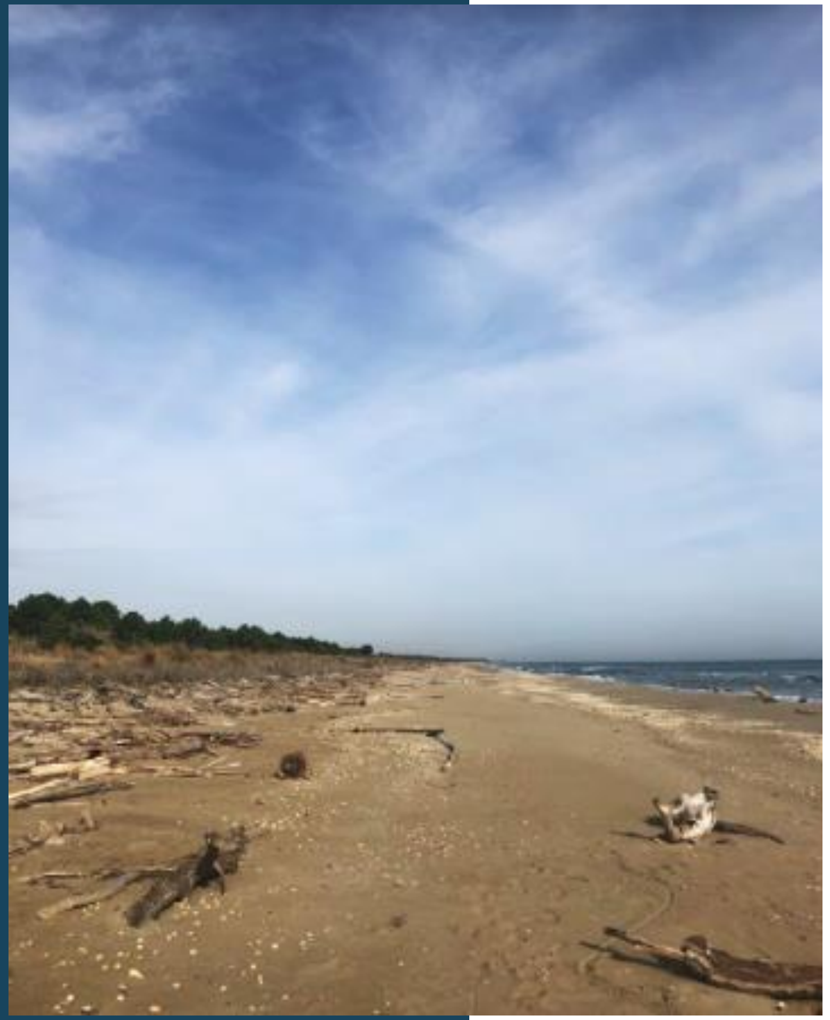
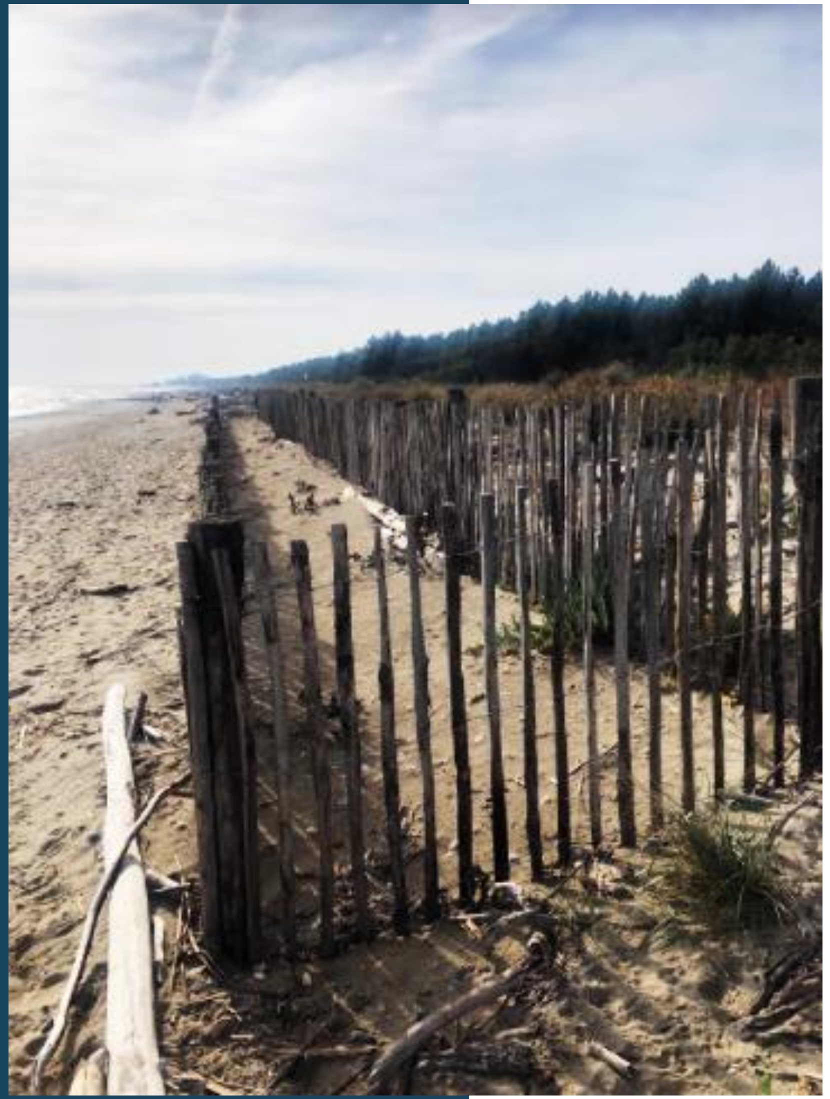




Using UAV topographic surveys for monitoring geomorphological evolution and restoration of the dune belt in Ravenna (Northern Adriatic Coast, Italy)

Regine Anne Faelga, Beatrice Maria Sole Giambastiani, Luigi Cantelli
Biological, Geological and Environmental Sciences Department, University of Bologna, Italy

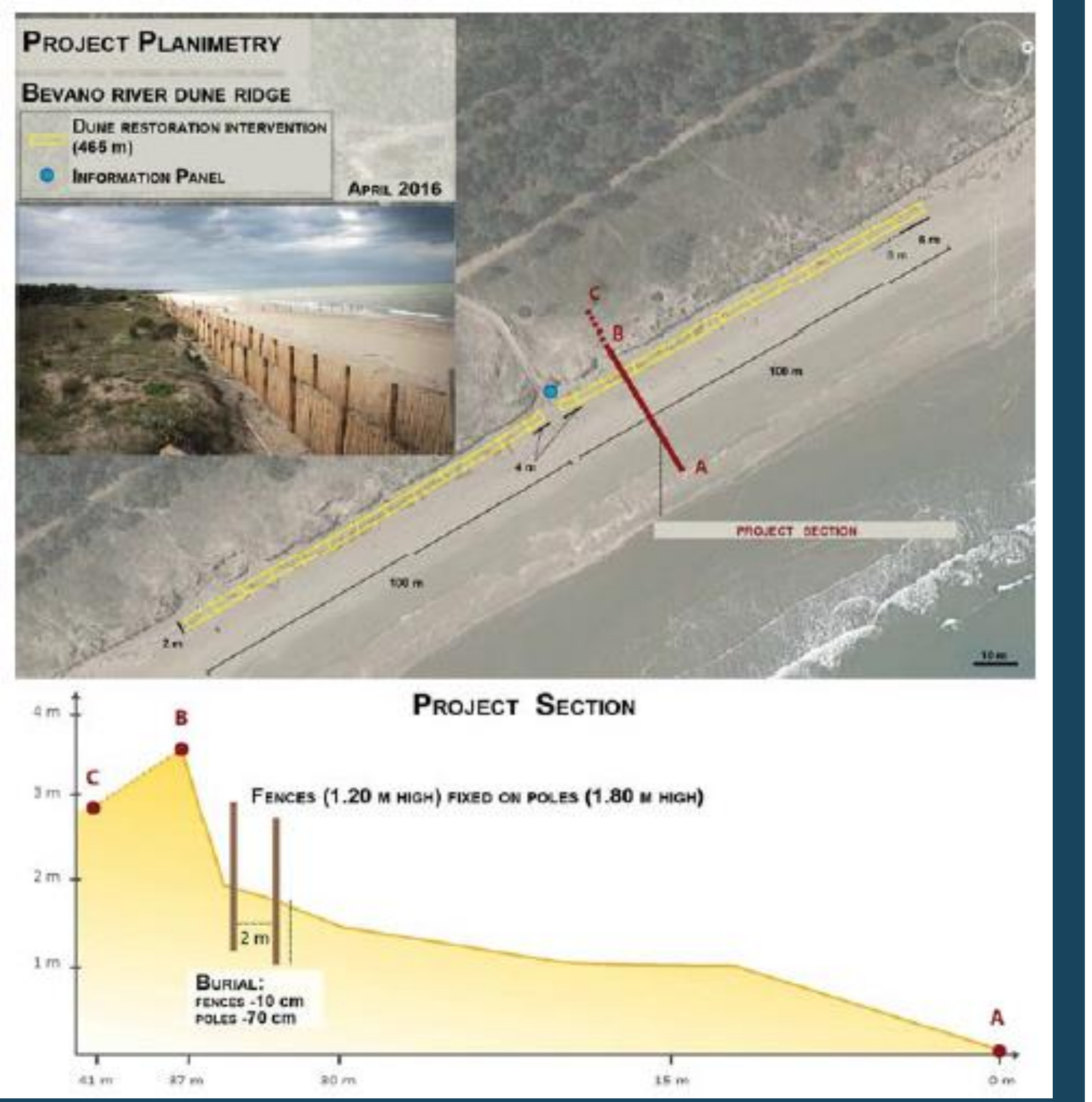
24 May 2022
Vienna, Austria

wacoma
Erasmus Mundus Joint Master Degree

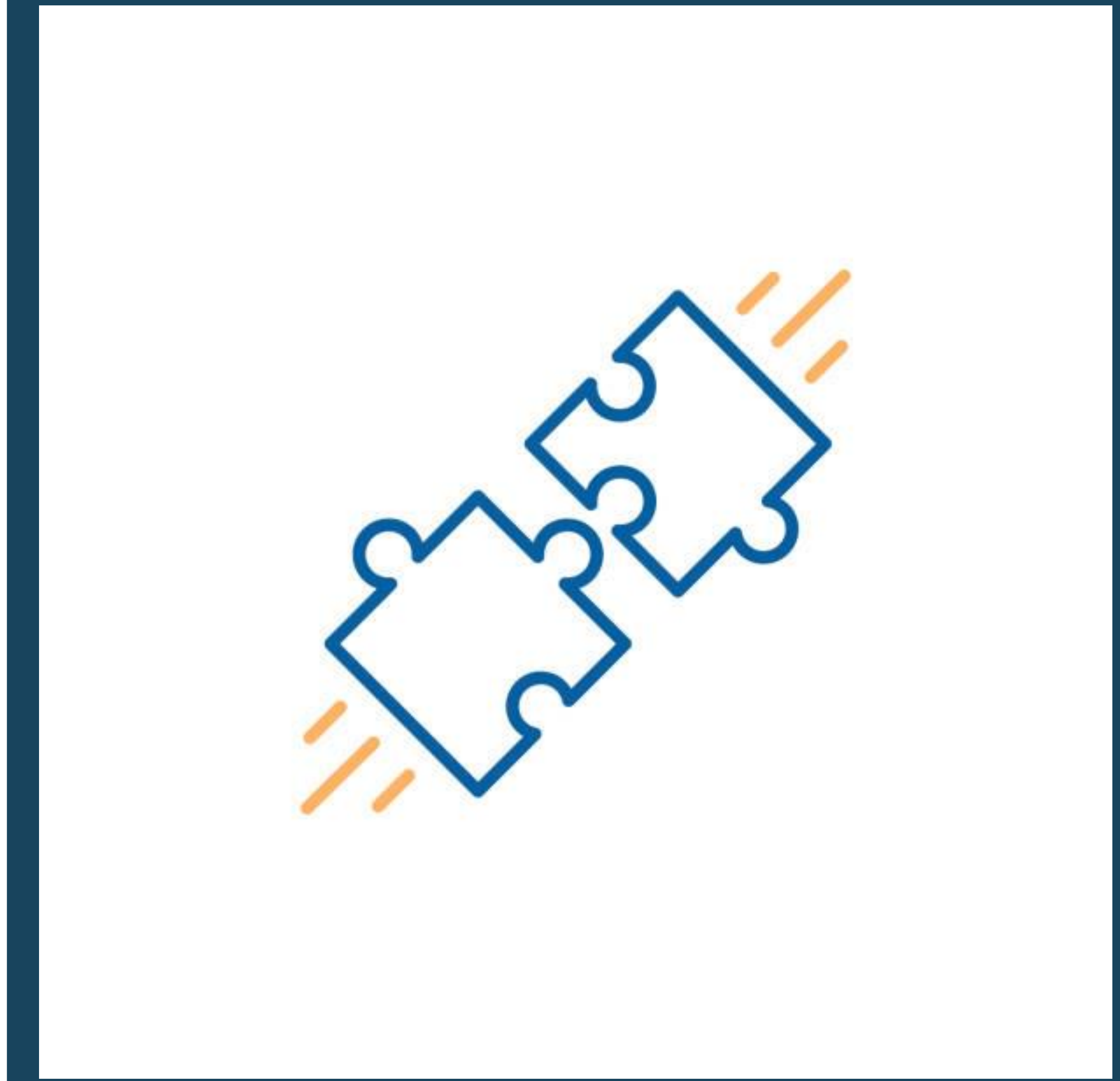
ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Erasmus Mundus

Perini et al., 2016



Giambastiani et al., 2016



www.istockphoto.com

Issues

Shore instability due to several morpho-dynamic factors (elev below MSL, natural subsidence)
Perini et al., 2016

Associate risks & exposure to hazards

widespread coastal erosion, seawater intrusions related to SLR, storm surges & land subsidence due to added human pressures and underground exploitation

Restoration

In 2016, installation of 2 windbreak wooden fences in front of the dune foot and parallel to the coast

stop wind, facilitate sand deposition & accumulation, favor embryo dune formation, prevent sand loss toward the inland (Giambastiani et al., 2016)

Gaps

Availability of repeat topographic surveys after installation → monitoring restoration efficacy

Establishing the added value of soft-engineering solutions could provide support for ICZM guidelines, DRR plans, and coastal system protection in Ravenna (Scarelli et al., 2017; Fernández-Montblanc et al., 2020)

Informed decision from quantitative data analysis using the proposed SfM & GCD approach

OBJECTIVES

Analyze the geomorphological changes from 2016 to 2021 using SfM* & GCD**

Establish a systematic workflow for dune evolution analysis using SfM & GCD

Validate the accuracy of the elevation & change detection models

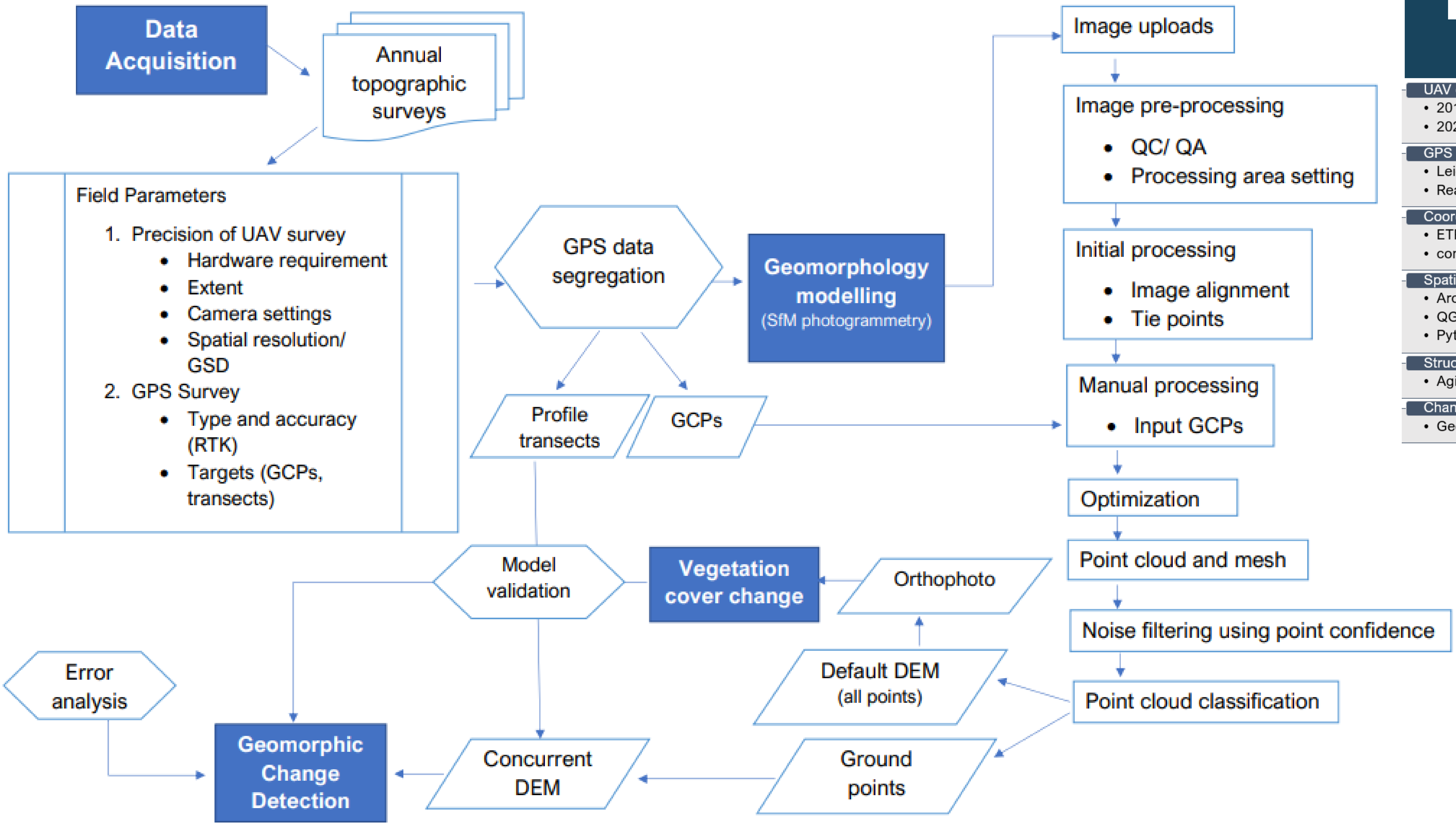
Assess the vegetation change using SfM-derived orthophotographs

* Structure from Motion

** Geomorphic Change Detection

METHODS

Methodological Framework



UAV drone images
- 2016 - DJI FC300X
- 2021 - DJI FC7203

GPS
- Leica DGPS (Viva GNSS GS15 GPS)
- Real Time Kinematic (RTK) system

Coordinate system
- ETRS 89 UTM Zone 32N
- conversion tool: ConveRgo_ge

Spatial analysis & mapping
- ArcMap 10.6.1
- QGIS Desktop 3.22.4
- Python 3.9

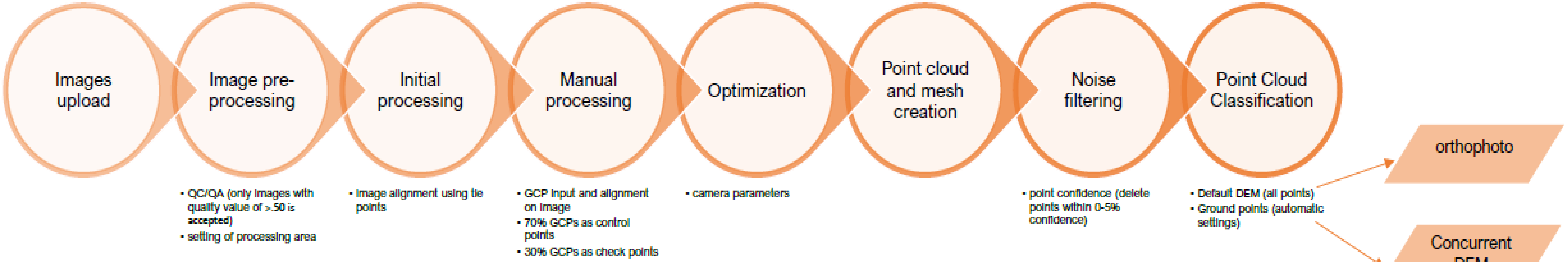
Structure from Motion photogrammetry
- Agisoft Metashape Professional 1.7.4 build 12898

Change Detection
- Geomorphic Change Detection (GCD) Software, Riverscapes Consortium

Survey details
- October 26 2016 (S4)
- October 25 2021 (W4)

SfM

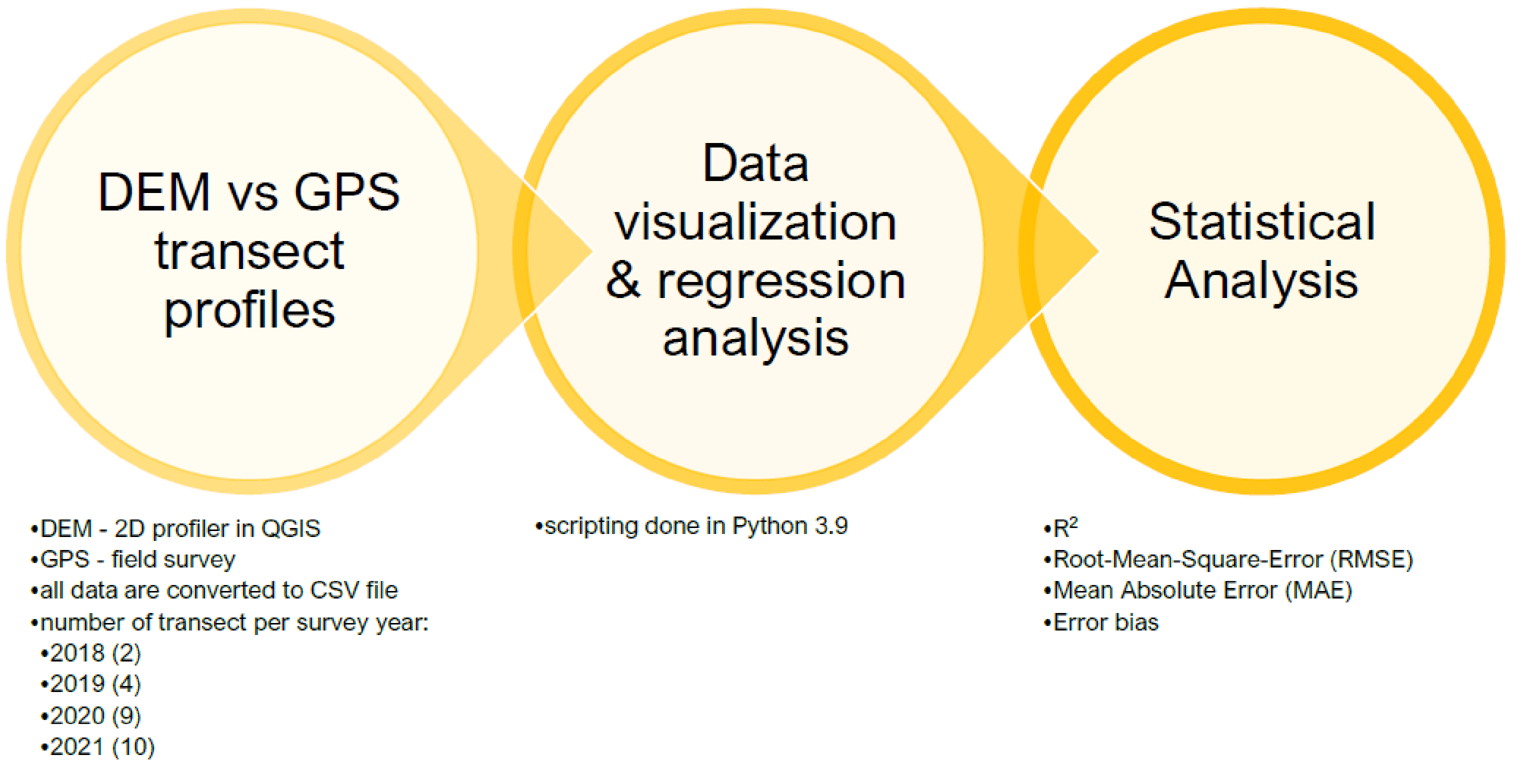
Agisoft LLC, 2021



DEM validation

METHODS

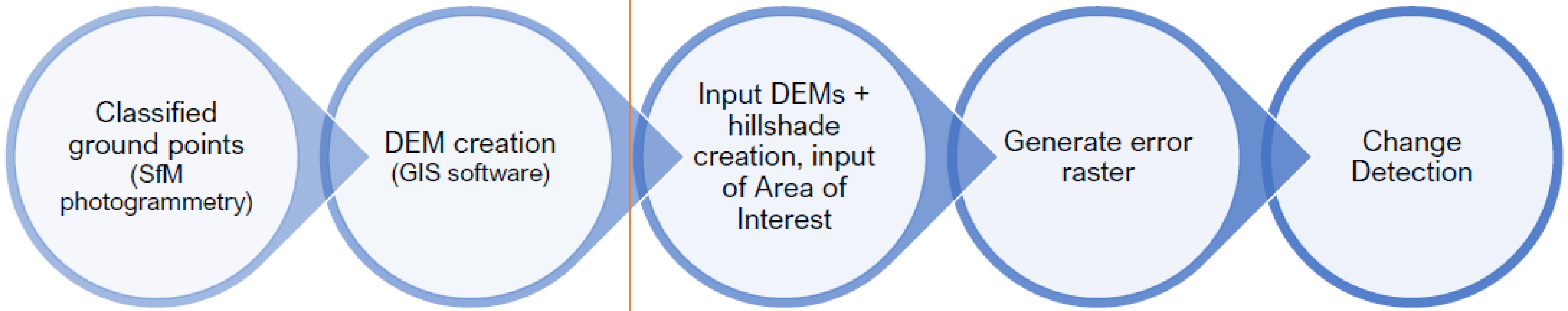
Workflows



METHODS
Workflows

Geomorphic Change
Riverscapes Consortium, 2021

Geomorphic Change Detection (GCD) toolbox



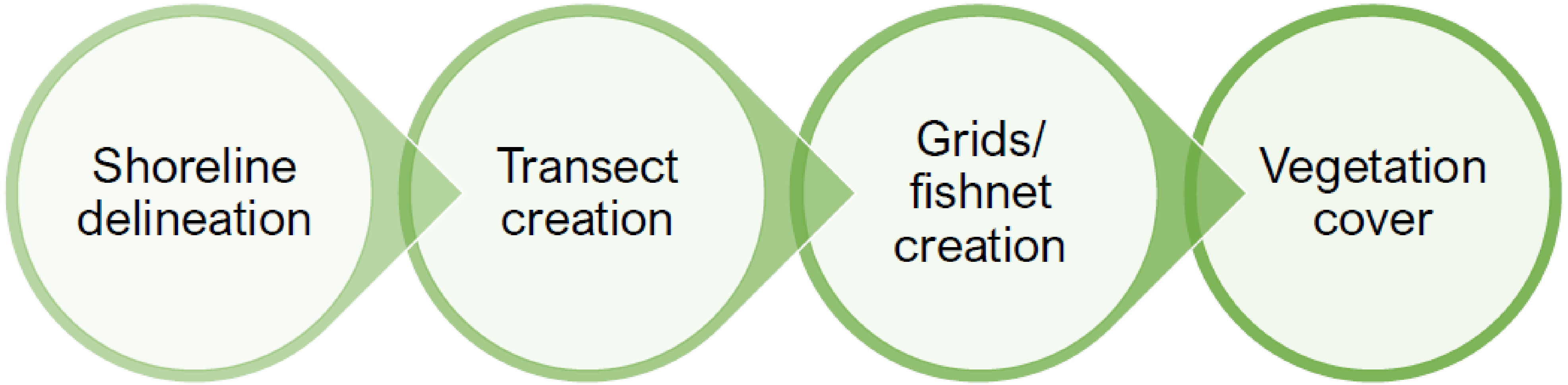
DEM creation (GIS software)
- LAS to Raster, **0.1m x 0.1m**
  - Value field: Elevation
    Interpolation type: Binning
    Cell assignment type: **Minimum**
    Void Fill method: Natural Neighbor
    Cell size: 0.1m
- **concurrency shapefile** (area extent) to ensure each raster cells are in exact same space

Input DEMs + hillshade creation, input of Area of Interest
- New and old DEM
- foredune to beach

Generate error raster
- Error Model - uniform error value applied across the entire surface
- **total error value of the control points from SfM**
- Oct 2016 - 0.046m
  Mar 2017 - 0.016m
  Jul 2017 - 0.086m
  Oct 2018 - 0.04m
  Oct 2019 - 0.039m
  Nov 2020 - 0.082m
  Oct 2021 - 0.032m

Change Detection
- AOI as the CD area
- Uncertainty Analysis
  - Probabilistic thresholding at 95% C.I.

Vegetation Change
Silvestri et al., 2020

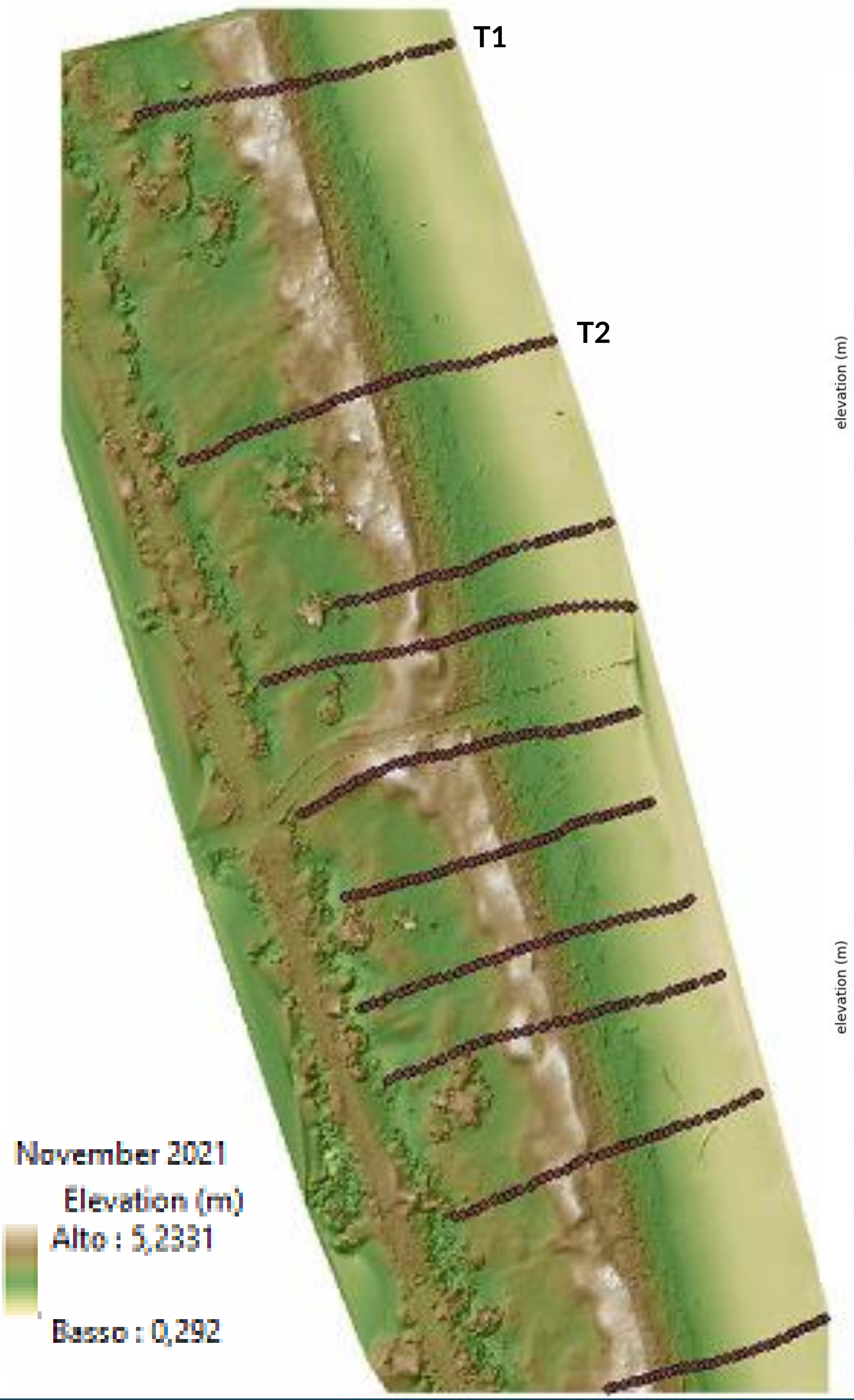


Shoreline delineation
- ISO cluster unsupervised classification of 2021 orthophotograph
- raster to polygon
- Majority Filter
- manual digitization

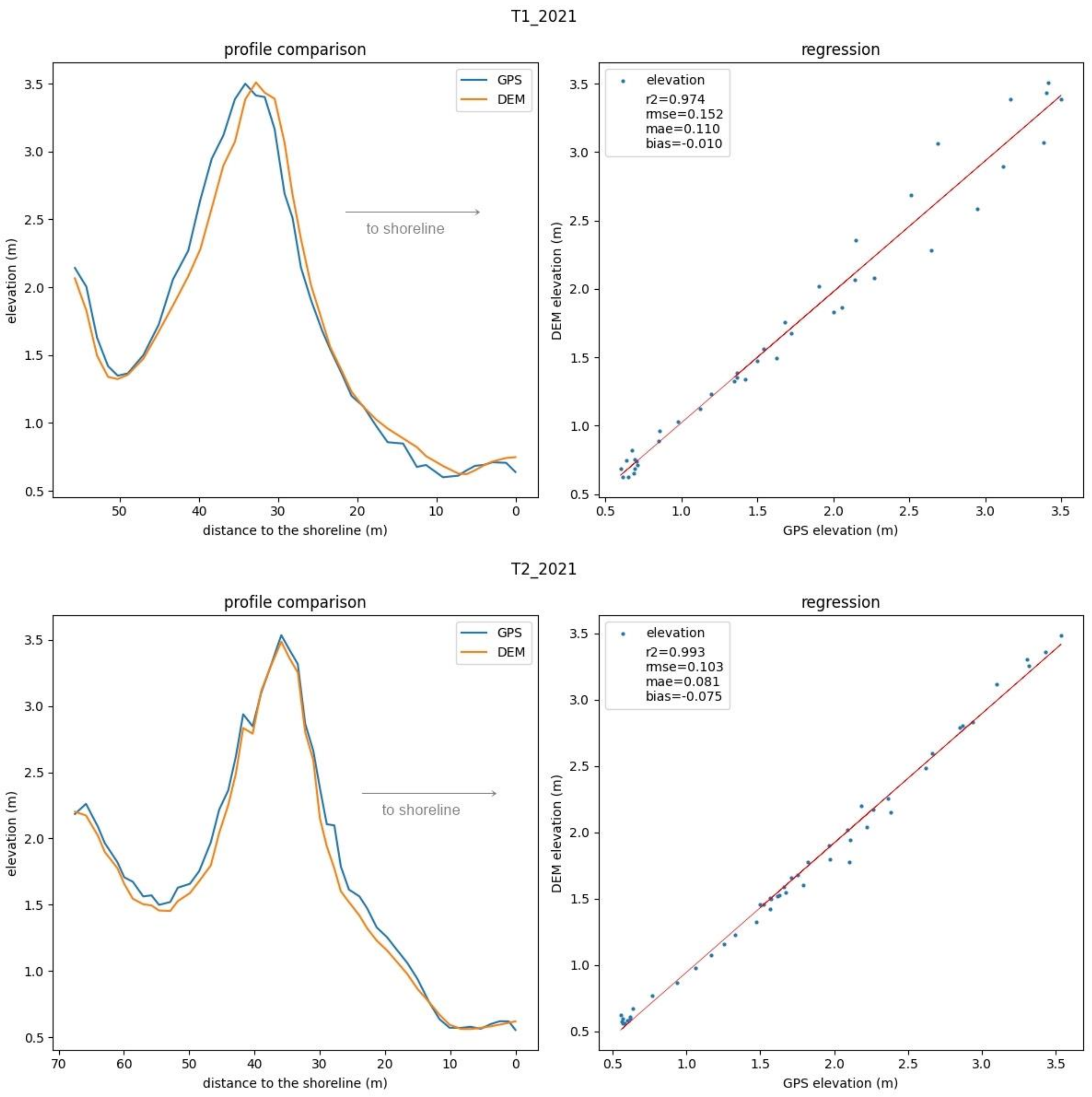
Transect creation
- location selection based on selected 2021 survey transects
- 60 m left of shoreline

Grids/ fishnet creation
- 1m x 1m based on transect location & length
- centroid creation from grids

Vegetation cover
- manual delineation of cover types using 2016 and 2021 orthophoto
- vegetation, logs, bare sand
- percent cover calculation per transect



2021

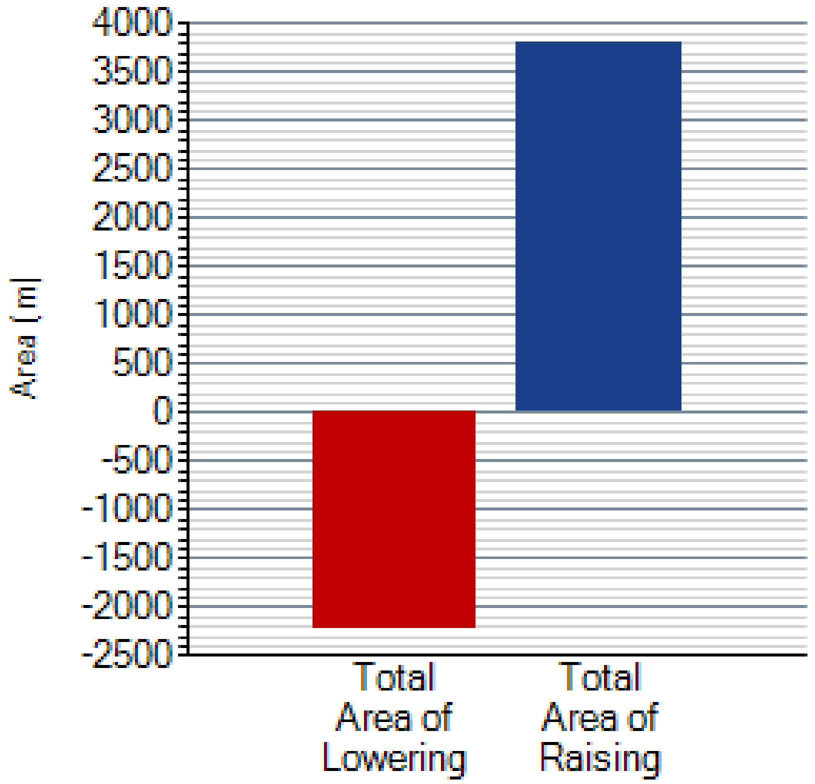


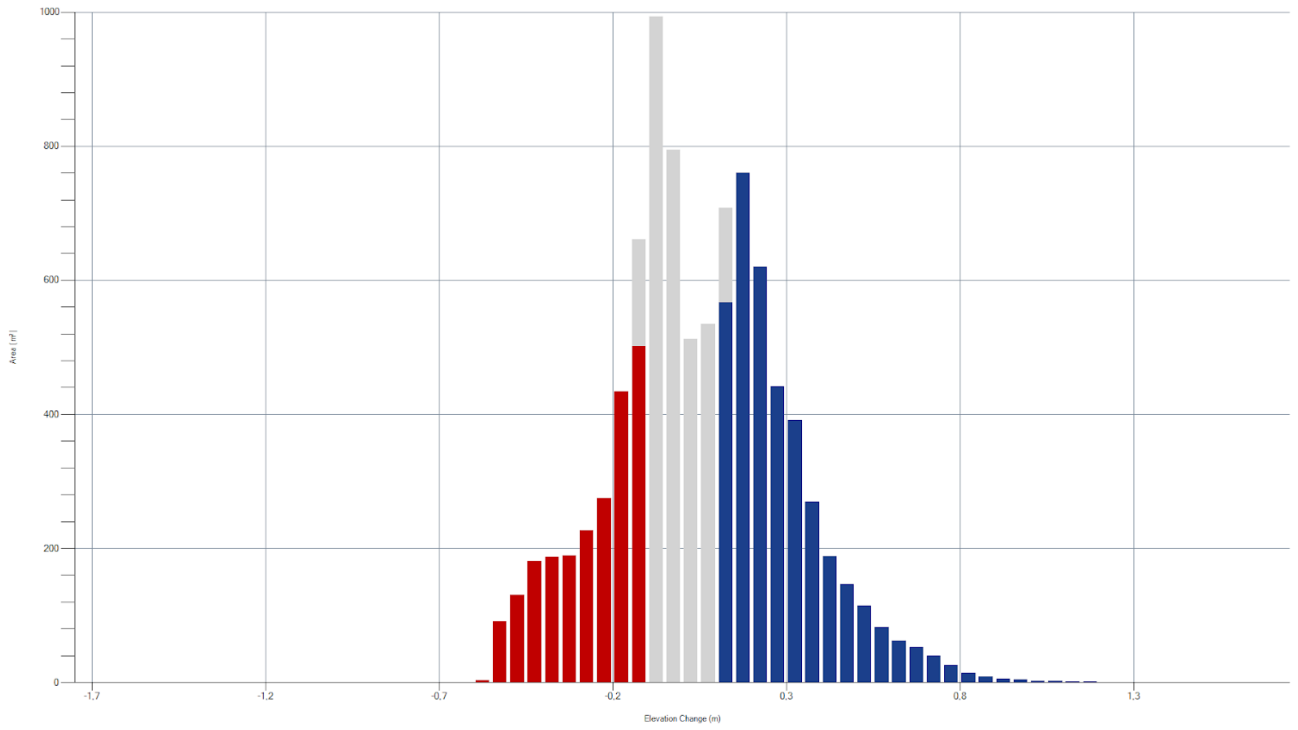
year	transect	r2	rmse	mae	bias
2021	1	0.974	0.152	0.110	-0.010
	2	0.993	0.103	0.081	-0.075
	3	0.985	0.102	0.069	-0.011
	4	0.963	0.162	0.109	-0.036
	5	0.992	0.098	0.072	-0.026
	6	0.987	0.095	0.077	-0.017
	7	0.978	0.130	0.097	-0.036
	8	0.977	0.130	0.103	0.014
	9	0.994	0.071	0.051	0.026
	10	0.998	0.071	0.057	0.051

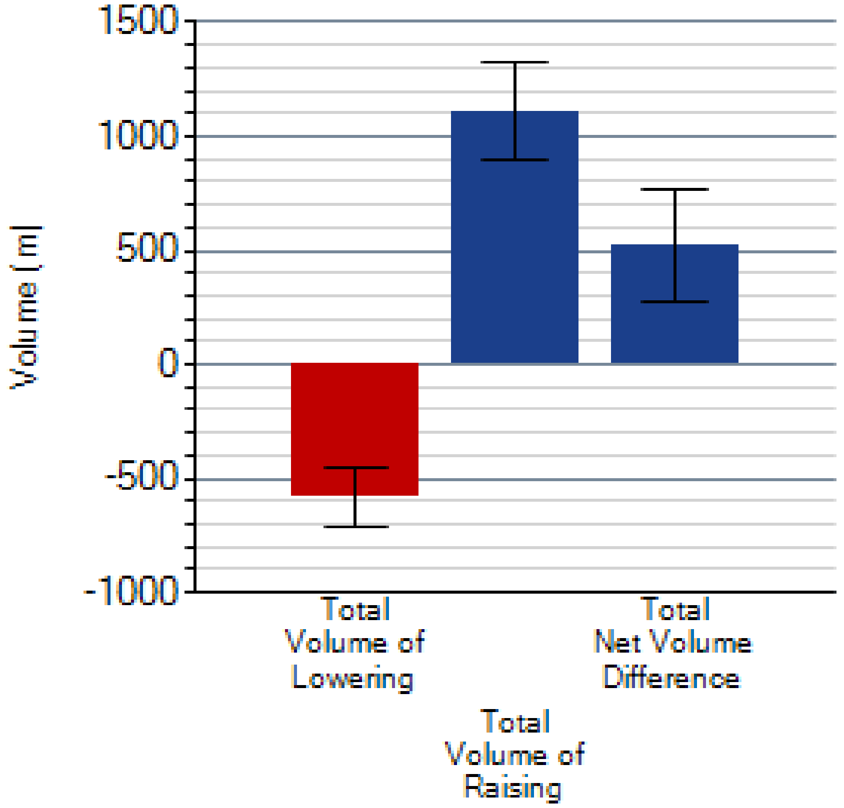
- R^2 and RMSE quantify how well the regression model fits in both percentage and absolute terms
- Mean Absolute Error (MAE) - measure of errors between paired observations
- Bias Error - the amount that the DEM elevation values differ from the GPS values

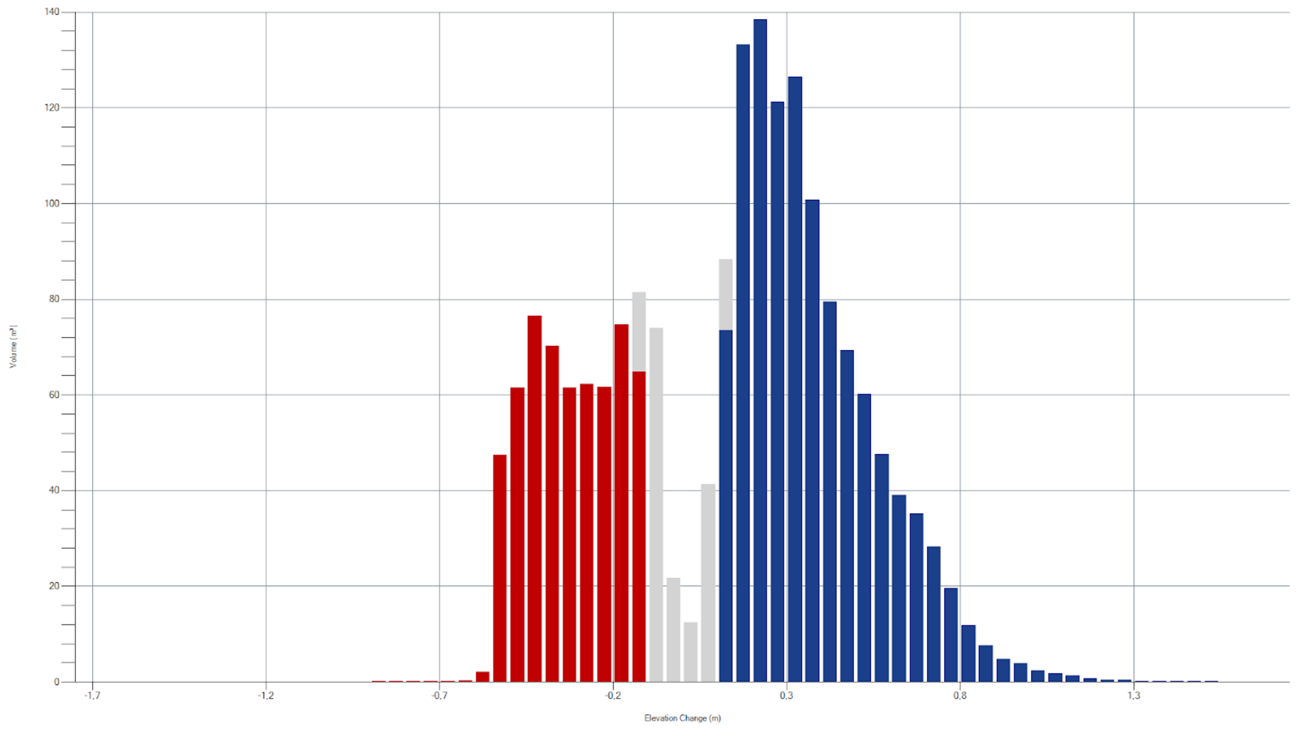
RESULTS

DEM validation – sample transects



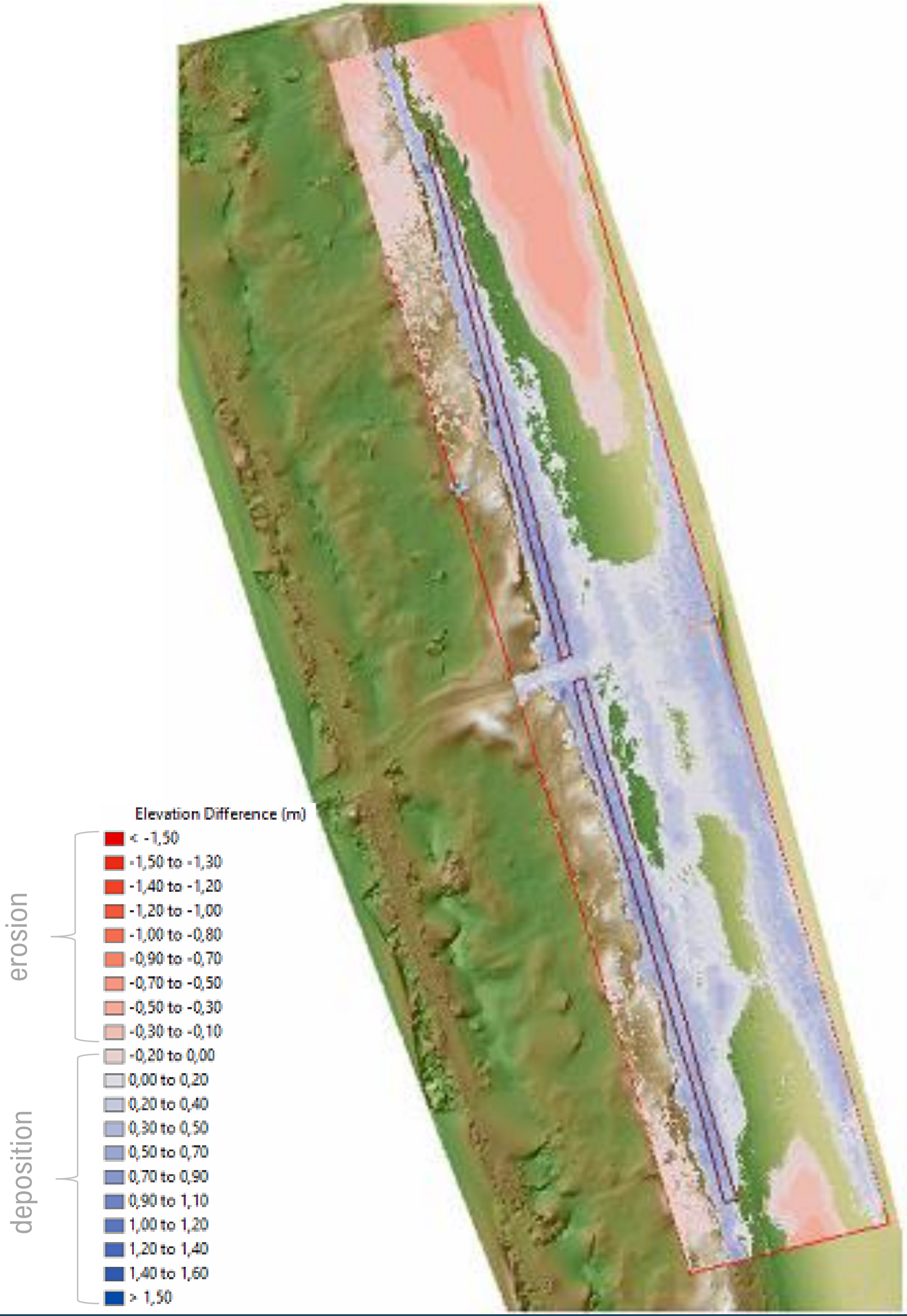






RESULTS

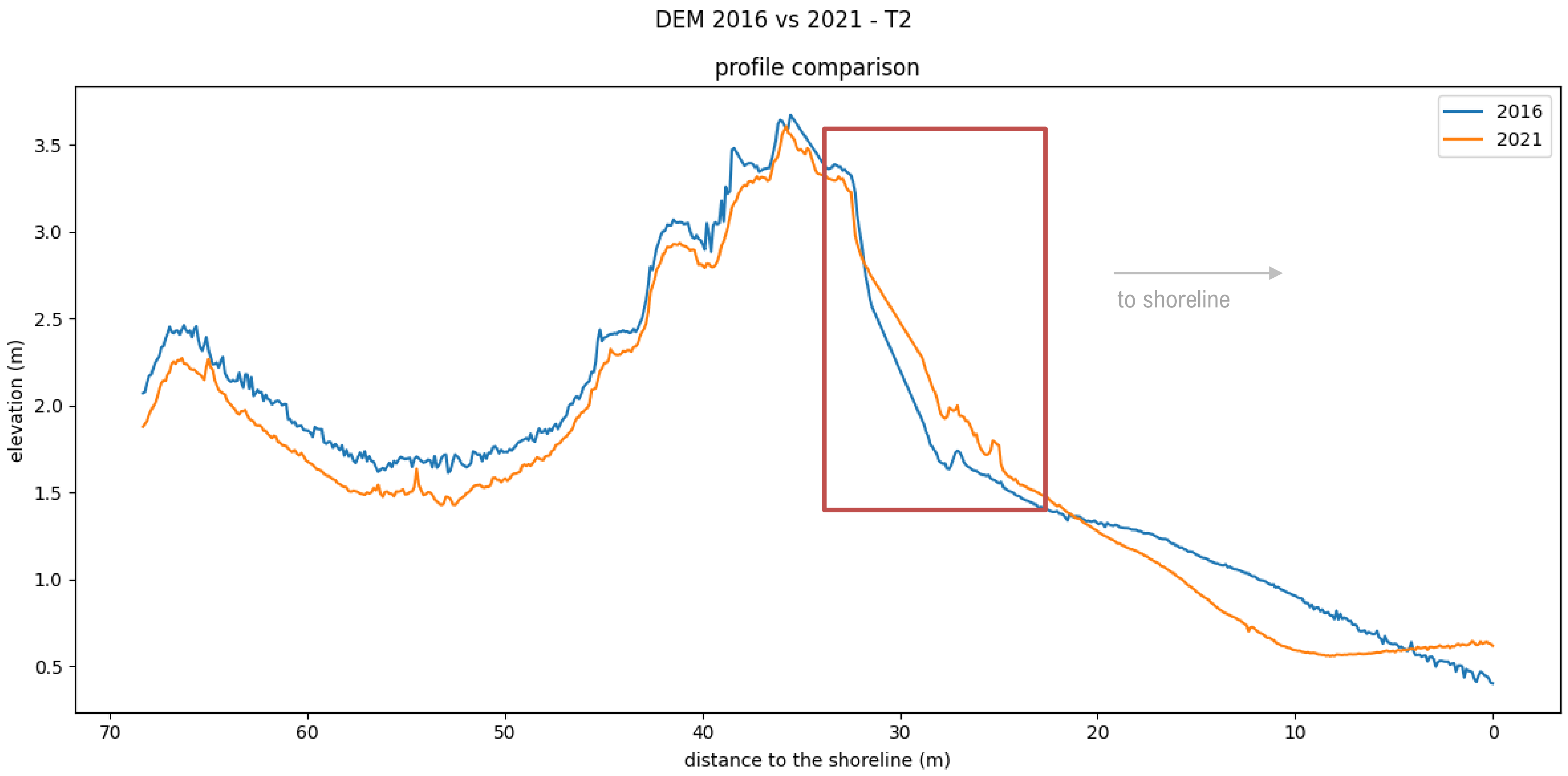
Geomorphic Change Detection – Oct 2021 vs Oct 2016 DEMs

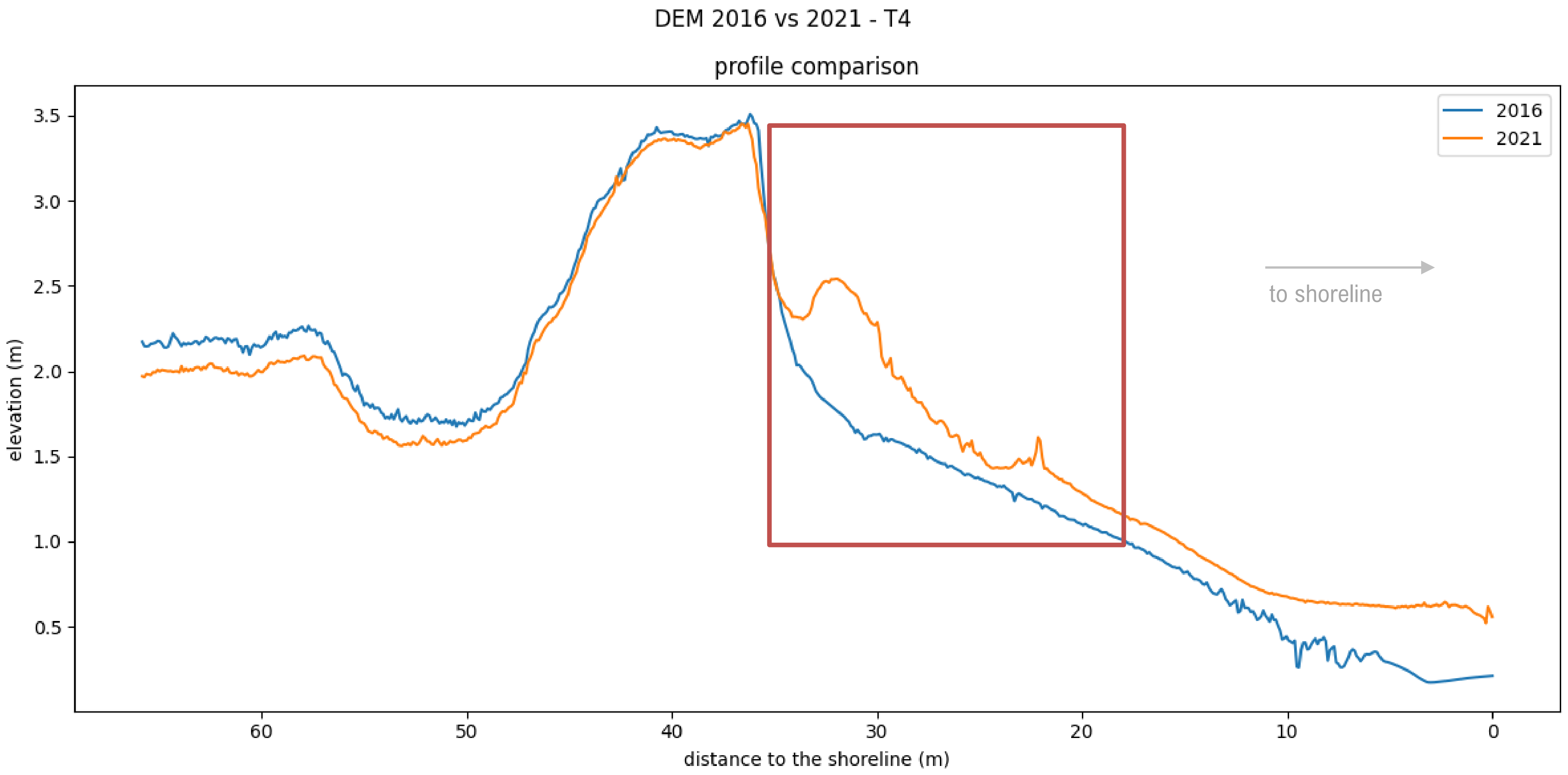


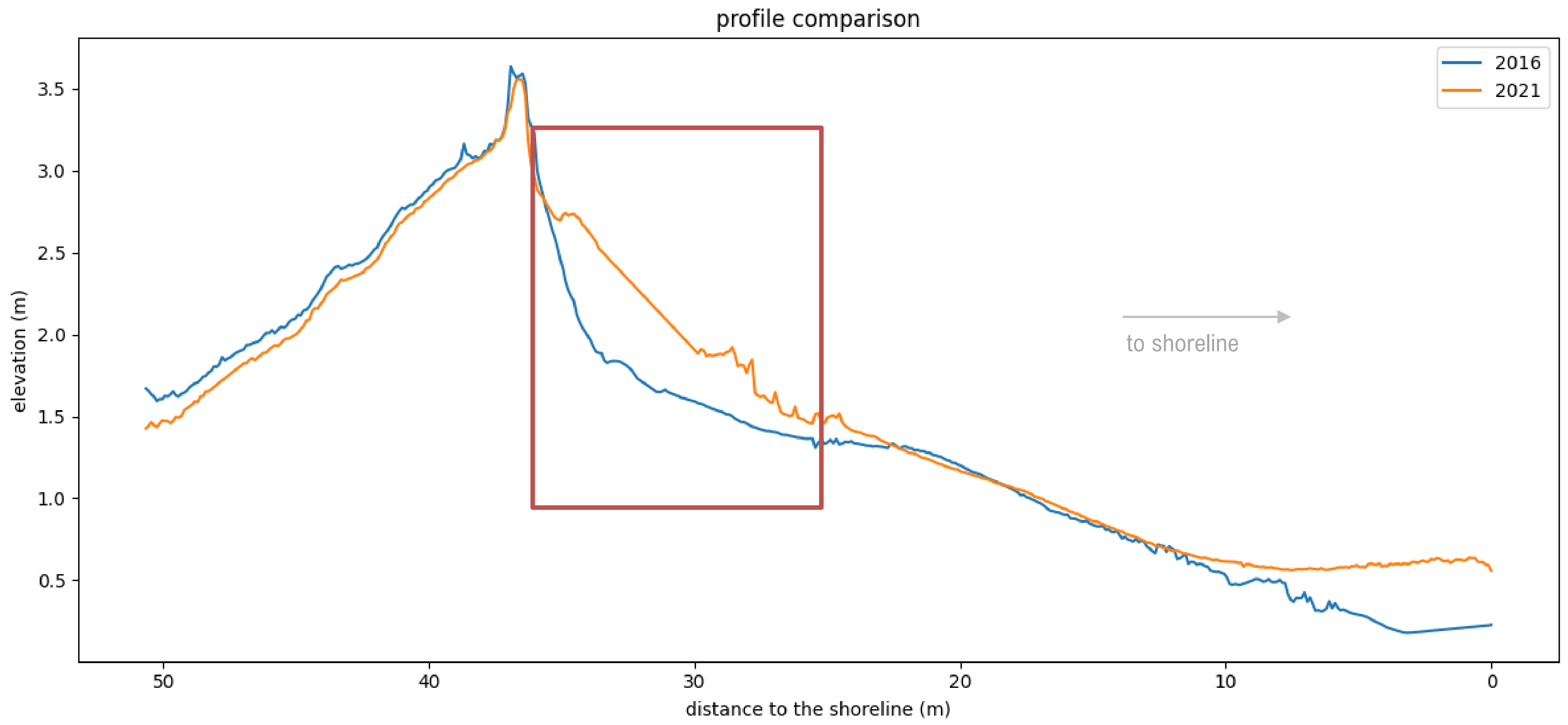
Attribute	Raw	Thresholded DoD Estimate:		
AREAL:				
Total Area of Surface Lowering (m^2)	4,168	2,221		
Total Area of Surface Raising (m^2)	4,986	3,799		
Total Area of Detectable Change (m^2)	NA	6,020		
Total Area of Interest (m^2)	9,154	NA		
Percent of Area of Interest with Detectable Change	NA	66%		
VOLUMETRIC:			± Error Volume	% Error
Total Volume of Surface Lowering (m^3)	696	584 ±	124	21.32%
Total Volume of Surface Raising (m^3)	1,177	1,109 ±	213	19.20%
Total Volume of Difference (m^3)	1,873	1,692 ±	337	19.93%
Total Net Volume Difference (m^3)	481	525 ±	247	46.99%
VERTICAL AVERAGES:			± Error Thickness	% Error
Average Depth of Surface Lowering (m)	0.17	0.26 ±	0.06	21.32%
Average Depth of Surface Raising (m)	0.24	0.29 ±	0.06	19.20%
Average Total Thickness of Difference (m) for Area of Interest	0.20	0.18 ±	0.04	19.93%
Average Net Thickness Difference (m) for Area of Interest	0.05	0.06 ±	0.03	46.99%
Average Total Thickness of Difference (m) for Area With Detectable Change	NA	0.28 ±	0.06	19.93%
Average Net Thickness Difference (m) for Area with Detectable Change	NA	0.09 ±	0.04	46.99%
PERCENTAGES (BY VOLUME)				
Percent Elevation Lowering	37%	34%		
Percent Surface Raising	63%	66%		
Percent Imbalance (departure from equilibrium)	13%	16%		
Net to Total Volume Ratio	26%	31%		

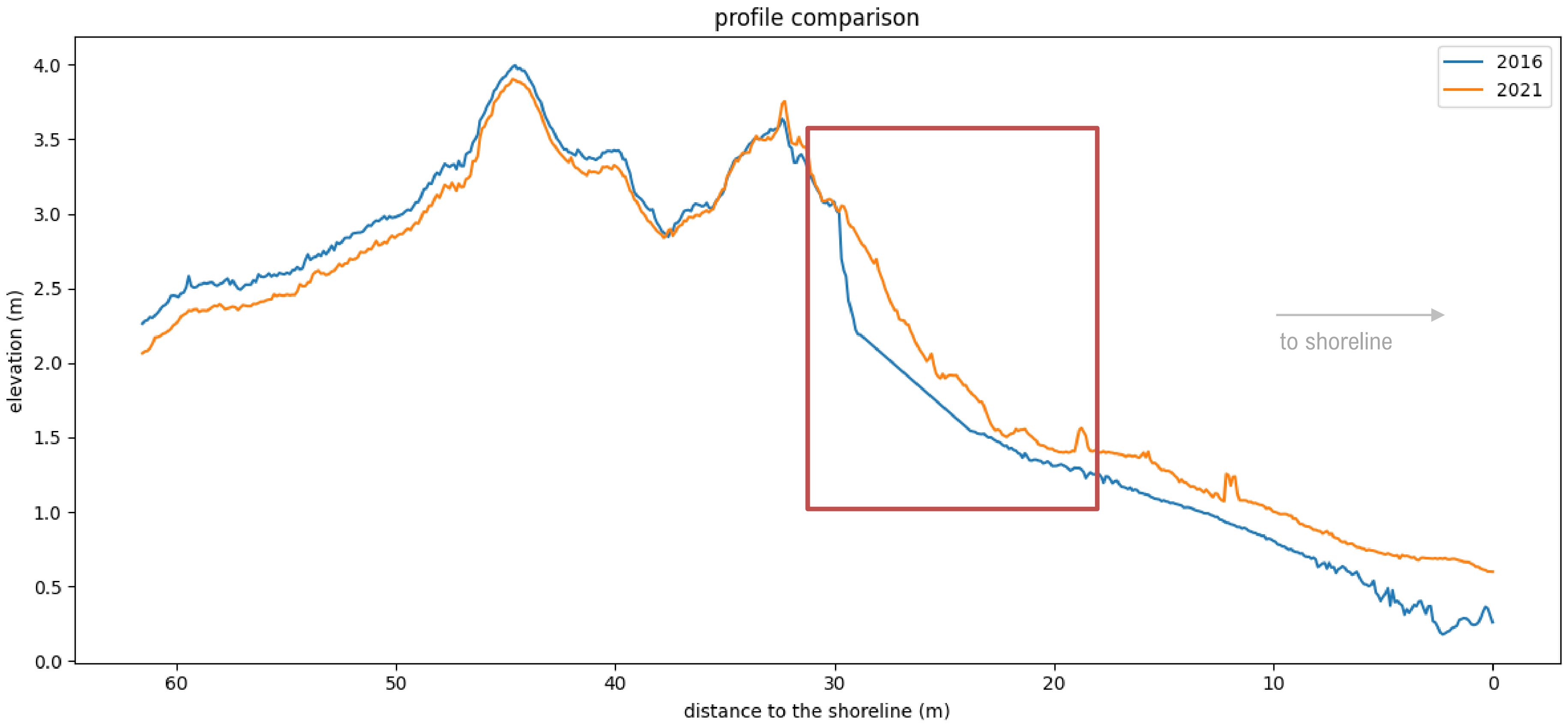
RESULTS

Geomorphic Change Detection – Oct 2021 vs Oct 2016 DEMs





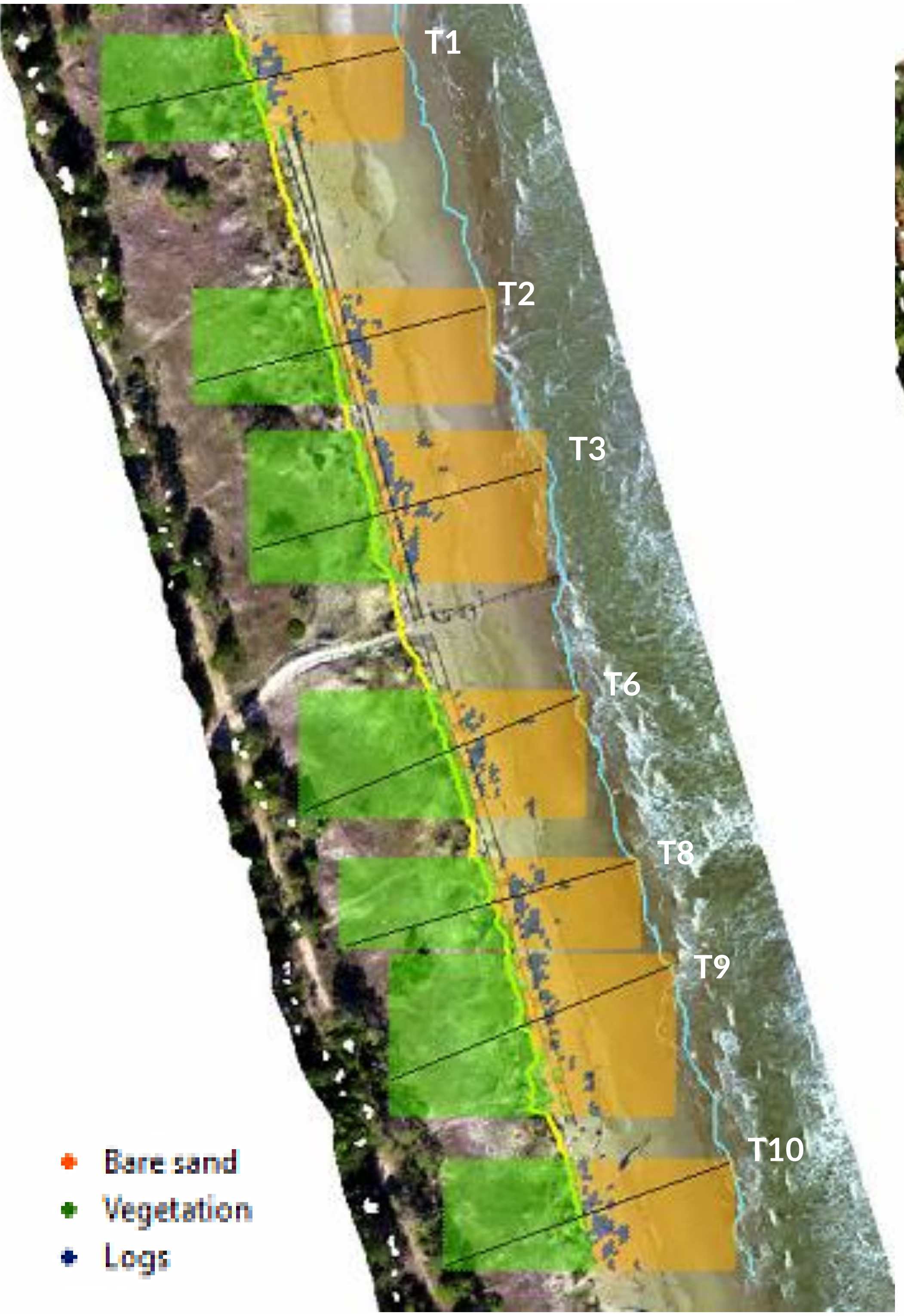




RESULTS

Transect profile comparison – sample transects of Oct 2021 vs Oct 2016

2016



2021

Percent Cover

RESULTS

Vegetation Change – Oct 2016 vs Oct 2021

DISCUSSION

Model fitting statistics show a good fit between the DEM & GPS elevation values for the sample transects

DEM Validation

significant deposition in terms of area and volume

erosion has only been evident in the northern beach portion towards the end of the fence

Geomorphic Change Detection

observed progradation of the front dune, development of embryo dunes, decrease in slope and change from the 'falesia' shape to gentler slope

Shift in elevation along the back dune area may be due to misclassification of vegetation to ground points

Transect Profile Comparison

An overall increase in vegetation cover along the dune foot has been observed

Increase of debris (logs) near the restoration fence has also been evident

Vegetation Change

CONCLUSION

- Seasonal change, wind, waves, and tides contribute greatly to the annual erosion and deposition dynamics in the area

- The windbreak fence has proven to be an effective intervention to prevent dune erosion since significant geomorphological changes and vegetation colonization have occurred based on 2021 vs 2016 data

  main sand accumulation & progradation were observed along the front dune & dune foot where the fences were established

  increase of vegetation & debris cover within and near the fence

- Applying a uniform and systematic workflow to SfM photogrammetry is important to identify and reduce errors in elevation modelling

- GCD can be an effective tool for coastal dune monitoring

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THANK YOU!

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Regine Anne Faelga*, Beatrice Maria Sole Giambastiani, Luigi Cantelli
Biological, Geological and Environmental Sciences Department, University of Bologna, Italy
regineanne.faelga@studio.unibo.it, beatrice.giambastiani@unibo.it, luigi.cantelli@unibo.it

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