Multispectral Imagery:

Smart Cotton Farming

Date: 07-Feb-2024

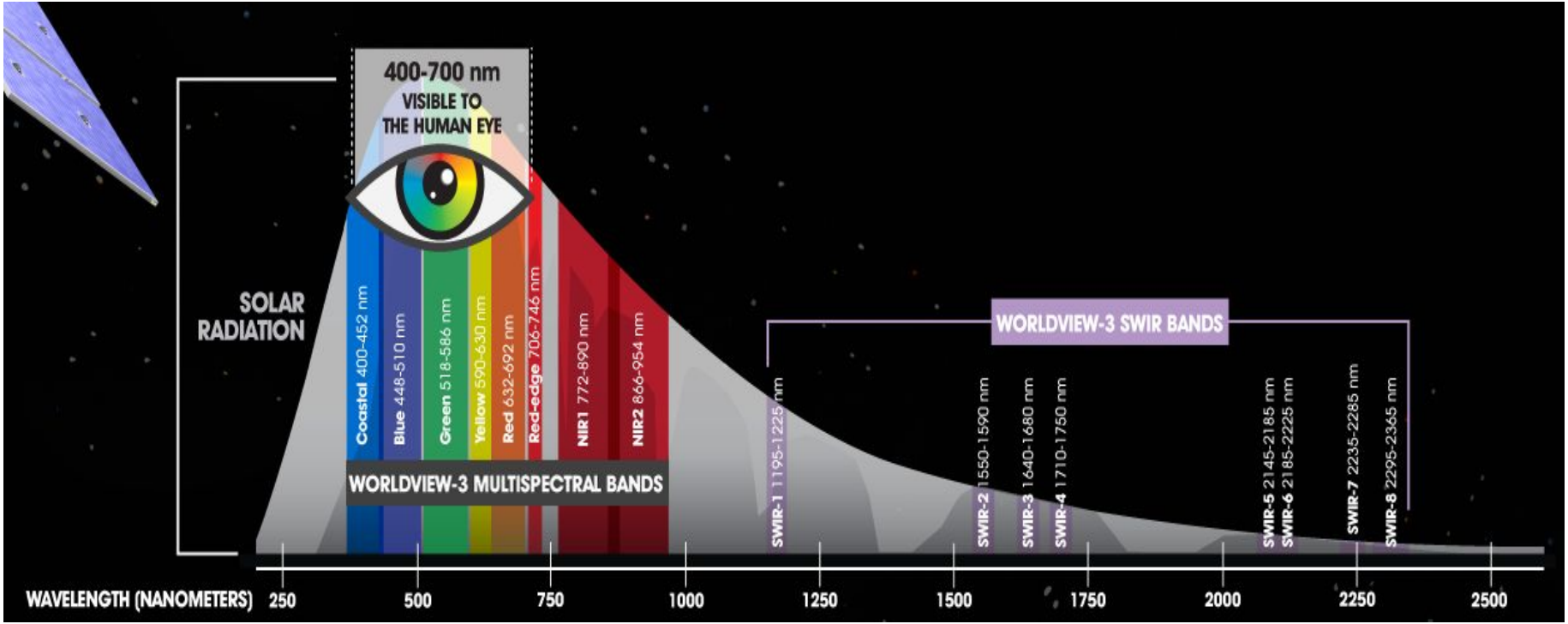
Outline

- Introduction
- Multi Spectral Imaging
- Spectral Bands
- RGB Images vs Multispectral Images
- Image Acquisition
- Images of Individual Bands and Orthomosaics
- Vegetation Index
- Vegetation Index Maps for Collected Data
- Applications
- References

Introduction

- RGB Imagery: Image formed using three visible spectrums- Red, Green and Blue
- Multispectral Imagery: Capturing images across multiple bands of electromagnetic spectrum providing diverse dataset used for remote sensing, vegetation analysis, land cover analysis etc.
- Hyperspectral Imagery: Acquires the data across a multitude of narrow contiguous spectral bands for detailed spectral analysis for mineral identification, precise agriculture, geology, etc.

Introduction



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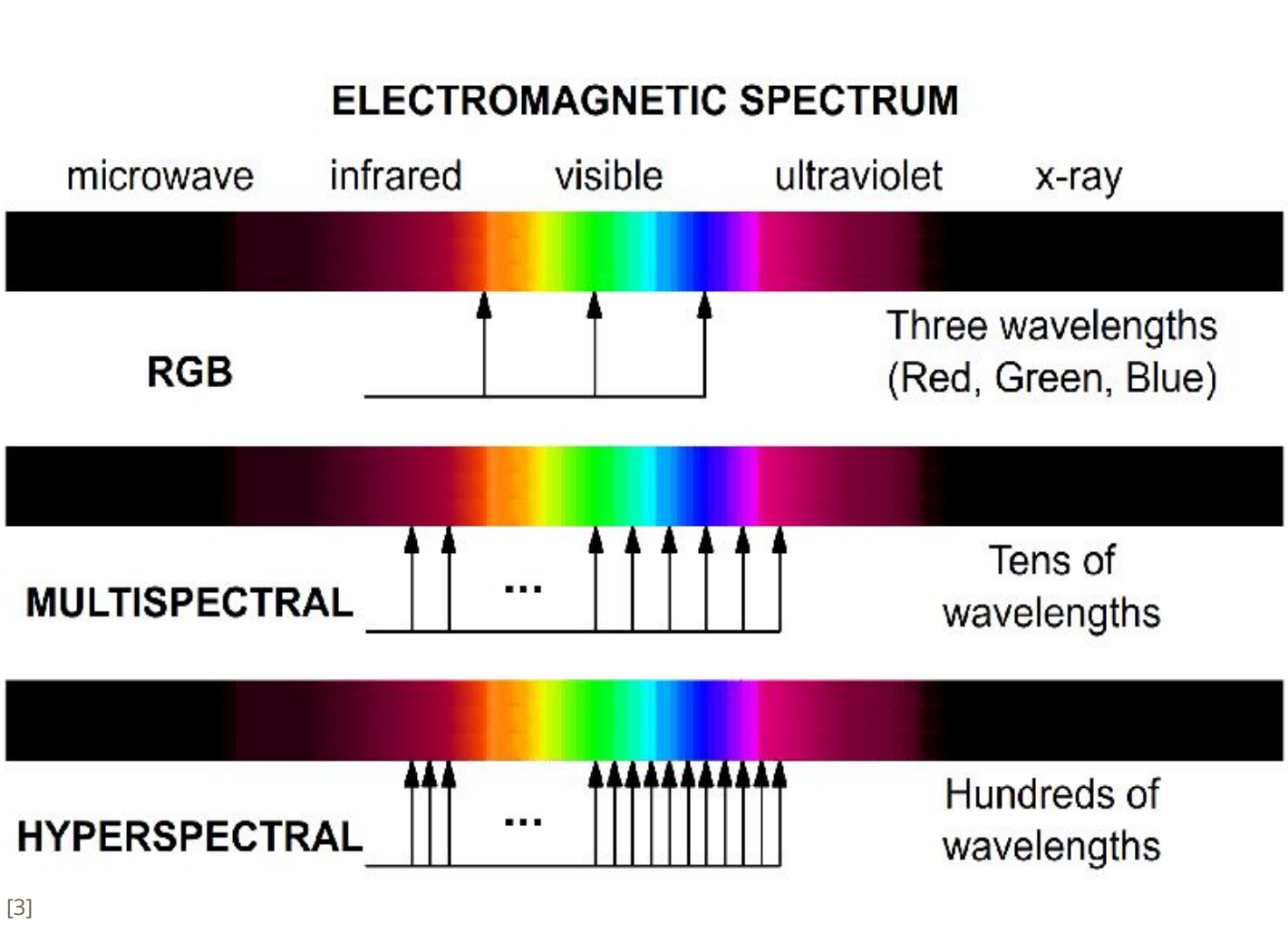
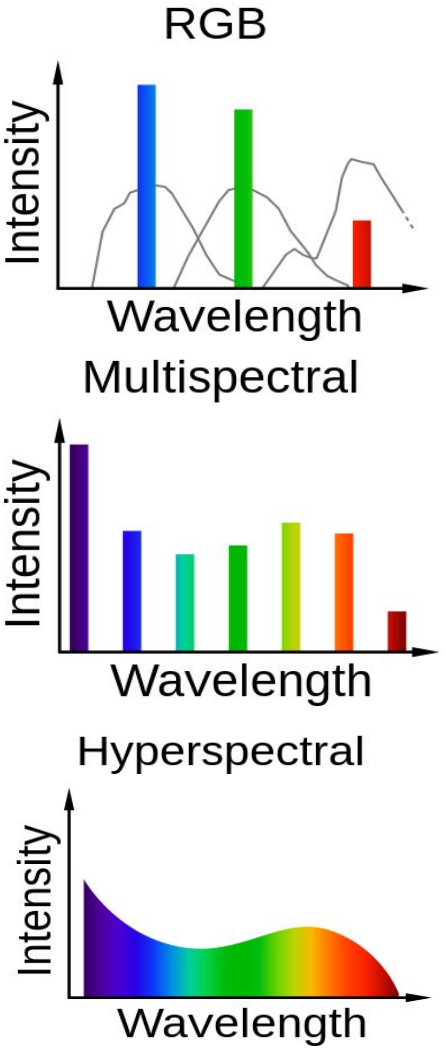
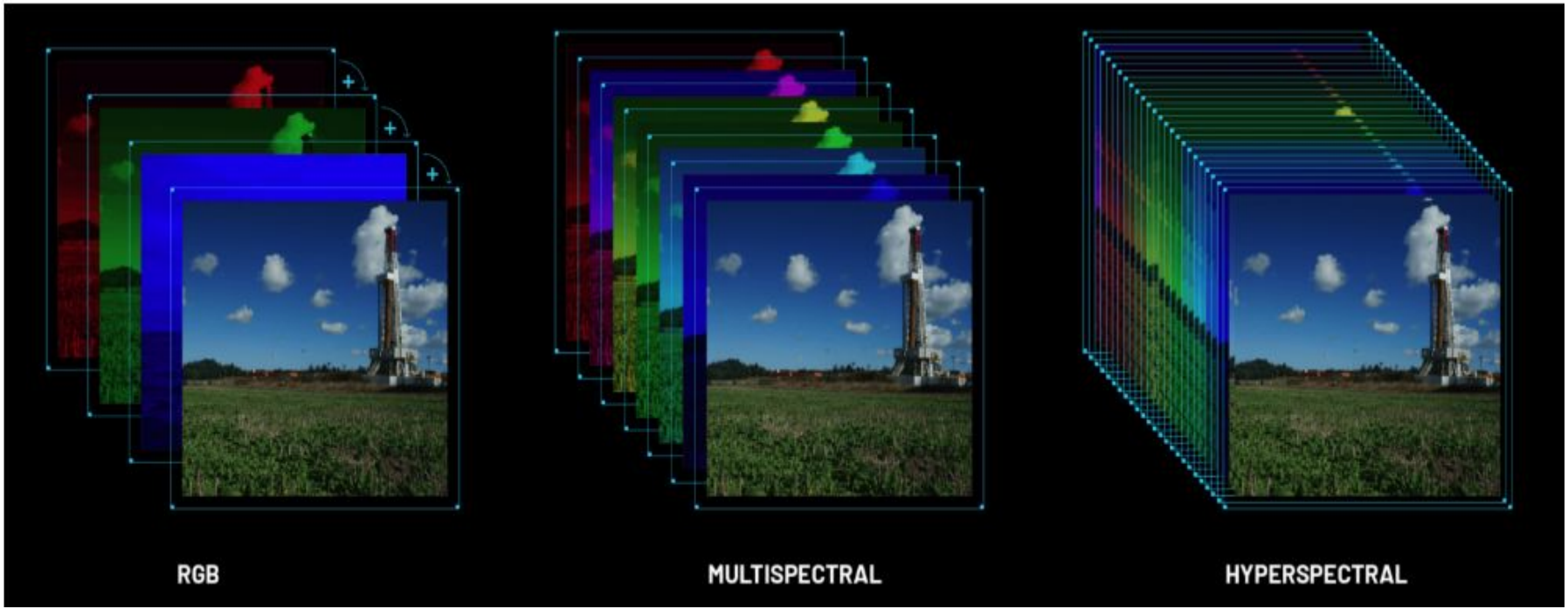
maxar


ELECTROMAGNETIC SPECTRUM
microwave
infrared
visible
ultraviolet
x-ray
RGB
Three wavelengths
(Red, Green, Blue)
MULTISPECTRAL
...
Tens of
wavelengths
HYPERSPECTRAL
...
Hundreds of
wavelengths


RGB
Intensity
Wavelength
Multispectral
Intensity
Wavelength
Hyperspectral
Intensity
Wavelength

[3]

Introduction



[4]

RGB vs Multispectral Vs Hyperspectral Images

Multi Spectral Imaging

- Multispectral Imaging is a technique to capture and analyze image data within specific wavelengths across the electromagnetic spectrum
- Provides a comprehensive view beyond visible wavelengths
- Multispectral systems allows discrimination of different types of vegetation, rocks and soils, clear and turbid water etc.
- Applications in wide range of fields and industries like, Agriculture, Remote Sensing, Medical Imaging, Security and Defense, Mineralogy, Environmental Monitoring etc.

[5]

Spectral Bands

Multispectral Images can be divided into the following bands:

1. Blue (450 to 515 nm): Deep water imaging, Vegetation Health etc.
2. Green (525 to 605 nm): Land Cover Mapping, Vegetation Analysis, etc.
3. Red (640 to 690 nm): Vegetation Health assessment, etc.
4. Near-Infrared (750 to 900 nm): Vegetation Imaging, Vegetation Health Monitoring, etc.
5. Mid-Infrared (1550 to 1750 nm): Vegetation, Soil Moisture Content, etc.
6. Far- Infrared (2080 to 2350 nm): Imaging Soil Moisture, Geological Features, fires, etc.
7. Thermal Infrared (10,400 to 12,500 nm): Thermal Mapping, Temperature Analysis, etc.

RGB Images vs Multispectral Images

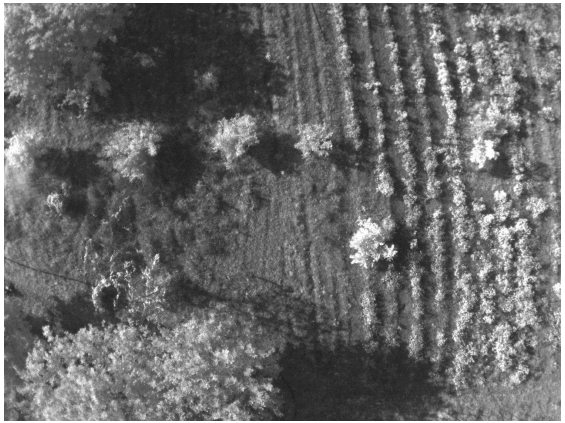
Categories	RGB Images	Multispectral Images
Color Information	Captures images in True Color as perceived by Humans	Captures images including and beyond visible spectrum
Spectral Resolution	Limited spectral resolution. Captures Only R, G, B wavelengths	Captures multiple wavelengths across electromagnetic spectrum like NIR, RedEdge, SNIR, Thermal etc.) including RGB.
Spatial Resolution	Generally higher resolution images	Comparatively lower resolution images
Vegetation Analysis	Limited information on Crop Health Assessment	Health monitoring, Vegetation Analysis, Soil moisture analysis etc. can be done using spectral signatures of different bands and its transformations
Applications in Agriculture	Yield prediction, Stressed plant detection, Animal Detection	Precision Agriculture, Health monitoring
Cost	Relatively lower cost	Higher

Image Acquisition

- The images presented in the next slides are the aerial images taken using Multispectral Camera at the Cotton Field, IITGN Organic Farm, Indian Institute of Technology Gandhinagar, Gujarat- 382355.
- Total Four Spectral Signatures are obtained of Green, Red, RedEdge, and Near Infrared (NIR) from the camera
- The images are taken from the altitudes of 20 m and 30 m
- Image Acquisition was carried out on 11.12.2023 and 05.01.2024

Image Acquisition

GREEN



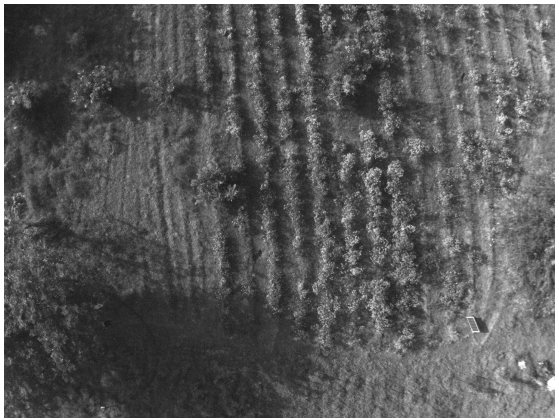
NIR

RED

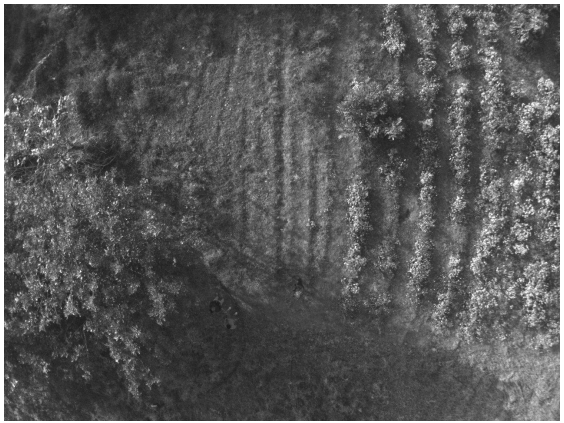
REDEDGE

Green Band Images

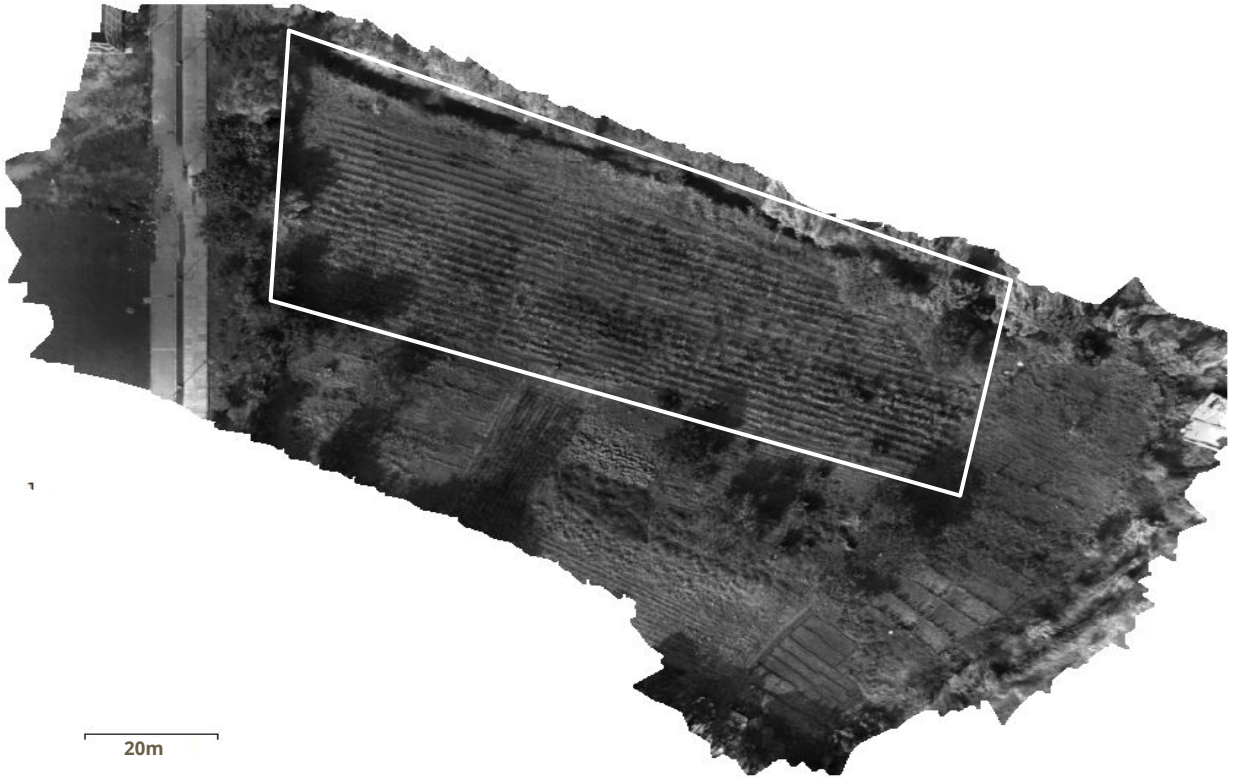
30 m



20 m



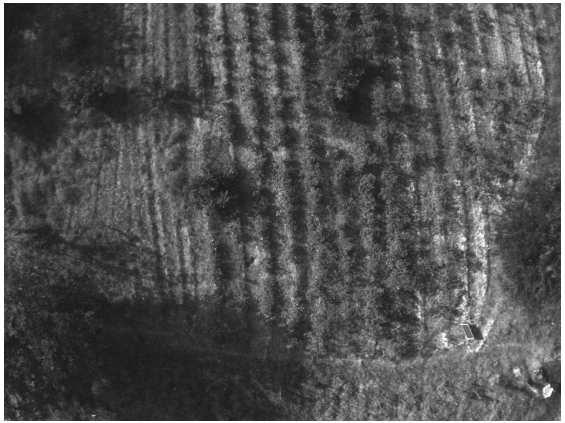
Orthomosaic



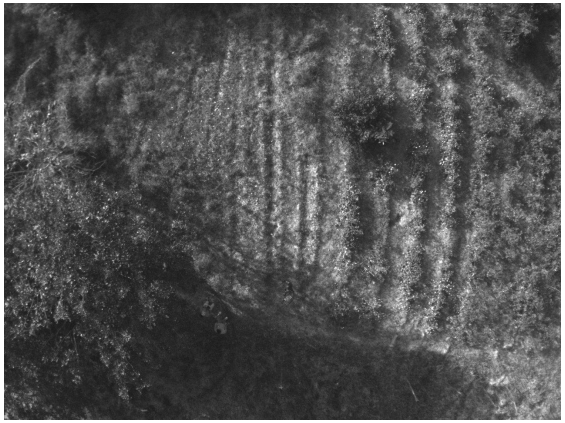
Orthomosaic from Green Band Images taken on 11.12.2023 (30m)

Red Band Images

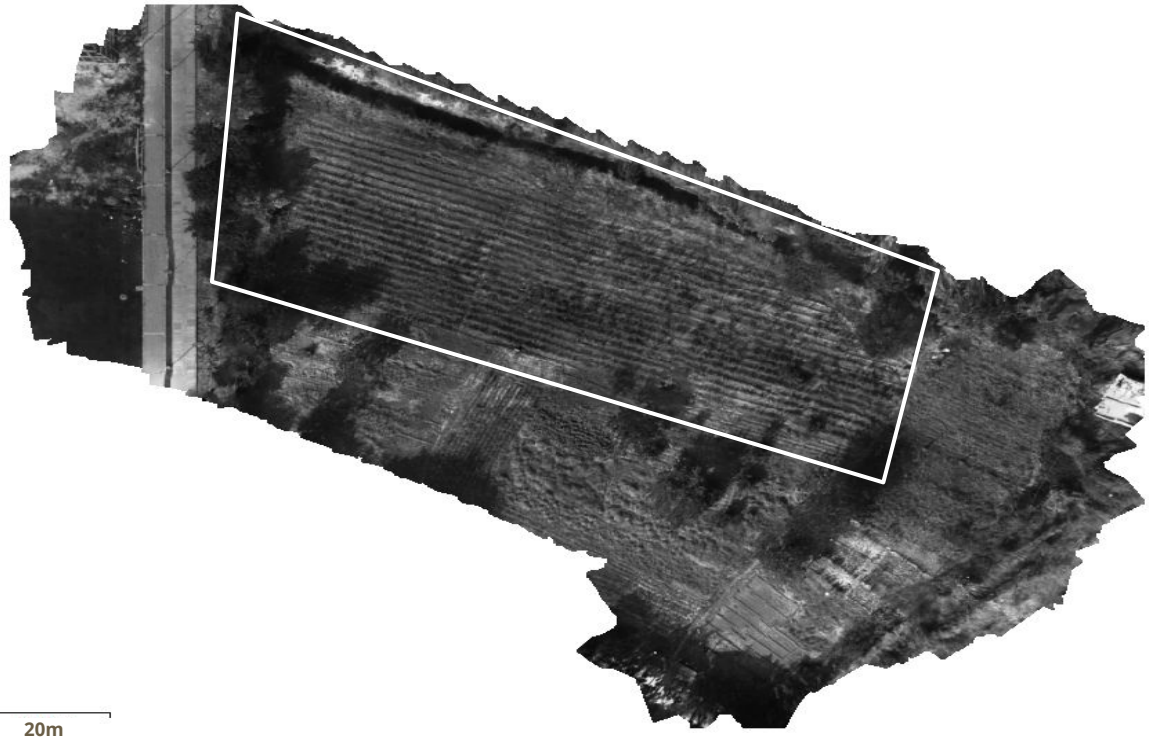
30 m



20 m



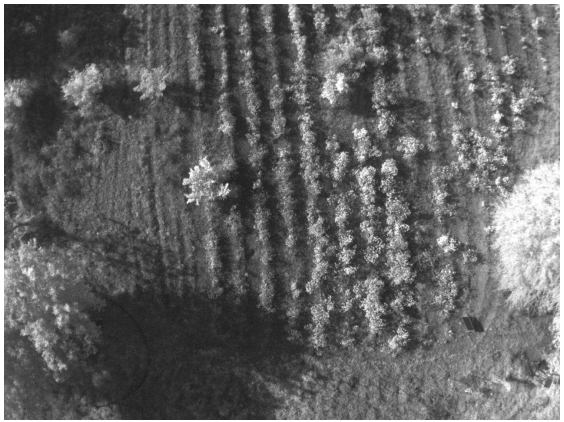
Orthomosaic



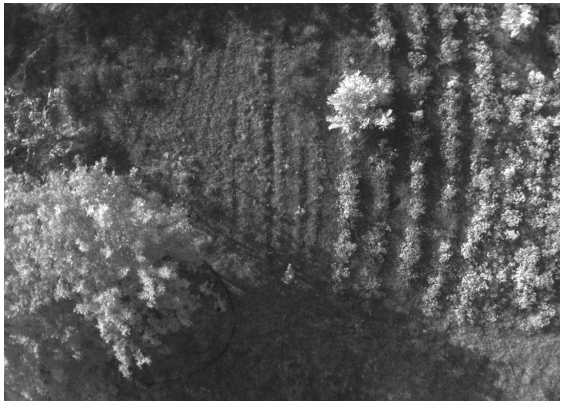
Orthomosaic from Red Band Images taken on 11.12.2023 (30m)

NIR Band Images

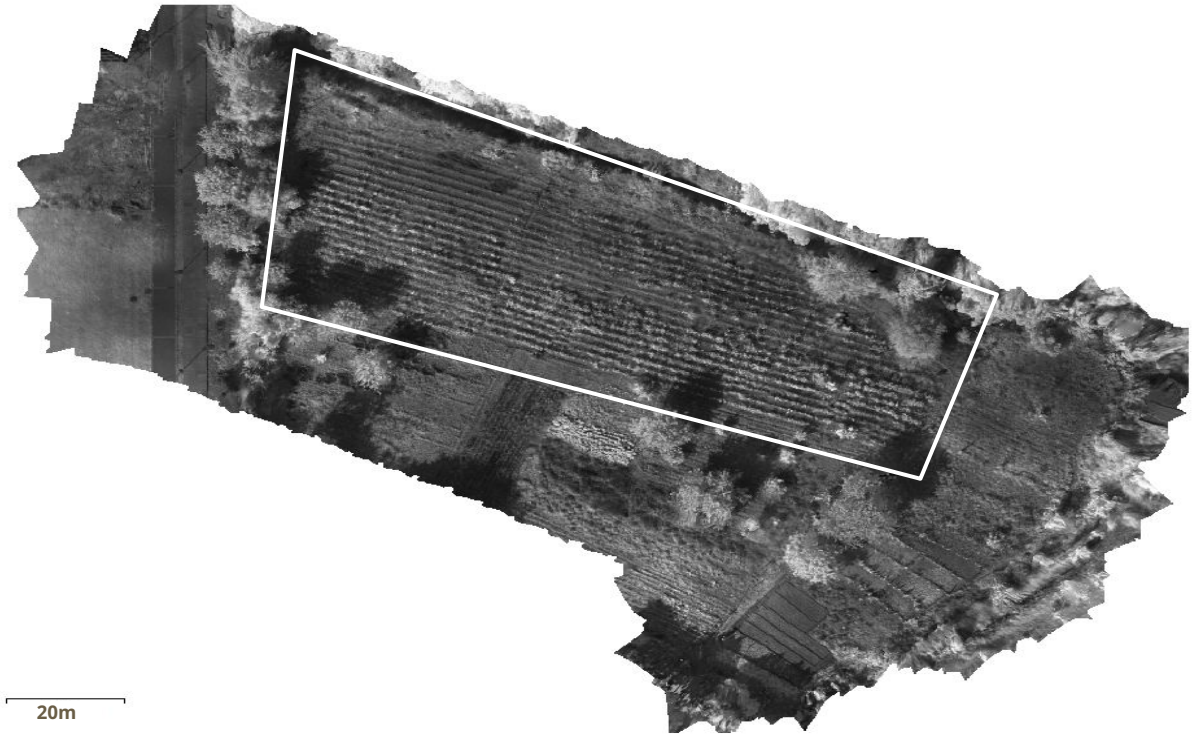
30 m



20 m



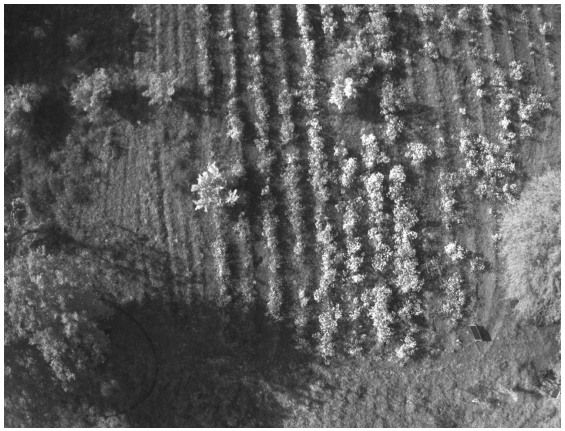
Orthomosaic



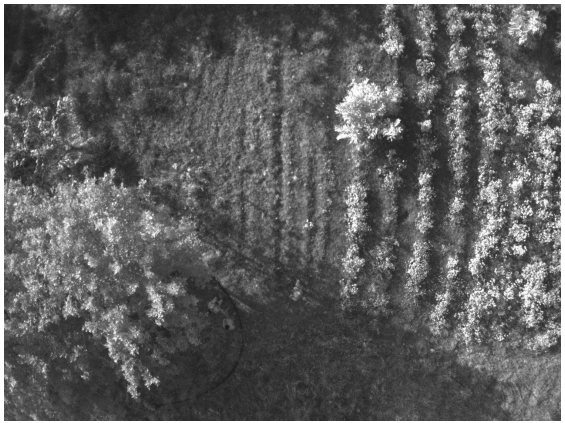
Orthomosaic from NIR Band Images taken on 11.12.2023 (30m)

RedEdge Band Images

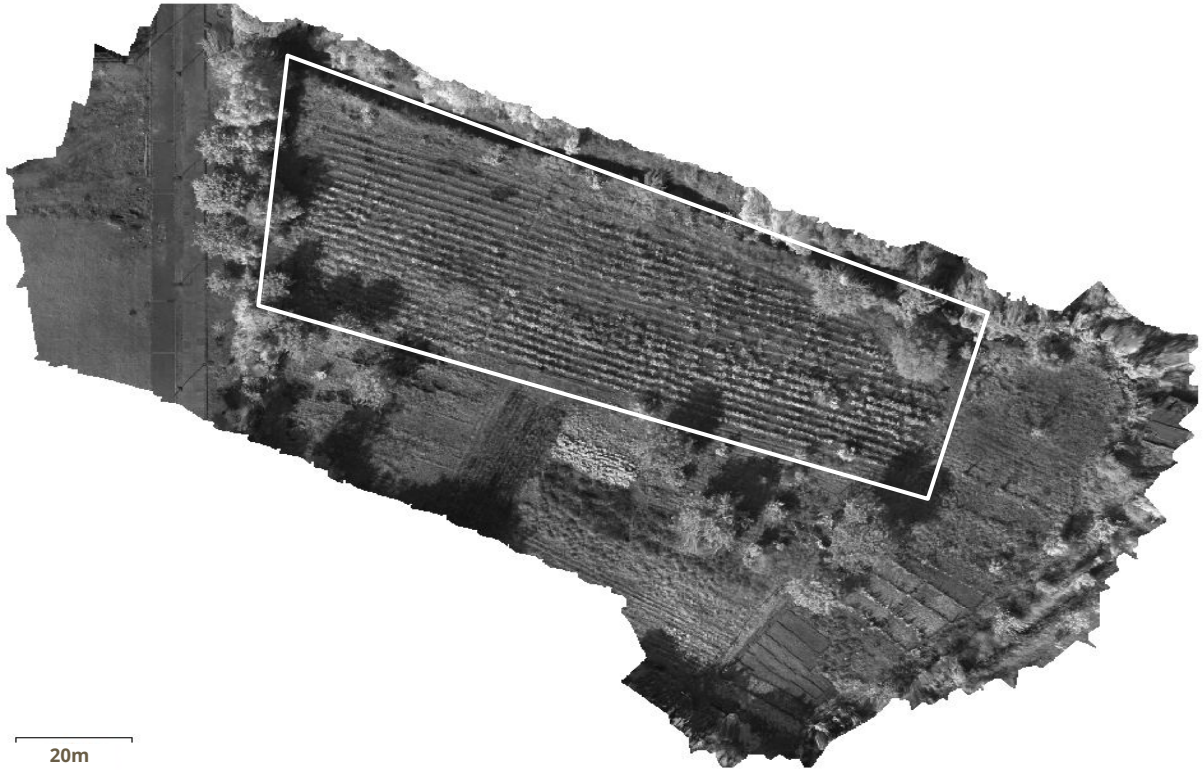
30 m



20 m



Orthomosaic



Orthomosaic from RedEdge Band Images taken on 11.12.2023 (30m)

Vegetation Index

- Vegetation Index: Numerical Index obtained from Transformation of Two or more spectral band images to enhance the interpretation of vegetation features
- The Vegetation indices are used in the applications of agriculture, forestry, environmental monitoring, structural variations, etc.
- Vegetation Indices obtained from the spectral bands Blue, Green, Red, Red-Edge, and Near Infrared (NIR) are mentioned in the upcoming slides

[6][7]

Vegetation Index

Sr. No	Index	Equation	Details
1.	Green-Red Vegetation Index (GRVI)	GRVI = (Green - Red) / (Green + Red)	Determines vegetation cover and soil cover, to detect plant's phenological stages
2.	Normalized Difference Vegetation Index (NDVI)	NDVI = (NIR - Red) / (NIR + Red)	Categorizes Density of Vegetation cover and plant's phenological stages
3.	Green Normalized Difference Vegetation Index (GNDVI)	GNDVI = (NIR - Green) / (NIR + Green)	Indicator of Photosynthetic activities or greenness, to determine water and Nitrogen uptake in the crop canopy
4.	Normalized Difference Red Edge Index (NDRE)	NDRE = (NIR - RedEdge) / (NIR + RedEdge)	Use Red-edge which penetrates more deeply then Red band. Detects variation in crop health in advance stages

Vegetation Index

Sr. No	Index	Equation	Details
5.	Two Band Enhanced Vegetation Index (EVI2)	EVI2 = 2.5(NIR - Red) / (NIR + 2.4RED + 1)	Measures area with dense canopy, More responsive towards canopy structure variations to quantify vegetation greenness
6.	Soil Adjusted Vegetation Index (SAVI)	SAVI = 1.5(NIR - Red) / (NIR + Red + 0.5)	Minimize the influence of soil and increases dynamic range signaled by vegetation, ideal for early stage emergence detection
7.	Optimized Soil Adjusted Vegetation Index (OSAVI)	OSAVI = 1.16(NIR - Red) / (NIR + Red + 0.16)	Indicator of denser vegetation, minimize the effect of soil background reflectance with soil adjustment coefficient 0.16
8.	Transformed Difference Vegetation Index (TDVI)	TDVI = √(0.5 + (NIR -Red) / (NIR+Red))	Vegetation cover mapping

Vegetation Index

Sr. No	Index	Equation	Details
9.	Chlorophyll Index Geen (CIG)	CIG = (NIR/Green) - 1	Health and state of the crops using Green and NIR bands
10.	Chlorophyll Index Red-Edge (CIRE)	CIRE = (NIR/RedEdge) - 1	Health and state of the crops using Red-Edge and NIR, sensitive then CIG
11.	Modified Green-Red Vegetation Index (MGRVI)	MGRVI = $(Green^2 - Red^2) / (Green^2 + Red^2)$	Vegetation cover
12.	Modified Normalized Difference Water Index (NDWI)	NDWI = [(Blue + Green)/2 - (NIR + Red)/2] / [(Blue + Green)/2 + (NIR + Red)/2]	Monitors crop water status

Vegetation Index

Sr. No	Index	Equation	Details
13.	Green Leaf Index (GLI)	(2Green - Red -Blue) / (2Green + Red + Blue)	Greenness of the field
14.	Red-Green_Blue Vegetation Index (RGBVI)	$(Green^2 - Blue*Red) / (Green^2 + Blue*Red)$	Soil and vegetation differentiation
15.	Visible Atmospherically Resistant Index (VARI)	(Green - Red) / (Green + Red - Blue)	Emphasizes vegetation in visible spectrum, while mitigating illumination difference and atmospheric effects
16.	Leaf Area Index (LAI)	Leaf Area/ Ground Area	Ratio of greenness to the soil/background to

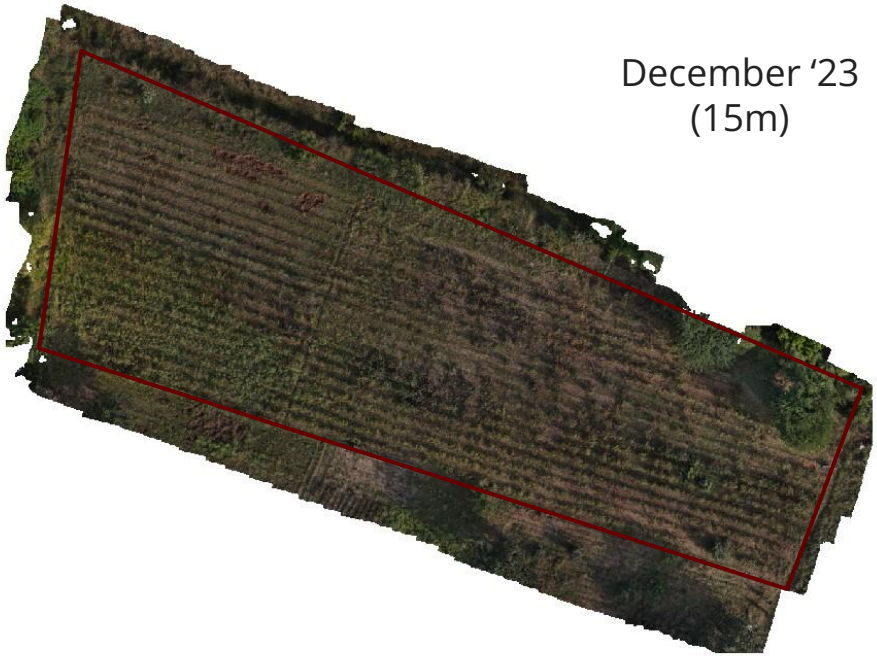
Raster Transformations of Images to Vegetation Indices

- The Images captured from Multispectral Camera in four bands (Green, Red, RedEdge and NIR) are stitched and transformed into the Vegetation Index Maps
- The Vegetation maps are generated using Agisoft Metashape Software
- Total Eleven Index maps are generated by implementing the equations presented in the Table 1.
- The Transformations shown in the upcoming slides are performed on the data collected on 11.12.2023 (30 m) and 05.01.2024 (30 m) for each index

RGB Images From Drone

January ‘24
(15m)

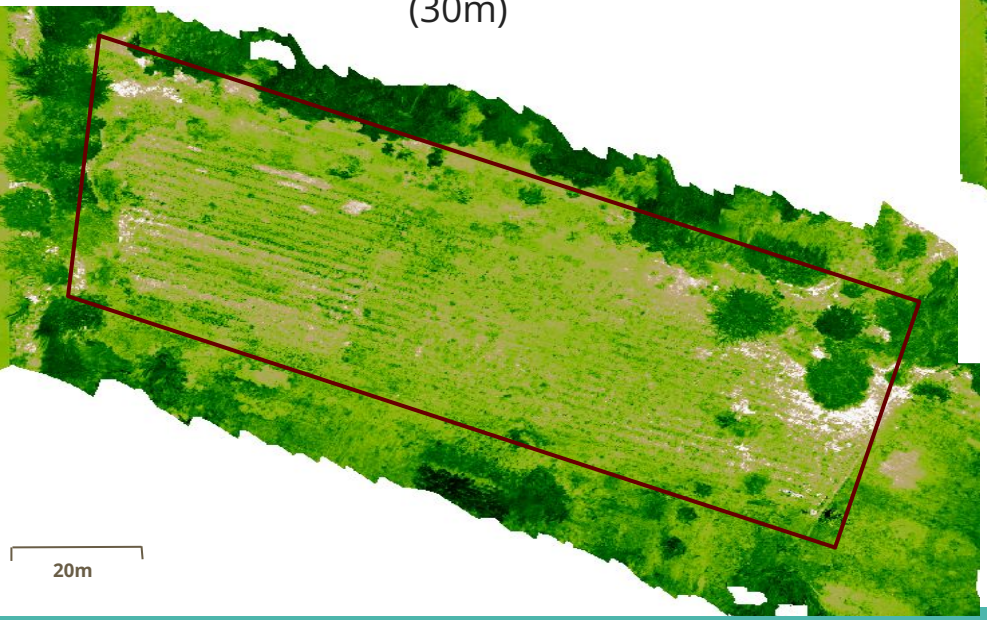
December ‘23
(15m)



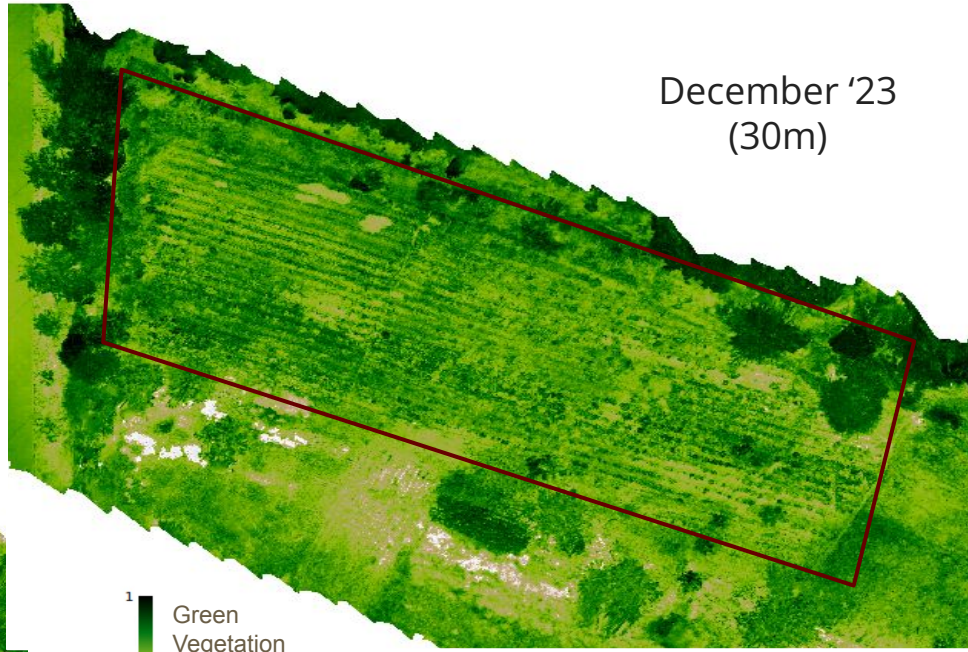
A difference in vegetation is visible in RGB images taken near the date of multi-spectral image acquisition

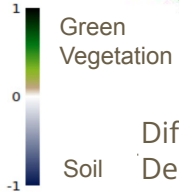
Green-Red Vegetation Index (GRVI)

January ‘24
(30m)



December ‘23
(30m)



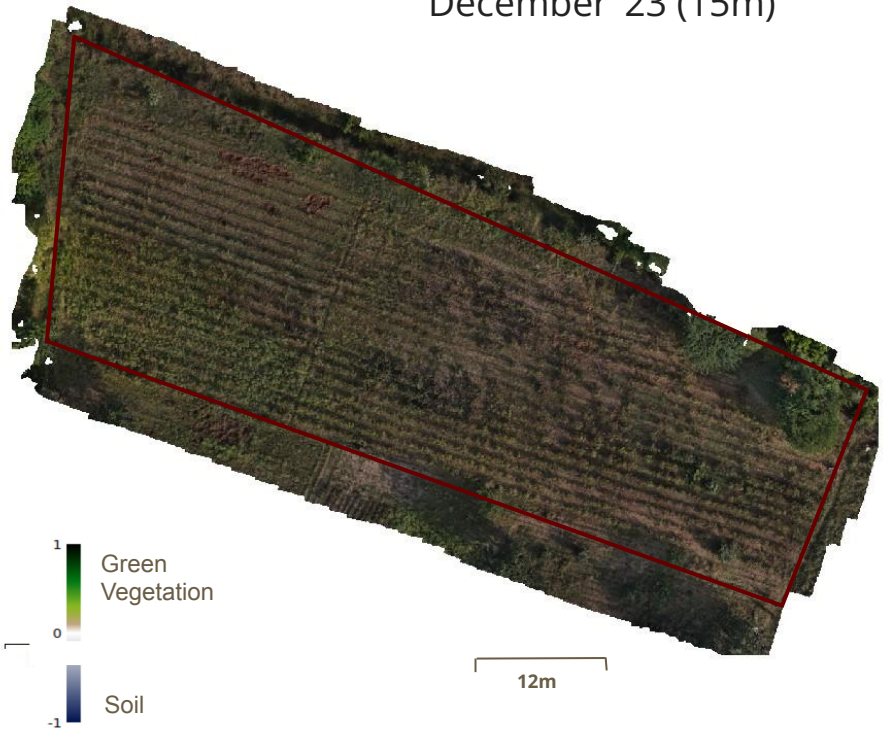


Difference in Vegetation in the month of January and December can be visually verified from this images.

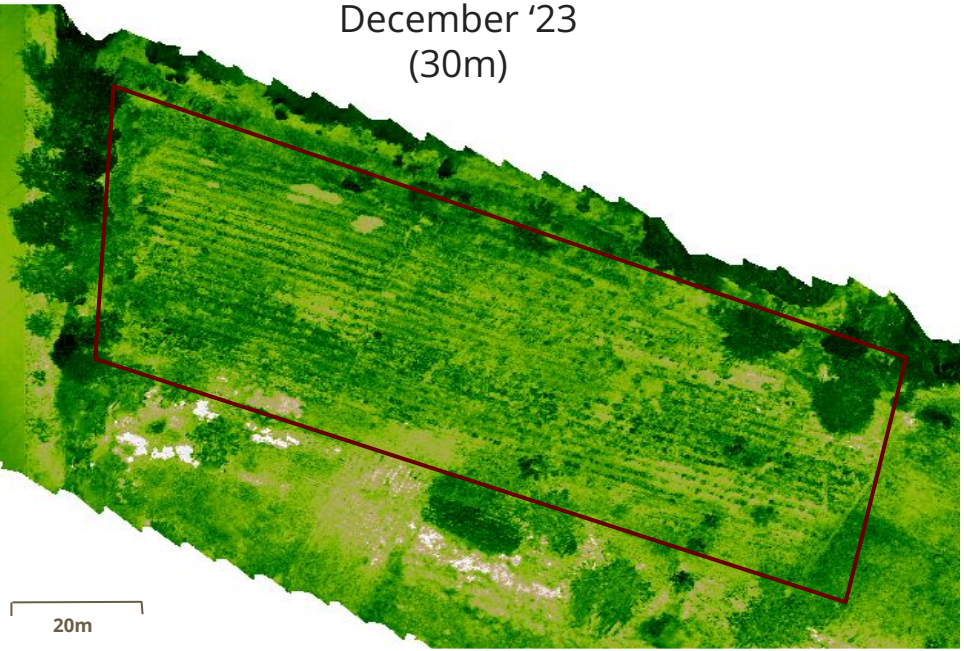
GRVI = (Green - Red) / (Green + Red)

GRVI vs RGB

December ‘23 (15m)



December ‘23 (30m)

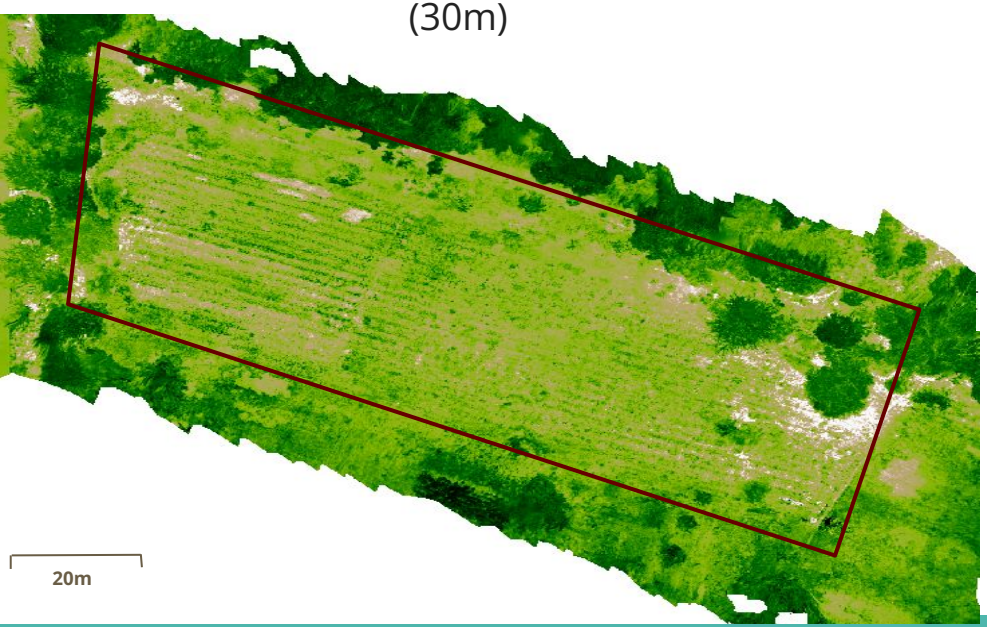


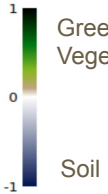
A difference in vegetation in the multispectral images taken in December can be visually verified from the orthomosaic of the images taken from RGB drone

GRVI vs RGB

January ‘24
(15m)

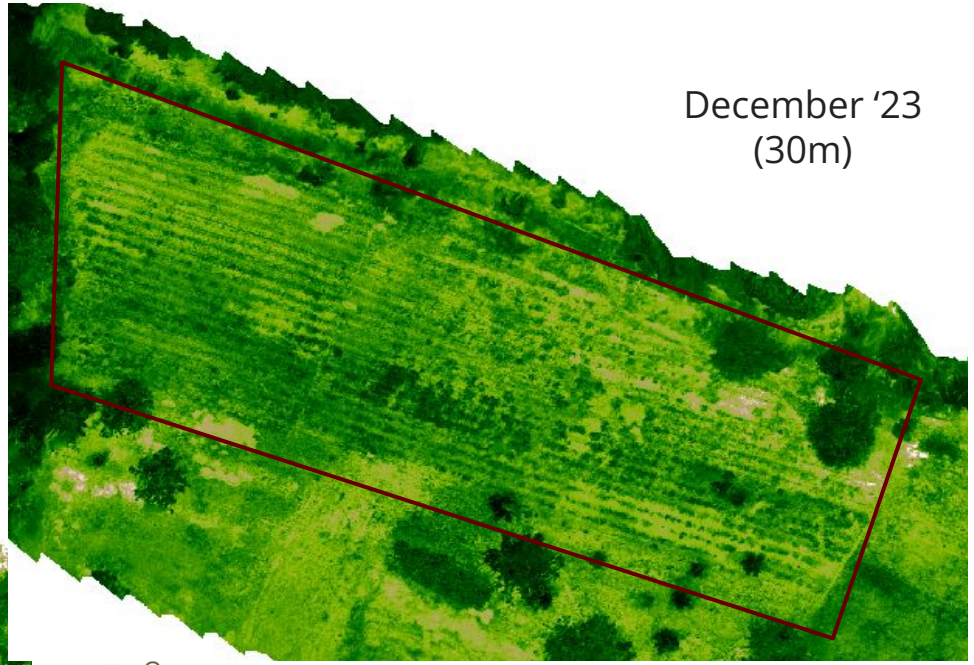
January ‘24
(30m)

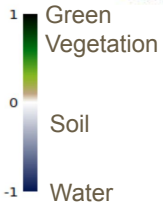




A difference in vegetation in the multispectral images taken in January can be visually verified from the orthomosaic of the images taken from RGB drone

Normalized Difference Vegetation Index (NDVI)



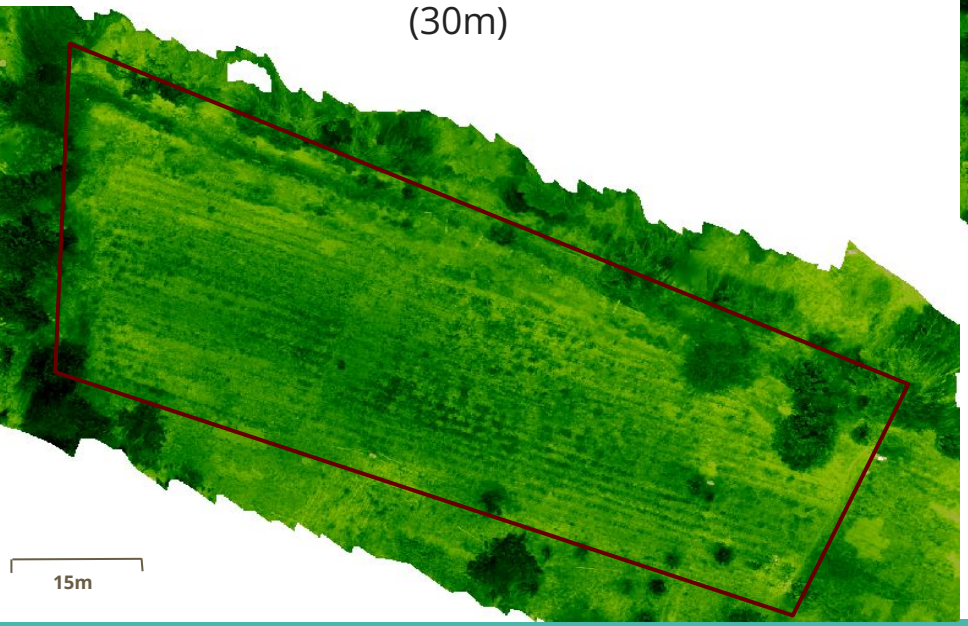


Difference in Vegetation cover in the month of Janua and December can be visually verified from this images.

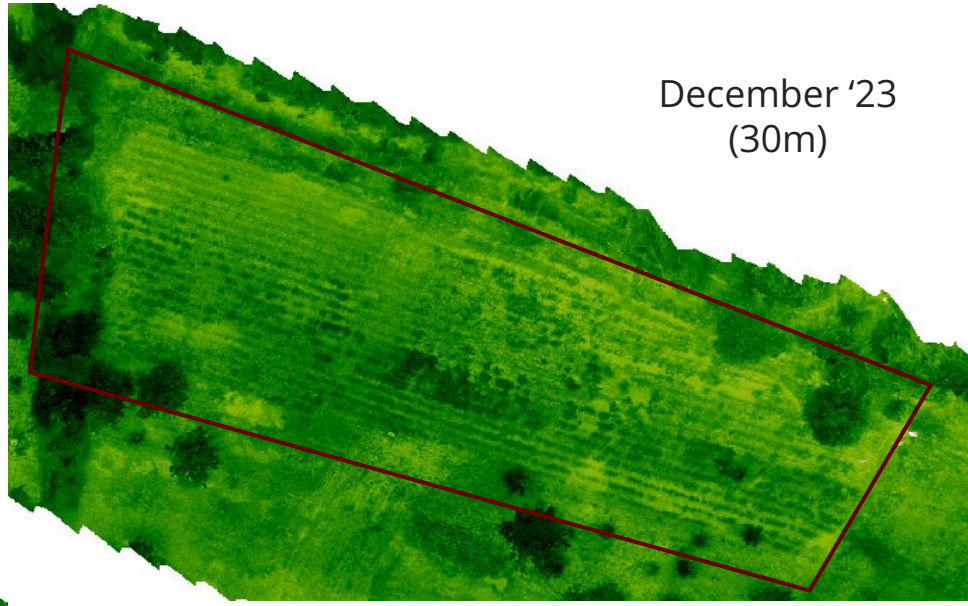
NDVI = (NIR - Red) / (NIR + Red)

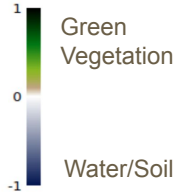
Green Normalized Difference Vegetation Index (GNDVI)

January ‘24
(30m)



December ‘23
(30m)

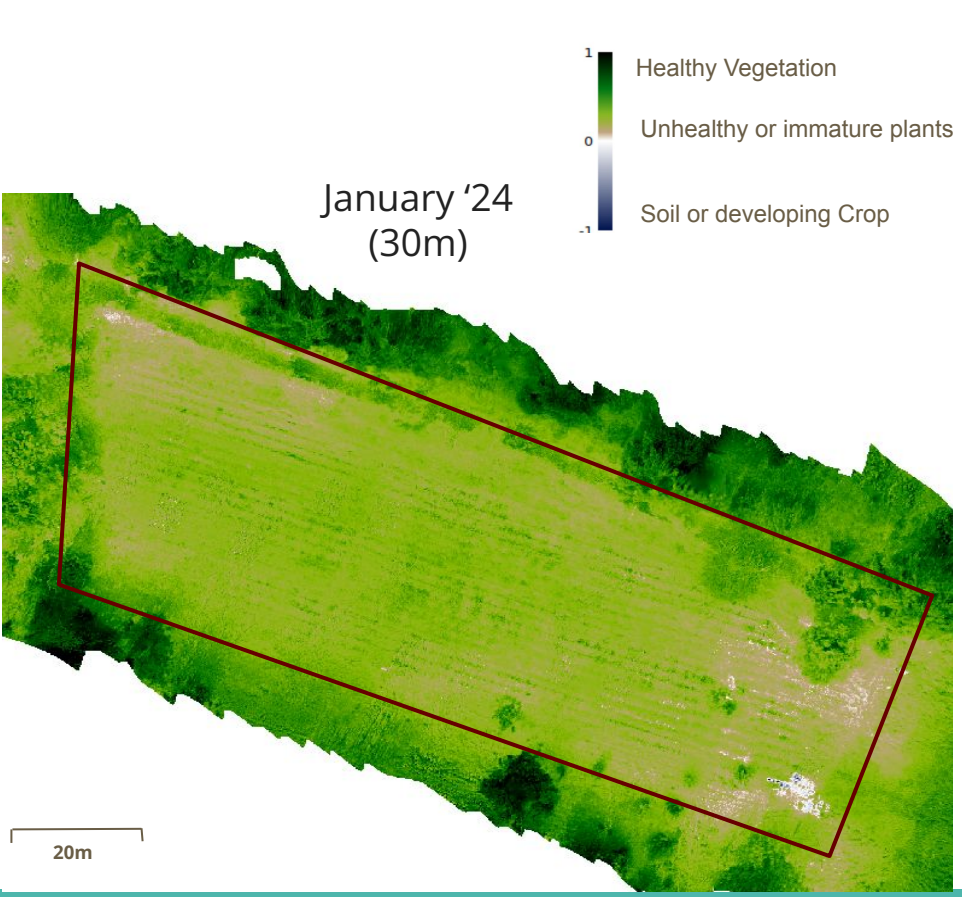


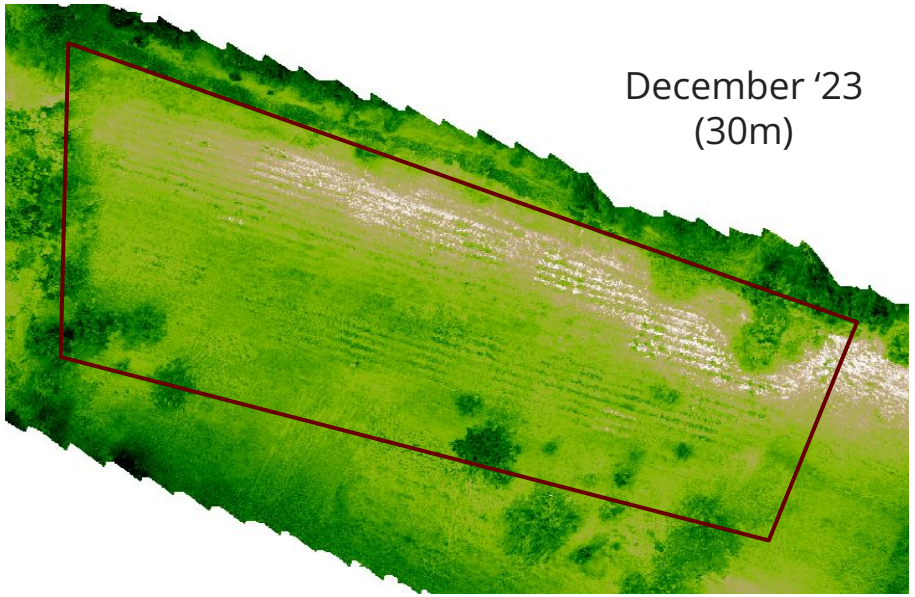


Difference in Vegetation in the month of January and December can be visually verified from this images.

GNDVI = (NIR - Green) / (NIR + Green)

Normalized Difference Red Edge Index (NDRE)





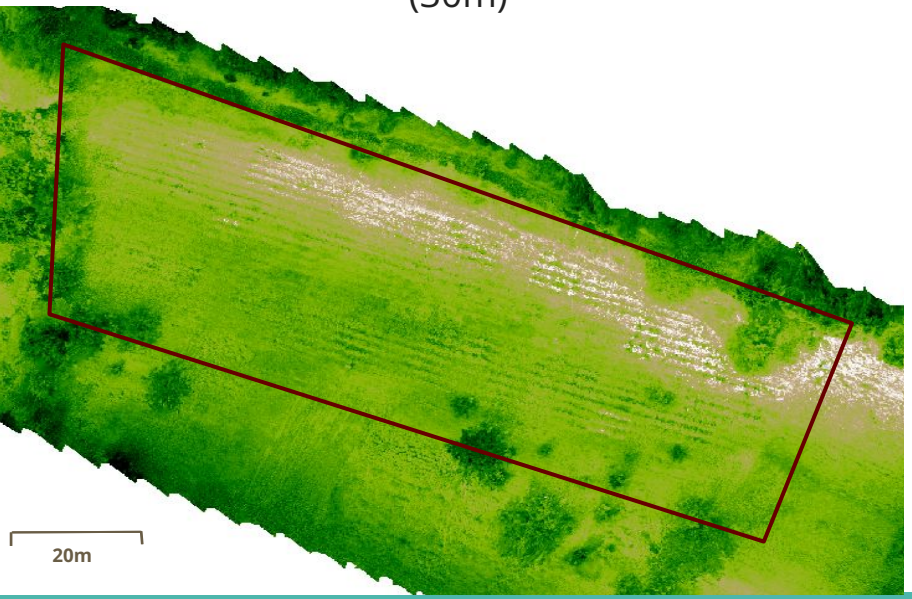
Vegetation as well as health of the plants can be detected from this index. The prominent diseased area at the time is visible in the white region

NDRE = (NIR - RedEdge) / (NIR + RedEdge)

NDRE vs RGB

December ‘23 (15m)

December ‘23 (30m)



Healthy Vegetation

Unhealthy or immature plants

Soil or developing Crop

Vegetation area of the multispectral images taken in December can be visually verified from the orthomosaic of the images taken from RGB drone. It is important to note that health of the plants are not visible in RGB images

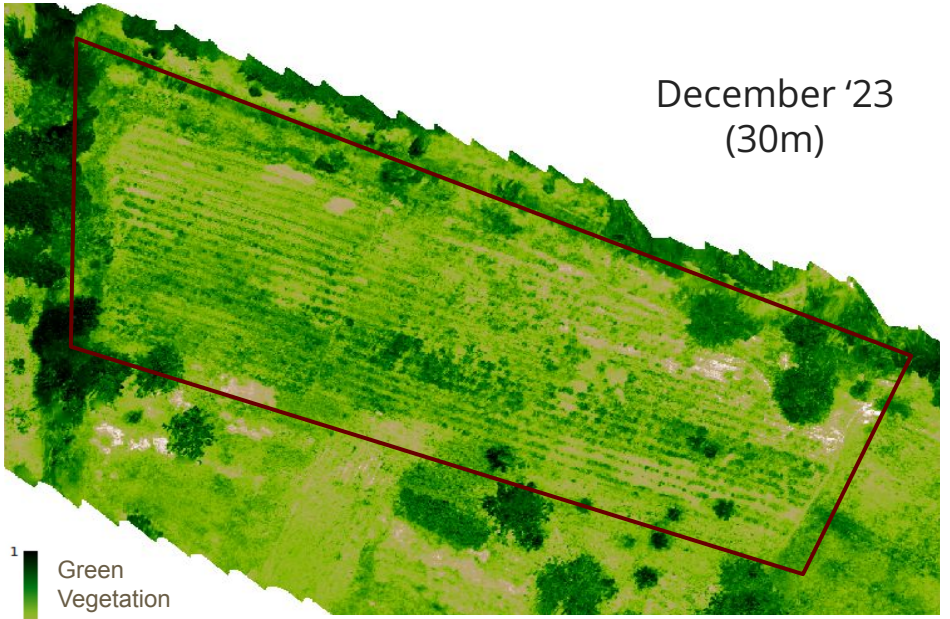
NDRE vs RGB

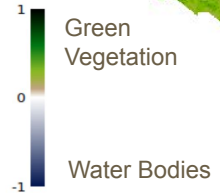
January ‘24
(15m)

January ‘24
(30m)

Vegetation area of the multispectral images taken in January can b
visually verified from the orthomosaic of the images taken from R
drone. It is important to note that health of the plants are not visi
in RGB images

Two Band Enhanced Vegetation Index (EVI2)





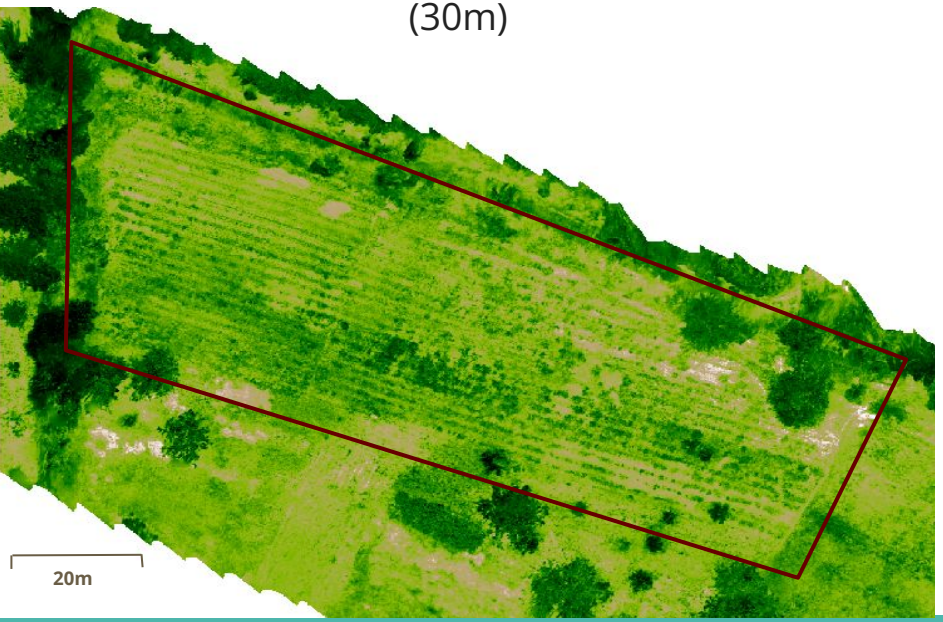
Analysis of vegetation cover and greenness can done using EVI2 index between multispectral im taken from December and Januray

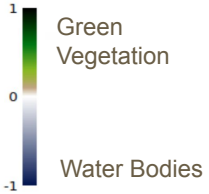
$$EVI2 = 2.5(NIR - Red) / (NIR + 2.4RED + 1)$$

EVI2 vs RGB

December ‘23 (15m)

December ‘23 (30m)

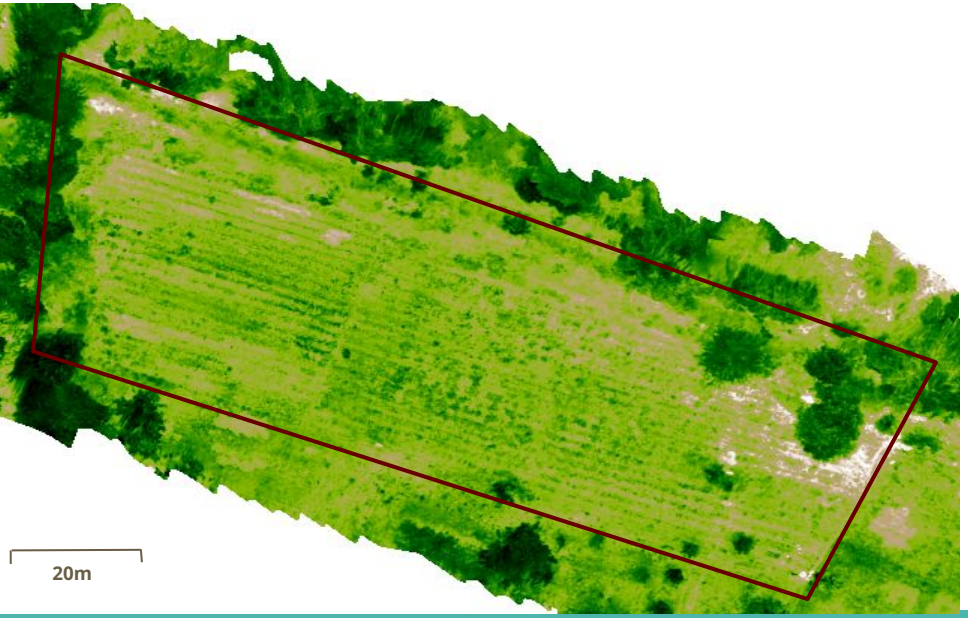




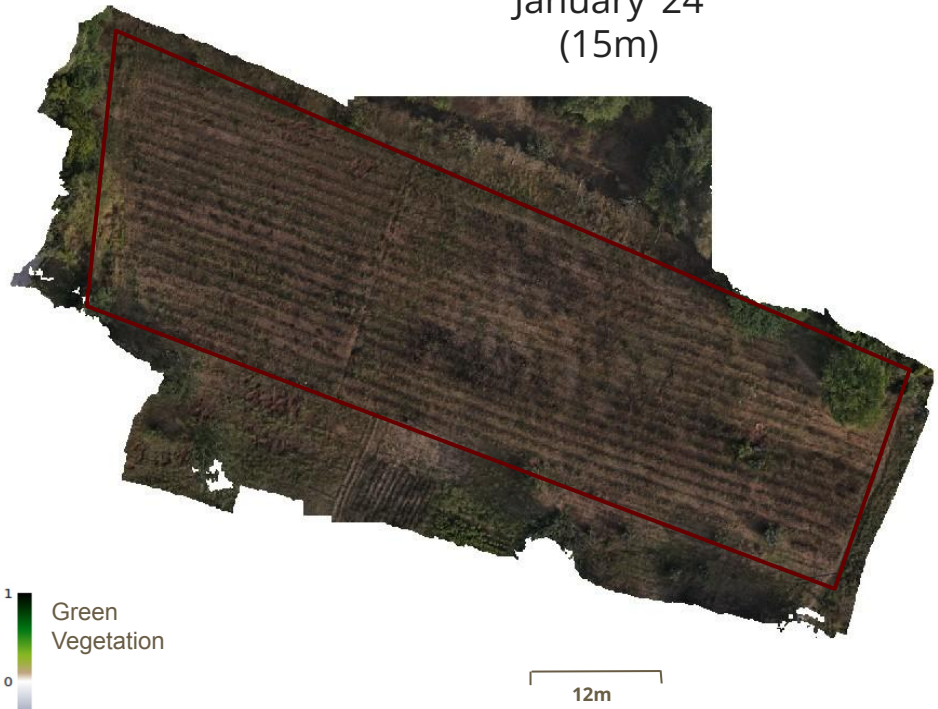
A difference in vegetation in the multispectral image taken in December can be visually verified from the orthomosaic of the images taken from RGB drone

EVI2 vs RGB

January ‘24
(30m)



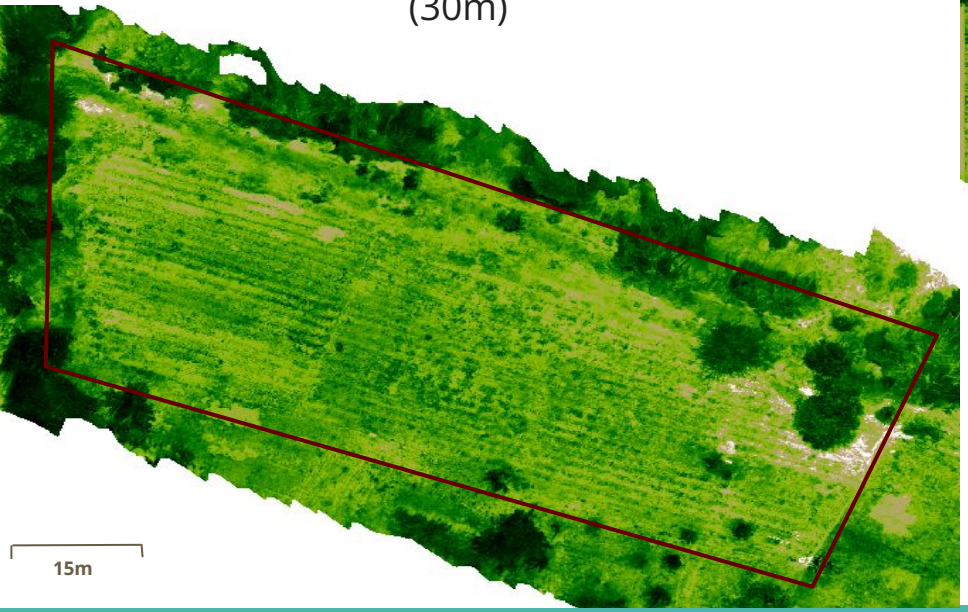
January ‘24
(15m)



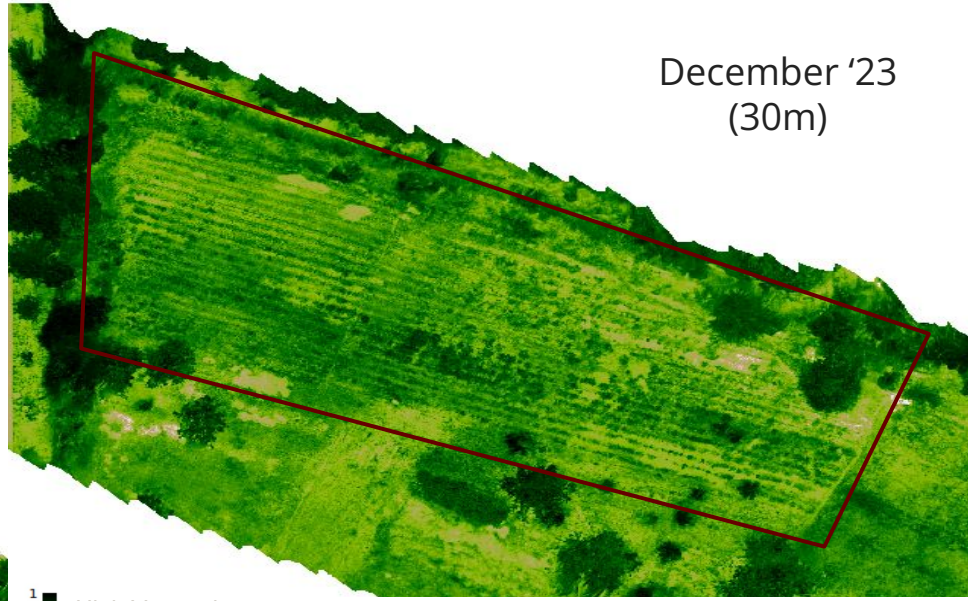
A difference in vegetation in the multispectral images taken in January can be visually verified from the orthomosaic of the images taken from RGB drone

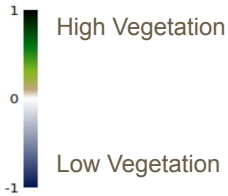
Optimized Soil Adjusted Vegetation Index (OSAVI)

January ‘24
(30m)



December ‘23
(30m)





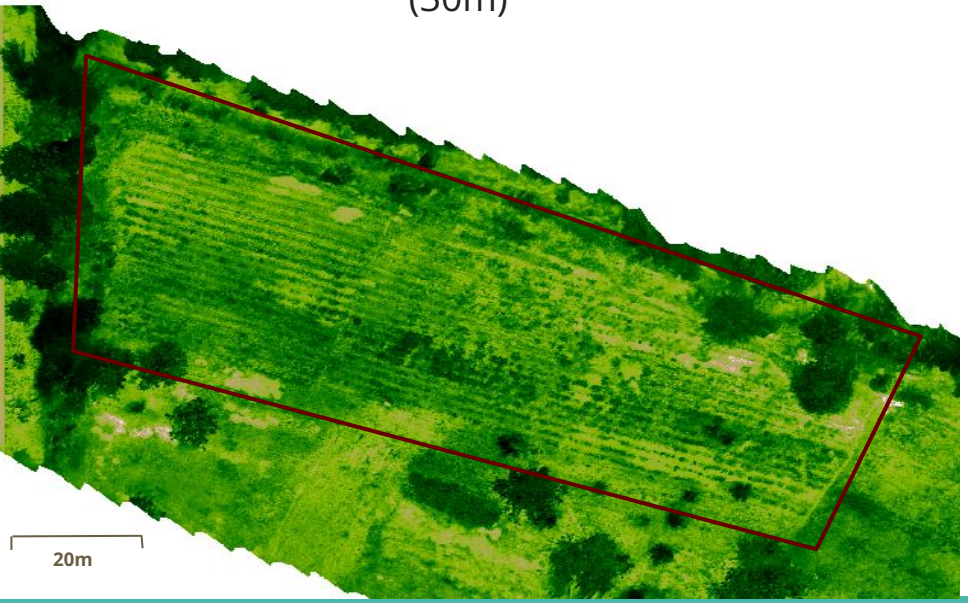
Visual Difference between the vegetation is prominent between the multispectral images taken from December and January

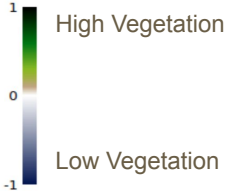
OSAVI = (NIR - Red) / (NIR + Red + 0.16)

OSAVI vs RGB

December ‘23 (15m)

December ‘23 (30m)



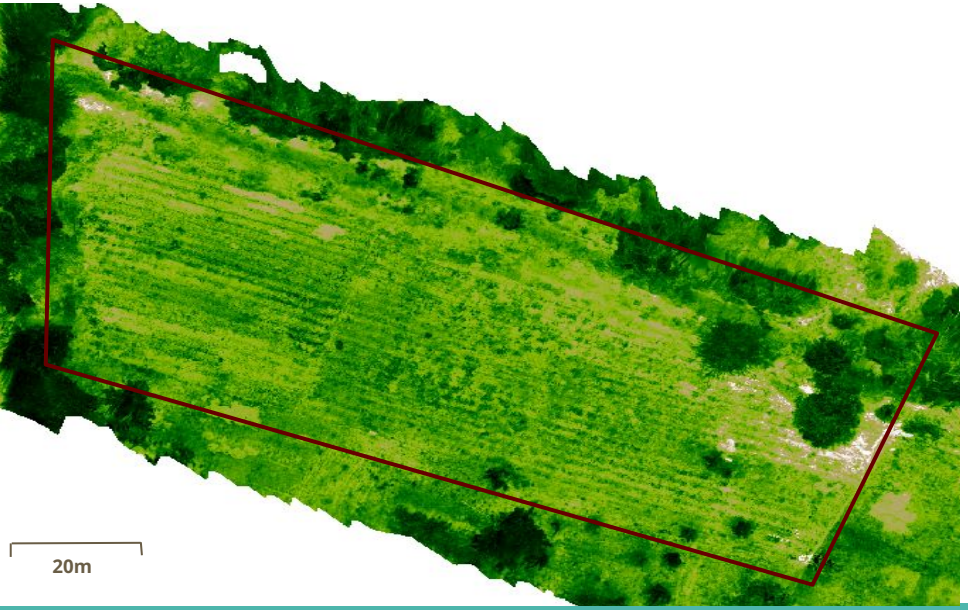


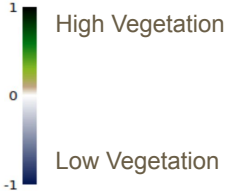
A difference in vegetation in the multispectral images taken in December can be visually verified from the orthomosaic of the images taken from RGB drone

OSAVI vs RGB

January ‘24
(15m)

January ‘24
(30m)

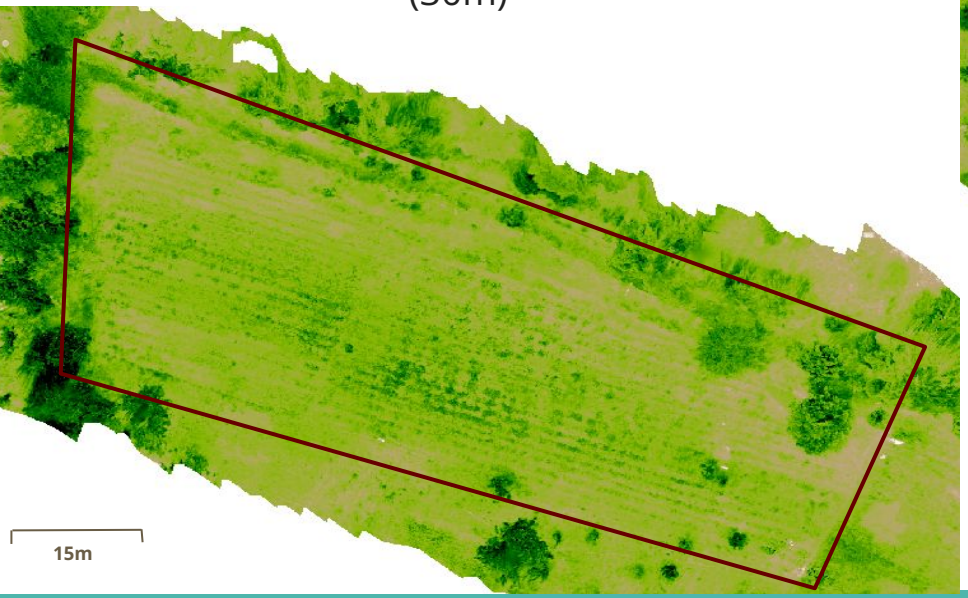




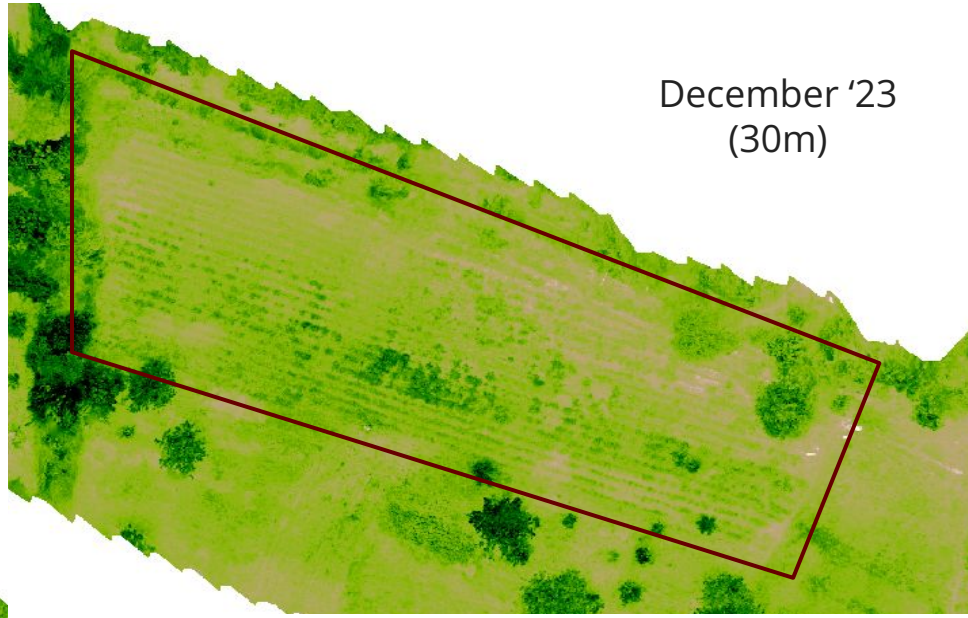
A difference in vegetation in the multispectral images taken in January can be visually verified from the orthomosaic of the images taken from RGB drone

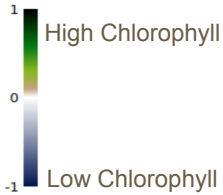
Chlorophyll Index Green (CIG)

January ‘24
(30m)



December ‘23
(30m)



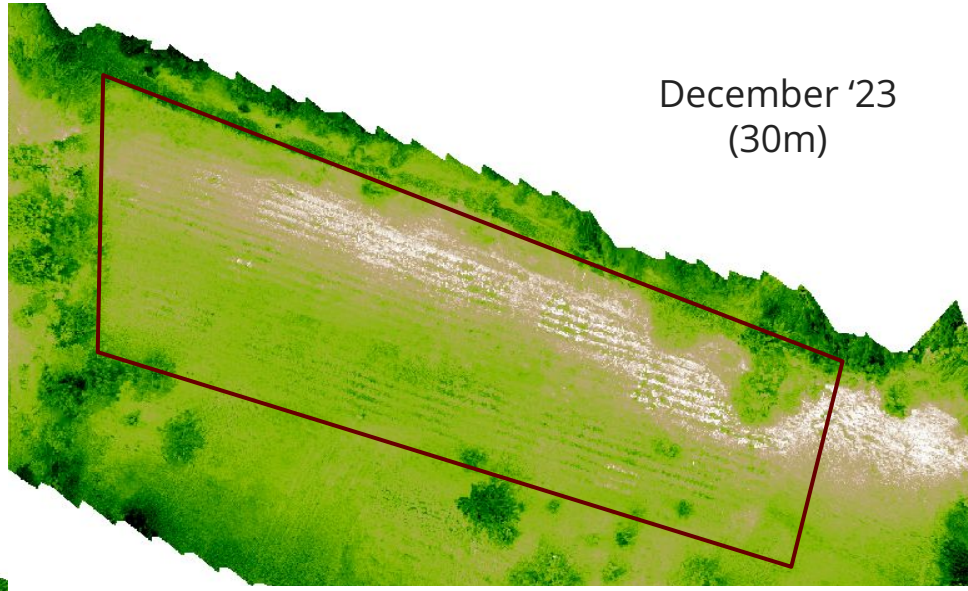


The difference in Chlorophyll content is visibly different between the vegetation map of December and January which indicates the vegetation proportion in the area

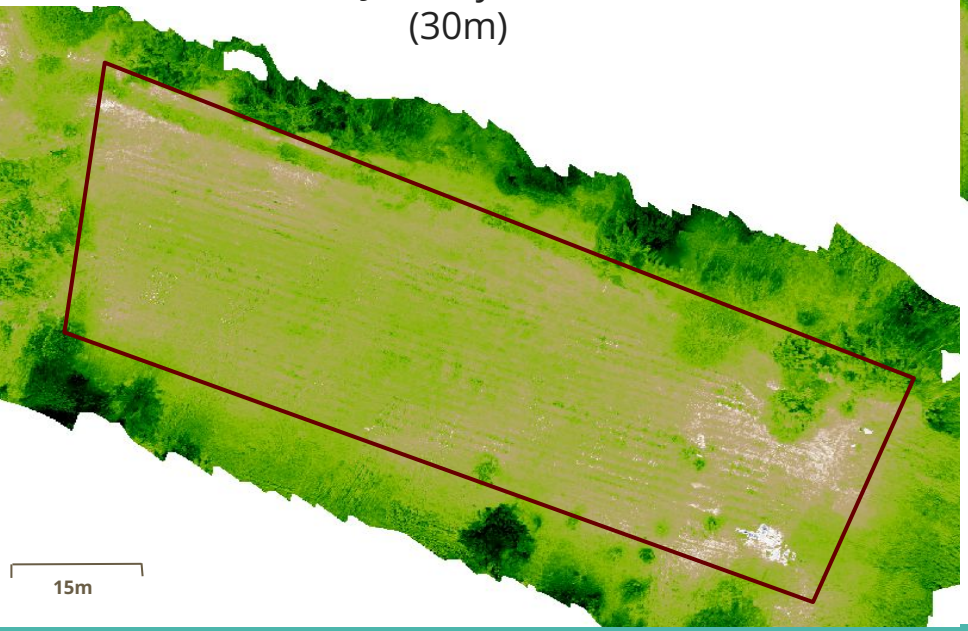
CIG = (NIR/Green) - 1

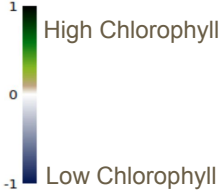
Chlorophyll Index Red-Edge (CIRE)

December ‘23
(30m)



January ‘24
(30m)





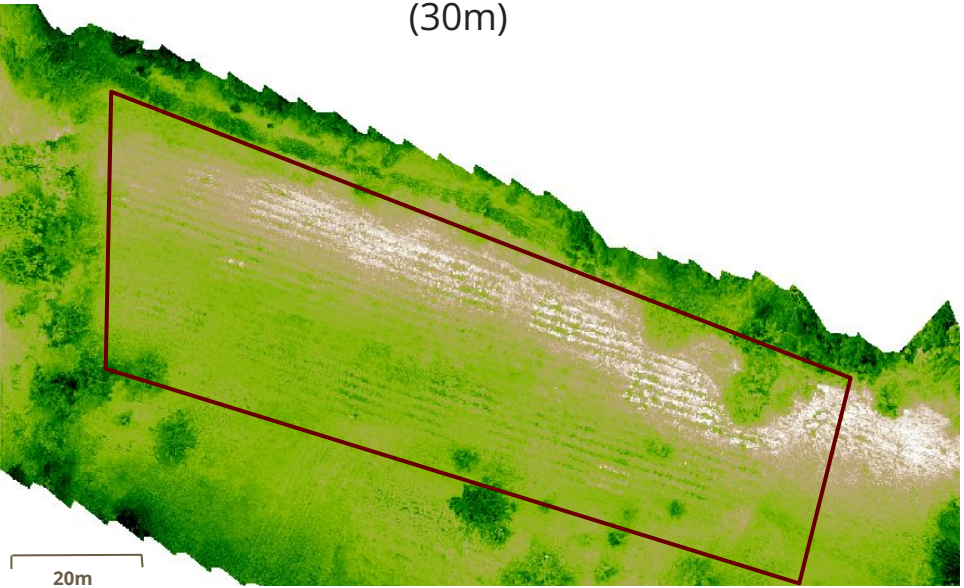
The difference in Chlorophyll content is visibly different between the vegetation map of December and January which indicates the vegetation proportion in the area using NIR and RedEdge

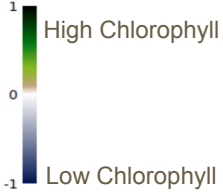
CIRE = (NIR/RedEdge) - 1

CIRE vs RGB

December ‘23 (15m)

December ‘23 (30m)

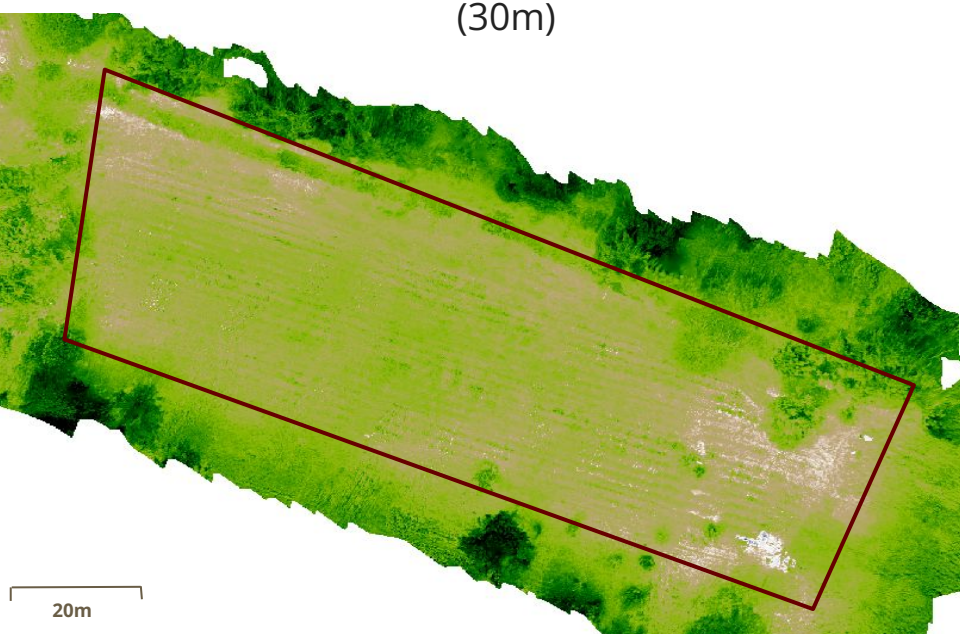




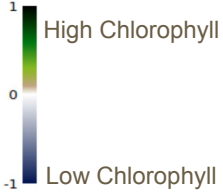
A difference in chlorophyll content in the multispectral images taken in December can be mapped from the vegetation cover of orthomosaic of the images taken from RGB drone

CIRE vs RGB

January ‘24
(30m)



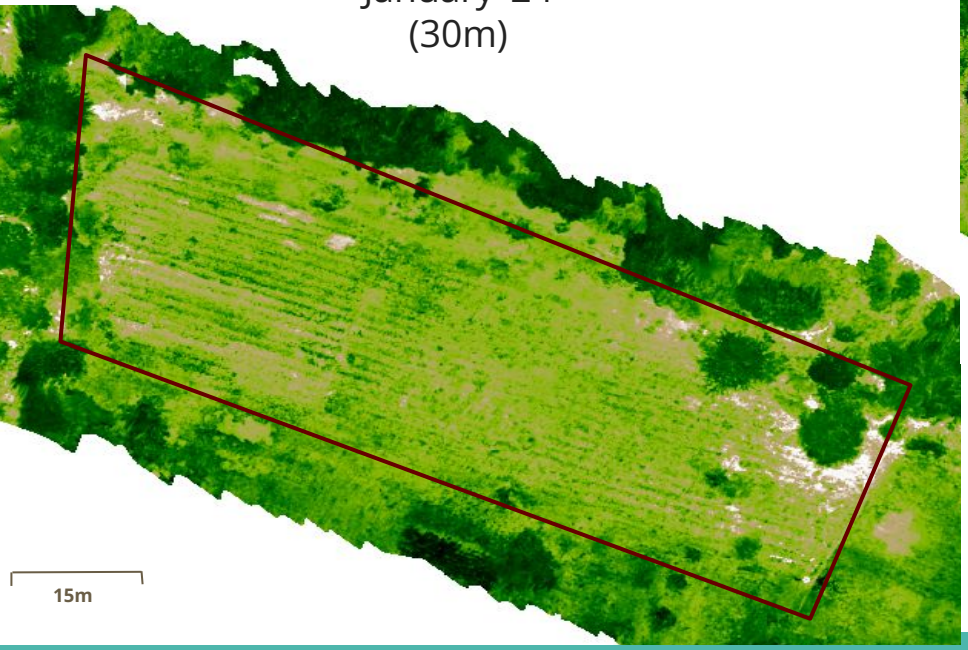
January ‘24
(15m)



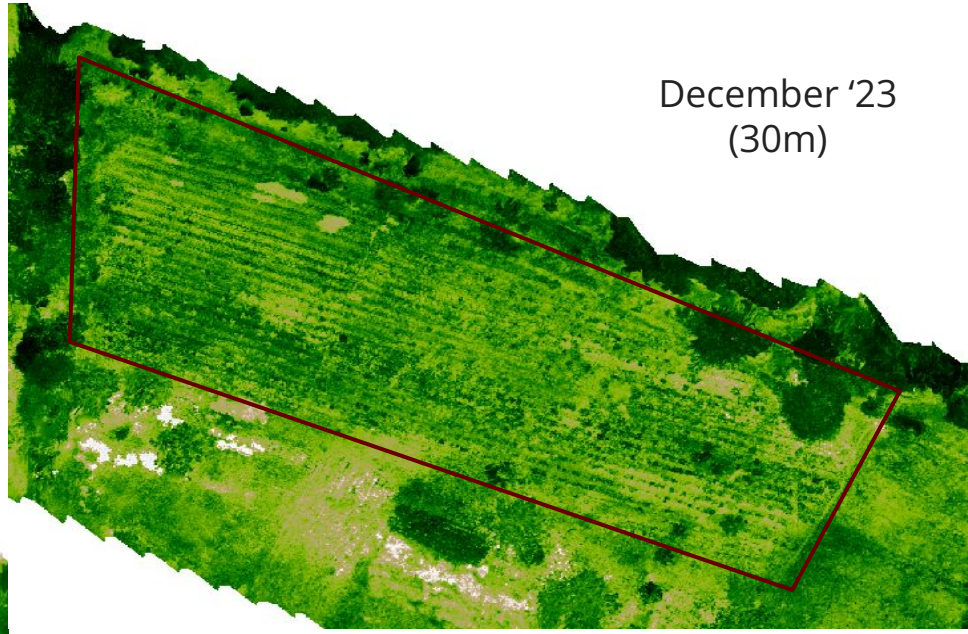
A difference in chlorophyll content in the multispectral images taken in January can be mapped from the vegetation cover of orthomosaic of the images taken from RGB drone

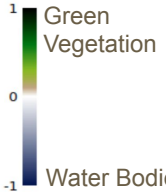
Modified Green-Red Vegetation Index (MGRVI)

January ‘24
(30m)



December ‘23
(30m)





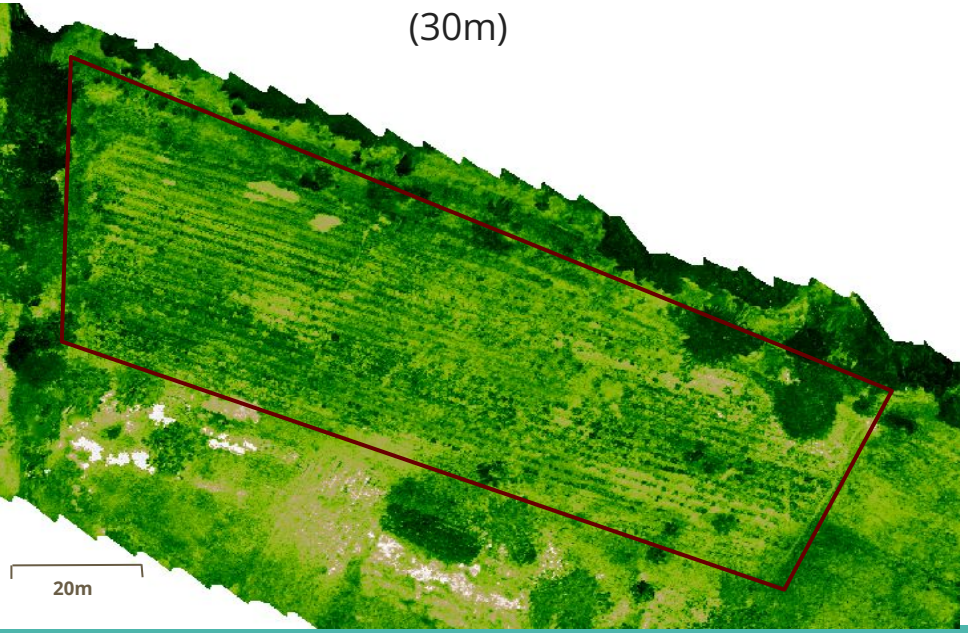
Difference in Vegetation in the month of January and December can be visually verified from this images.

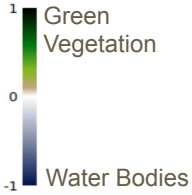
$$MGRVI = (Green^2 - Red^2) / (Green^2 + Red^2)$$

MGRVI vs RGB

December ‘23 (15m)

December ‘23 (30m)

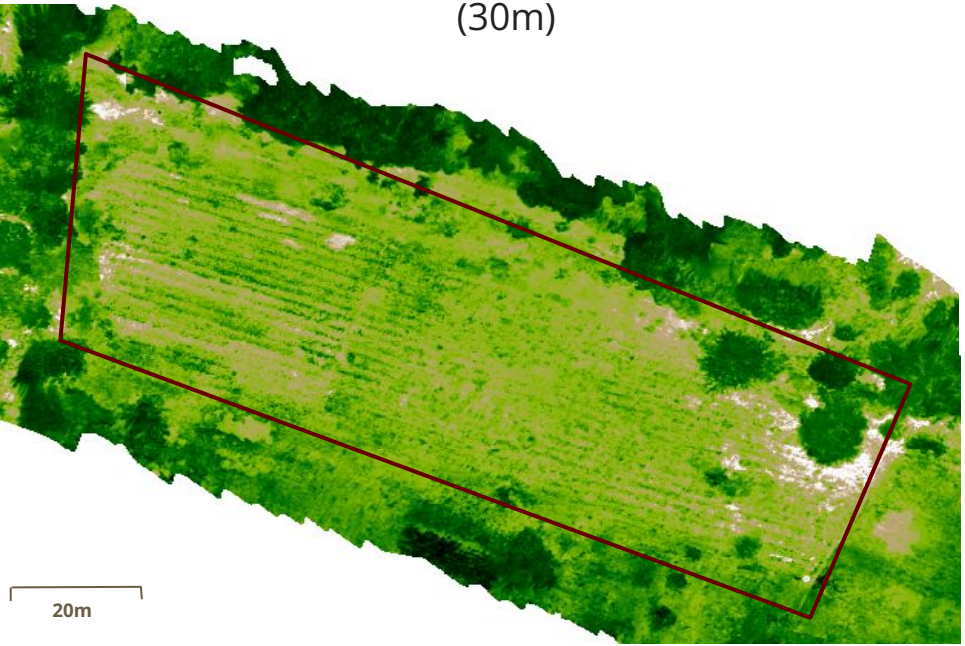




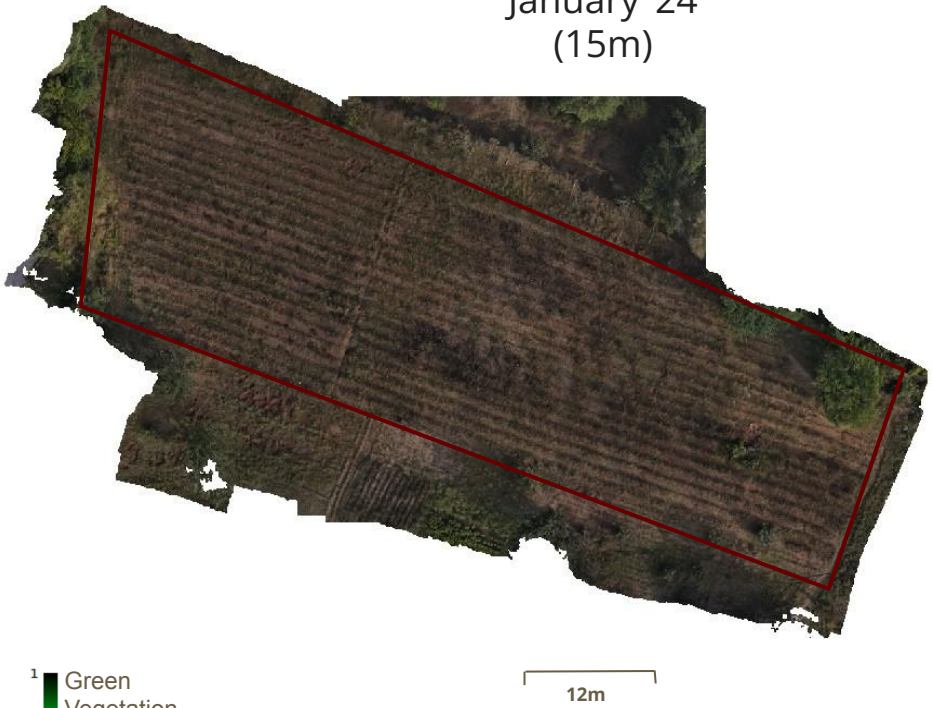
A difference in vegetation in the multispectral images taken in December can be visually verified from the orthomosaic of the images taken from RGB drone

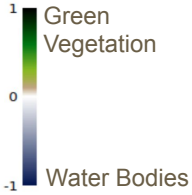
MGRVI vs RGB

January ‘24
(30m)



January ‘24
(15m)



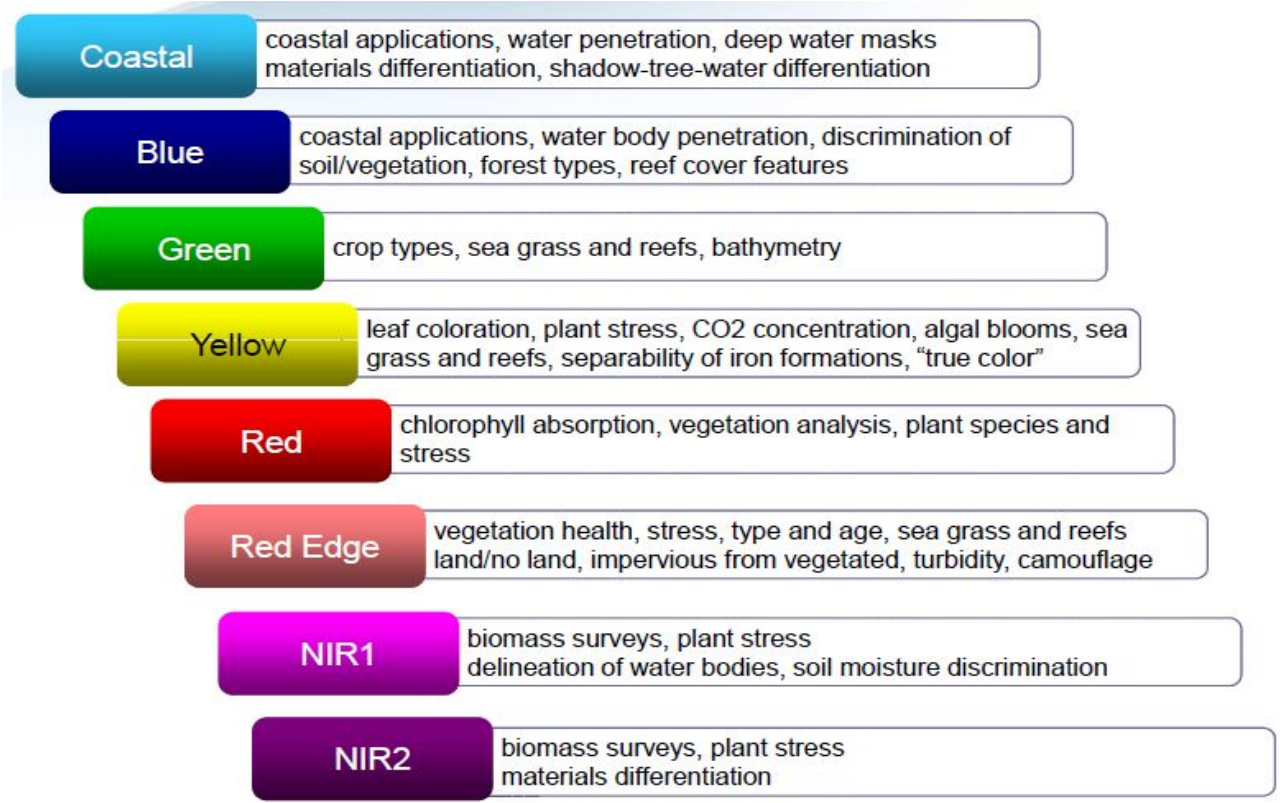


A difference in vegetation in the multispectral images taken in December can be visually verified from the orthomosaic of the images taken from RGB drone

Best vegetation index

- Enhanced Vegetation Index (EVI2):
  - EVI is an enhancement of NDVI
  - provides improved sensitivity in high biomass regions
  - useful in areas with dense or overlapping vegetation
  - more accurate representation of plant health.
- Soil Adjusted Vegetation Index (SAVI):
  - minimize the influence of soil brightness in the index values.
  - beneficial when working in areas with varying soil conditions.

Applications



[1]

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[1] Ken Joyce, Bill Baugh. Uncovering Hidden Intelligence with Multispectral Imagery. (2017). Online: https://blog.maxar.com/earth-intelligence/2017/uncovering-hidden-intelligence-with-multispectral-imagery

[2] C. Willy, C. Yeon-Ho, G. Zabih, B. Hassan, Navid. Optical Camera Communications: Principles, Modulations, Potential and Challenges. (2020). Electronics. 9. 1339. 10.3390/electronics9091339.

[3] Z. Jaime. (2015). Feature extraction and data reduction for hyperspectral remote sensing Earth observation.

[4] Migel Tissera. A Comprehensive Introduction to Hyperspectral data unveiling the unseen Part. (2023) Online: https://metaspectral.com/2023/10/20/a-comprehensive-introduction-to-hyperspectral-data-unveiling-the-unseen-part-i/

[5] Jensen J. Robert. Remote Sensing of the Environment: An Earth Resource Perspective. (2000).

[6] Paul Reuben Mwinuka, Sixbert K. Mourice, Winfred B. Mbungu, Boniphace P. Mbilinyi, Siza D. Tumbo, Petra Schmitter. UAV-based multispectral vegetation indices for assessing the interactive effects of water and nitrogen in irrigated horticultural crops production under tropical sub-humid conditions: A case of African eggplant. Agriculture Water Management. Vol. 266. 2022.

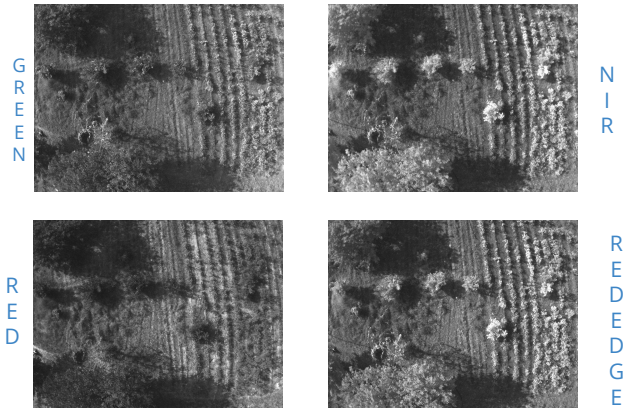
[7] Guan Y, Grote K. Assessing the Potential of UAV-Based Multispectral and Thermal Data to Estimate Soil Water Content Using Geophysical Methods. *Remote Sensing*. 2024; 16(1):61

Thank You

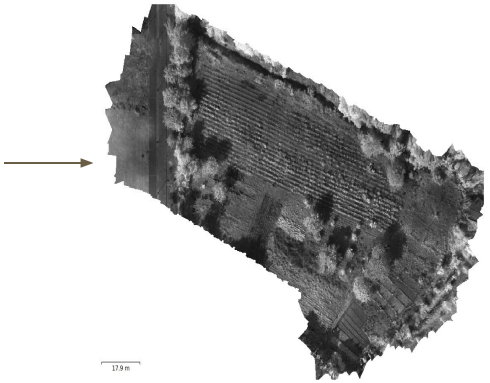
Smart Farming of Cotton using Aerial Imagery and Computer Vision

Further Analysis

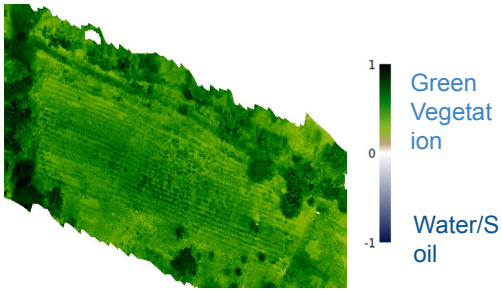
Image Acquisition

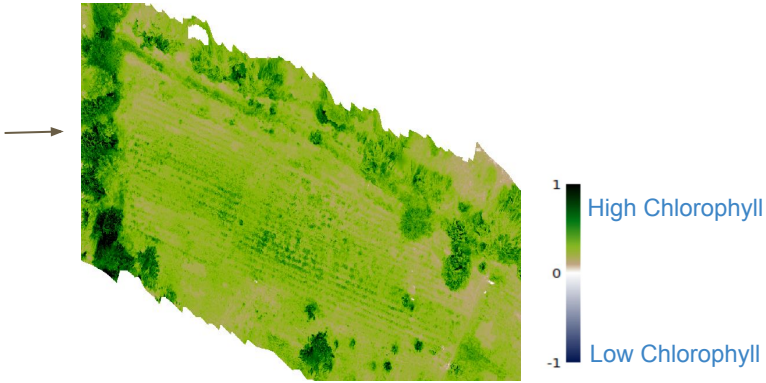


Orthomosaic



Vegetation Index

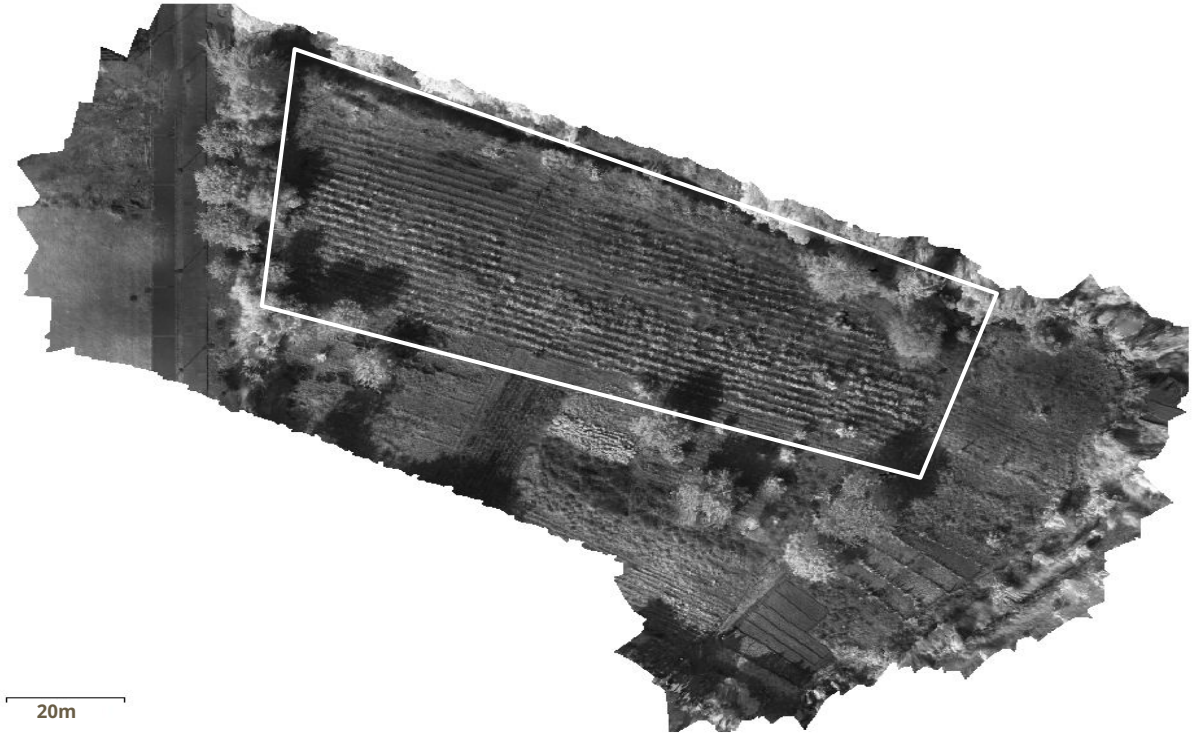




Information about crop

- Determines vegetation cover
- soil cover
- detect plant's phenological stages
- Monitors crop water status
- Stress level

Orthomosaic



Orthomosaic from NIR Band Images taken on 11.12.2023 (30m)