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LUFTBILD UMWELT PLANUNG

GEOINFORMATION
in der Umweltplanung | Environmental Planning
Technische Universität Berlin

FirSt 2.0

Hyperspectral UAV image data and the early detection of bark beetle infestation in spruce forests

Alexander Marx, Ahuvit Trumper, Jonannes May,
Simon König, Dr. Michael Förster

WALDBESITZERVERBAND NIEDERSACHSEN

THÜNEN

Landesbetrieb Wald und Holz Nordrhein-Westfalen

ORORA TECHNOLOGIES

NATIONALPARK Bayerischer Wald

Landesforst Mecklenburg-Vorpommern
Wald schafft Zukunft

LiveEO

Projekt FIRST 2.0

Project name

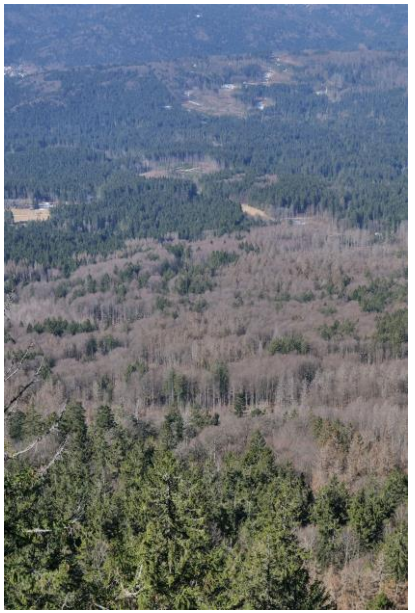
- **F**orest **D**amage **i**nventory **b**ased on **r**apid **S**atellite **t**echnologies (Objective: Software)

Objective of Hyperspectral Workpackage

- Better understand the light – canopy relationships related to stress situations
- Give recommendations for use of satellite data

Test Area & Motivation

- **Test Area**: Arnsberger Wald (and other)
- Drought induced spruce bark beetle calamity in Germany since 2020
- Early detection of bark beetle infested spruces desirable
- UAV borne hyperspectral remote sensing: useful tool to assess health status of the forest canopy



Data: Hyperspectral

Sensor:

- Headwall Nano-Hyperspec
- Spectral range: 399 to 1002 nm
- Bands: 271

Flying area

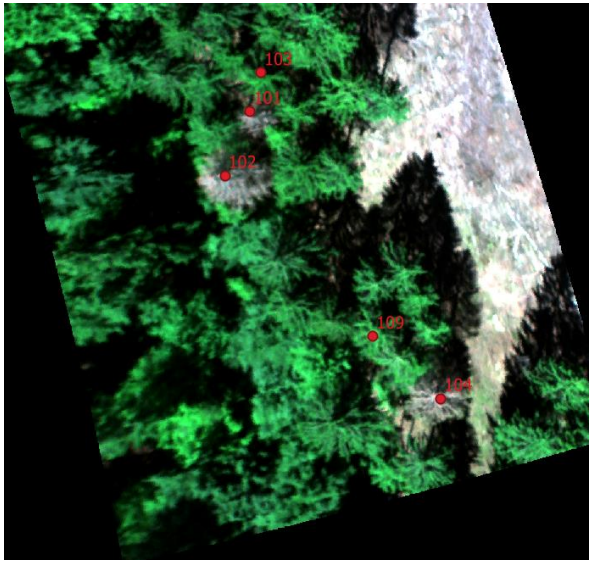
- 9.6 hectares

Dates of successful imaging campaigns:

- 2021-04-28
- 2021-06-14

Data: Ground reference

Collected repeatedly throughout the year



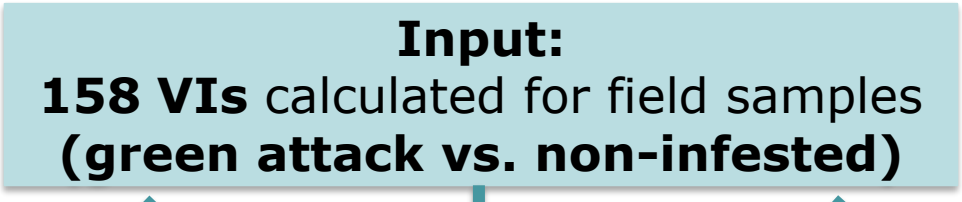
Tree_ID	Observations Descr.	Species	est_inf_date	flight_date	flight-inf days	inf_class	Inf_class_nom
103	beim Einbohren	Ips typ.	19.05.21	14.06.21	26.00	2	green_attack
109	beim Rammelkammer anlegen	Ips typ.	21.05.21	14.06.21	24.00	2	green_attack
110	Käfer sitzt auf Stamm, bohrt sich	Ips typ.	19.05.21	14.06.21	26.00	2	green_attack
111	Frisch eingebohrt	Ips typ.	01.06.21	14.06.21	13.00	2	green_attack
101	ausgeflogen	Ips typ.	01.10.20	14.06.21	256.00	3	red_attack/dead
102	ausgefolgen	Ips typ.	01.10.20	14.06.21	256.00	3	red_attack/dead
104	bereit auszufliegen	Ips typ.	01.10.20	14.06.21	256.00	3	red_attack
105	oberhalb länger eingebohrt	Ips typ.	01.10.20	14.06.21	256.00	3	red_attack
181	nicht befallen	x	10.10.21	14.06.21	x	1	non-infested
182	nicht befallen	x	10.10.21	14.06.21	x	1	non-infested
183	nicht befallen	x	10.10.21	14.06.21	x	1	non-infested
184	nicht befallen	x	10.10.21	14.06.21	x	1	non-infested

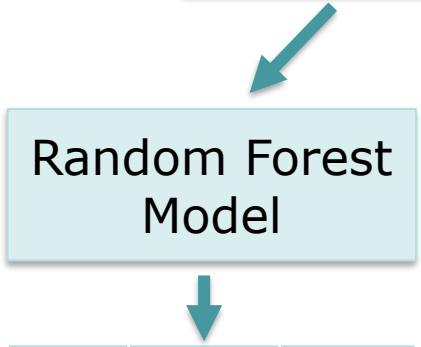
Research Questions

- Which vegetation indices (VIs) have the most predictive power for detecting bark beetle infested spruces? (green-attack vs. non-infested)

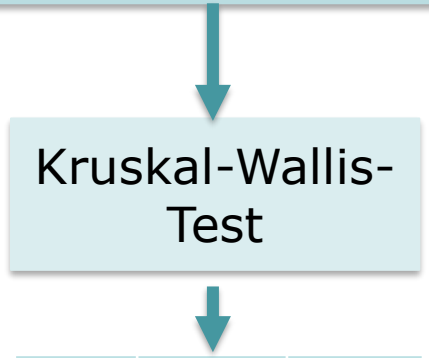
- Which method is useful for assessing the individual performance of the candidate VIs?

Selection of 20 most important from 158 Vegetation Indices – 3 Methods tested





VI	MDG	Rank
X_i	I_1	1
X_i	I_2	2
X_i	I_3	3
…	…	…
X_i	I_{158}	158



VI	KW-H	Rank
X_i	H_1	1
X_i	H_2	2
X_i	H_3	3
…	…	…
X_i	H_{158}	158

VI	KS-Z	Rank
X_i	Z_1	1
X_i	Z_2	2
X_i	Z_3	3
…	…	…
X_i	Z_{158}	158

Selection of 20 most important from 158 Vegetation Indices – 3 Methods tested

Input:
158 VIs calculated for field samples
(green attack vs. non-infested)

Random Forest Model

VI	MDG	Rank
X_i	I_1	1
X_i	I_2	2
X_i	I_3	3
…	…	…
X_i	I_{158}	158

Kruskal-Wallis-Test

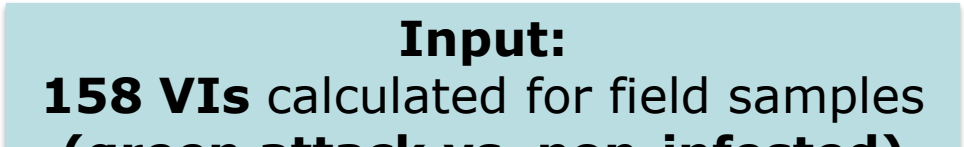
VI	KW-H	Rank
X_i	H_1	1
X_i	H_2	2
X_i	H_3	3
…	…	…
X_i	H_{158}	158

Kolmogorov-Smirnov-Test

VI	KS-Z	Rank
X_i	Z_1	1
X_i	Z_2	2
X_i	Z_3	3
…	…	…
X_i	Z_{158}	158

2-Klassen Fall

Selection of 20 most important from 158 Vegetation Indices – 3 Methods tested



Random Forest Model		
VI	MDG	Rank
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…	…	…
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Kruskal-Wallis-Test		
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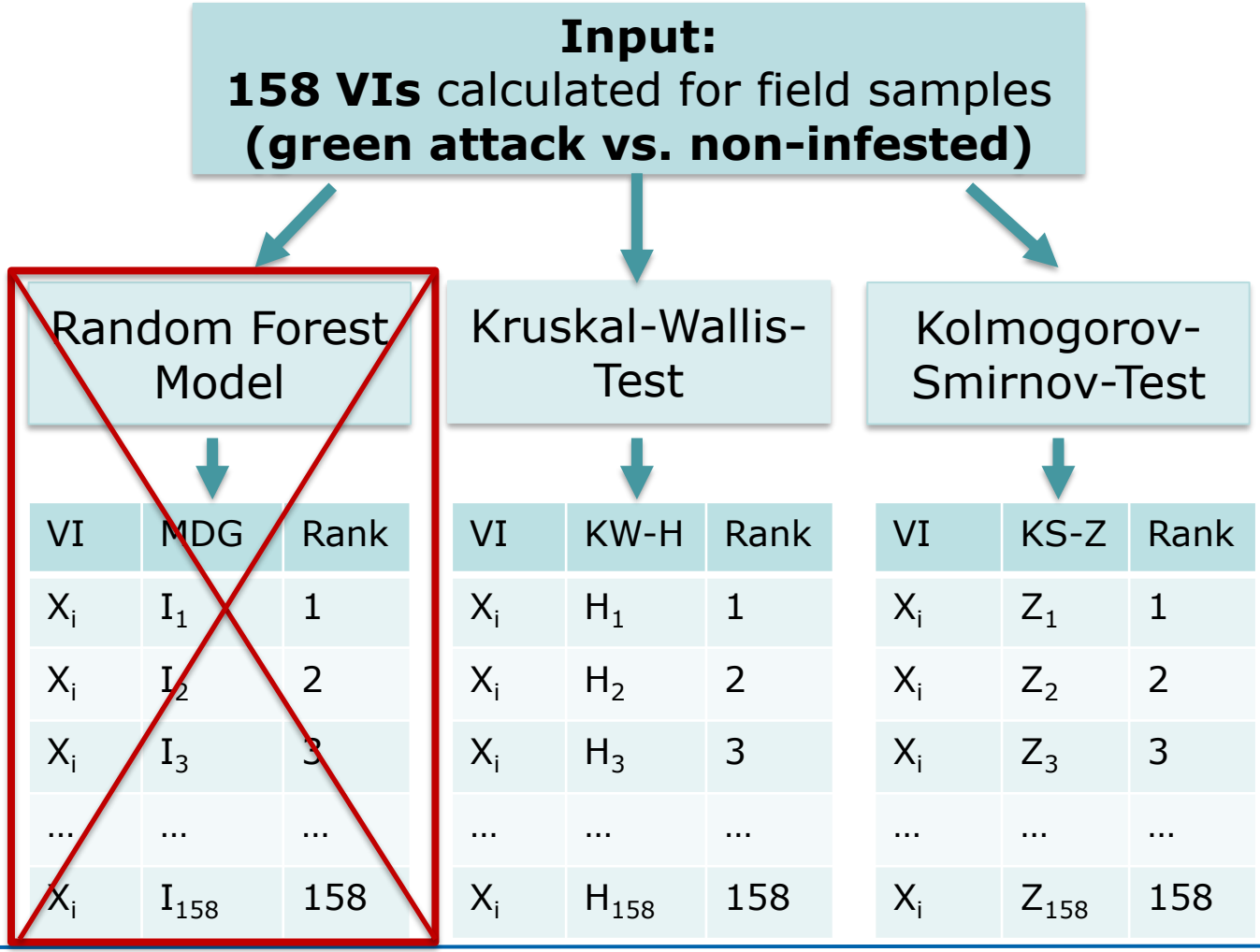
…	…	…
X_i	H_{158}	158

3-Klassen Fall

Kolmogorov-Smirnov-Test		
VI	KS-Z	Rank
X_i	Z_1	1
X_i	Z_2	2
X_i	Z_3	3
…	…	…
X_i	Z_{158}	158

Selection of 20 most important from 158 Vegetation Indices – 3 Methods tested

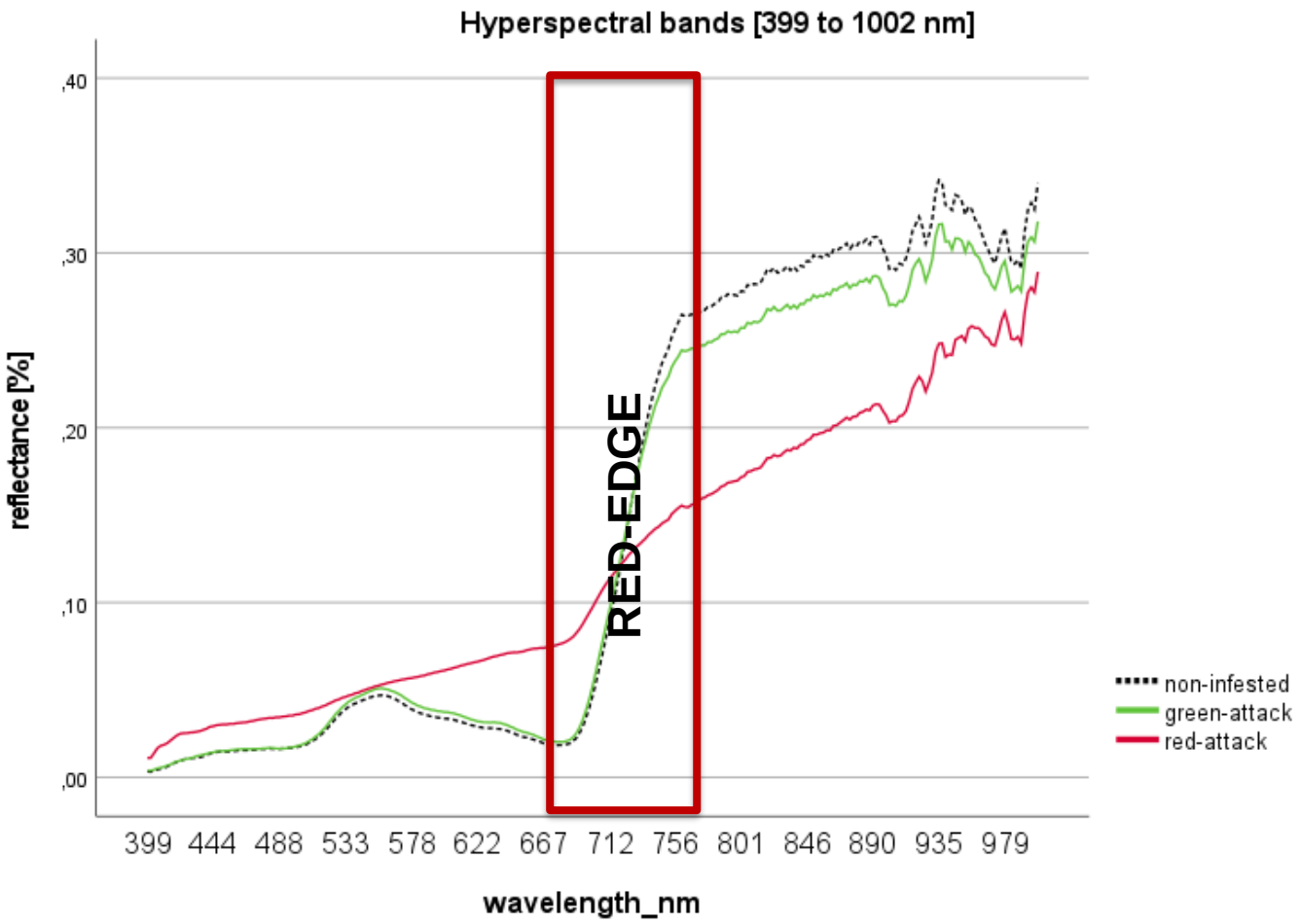


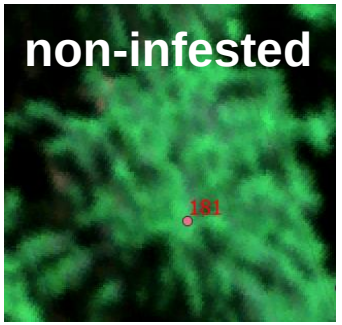
VI	MDG	Rank
X_i	I_1	1
X_i	I_2	2
X_i	I_3	3
…	…	…
X_i	I_{158}	158

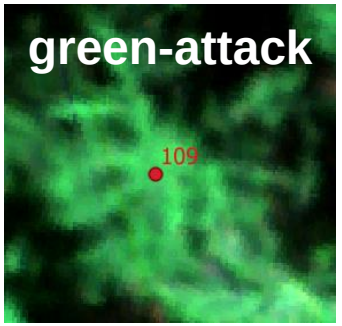
VI	KW-H	Rank
X_i	H_1	1
X_i	H_2	2
X_i	H_3	3
…	…	…
X_i	H_{158}	158

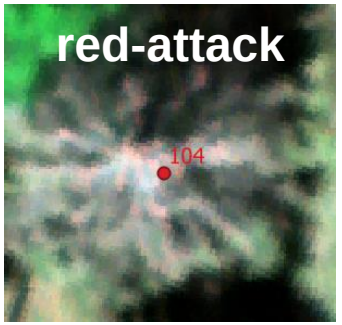
VI	KS-Z	Rank
X_i	Z_1	1
X_i	Z_2	2
X_i	Z_3	3
…	…	…
X_i	Z_{158}	158

Hyperspectral Line Plot for class samples



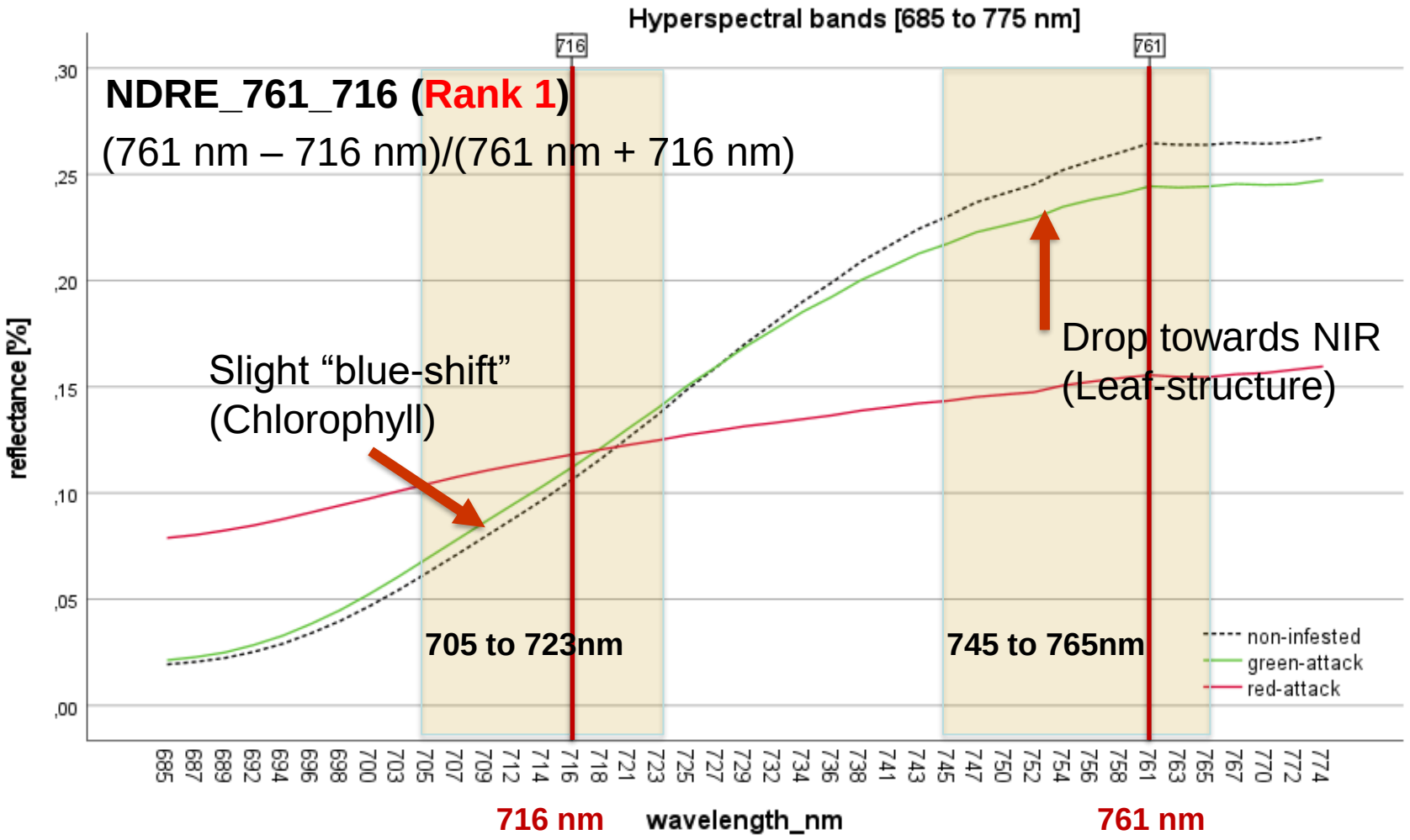






Most important spectral regions for VI formation

Upper and lower part of the Red-Edge spectrum



Compare scientific literature

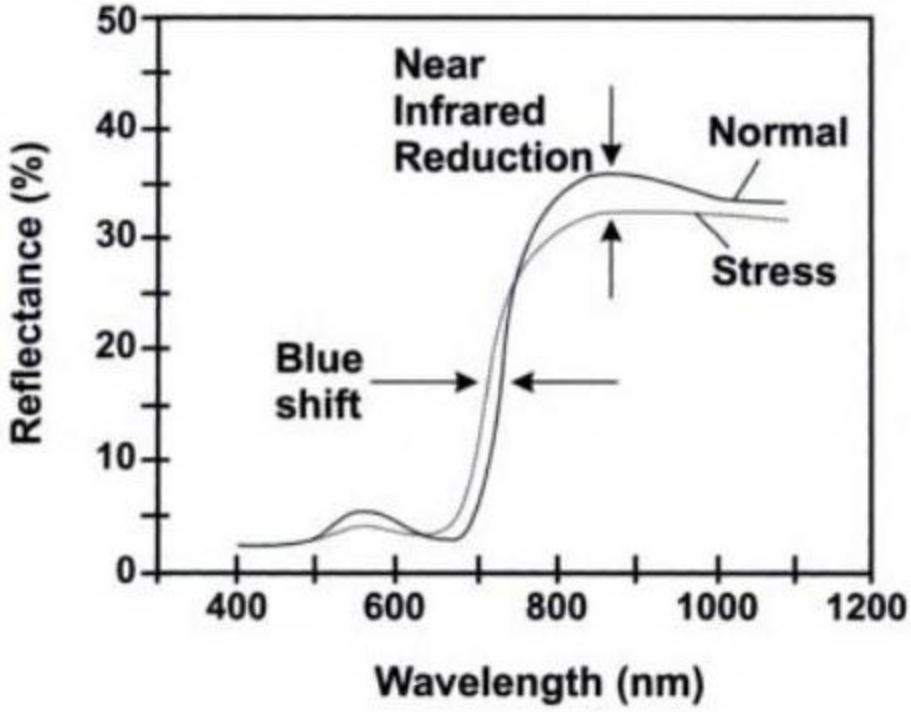
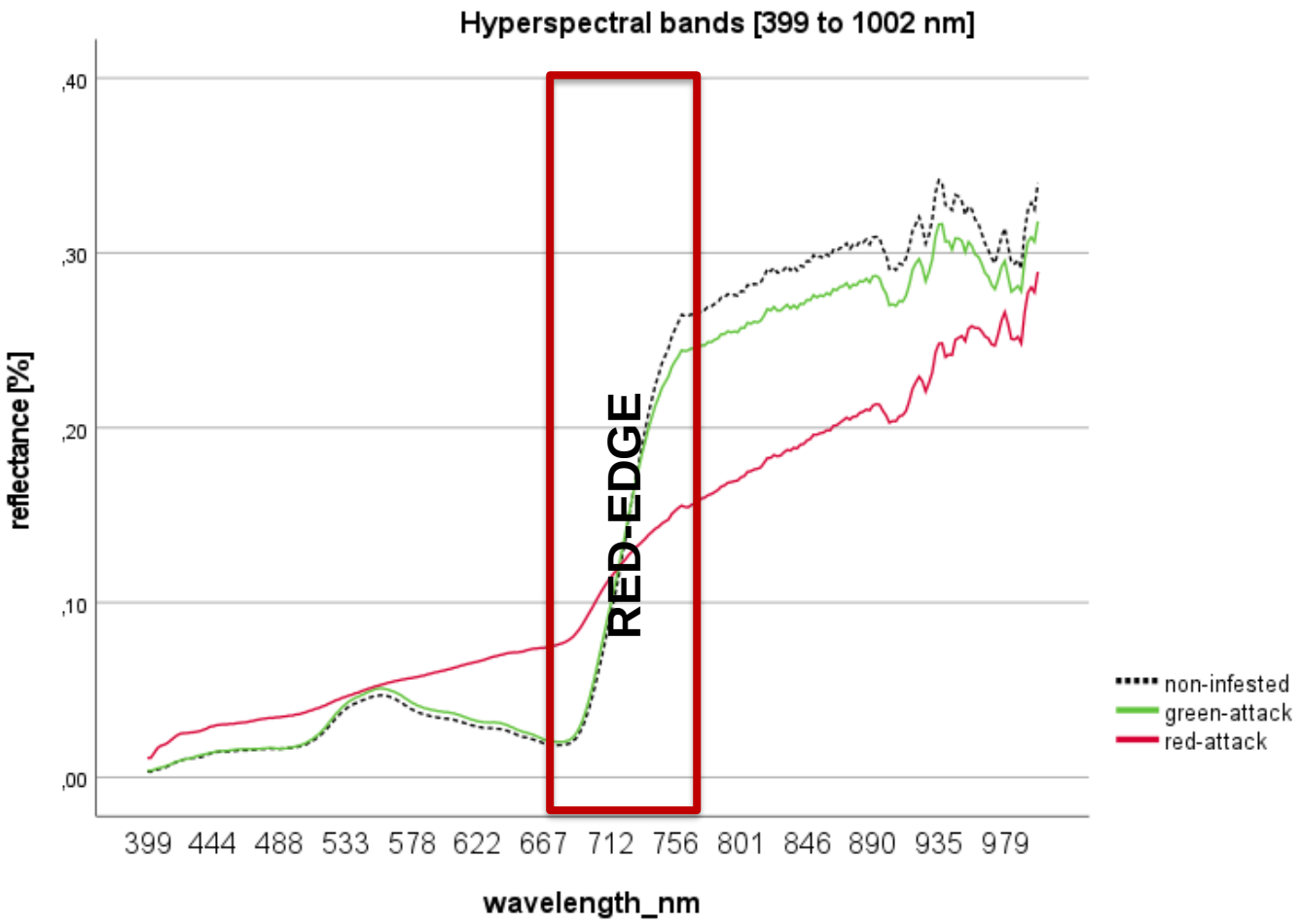
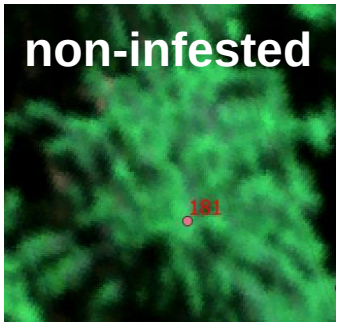
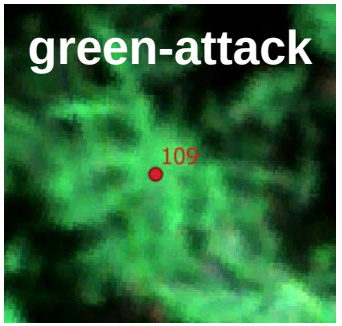


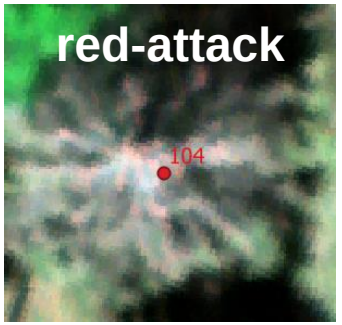
FIGURE 8.6 Spectral response curve shows the expected changes in green leaves under stress. A small reduction in green light reflectance, an increase in red light reflectance, and a reduction in near-infrared light reflectance has been observed. The shift of the red-edge of leaf reflectance to shorter wavelengths, called the blue shift, is a universal property of leaves under stress. (From Reid, N. J. 1987. *Environ. Sci. Technol.*, 21: 428–429. With permission.)

Hyperspectral Line Plot for class samples









Additional suitable wavelengths of particular VIs

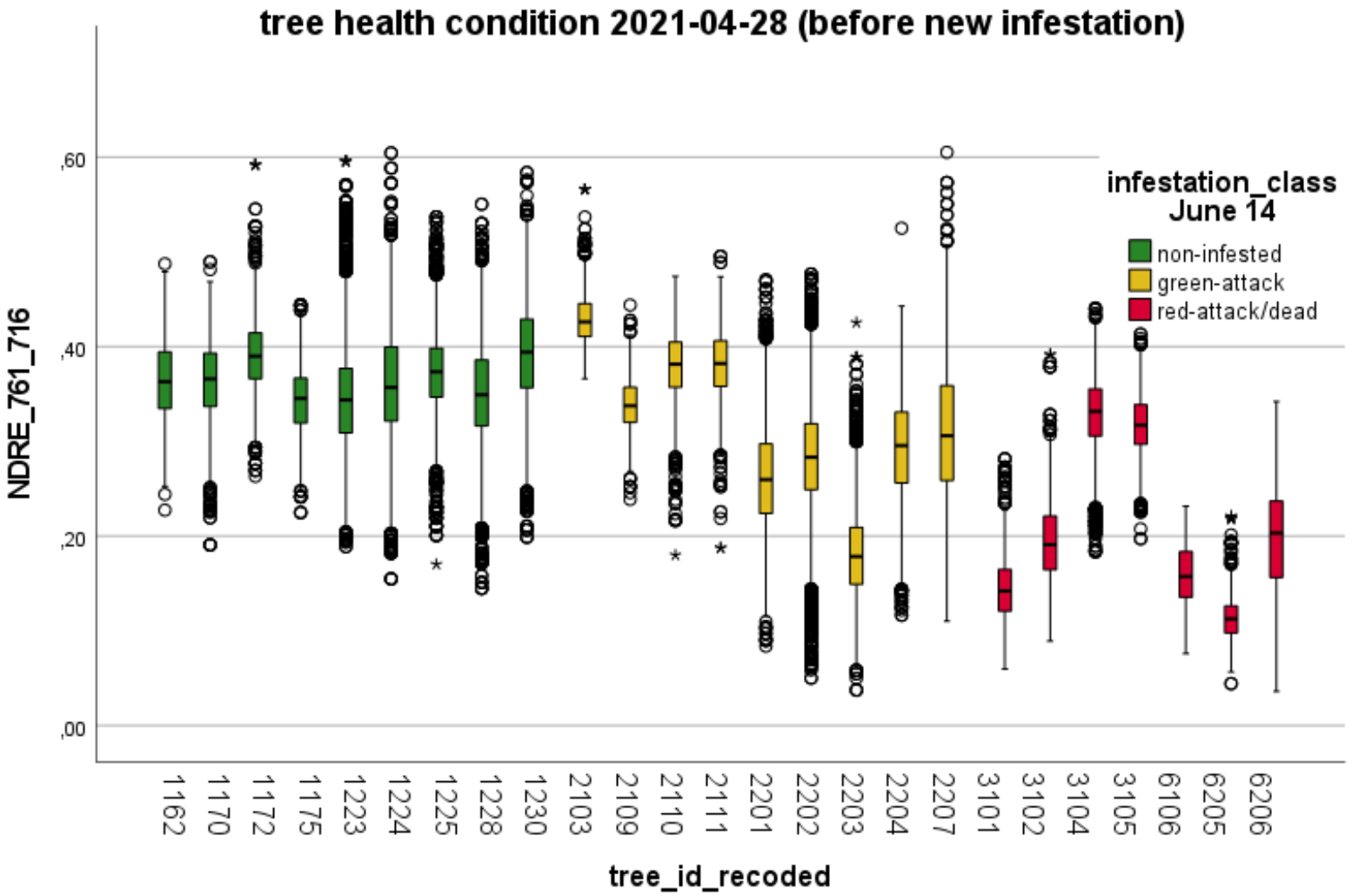
Maccioni =(**781 nm** – 709 nm)/(**781** nm – **680 nm**). (**Rank 14**)

(Maccioni, Agati, & Mazzinghi, 2001)

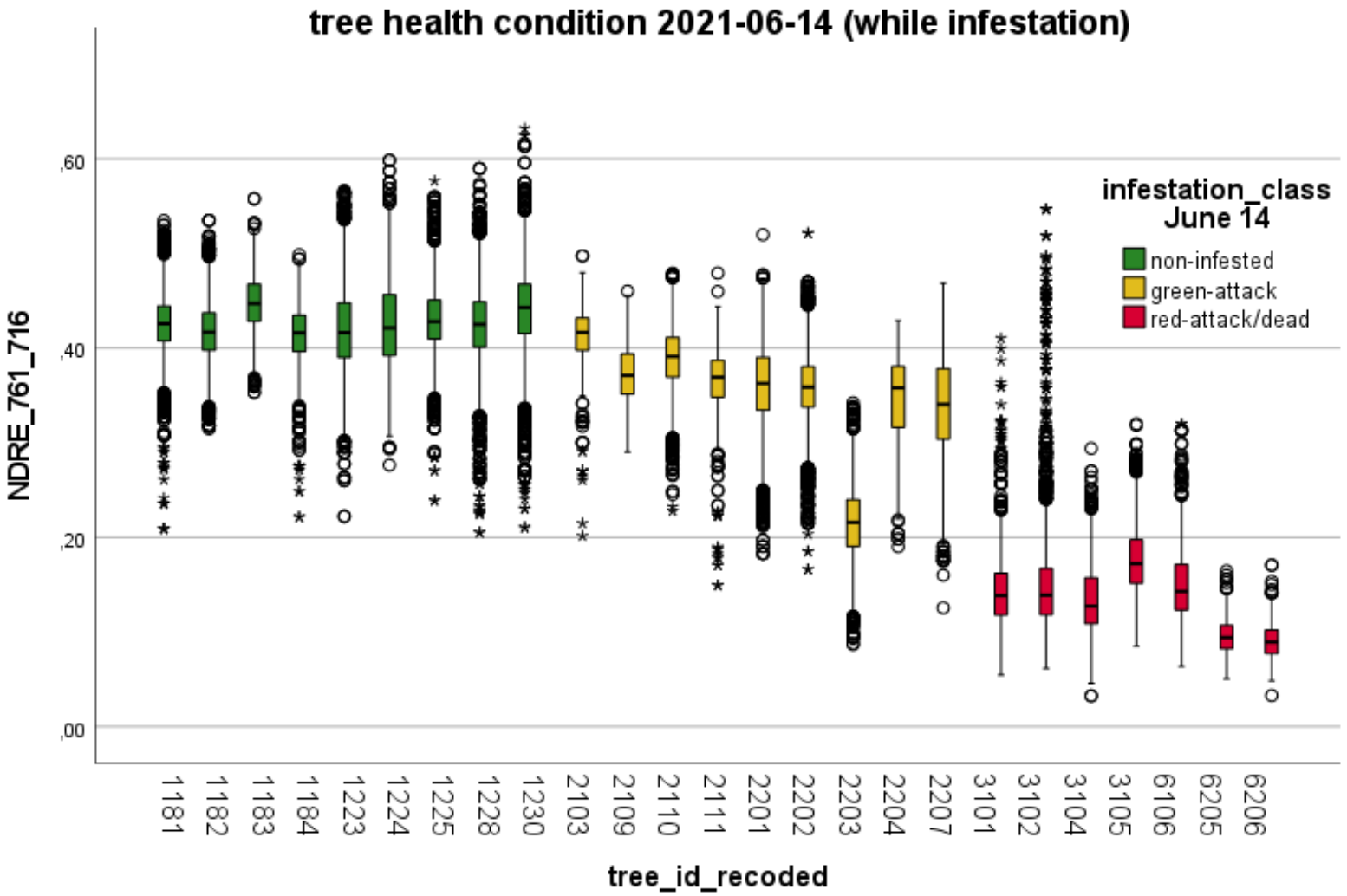
MTCI = (754 nm- 709nm)/(709 nm - **680 nm**). (**Rank 18**)

MERIS Terrestrial Chlorophyll Index
(Dash & Curran, 2004)

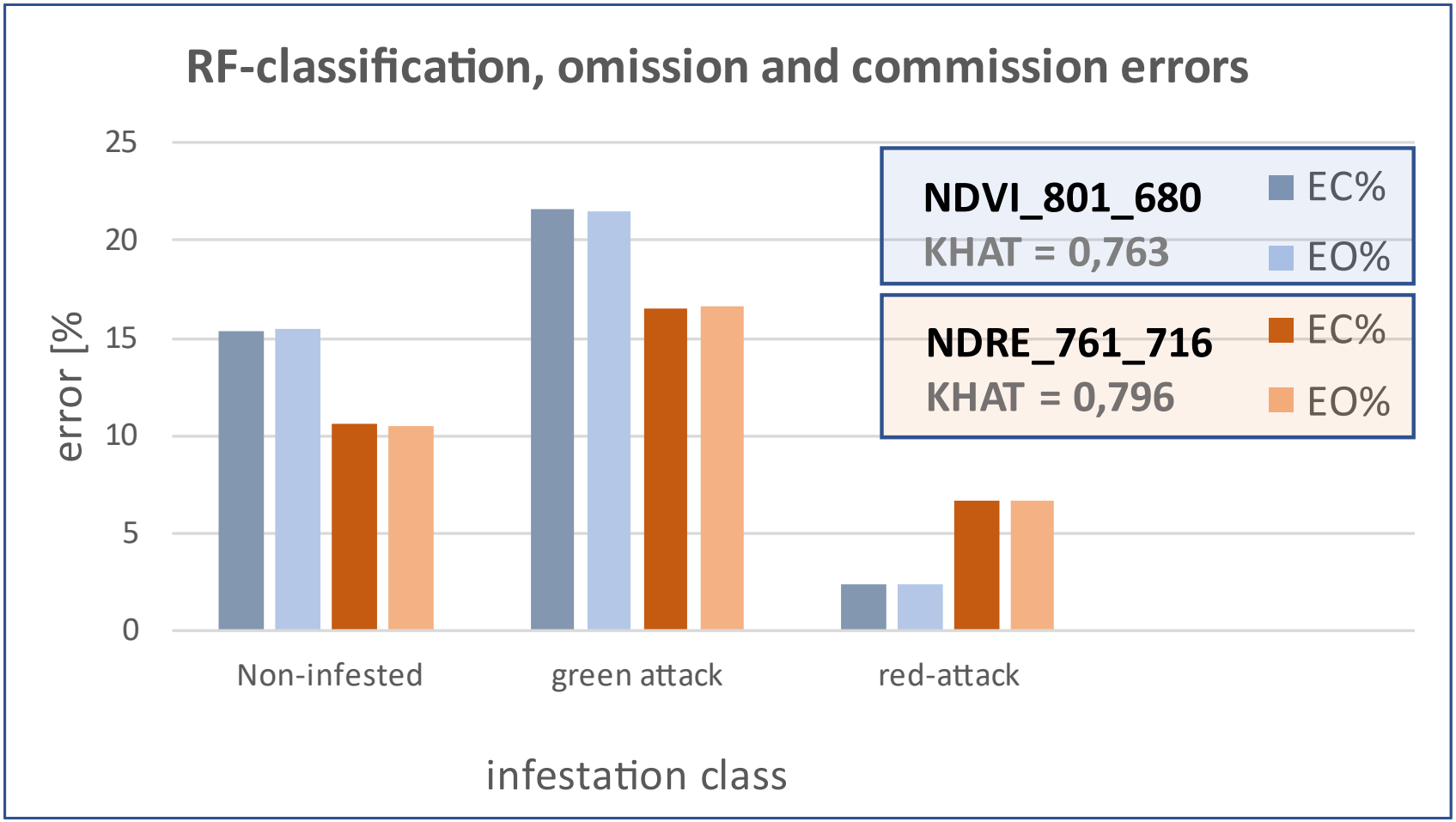
Boxplots for flight 21-04-28



Boxplots for flight 21-06-14



Classification – Based on Random Forest



Outlook: Upscaling to Sentinel-2

Band	Name	Wavelength range	Geometric resolution
B1	Coastal Aerosol	433 - 454 nm	60 m
B2	Blue	457 - 523 nm	10 m
B3	Green	542 - 578 nm	10 m
B4	Red	650 - 681 nm	10 m
B5	Red Edge 1	698 - 713 nm	20 m
B6	Red Edge 2	733 - 748 nm	20 m
B7	Red Edge 3	773 - 793 nm	20 m
B8	NIR	789 - 895 nm	10 m
B8A	Narrow NIR	855 - 876 nm	20 m
B9	Water vapor	930 - 950 nm	60 m
B10	SWIR - Cirrus	1365 - 1386 nm	60 m
B11	SWIR 1	1565 - 1656 nm	20 m
B12	SWIR 2	2103 - 2278 nm	20 m

NDRE_1 = (B6+B5)/(B6-B5) **NDRE_2** = (B7+B5)/(B7-B5)

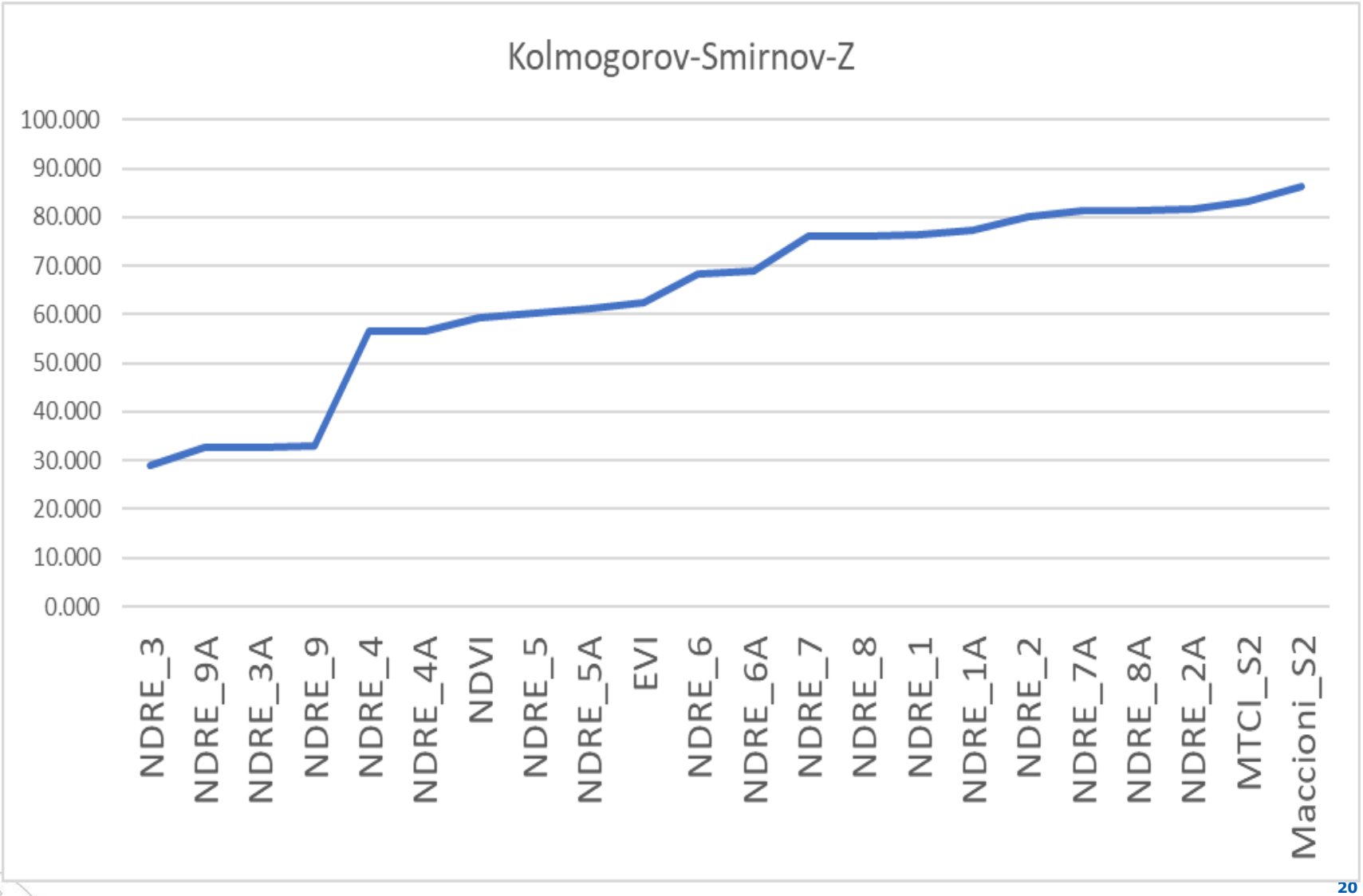
MTCI = (754 nm- 709nm)/(709 nm - 680 nm).

MTCI = (B6 – B5 /(B6 – B4)

Maccioni =(781 nm – 709 nm)/(781 nm – 680 nm).

Maccioni =(B7 – B5)/(B7 – B4)

KS-Test Sentinel 2 Vis (Green-Attack vs. Non-infested)



Best Vegetation Indices for Sentinel 2 (spectrally resampled from Hypersp. Data)

- Green-attack vs. Non-infested
  - MACCIONI
    - =(B7 – B5)/(B7 – B4)
    - =(re3– re1)/(re3– red).
    - LogReg: Nagelkerke=0.531,Model Accuracy=80.4%

- Green-attack vs. Non-infested vs. Red-attack
  - NDRE_8A
    - = (B8 - B5)/(B8 + B5 - B1)
    - = (NIR – re1)/(NIR + re1 – coastal blue)

Best Vegetation Indices for Planet Labs' SuperDove (spectrally resampled)

- Green-attack vs. Non-infested
  - NDRE_1A
  - = (B8 - B7)/(B8 + B7 - B1)
  - =(NIR – re)/(NIR + re – coastal blue)
  - LogReg: Nagelkerke=0.455, Model Accuracy=75.8%

- Green-attack vs. Non-infested vs. Red-attack
  - NDRE_1A
  - = (B8 - B7)/(B8 + B7 - B1)
  - =(NIR – re)/(NIR + re – coastal blue)

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Herzlichen Dank. Thank you.