Exploring the potential of explorative point clouds in floodplain maintenance

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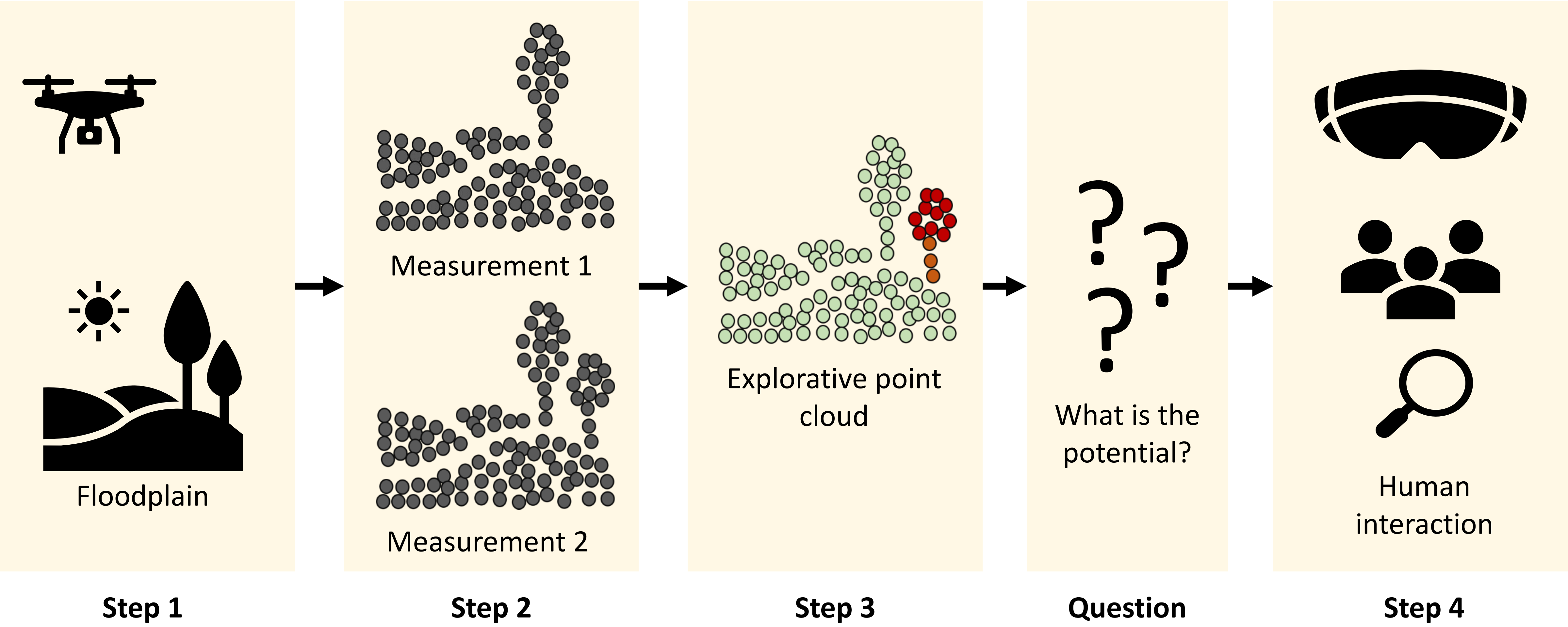
GIS survey

Van Oord
Marine ingenuity

TU Delft

GDMC

Short overview of the research



Exploring the potential of explorative point clouds in floodplain maintenance

Figure 1. Floodplain

Introduction: Maintenance of floodplains

- **Water management:**
  Floodplains

- **Keep them functional:**
  Periodic maintenance

- **Maintenance tasks:**
  Pruning, mowing overgrowth, bank erosion, gully maintenance, etc.

- **Assets:**
  Channels, bridges, culverts, roads, grids, etc.

Figure 2. Maintaining floodplains [1]

Exploring the potential of explorative point clouds in floodplain maintenance

What is a point cloud?

- **3D model**
  Collection of points with x, y, and z coordinates

- **Attributes**
  Intensity, return number, RGB (Red, Green, Blue) color values[4]

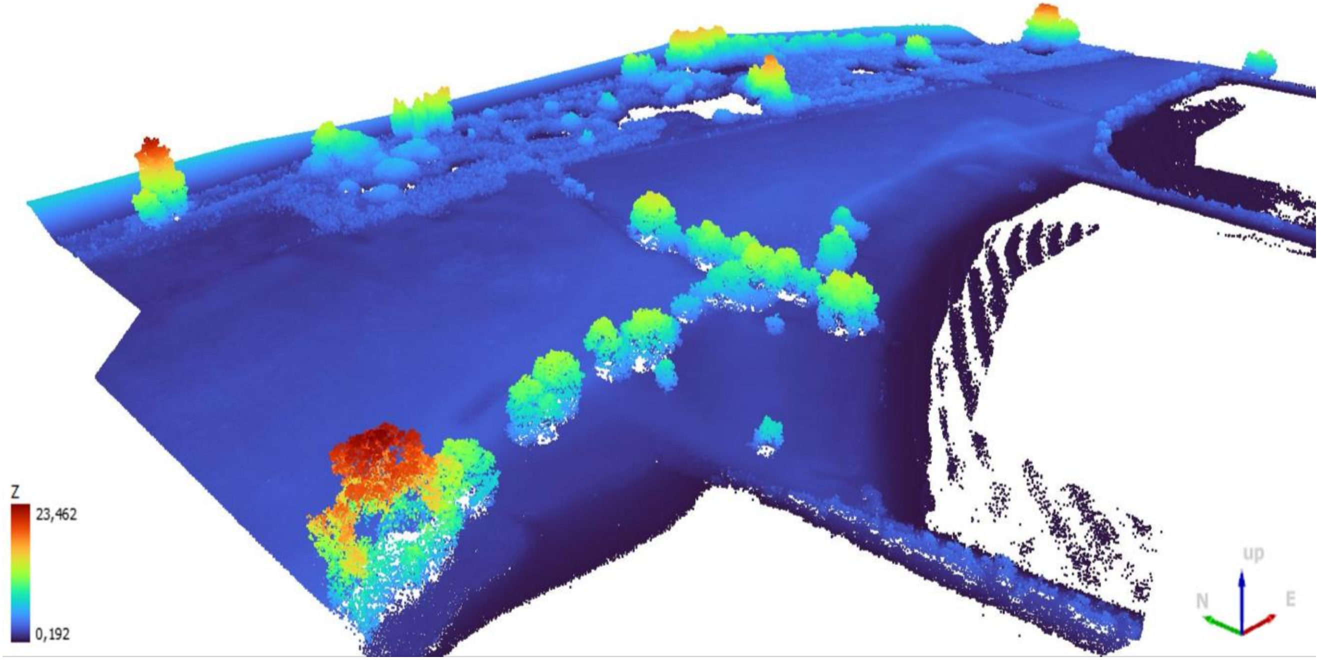
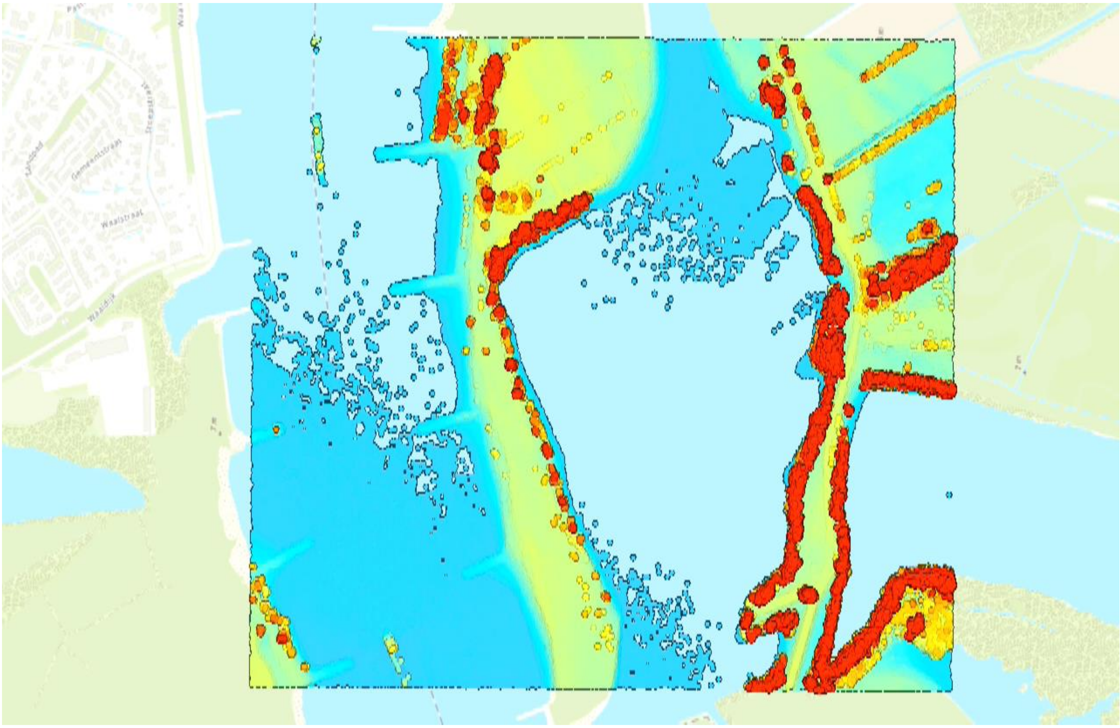


Figure 3. Point cloud – visualized based on its height

Exploring the potential of explorative point clouds in floodplain maintenance

Explorative point clouds

- Raw point clouds retain ***details*** and provide ***up-to-date information***
- Point clouds are ***underused due to further processing*** [11]
  - Time-consuming and loss of important information (spatial and semantic)
- **Explorative point clouds:** Point clouds that are enriched with additional information[10]



Video 1. Point cloud visualized based on its height

Van Oord Marine ingenuity

TUDelft

Problem Statement

Problem statement

Raw point clouds, generated through LiDAR, are an underused data source that has the potential for extracting valuable information

→ **Explore** the potential of *explorative point clouds* as versatile data resource

Figure 5. VR headset[3]

To what extent are explorative point clouds, generated from raw UAV-LiDAR data, useful in providing insights on change detection for floodplain maintenance?

Objective of the research

To explore the potential of *explorative point clouds*
for floodplain maintenance

Case study: WOCU[(1)] Rijntakken

- Maintenance of floodplains
  - Changes in **vegetation, terrain, and objects**
- Need for an in-depth data-driven maintenance process
- Remote Sensing
  - Effective and efficient to detect changes
  - In particular: using **point clouds**

Figure 4. WOCU Rijntakken[2]

[(1)] Waardengedreven Onderhoudscontract Uiterwaarden - Rijkswaterstaat

Data-driven: Remote sensing

Broad scope

Efficient (automated)

Effective

Accurate

Data visualization

Literature study

How to acquire point clouds?

- **Passive sensor:** Measures reflected solar radiation across different wavelengths.[12]
  - Photogrammetry

- **Active sensor:** Emits radiation toward a target and detects reflected radiation[13]
  - Light Detection and Ranging (LiDAR)

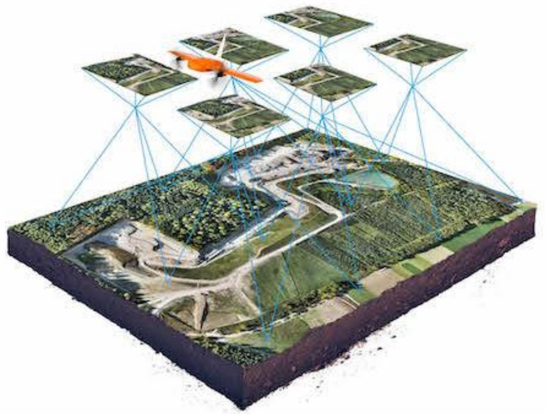


Figure 6. Photogrammetry [4]

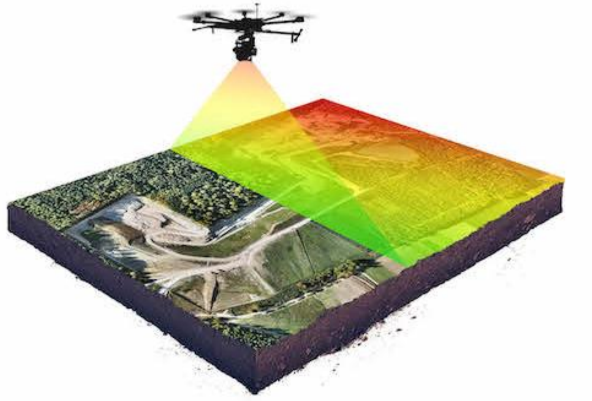


Figure 7. LiDAR [4]

UAV-LiDAR

- Light Detection and Ranging (LiDAR)
  - Advantage in areas of dense vegetation and floodplain mapping[14]
  - Not dependent on weather conditions[15]

- Unmanned Aerial Vehicle (UAV) – drone
  - Advantage: Autonomously operated, carries remote sensors, coverage, accessibility [16]

Figure 8. UAV-LiDAR

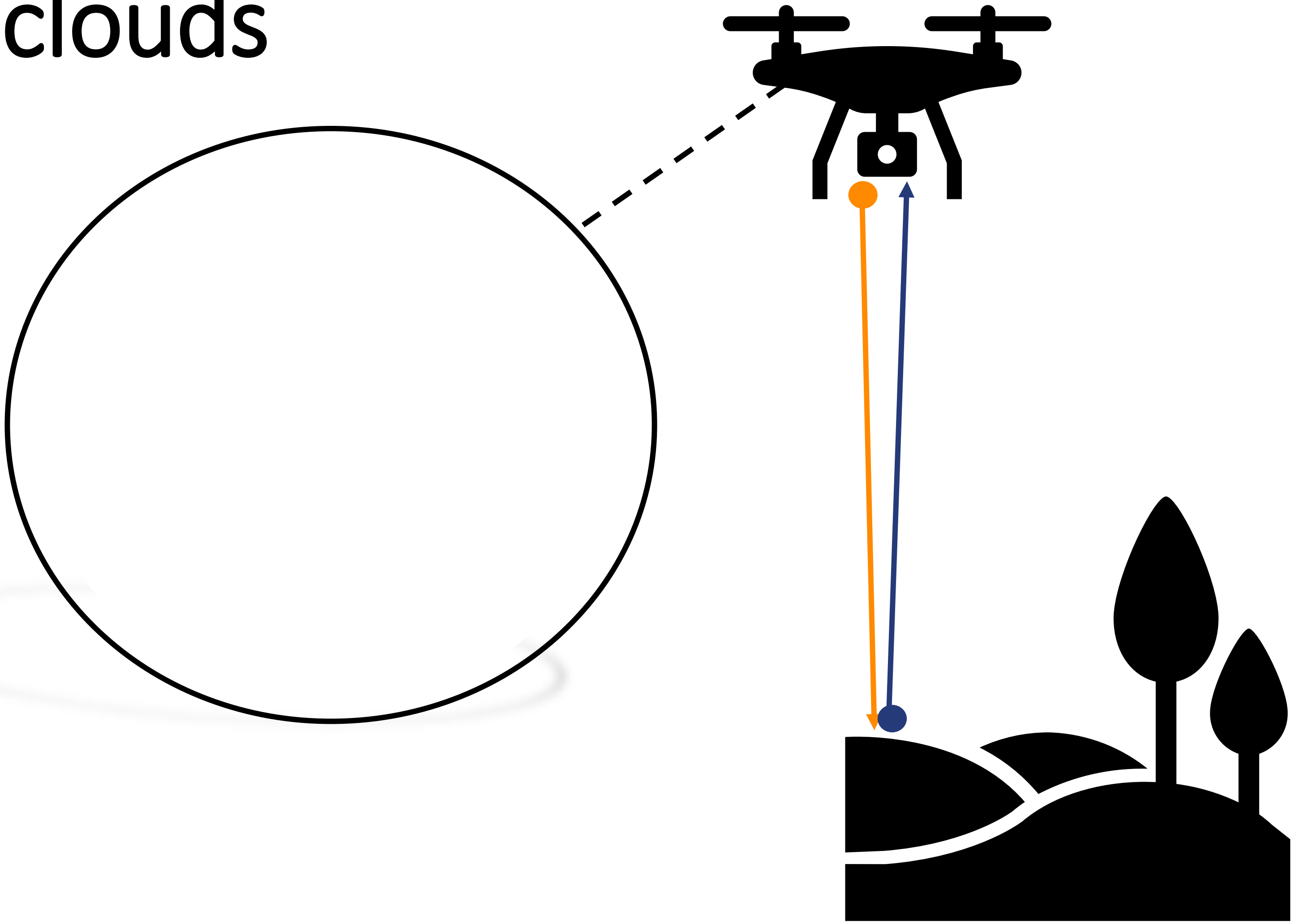
UAV-LiDAR point clouds

3D point is computed by using:

- Distance between sensor and target through time-of-flight (t) and speed of light (c)[17]

$$d = \frac{c \cdot t}{2}$$

- Position of the UAV vehicle
- Orientation of LiDAR sensor
- Real Time Kinematic (RTK) network



Relevant attributes

- Maintenance comes from changes:
  - **Attribute 1:** Change detection between two point clouds
- Floodplains consist largely of vegetation
  - **Attribute 2:** Normalized Difference Vegetation Index (NDVI)

Animation 1. Changes within point cloud over the time

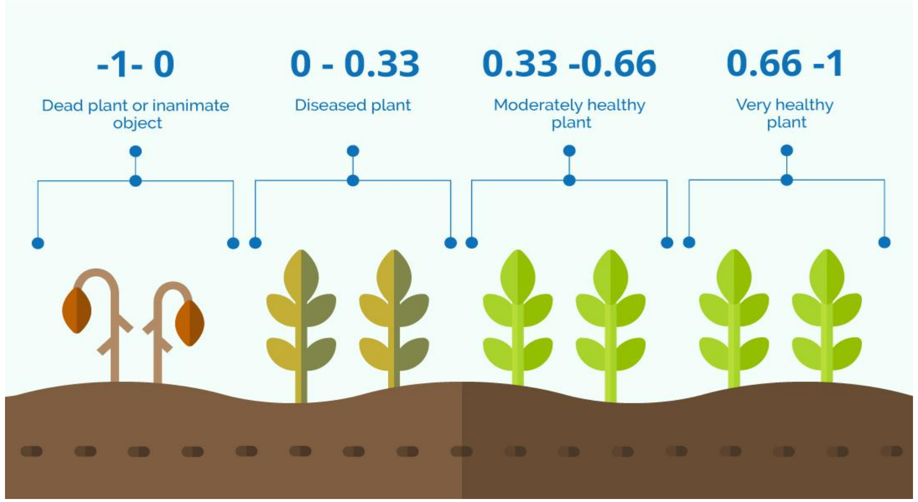
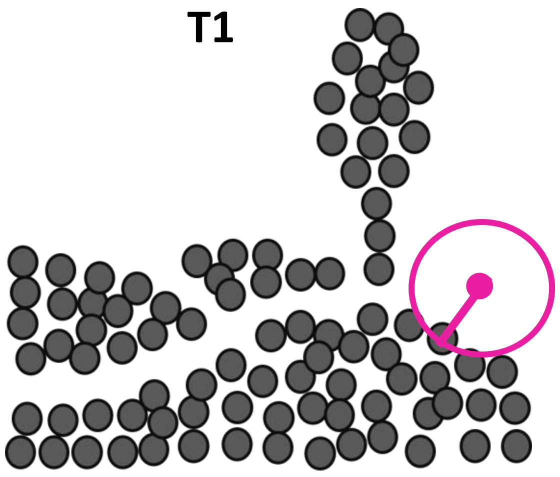
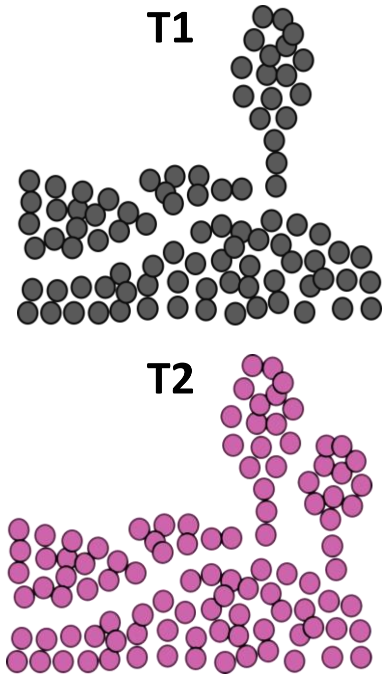
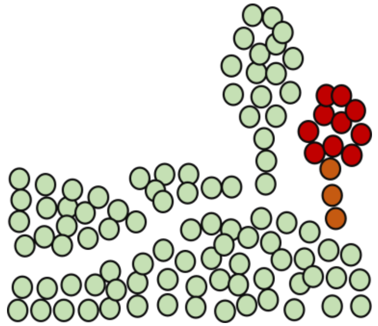


Figure 9. NDVI values [9]

Attribute 1: Cloud-to-Cloud distance







Enrich with the Cloud-to-Cloud distance

Find nearest neighbor distance[18]

Compare T1 and T2 point clouds

Find the cloud-to-cloud distance

Attribute 2: Normalized Difference Vegetation Index (NDVI)

- Absoption of spectra can be used to differentiate vegetation and assess their health [19]
- Multispectral remote sensing techniques and band composition:
  - Near Infrared & Red [20]

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

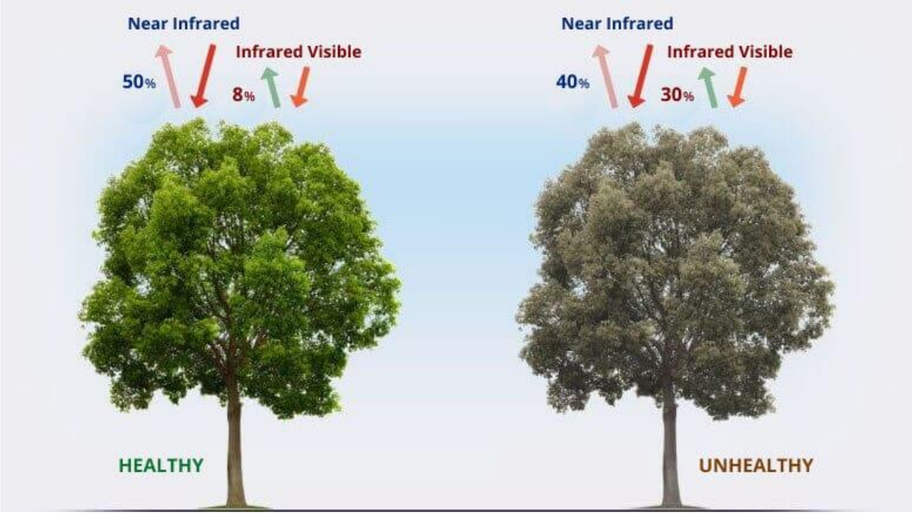
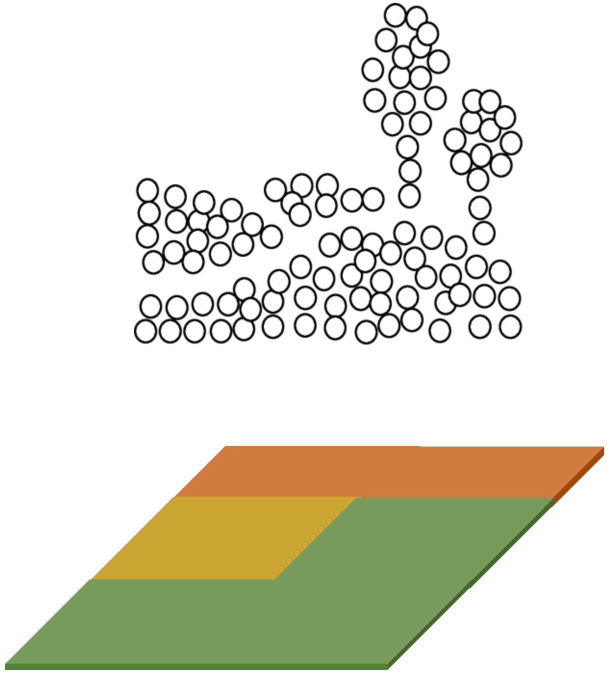
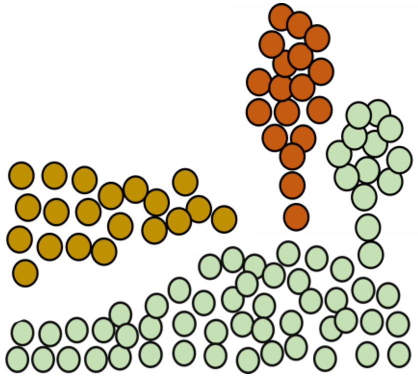


Figure 10. NDVI on vegetation[6]

Attribute 2:
Normalized Difference Vegetation Index (NDVI)





Enrich the point cloud with NDVI values

Point on Raster overlayer[21]

Add NDVI values to the point cloud

Visualisation of point clouds

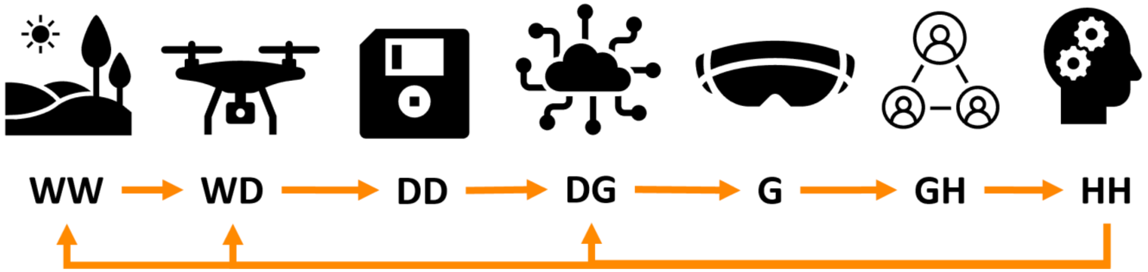
- Provide insight in complex data
- Interactive tools stimulate exploration
- Virtual Reality (VR): highly realistic representation as 1-to-1 model[22]

→ Reveal potential value of explorative point clouds

Figure 11. Virtual Reality (VR) [7]

WDGM model

- World, Digital model, Graphical representation, Mental representation
- Contains all processes within the geoinformation provision[23]
- Two ends: World and Mental representation
- Series of connecting processes



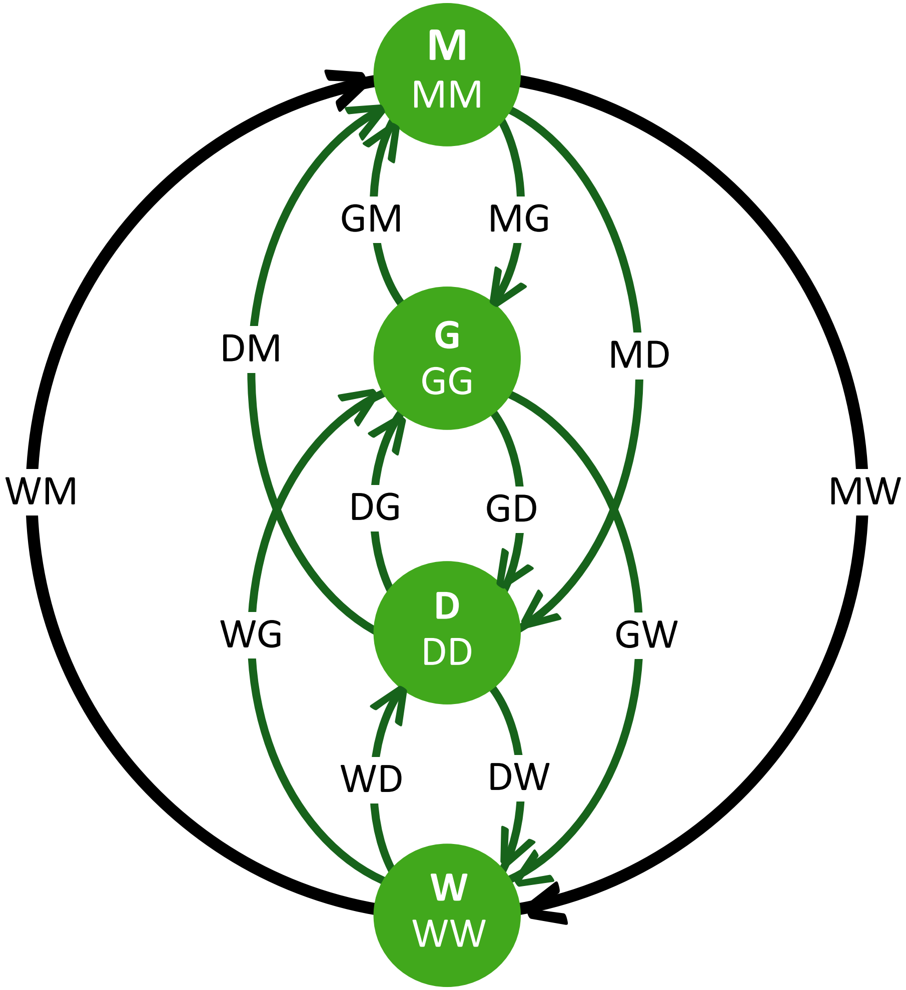


Figure 12. WDGM model [8]

Methodology

Workflow

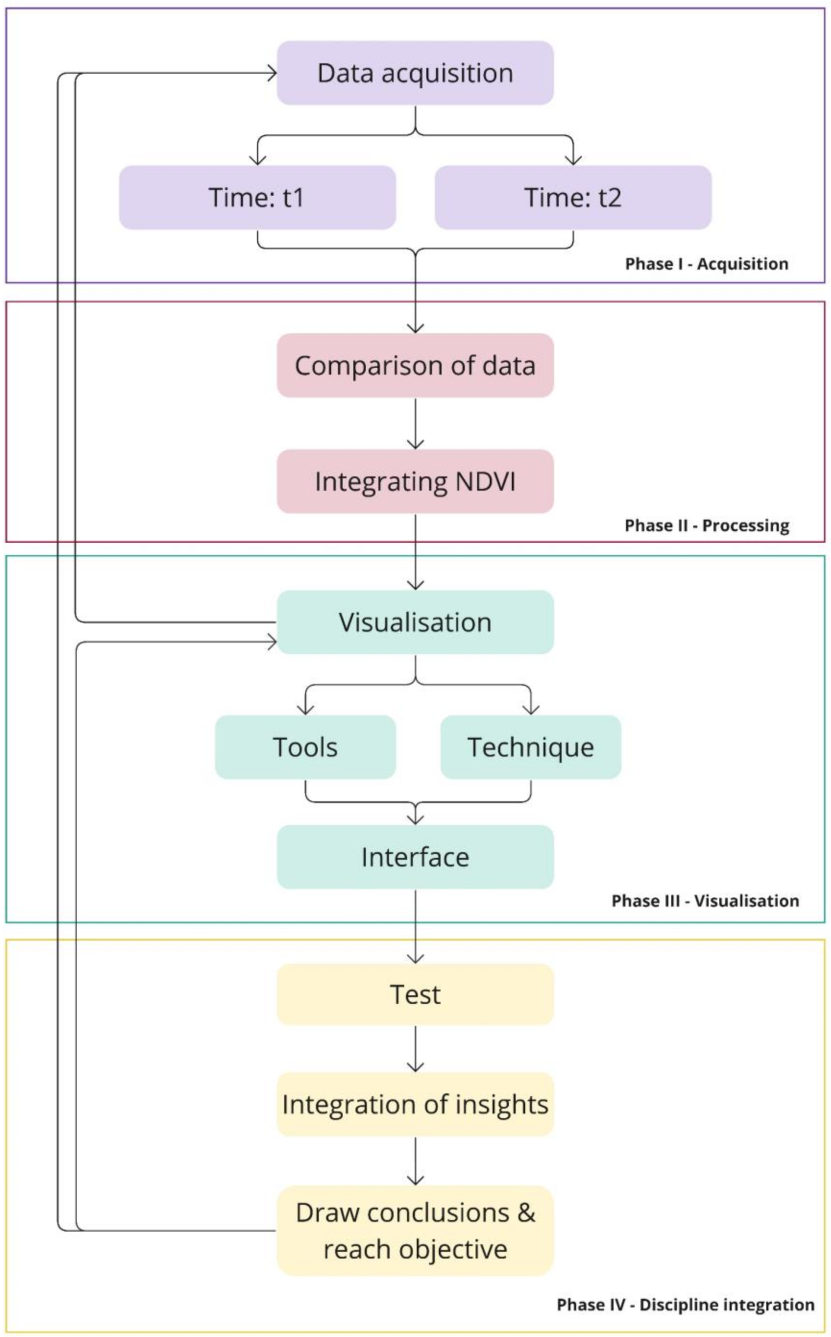
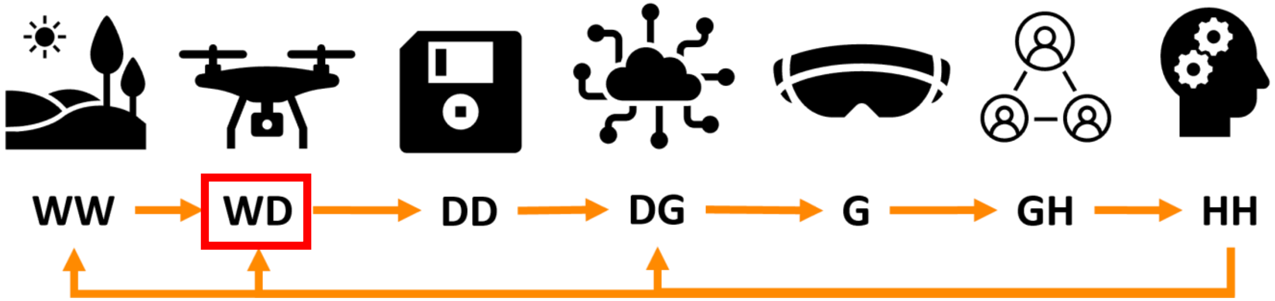
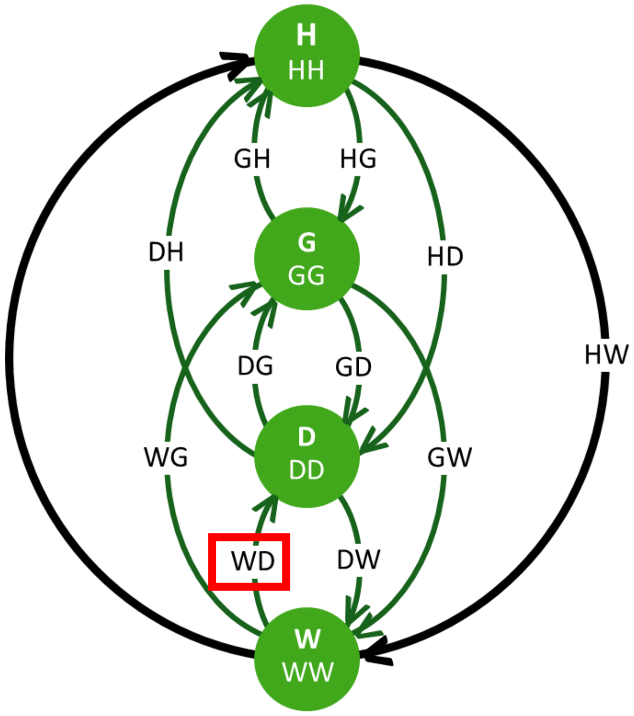


Figure 13. Workflow of the thesis

Phase I – Data acquisition





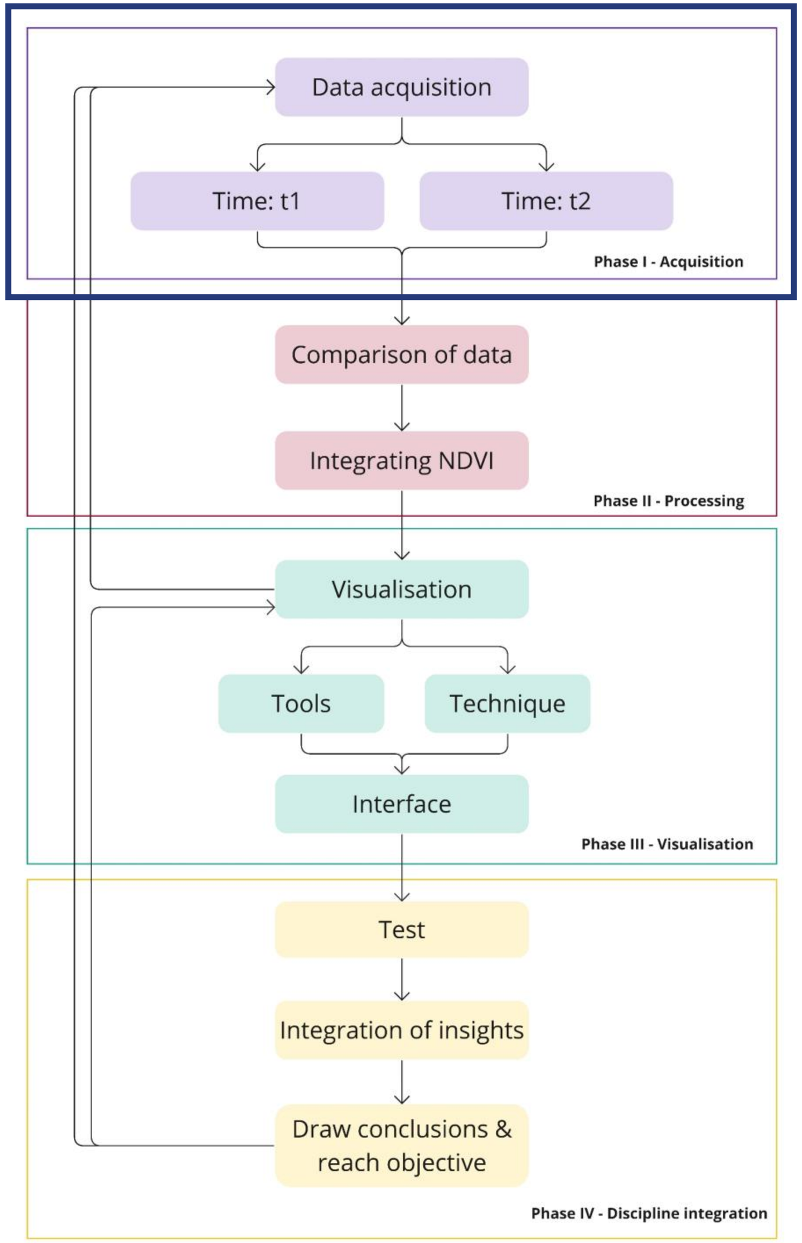
Phase I – Data acquisition

Step 1: Preperation of acquistion

- Research Scope
- Sensors & UAV
- Flight parameters

Step 2: Data acquisition

- T1 & T2 measurement



Data acquisition - Research Scope

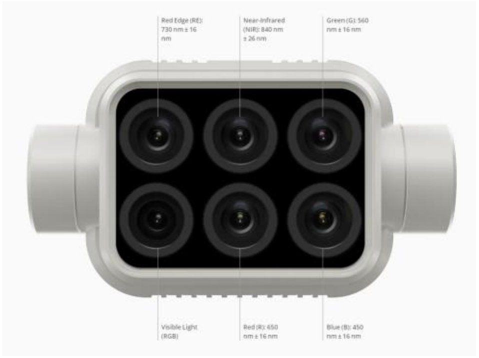
Restrictions:

- Within WOCU project
- Vegetation present
- Assets present
- Outer bend of the river (for detecting erosion)
- Flight restrictions (Aeret viewer)

Location: Lopik – de Vogelzang

Figure 14. Research Scope: Lopik – de Vogelzang, the Netherlands

Data acquisition - Preparation



Sensors

- **Pointcloud**
  LiDAR sensor
  Zenmuse L1

- **NDVI raster**
  Multispectral sensor
  Phantom 4

Flight Parameters	LiDAR	Multispectral
Sensor	Zenmuse L1	P4 Multispectral
Height	80 meter	60 meter
Speed	4 m/s	6.2 m/s
Front Overlap Ratio	70 %	70 %
Side Overlap Ratio	70 %	70 %
Course Angle	83 °	93 °
Resolution	1355 point/m^2	GSD = 3cm
Return mode	Triple	One

Table 2. Flight parameters

Data acquisition - In the field

Weather conditions

	T1	T2
Date	18 July	31 August
Wind speed (km/h)	4 km/h	10 km/h
Cloud cover	Partly Cloudy	Partly Cloudy
Wind direction	North-East	East

Table 3. Weather conditions

Figure 15. Acquisition in the field – Zenmuse L1 LiDAR & P4 Multispectral

Data acquisition - Raw data

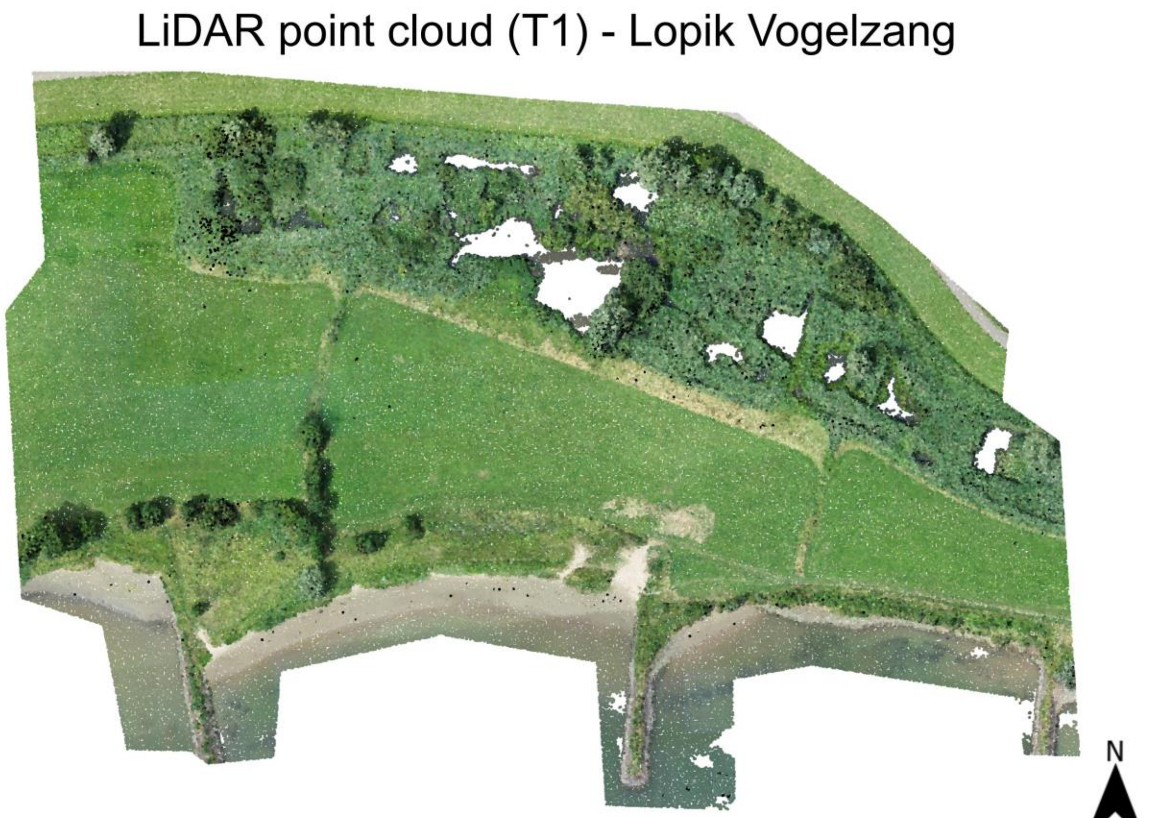


Figure 16. RGB point cloud (T1)

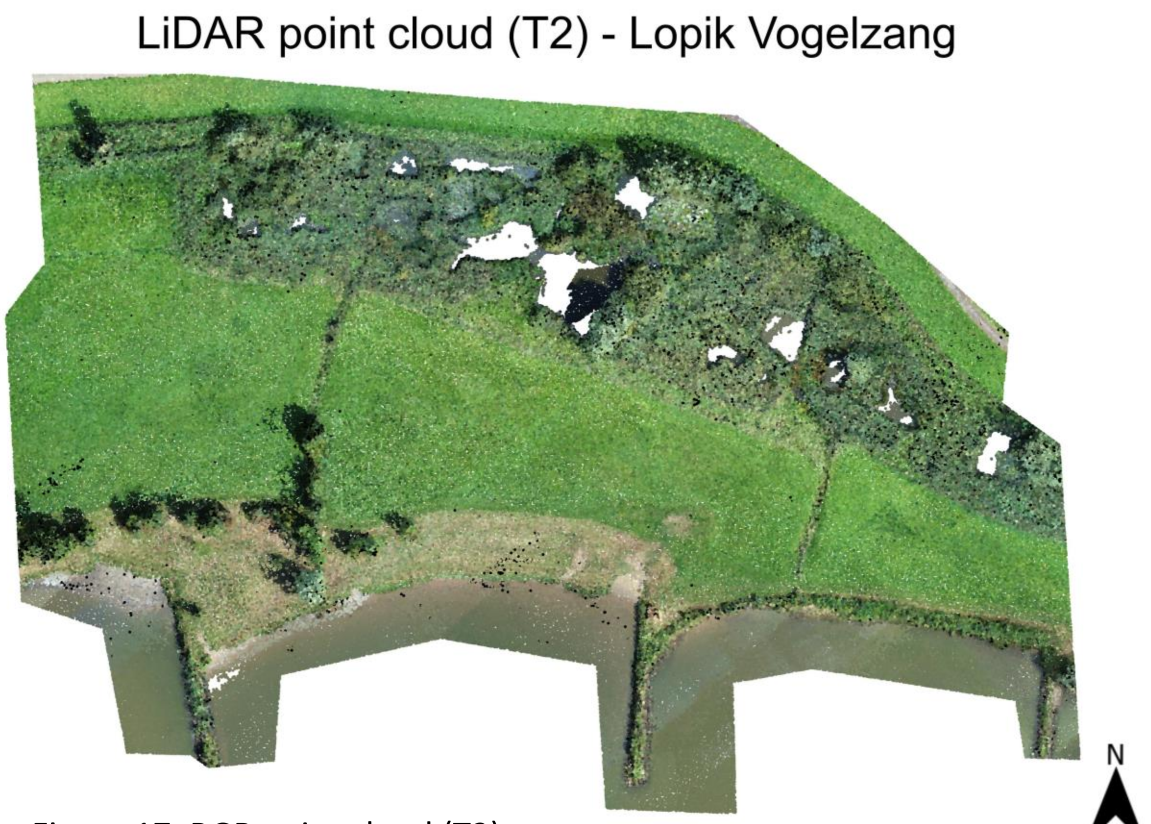


Figure 17. RGB point cloud (T2)

Data acquisition
- Raw data

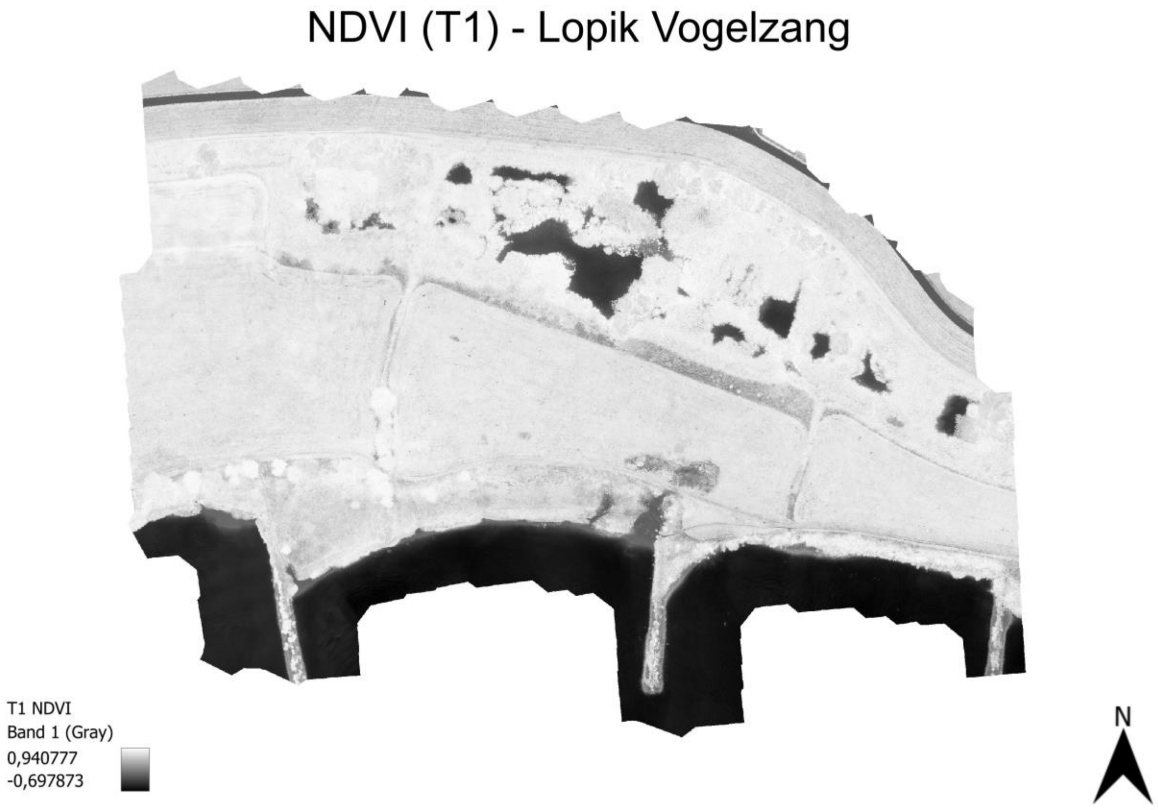


Figure 18. NDVI raster (T1)

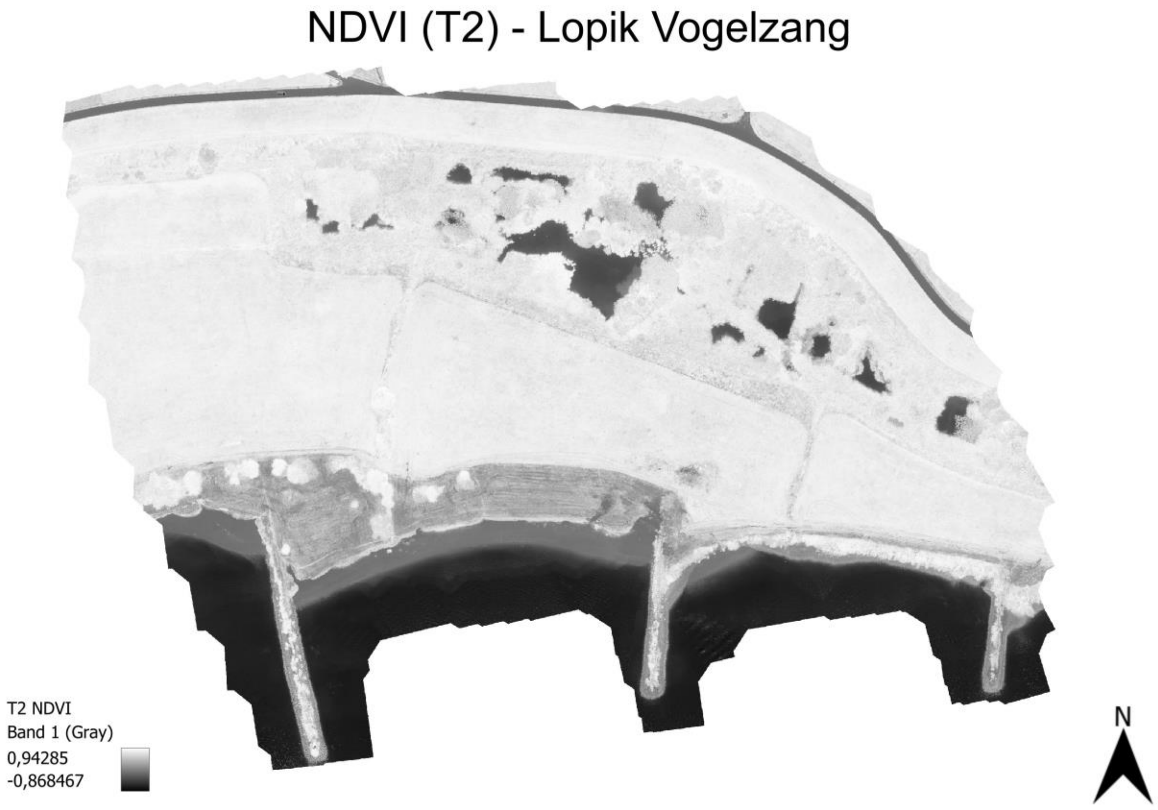
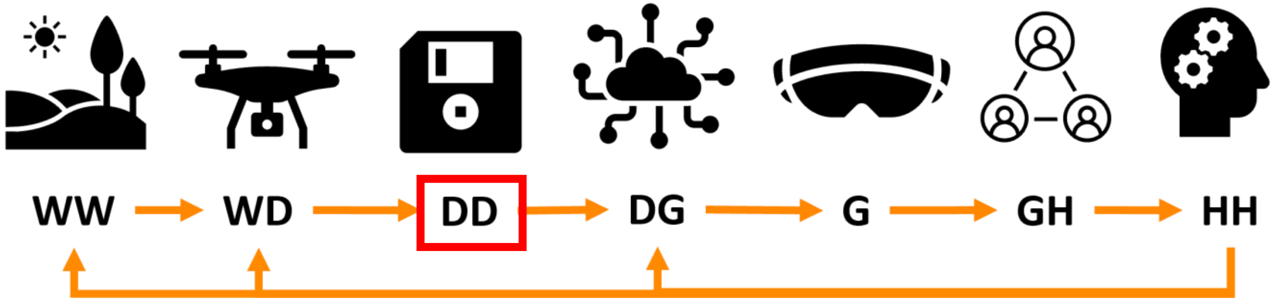
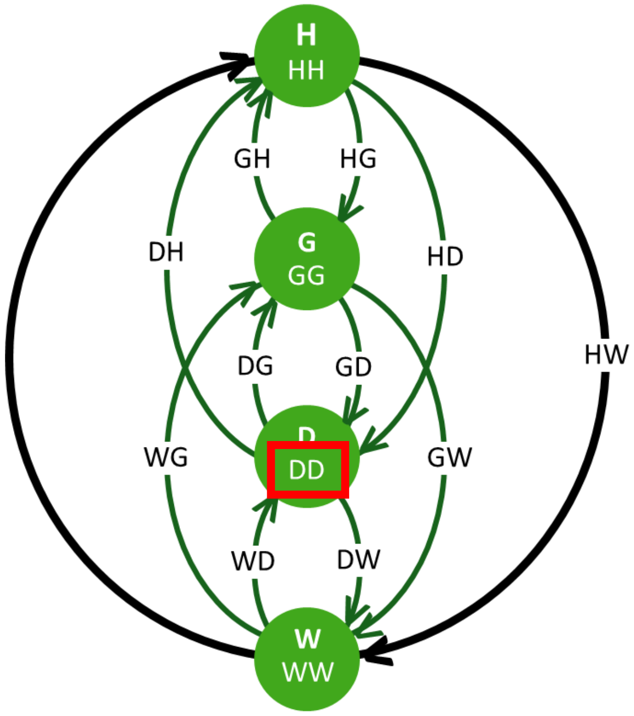


Figure 19. NDVI raster (T2)

Phase II – Processing





Phase II – Data Processing

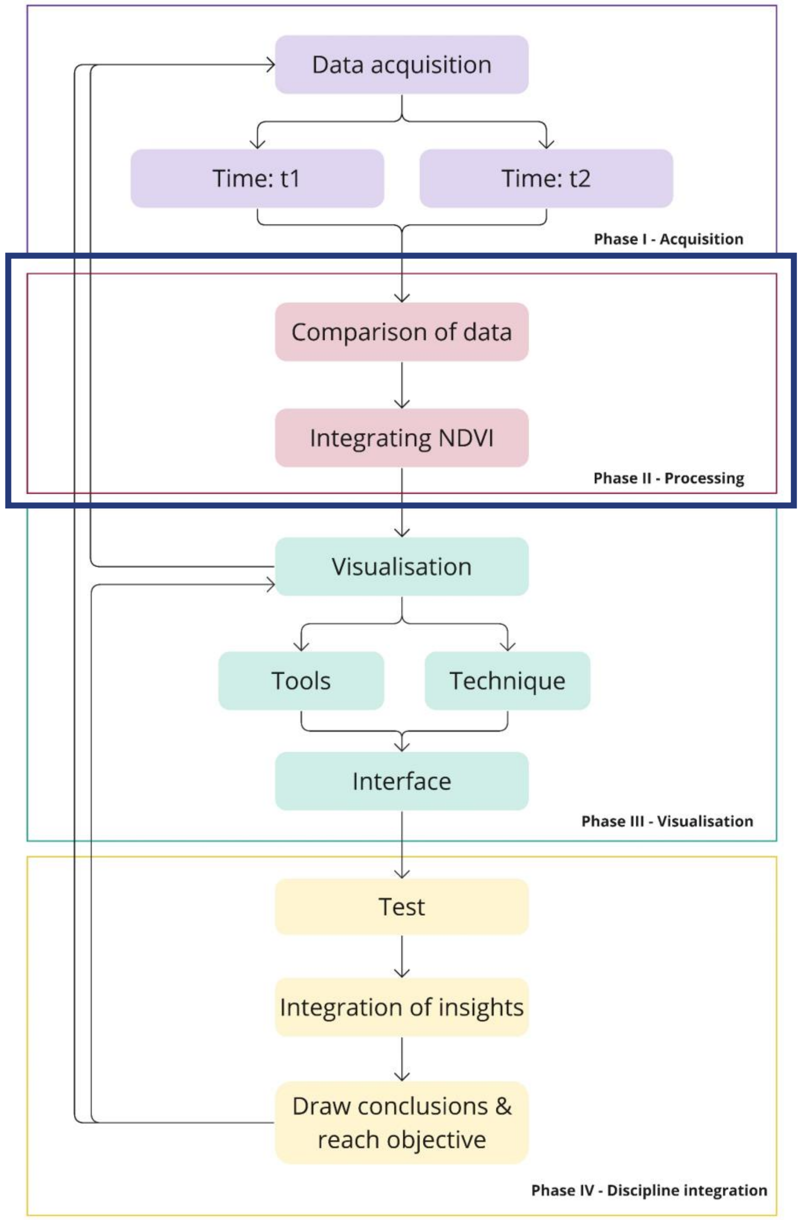
T1 ←→ T2

Step 1: Change detection

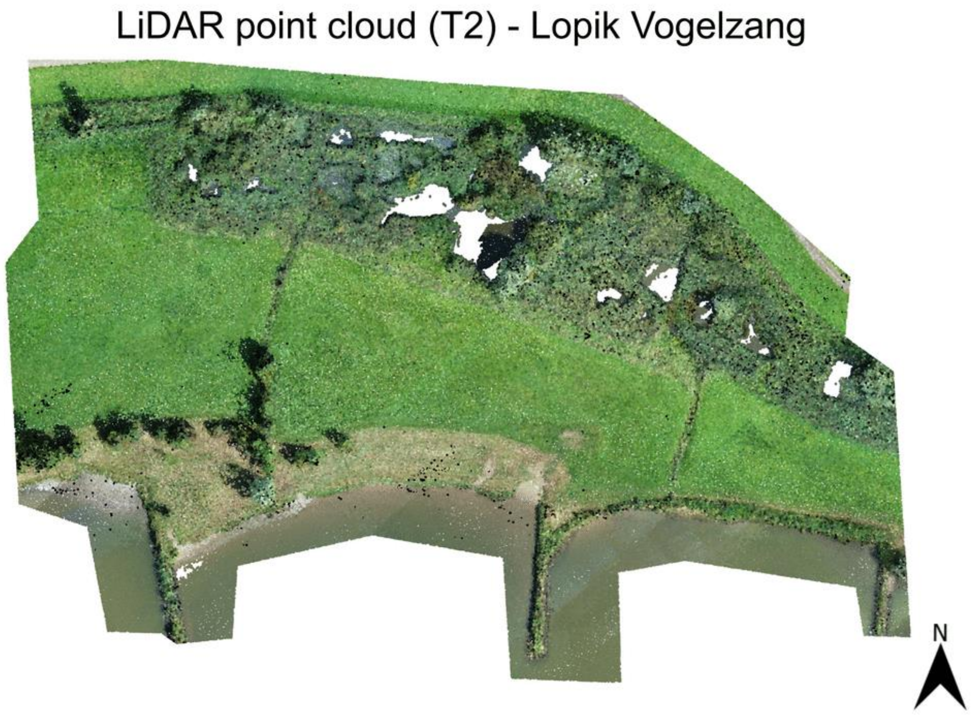
- Change detection between both T1 and T2 point cloud

Step 2: Data integration

- Integrating NDVI in point clouds



Data Processing - Change detection



Animation 2. RGB point cloud (T1 & T2)

Cloud-to-Cloud Distance (C2CD) – CloudCompare [4, 5]

→ Computes Euclidean distance by nearest neighbour pairs

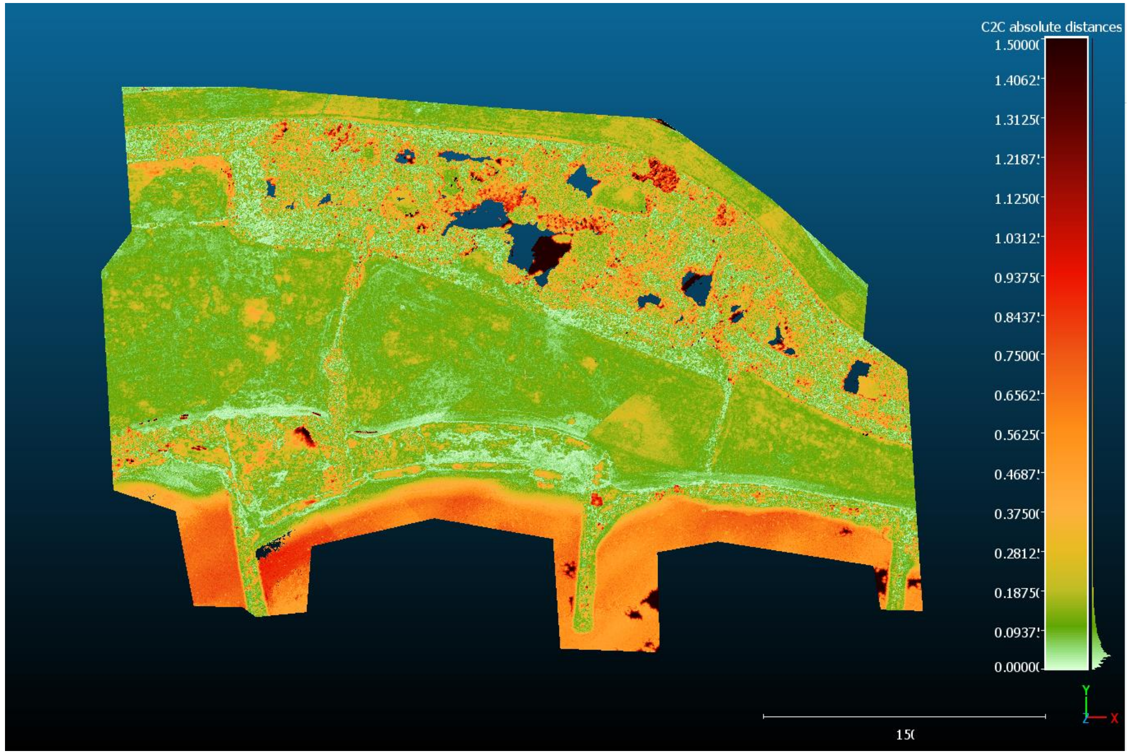


Figure 20. Cloud-to-cloud distance point cloud

Data Processing
- NDVI integration

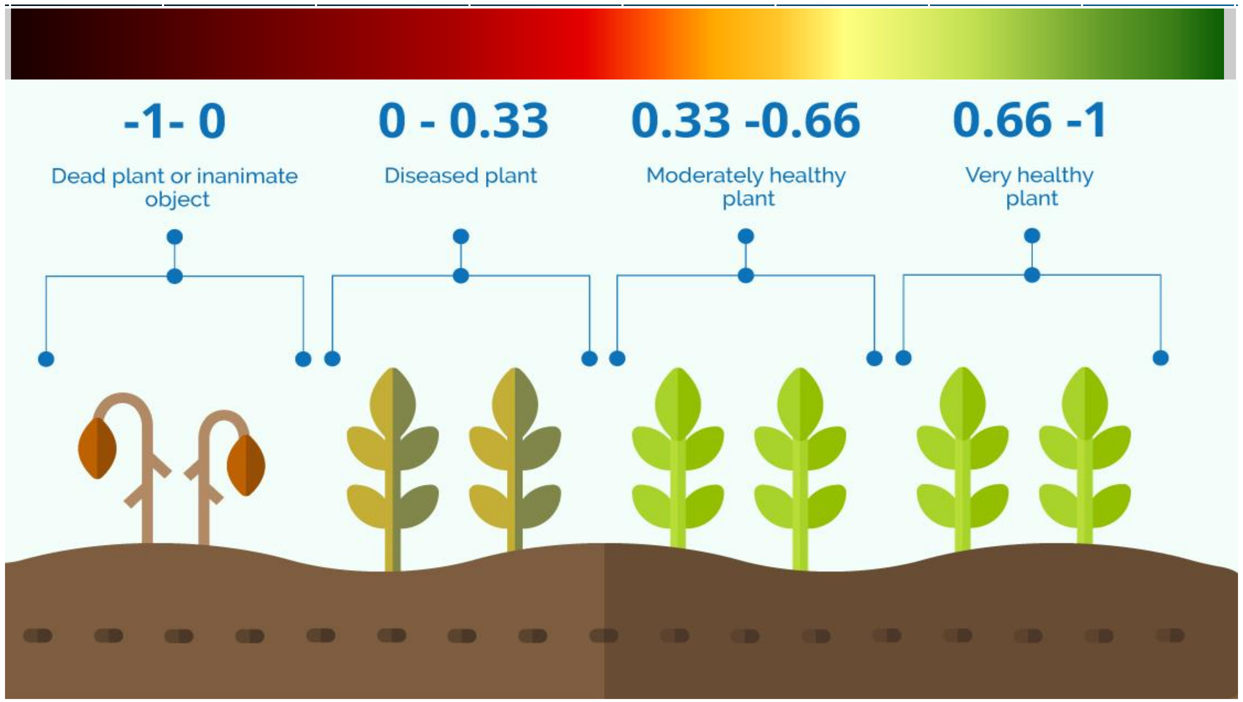
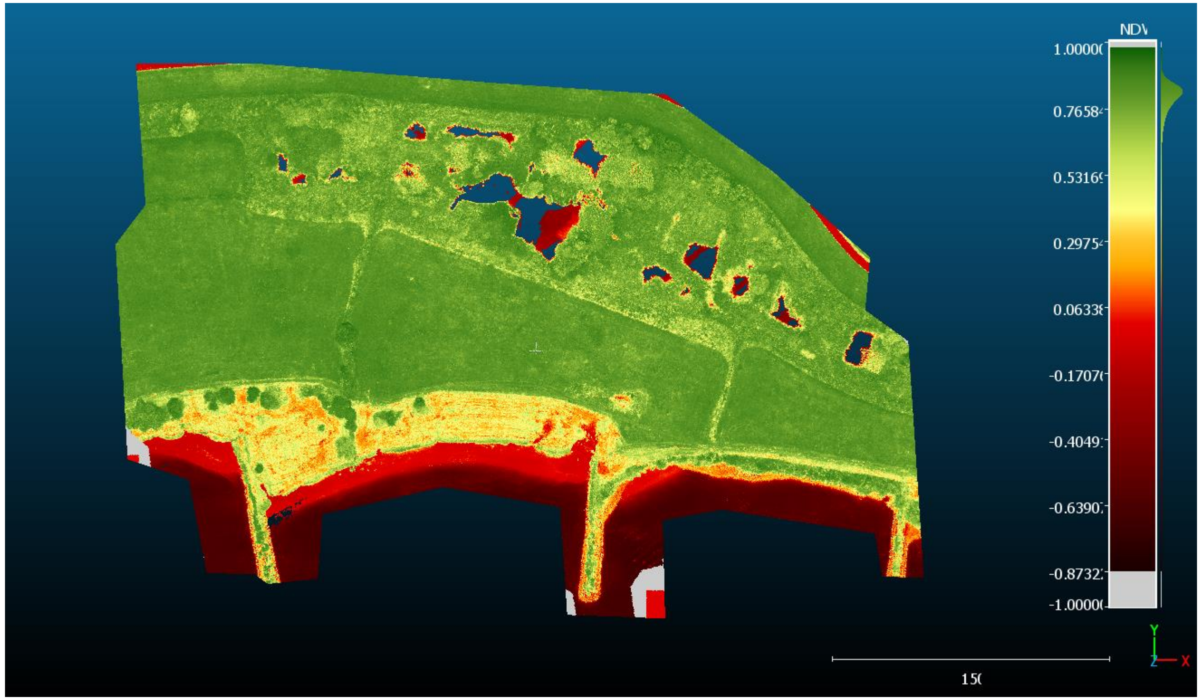
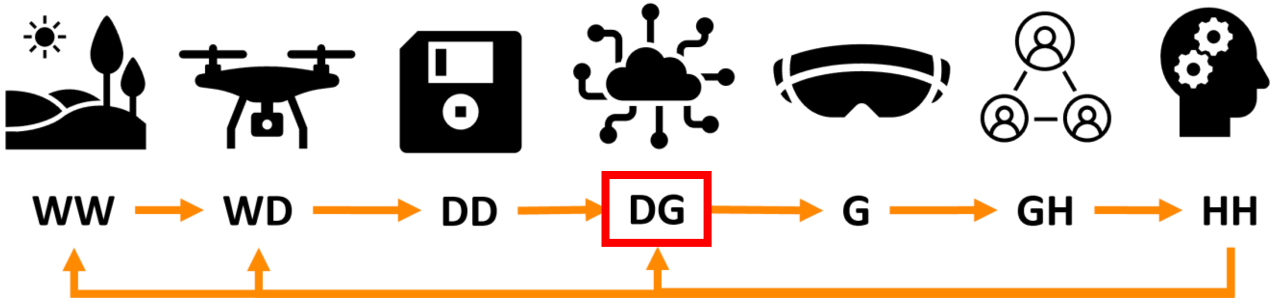


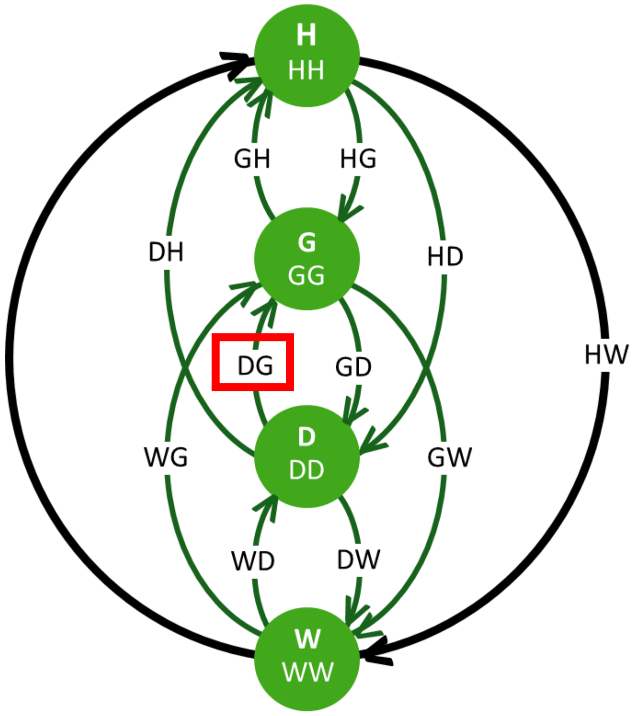
Figure 21. NDVI ranges of the color scale[9]



Figuur 22. NDVI point cloud (T2)

Phase III – Visualisation

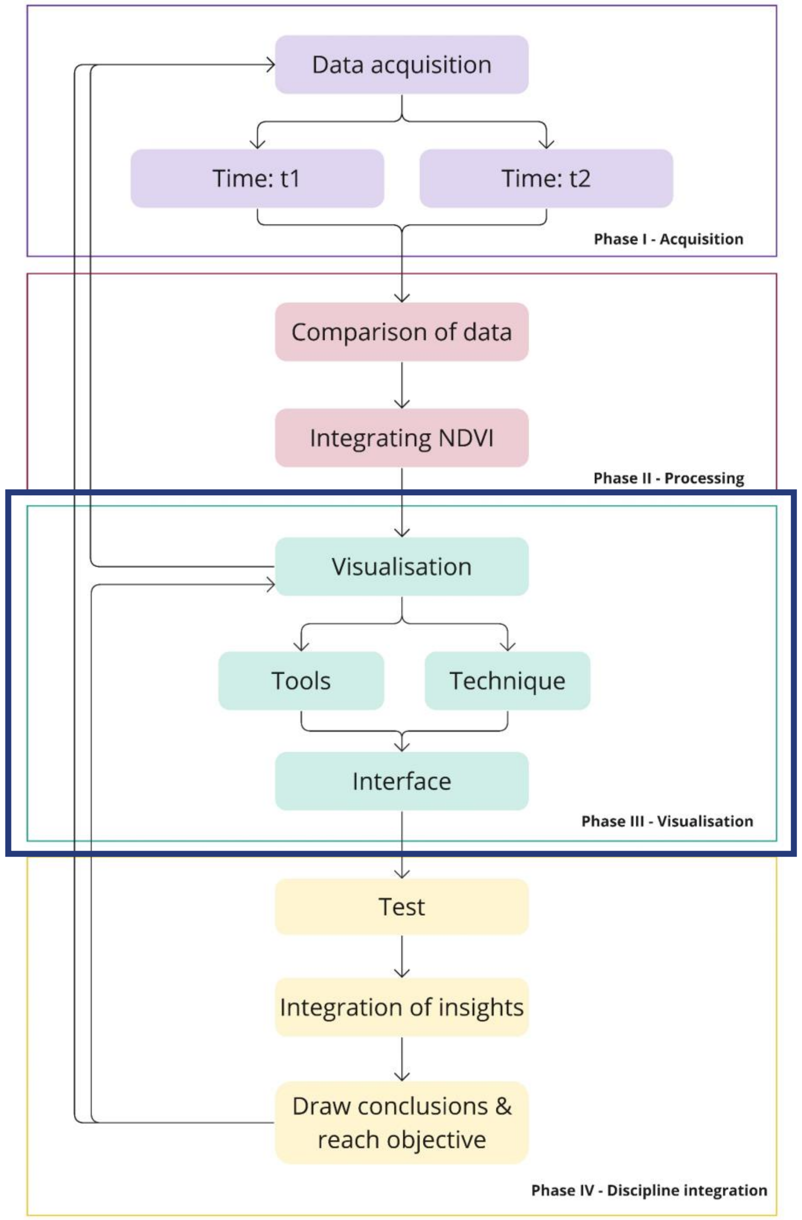




Phase III – Visualisation

Step 1: Interface
- Setting up the VR headset
- Pre-testing tools (zooming, rotating, filtering)

Step 2: Integrate data
- VR Sketch via SketchUp



Visualisation - Interface

- VR headset – Meta Quest Pro

Figure 23. Meta Quest Pro VR headset [10]

- VR Sketch: SketchUp plugin
  - Zoom, rotate, navigate
  - Filter and hide points
  - Number and size of the points displayed
  - Draw & highlight within point cloud
  - Switch between attributes (RGB, C2CD, NDVI)

Figure 24. Setting up VR headset

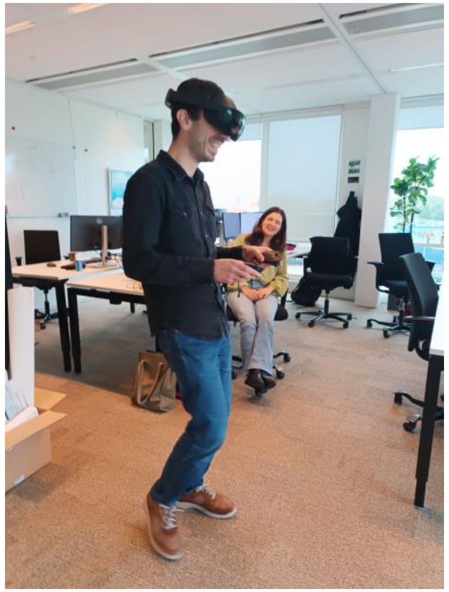
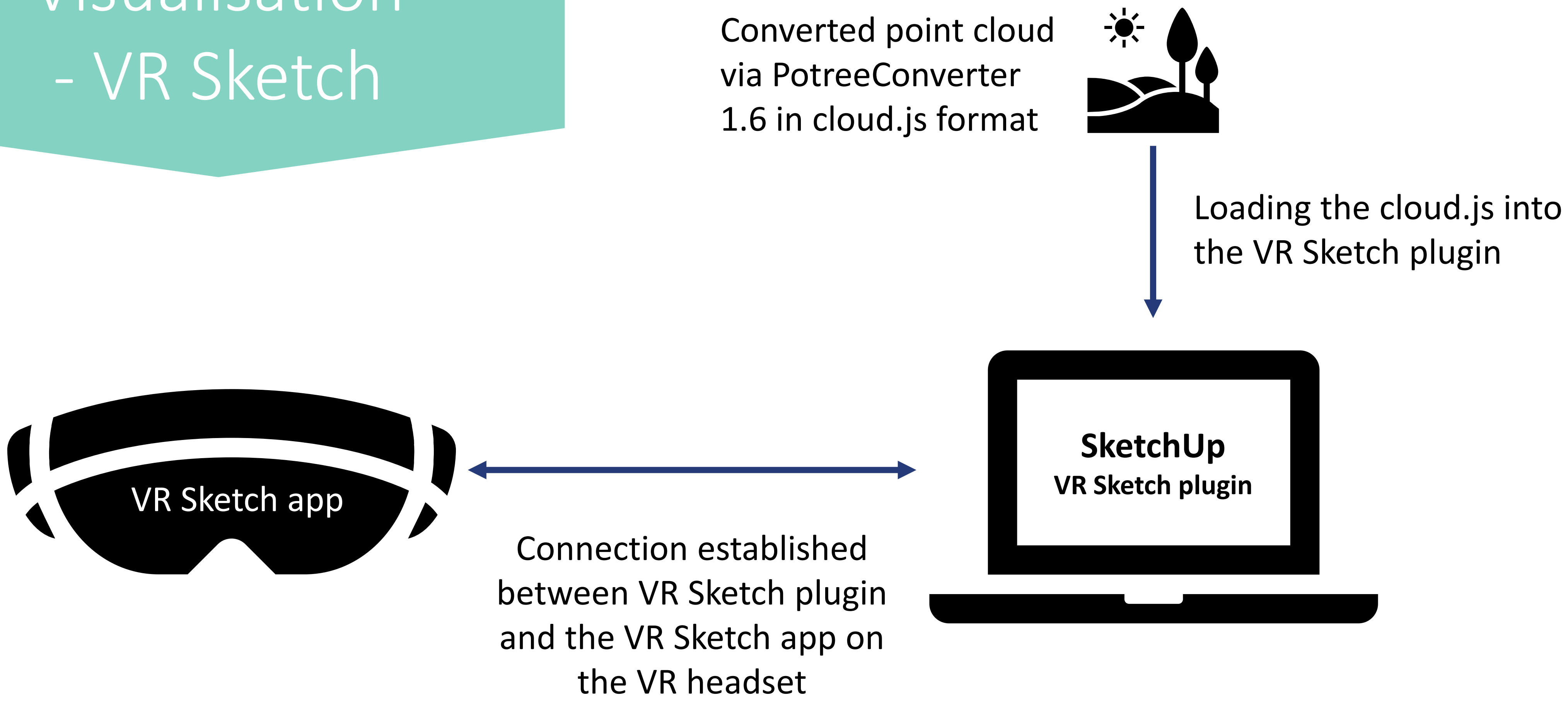


Figure 25. Testing VR headset

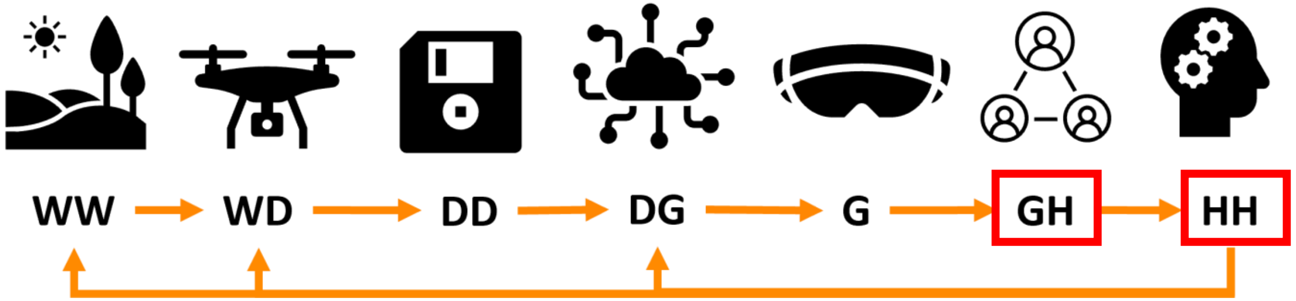
Figure 26. RGB point cloud in VR headset

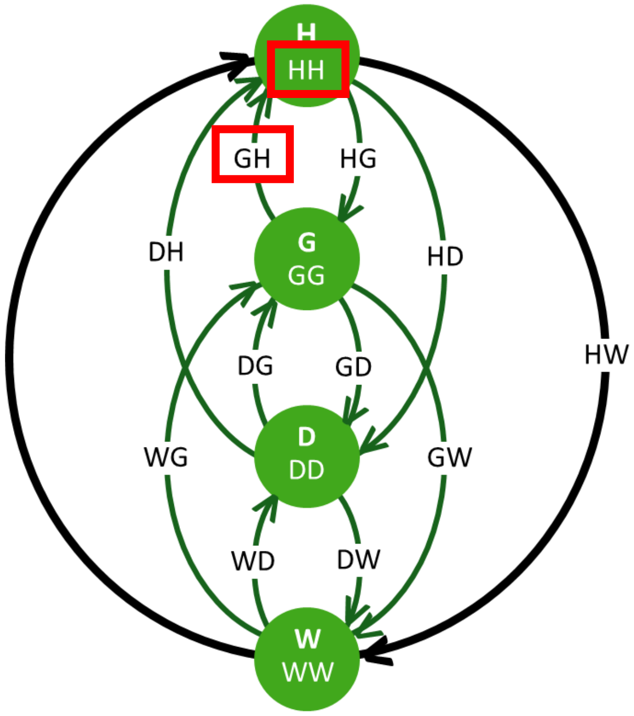
Visualisation - VR Sketch



Overview of loading point cloud data on the VR headset with the VR Sketch app

Phase IV – Discipline integration



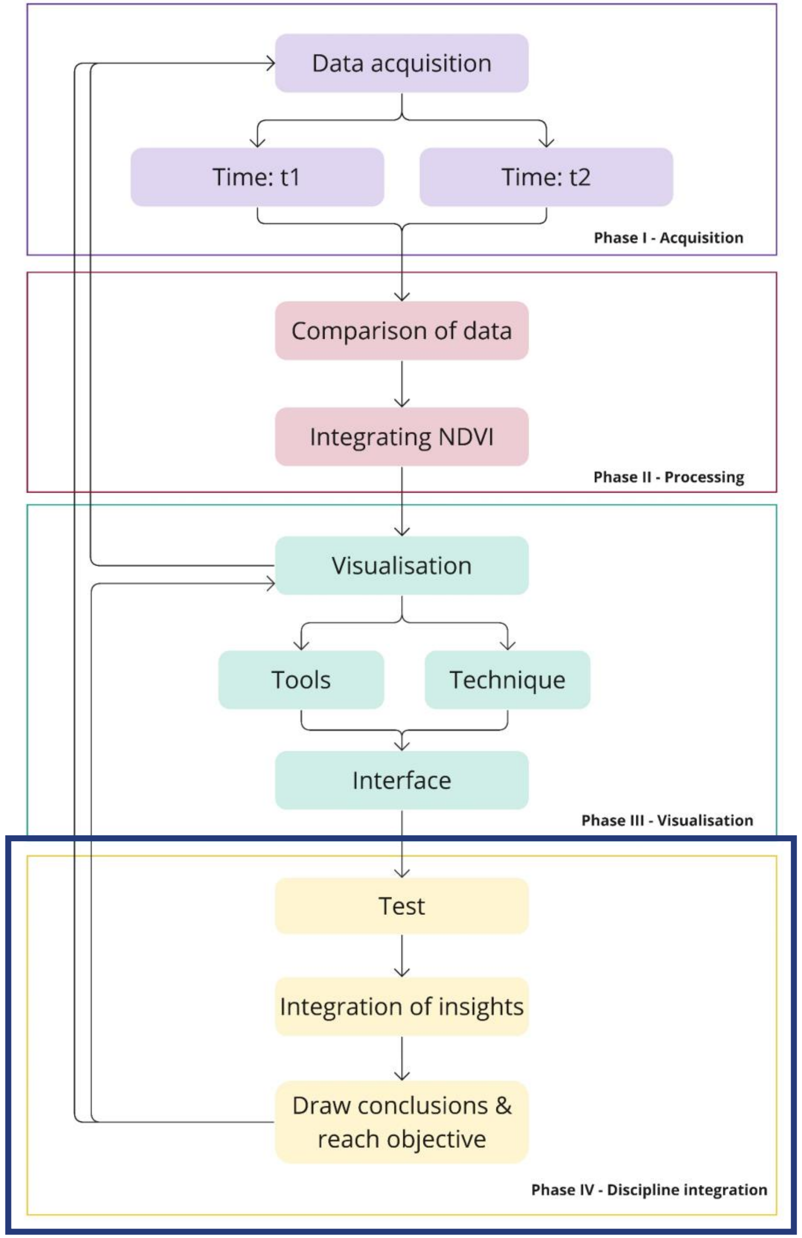


Phase IV – Discipline integration

Step 1: Testing visualisation
- Involved disciplines
- Visualisation
- Interview questions

Step 2: Integration of insights
- Analysis of human interaction

Step 3: Reach objective



Discipline Integration - Disciplines

Disciplines

Work Planner Civil and Water
Asset Management
Superintendent Green
Nature Development
Technical manager
Operational environmental manager
Area specialist
Strategic asset manager
Project manager
Project manager Civil and Water
Complaints Advisor
System Engineer

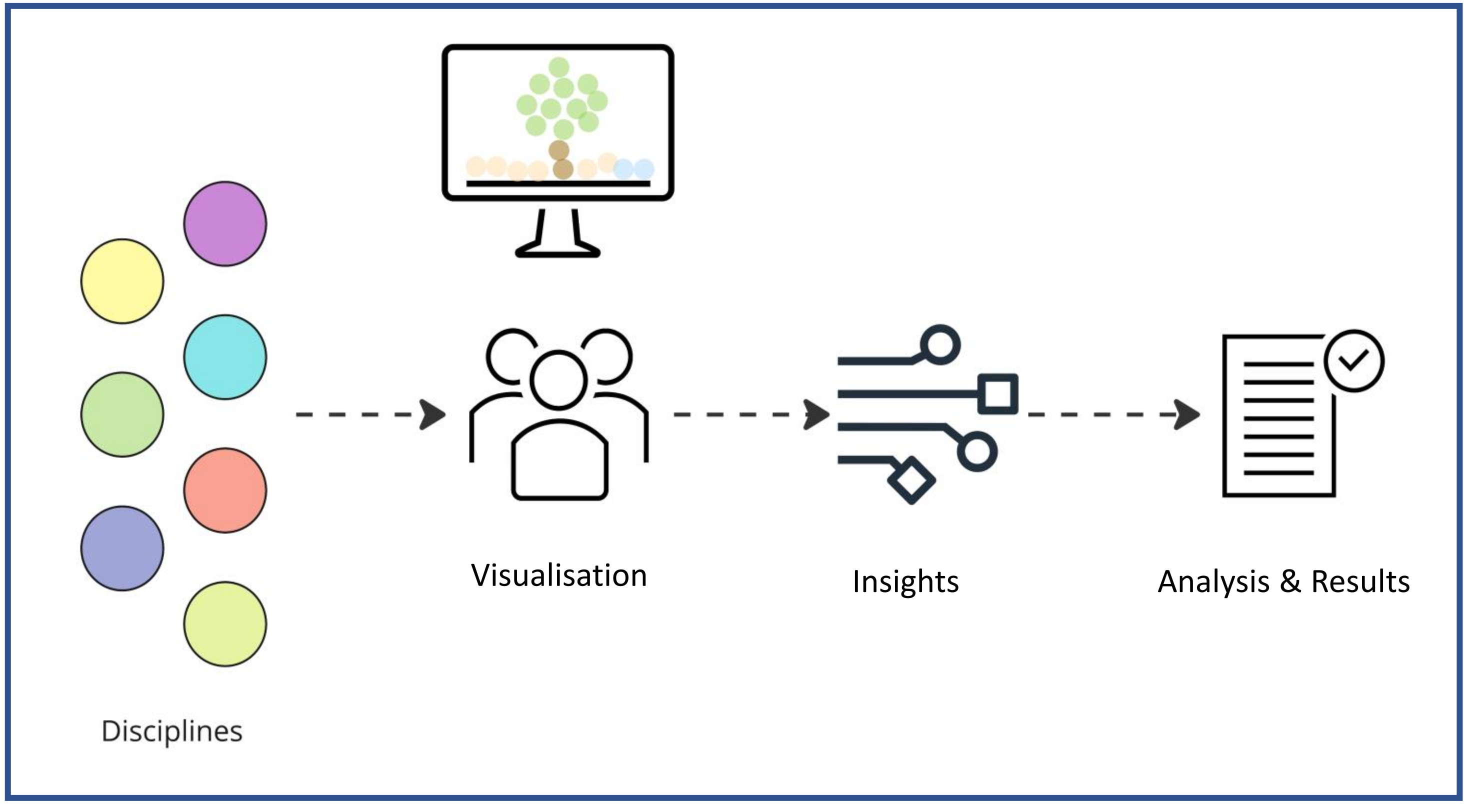


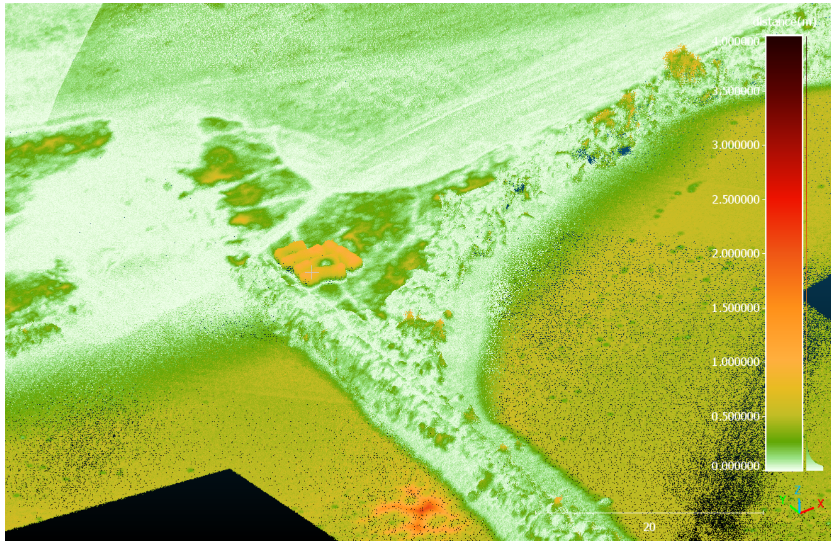
Figure 27. Overview of discipline integration

Discipline Integration - Visualisation

RGB point cloud

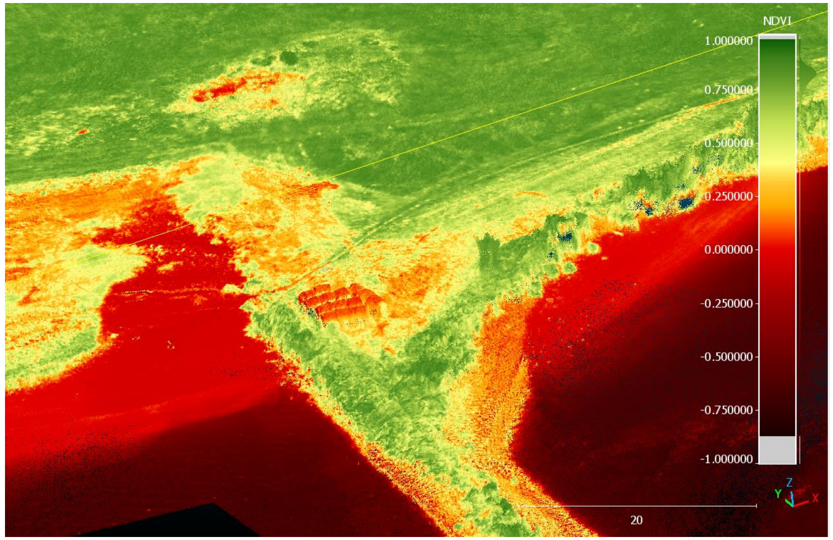
Figure 28. RGB point cloud

Distance point cloud



Figuur 29. Cloud-to-cloud distance point cloud

NDVI point cloud



Figuur 30. NDVI point cloud (T2)

Discipline Integration - Testing

Participant with the VR headset on

Video 2. Participant with VR headset

Streamed visualisation from the VR headset

Video 3. Streamed visualisation

Results

Results

*What is the **quality** of the acquired data?*

Sub-Question

Table 4. Quality assessment of the acquired data

	LiDAR data (Zenmuse L1)	Multispectral data (Phantom 4)
Accuracy	5 cm (vertical), 10 cm (horizontal)	3 cm
Resolution (spatial, temporal, spectral)	Spatial: 1200 points per m^2 Temporal: 45 days (between T1 and T2) Spectral: RGB (integrated)	Spatial: 3 cm GSD Temporal: 45 days (between T1 and T2) Spectral: Red, RedEdge, Green, Blue, RGB, NIR
Consistency	Wind speed: 5 km/h - North East	Wind speed: 10 km/h - North East
Completeness	Same extent	Same extent
Quality	✓	✓

Results

*What is the most **optimal threshold** for attributes in visualising changes in explorative point clouds?*

Sub-Question

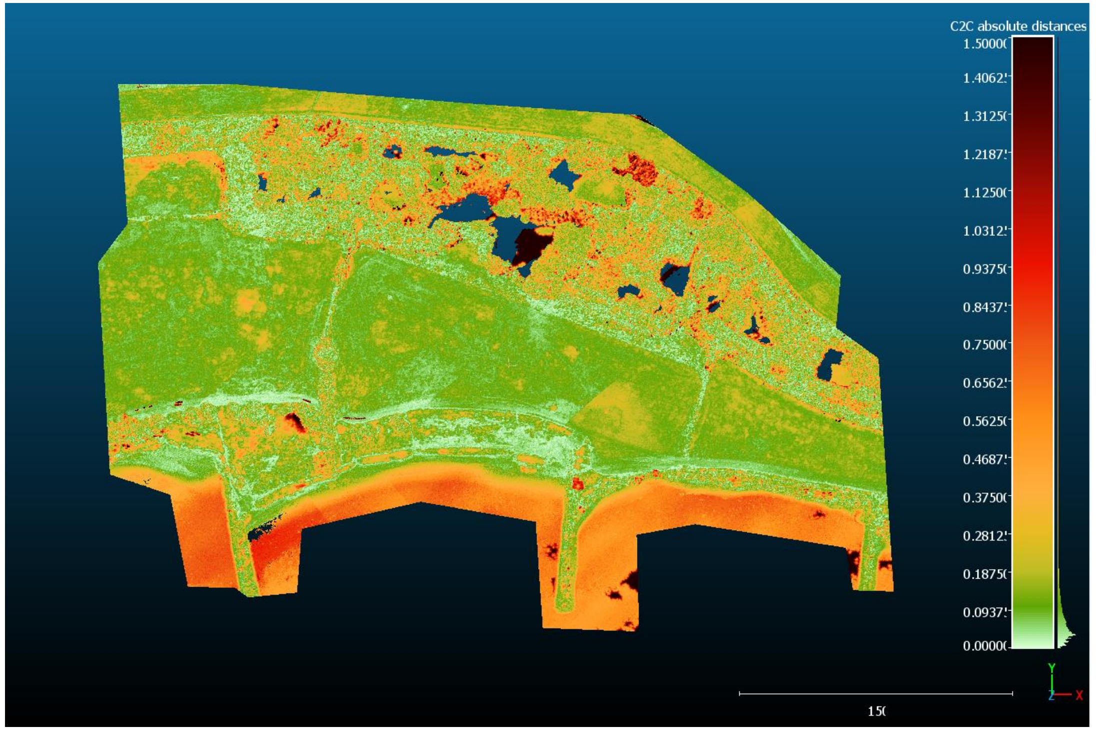


Figure 31. Cloud-to-cloud distance point cloud with optimal threshold of 1.5 meter

Set maximal distance to 1.5 meter

- Distribution of C2CD
- Time frame of 45 days
- Validated by different GIS experts

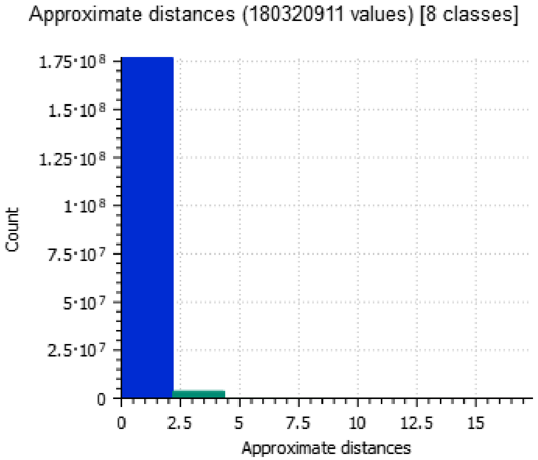


Figure 32. C2CD distribution (0-15 meter)

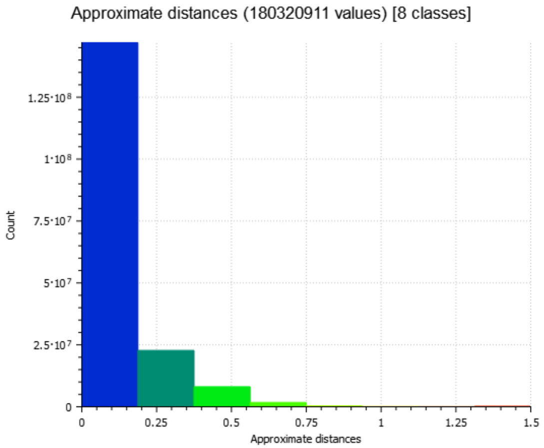


Figure 33. C2CD distribution (0-1.5 meter)

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Results

*What are the **potential applications** of explorative point clouds for different disciplines in floodplain maintenance?*

Sub-Question

Table 5. Insights on the added attributes of the explorative point cloud

RGB	Cloud-to-cloud distance	NDVI
Participation tool for stakeholders	Detecting bank erosion	Attenuation of a natural area
Detailed model of reality	Vegetation overgrowth	Assessment of flora status
Preparation of work activities	Controlling work activities	
Plot boundaries in 3D		
Limited view solution		
Digital remote site inspection		

Results

*What is the **most suitable attribute** to provide insights into changes in explorative point clouds for floodplain maintenance?*

Sub-Question

Figure 34. Screenshot of RGB point cloud within the VR headset

RGB point cloud

- Realistic 1-to-1 model
  - Preparation of work activities
  - Inspection of area
  - Participation of stakeholders

Potential iterations:

- Linking vegetation layer -> coarsening of vegetation
- Classification of vegetation types/species

Limitations

- Battery constrictions
- Wind conditions
- Temporal resolution
- Distortion multispectral sensor
- Computer memory
- VR headset (interruptions)
- Size of participants group

Conclusion

To what extent are explorative point clouds, generated from raw UAV-LiDAR data, useful in providing insights on change detection for floodplain maintenance?

Main Research Question

This thesis highlights that an explorative point cloud can thus be seen as **a chameleon, acting as a versatile tool within floodplain maintenance projects**, making raw LiDAR data, which is often underused, **a valuable resource**.

Future Research

Validation use cases	Coarsening of vegetation -> roughness index	Cost-benefit analysis	Upscaling challenges	Extent time interval
Expanding size and variety of participants group	Influence of visualization method	Toolset in VR Sketch	Weather conditions -> correction	Explorative point clouds in other projects

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Q&A

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