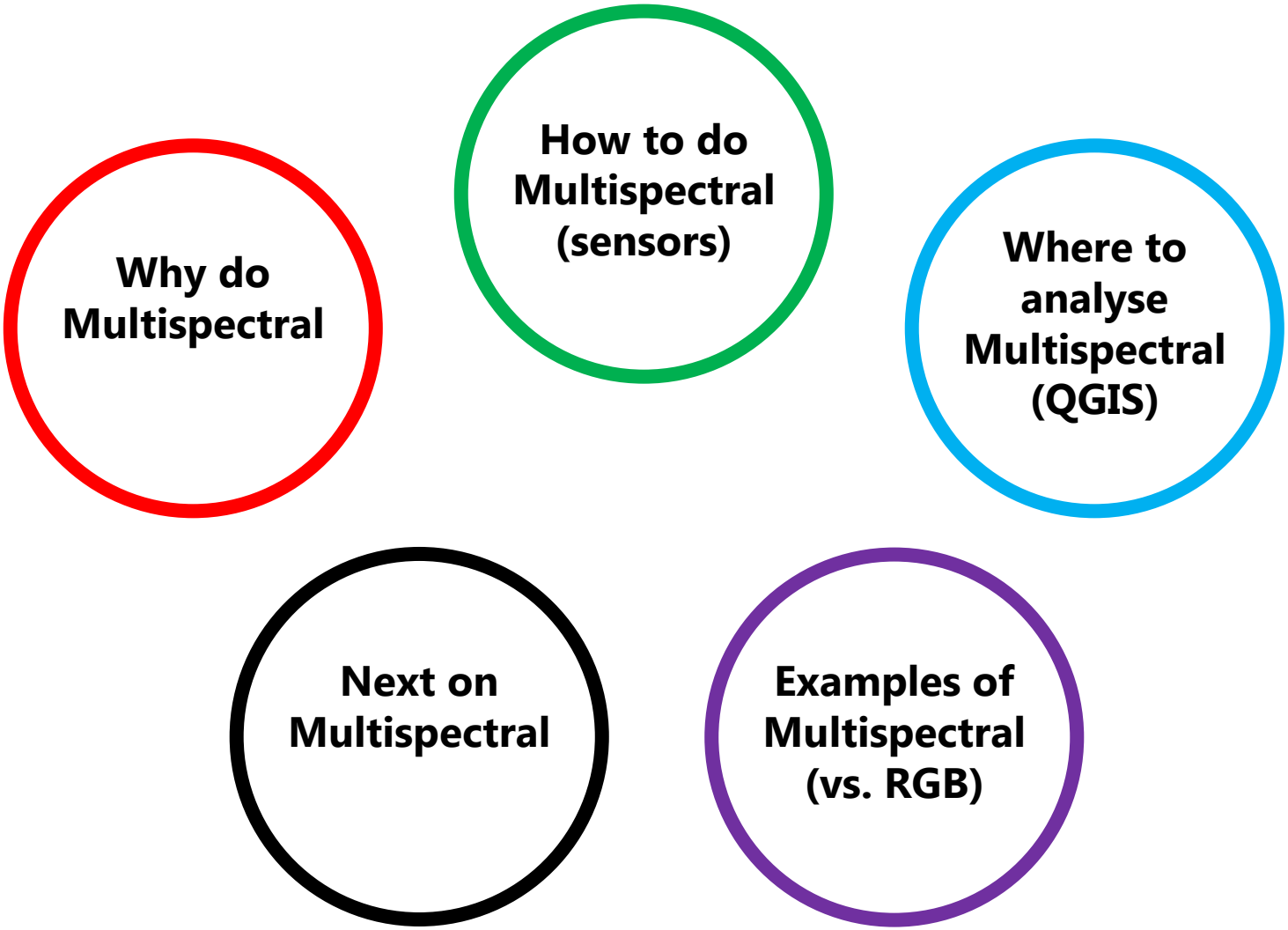




Concluding remarks – who won the first battle?

- **Importantly: These cameras are easy to use!!**
- **Only looked at a few indices (e.g. MaizeScanner)**
- **Often RGB performs as well as multispectral – we study greenness! If variation is there, we see it.**
- **NDRE proved good in some, OSAVI/SAVI did not prove superior, nExG performed in other cases. How to pick the right index? Two cameras? The scope?**
- **You still have a range of possibilities with a good RGB solution!!**
- **Segmentation improved results in some cases – maybe just per default?**
- **QGIS is one approach to explore this/handle data and make multiple comparisons**
- **Agricultural field vs breeding material– it's not the same: effect from different genotypes, e.g. greenness differences, canopy structure, shadows. Are we studying the trait or?**
- **And then there is the magic-wonderland of hyperspectral…**

Next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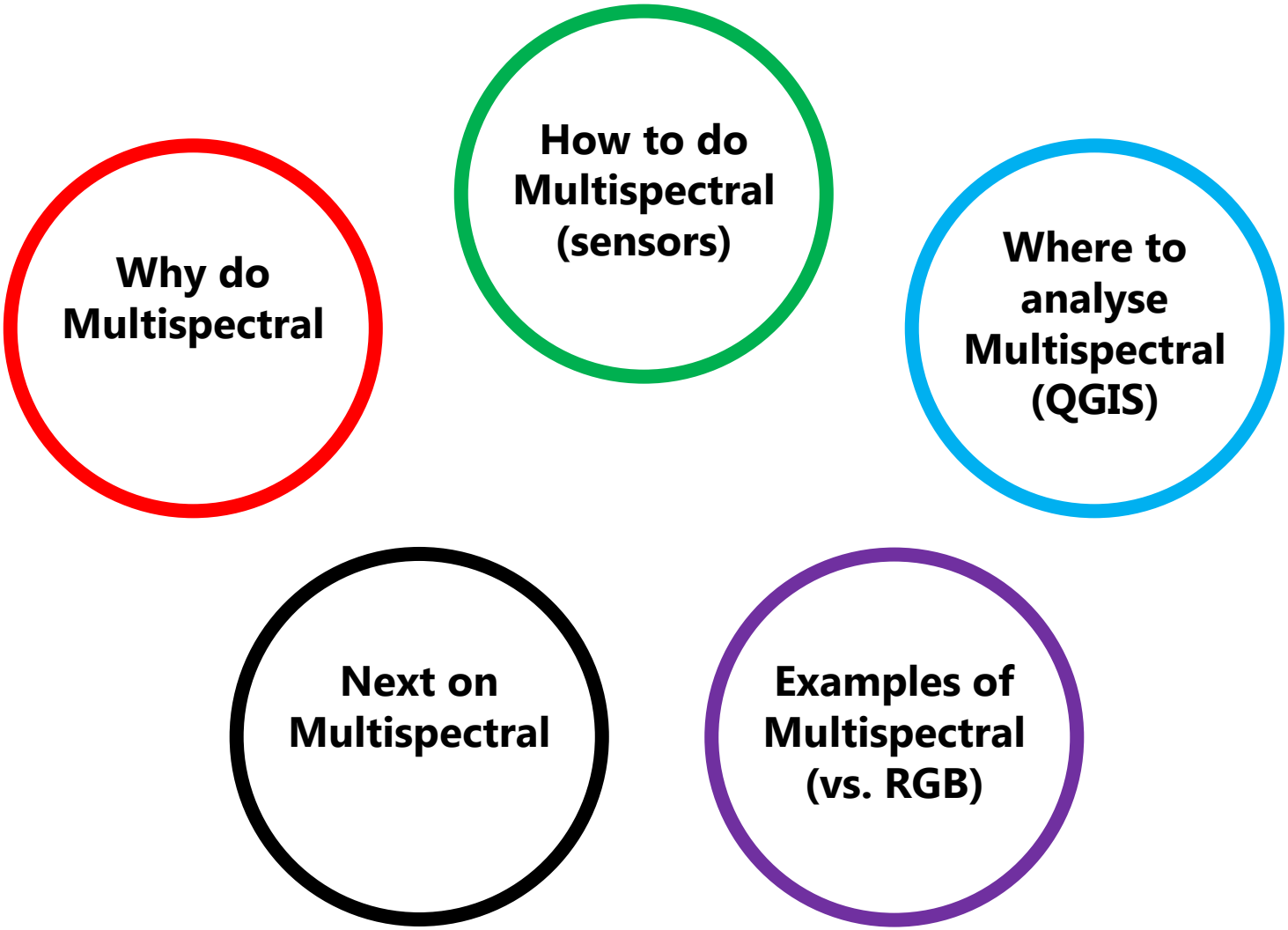
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Perspectives for the coming battles

Yield prediction winter barley

Rust in Kentucky bluegrass

Drought studies in RadiMax (incl thermal)

Statistical/physiological models, machine learning (EnBlightMe)

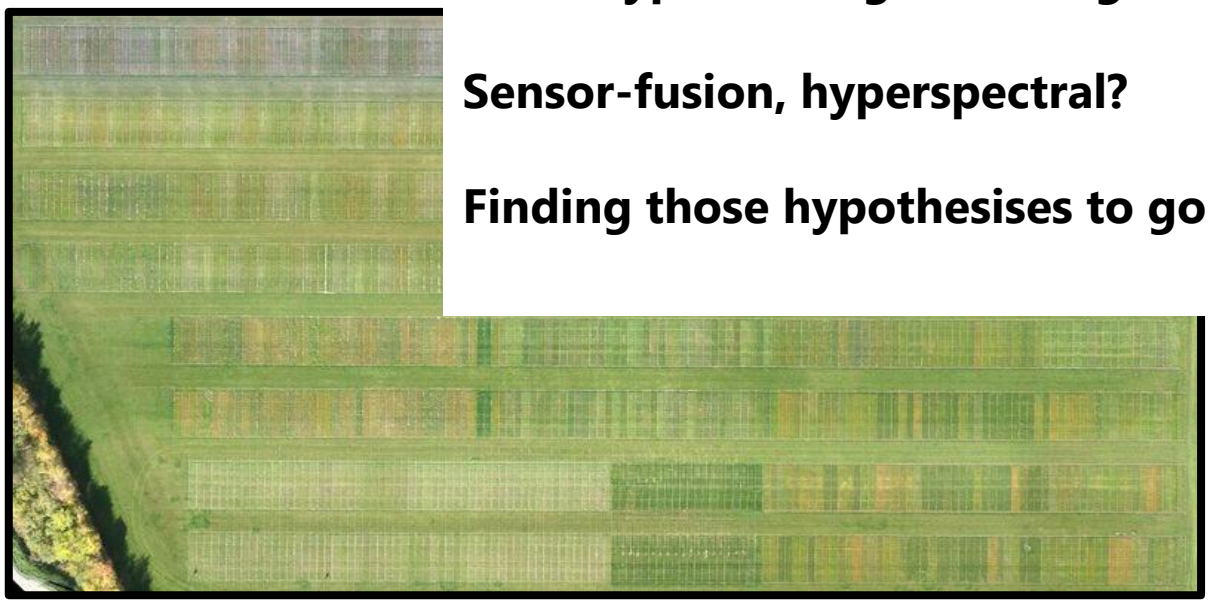
Repeatability; (subjective) ratings versus (objective) drone/buggie/handheld camera

Genotype diversity versus trait. Hunting variation

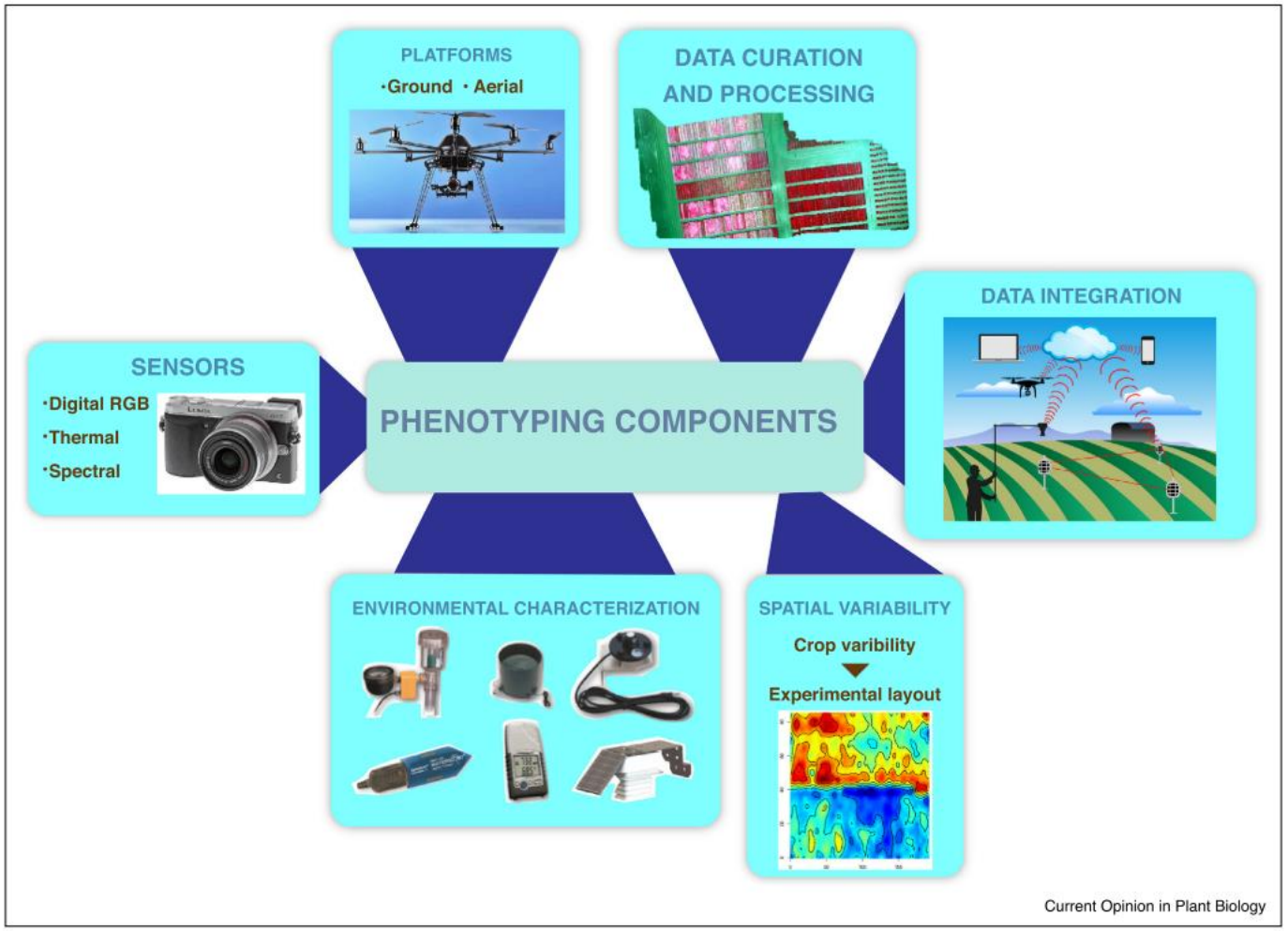
Phenotype ranking and bridge to genotyping

Sensor-fusion, hyperspectral?

Finding those hypothesises to go with!



Inspiration



Araus, J. L., & Kefauver, S. C. (2018). Breeding to adapt agriculture to climate change: affordable phenotyping solutions. *Current opinion in plant biology*.

Thank you for your attention – Questions?

- Thank you to enthusiastic partners and colleagues

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