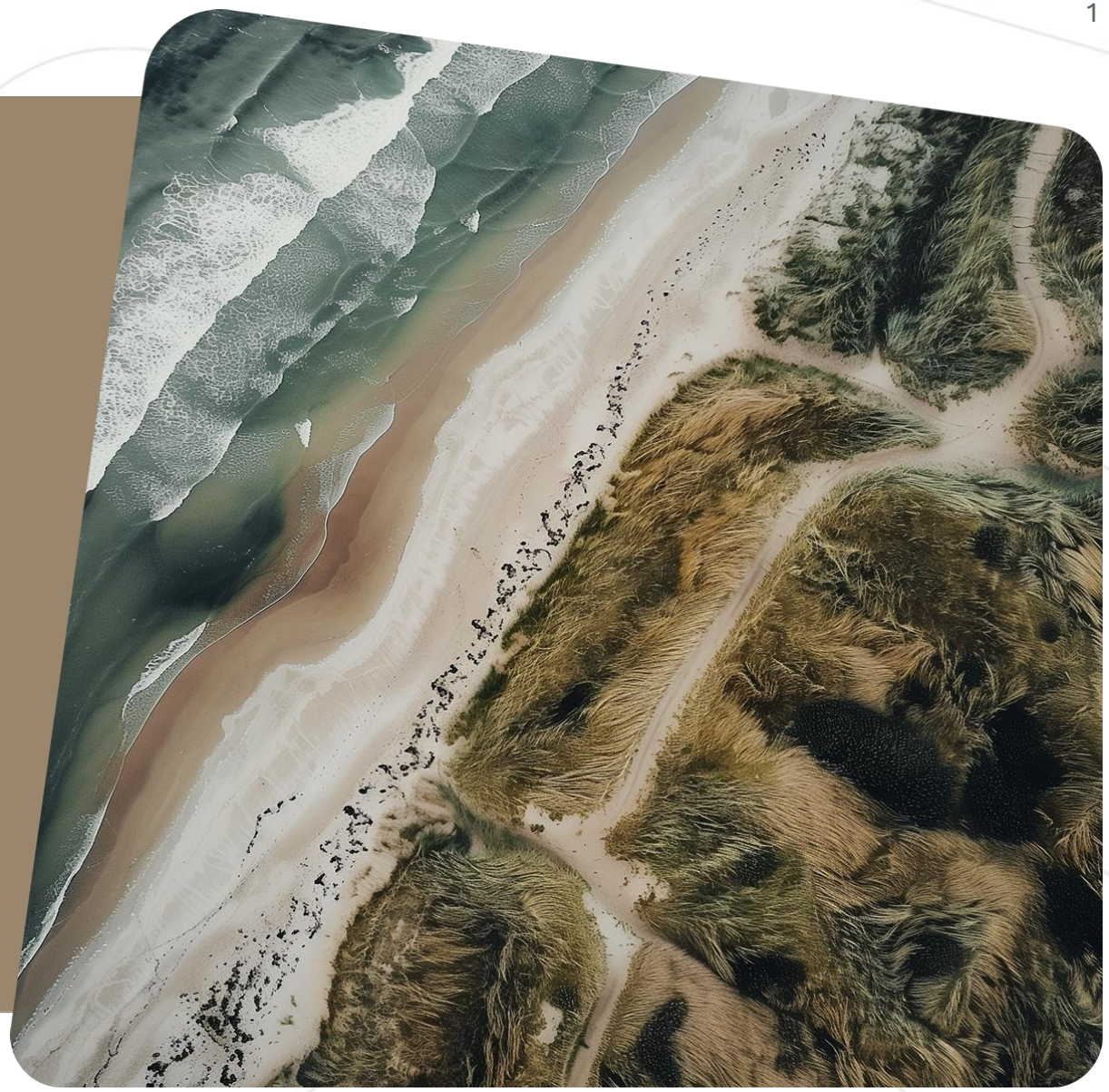
EU DuneFront

hybrid blue-grey Nature-based Solutions

Oliver Lojek
TU Braunschweig

GANBASE - Workshop
TAMU, Galveston, TX
October 7th, 2025



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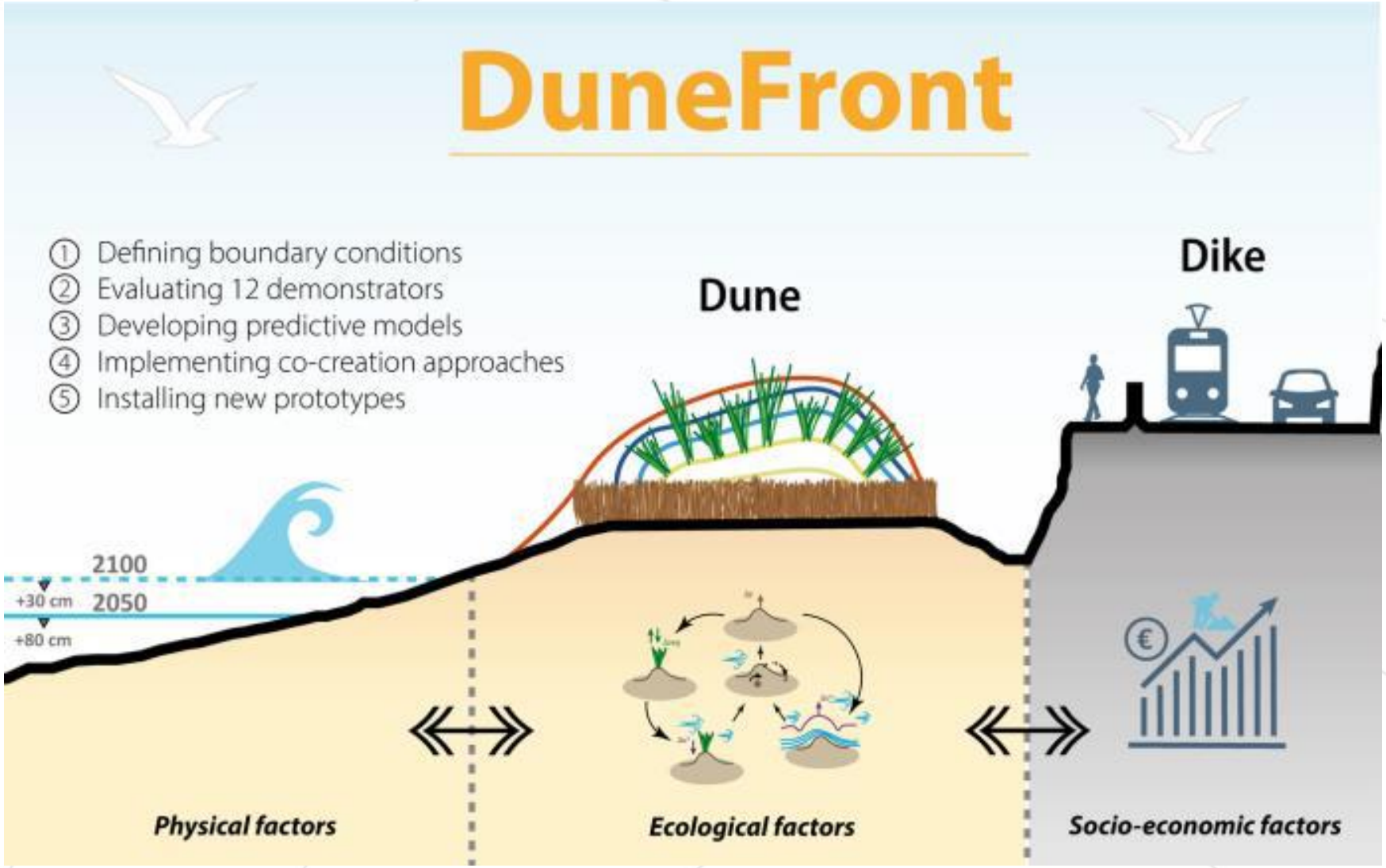
EU DuneFront – Innovation Action HORIZON 2024 program

- Demonstrator-based research and innovation
- Translating to design and functioning
- Co-creation of new prototypes



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- **HORIZON-CL6-2023-BIODIV-01-7**
  Demonstration of marine and coastal infrastructures as hybrid blue-grey Nature-based Solutions
- 2024 – 2027
- 5 mio. €
- 17 Partners + 1 Associated
- 12 Demonstrators

- Data assembly & densification for up-scaling of demonstrators and suitable locations across Europe

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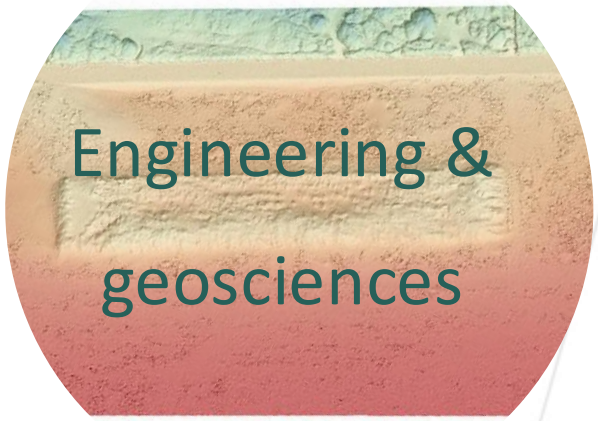

Ghent University

KU Leuven

Flanders Hydraulics

University Porto

University Bordeaux

University Perpignan

University Liitoral Opal Coast

Delft University

TU Braunschweig

Ghent University

University Bordeaux

Utrecht University

TU Braunschweig

Flanders Marine Institute

University Lund

Deltares

Texax A&M University

Maritime and coastal services

Jan De Nul NV

Dredging International

Ghent University

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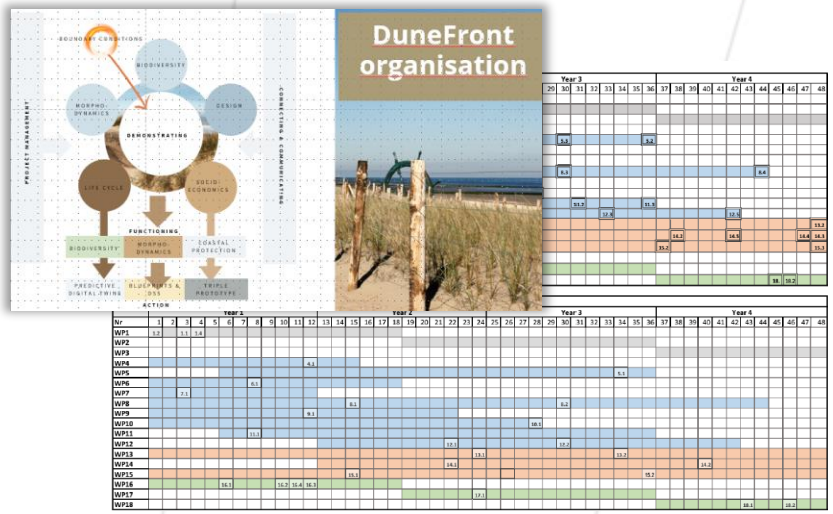
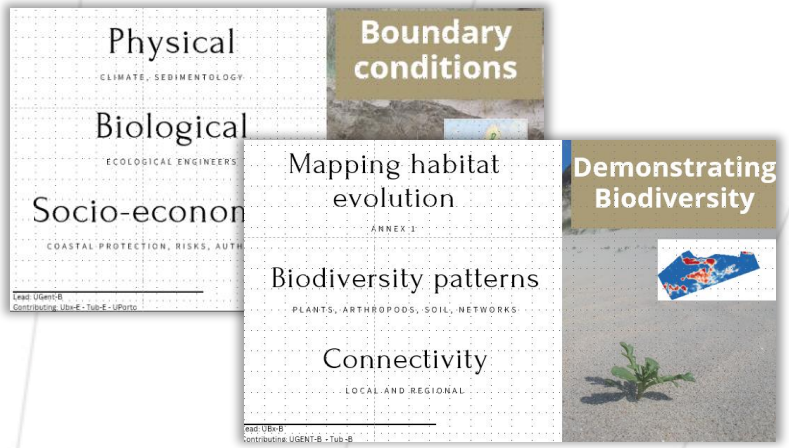
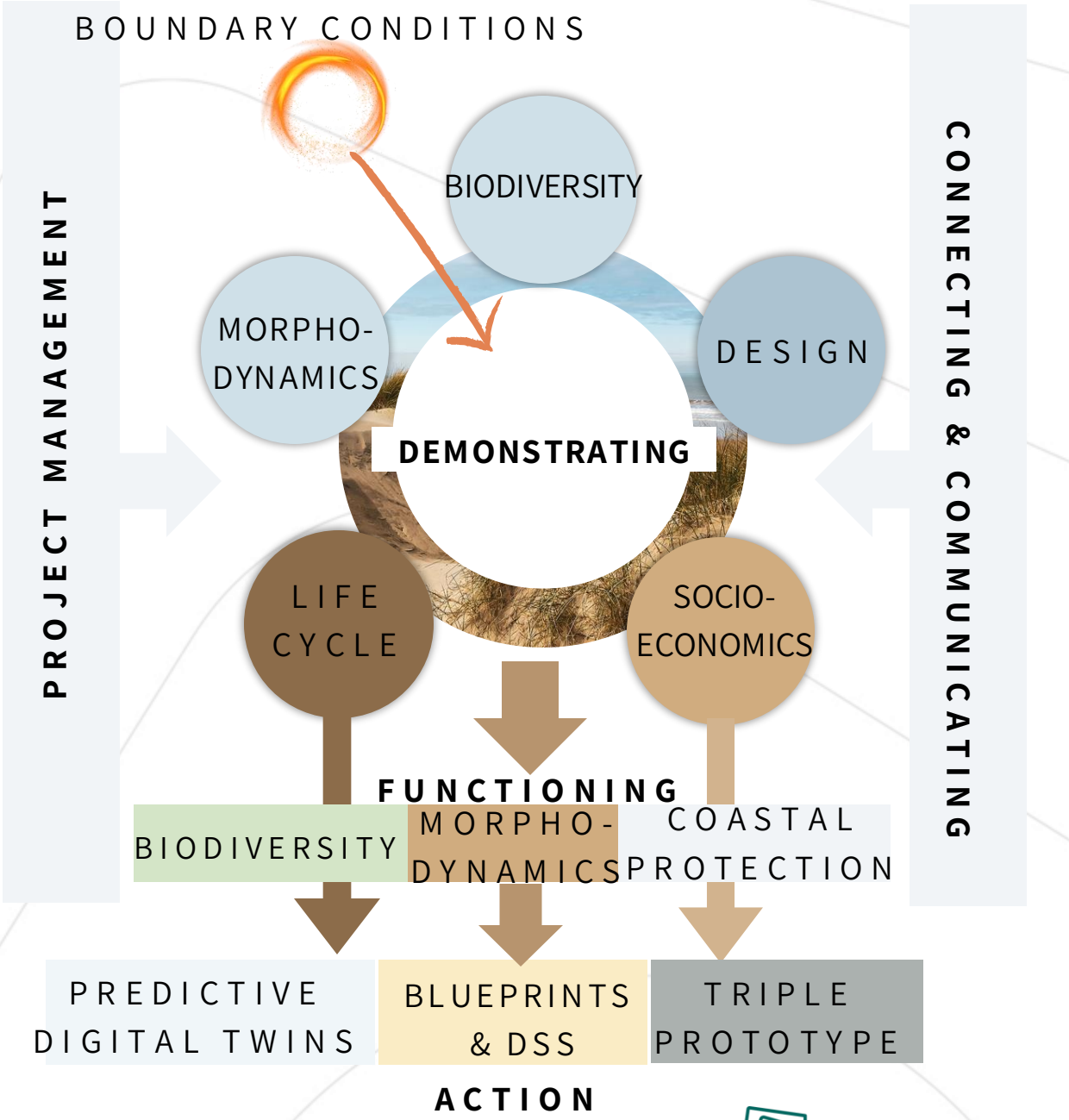


- **Total of 18 Work Packages**
- **Three sub-packages each**





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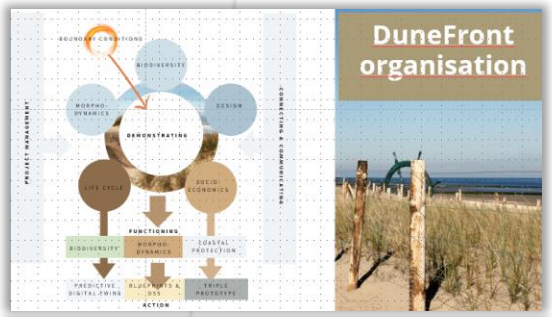

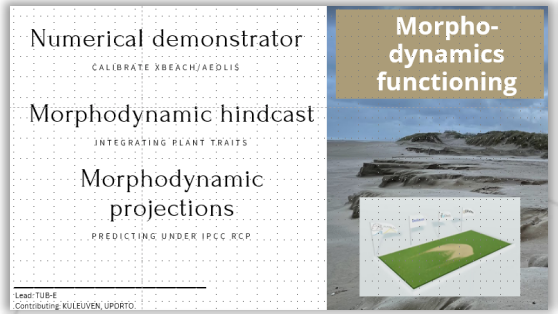

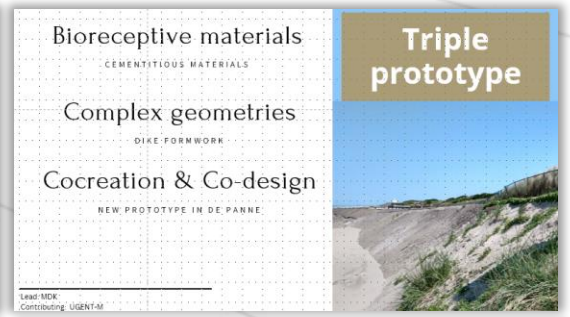

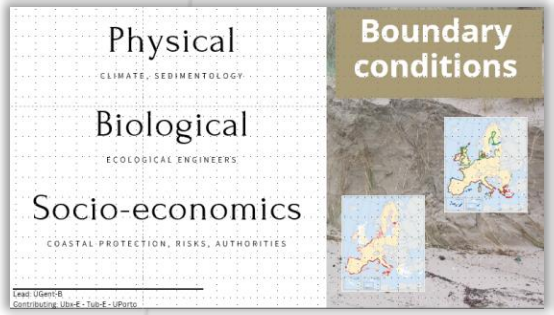

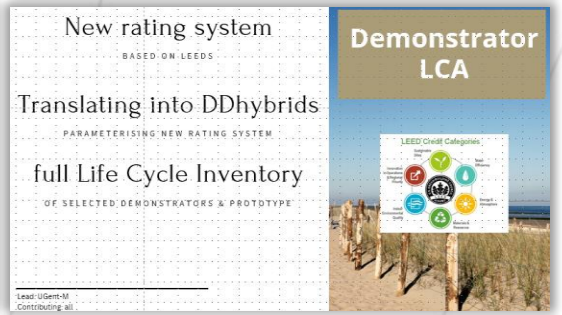

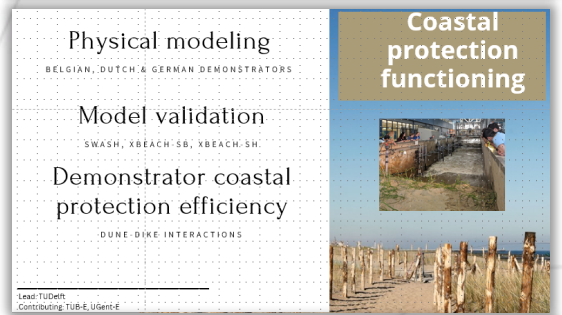

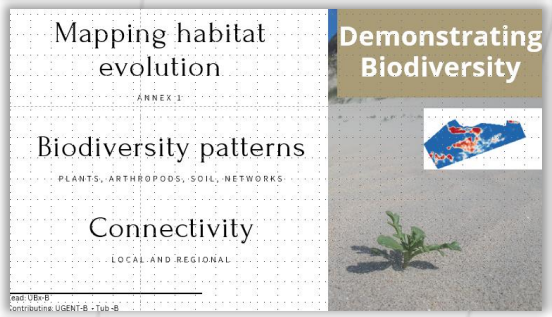

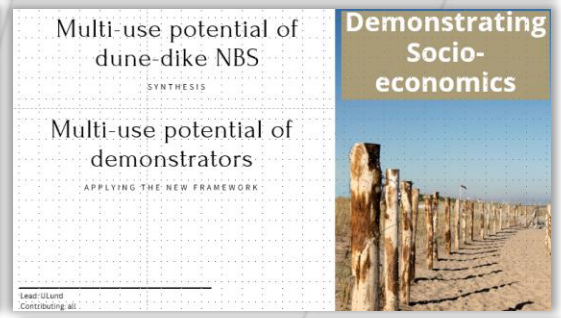

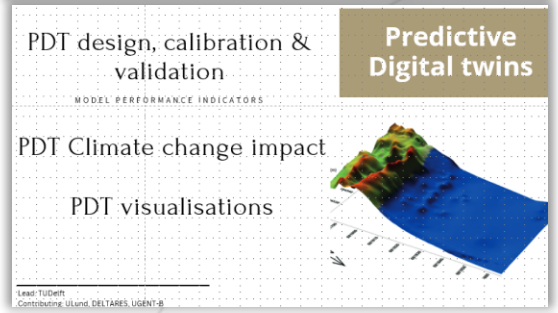

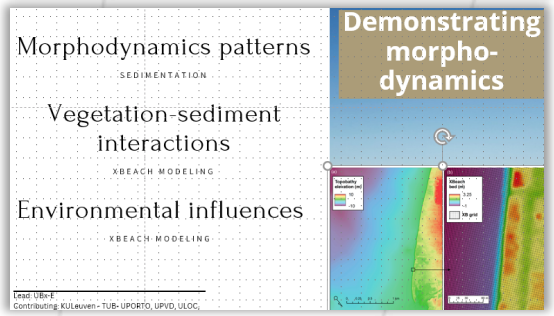

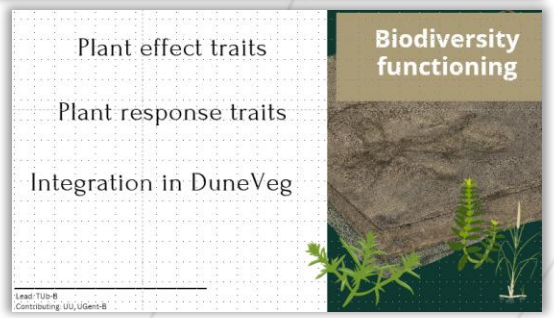

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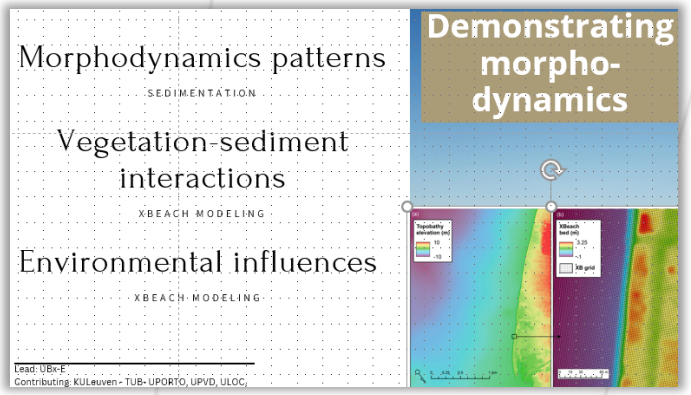
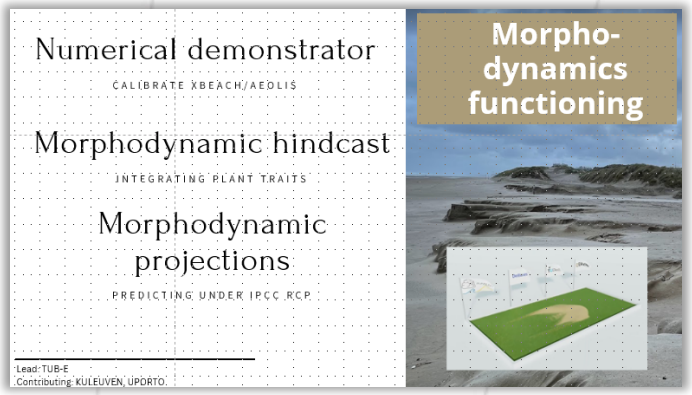
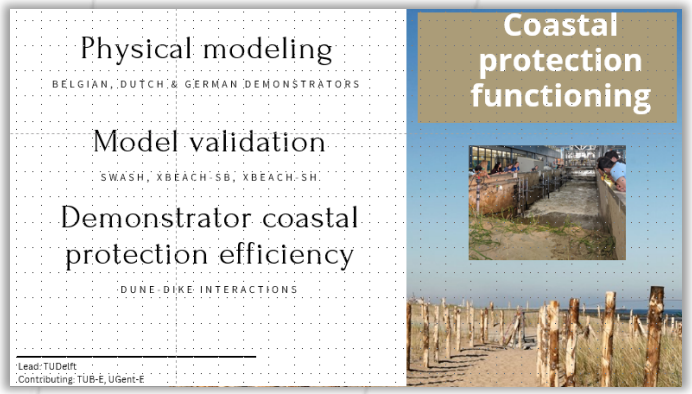


- **WP6 – Demonstrating Morphodynamics**
  - **Patterns** ✓
  - **Vegetation influences** ✓
  - **Environmental influences** ✓



- **WP11 – Morphodynamic Functioning**
  - **Numerical demonstrator models** ✓
  - **Hindcast modeling** ← Til April 2026
  - **Projections into what could be**



- **WP12 – Coastal protection functioning**
  - **Physical modeling** ← October – December 2025
  - **Model validation**
  - **Demonstrator potentials**

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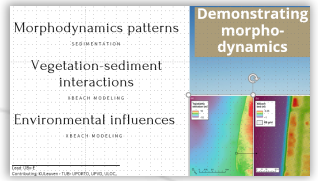
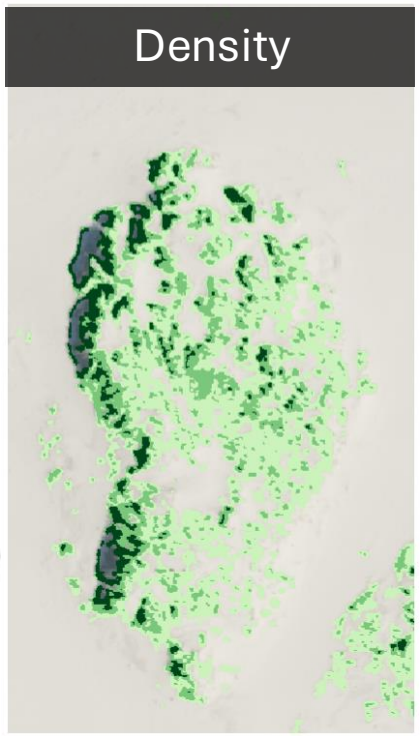
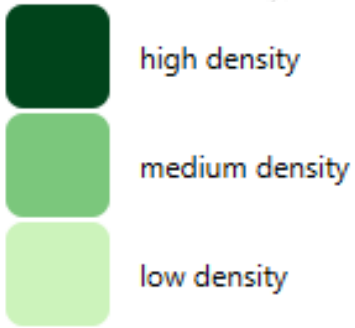
WP6: Morphodynamics



- **WP6.1 – Volume changes**
  - Data base of 20+ yrs of DEMs
- **WP6.2 – Vegetation interaction**
  - NDVI statistics
- **<u>WP6.3 – Environmental influences</u>**
  - CNN Model for vegetation maps





Density class	Threshold (~) for cell index	Density range (stems/m²)
High	< 111.6	> 500
Medium	111.6 - 161.8	195 - 500
Low	> 161.8	< 195

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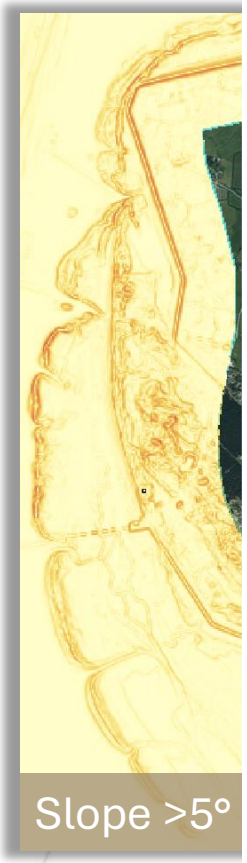
WP6.3: AI based vegetation detectiom

AI CNN application

- DigitalElevationMap
  - Slope based detection
  - Erosion/Sedimentation
- DigitalOrthoPhoto
  - Detect vegetation
  - Extract pixels inside Dune shape
  - Create shape mask
- Backwards / Forward evolution
- Inverse Distance Kriging of DEM onto 1x1m for CNN



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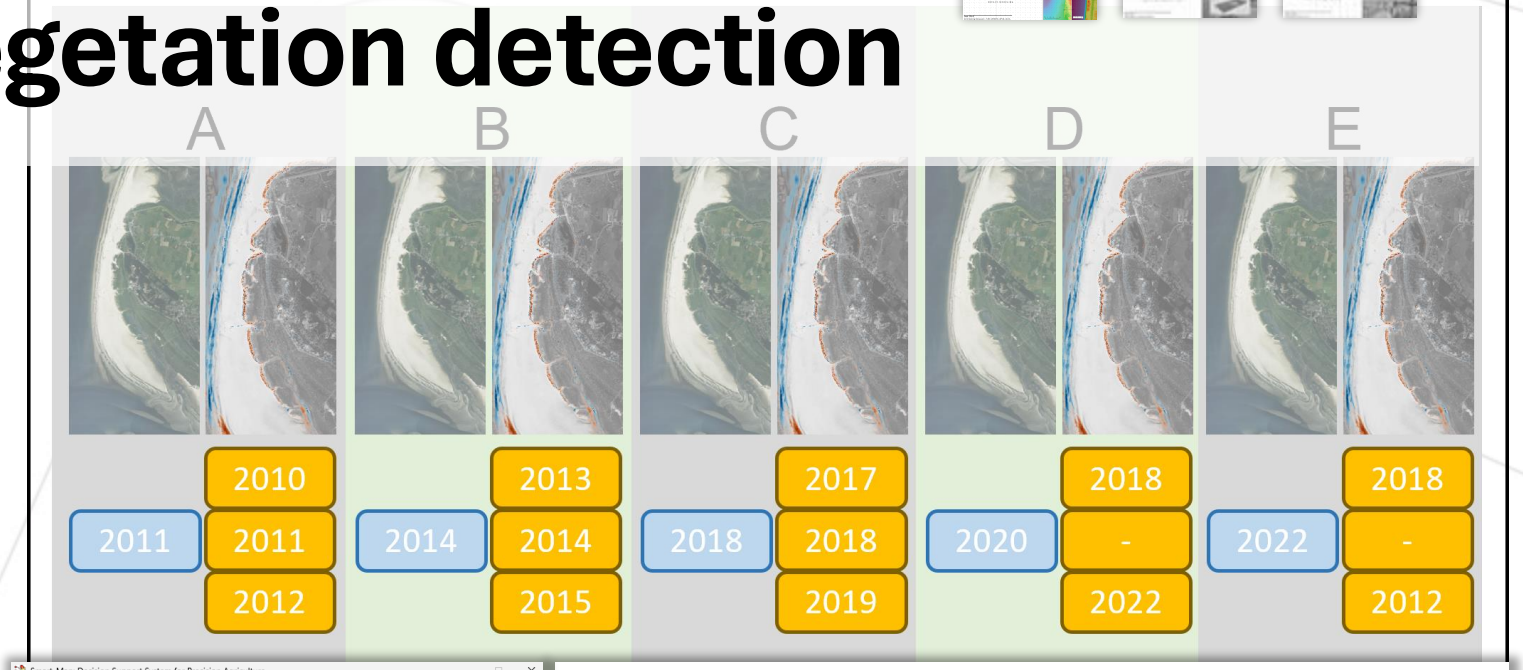
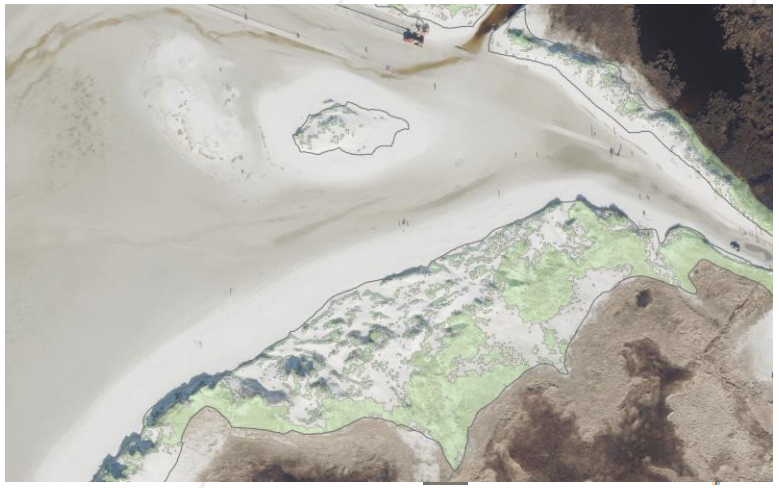
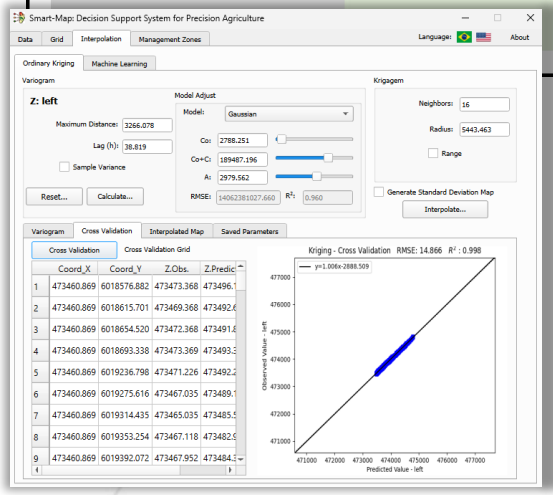
WP6.3: AI based vegetation detection

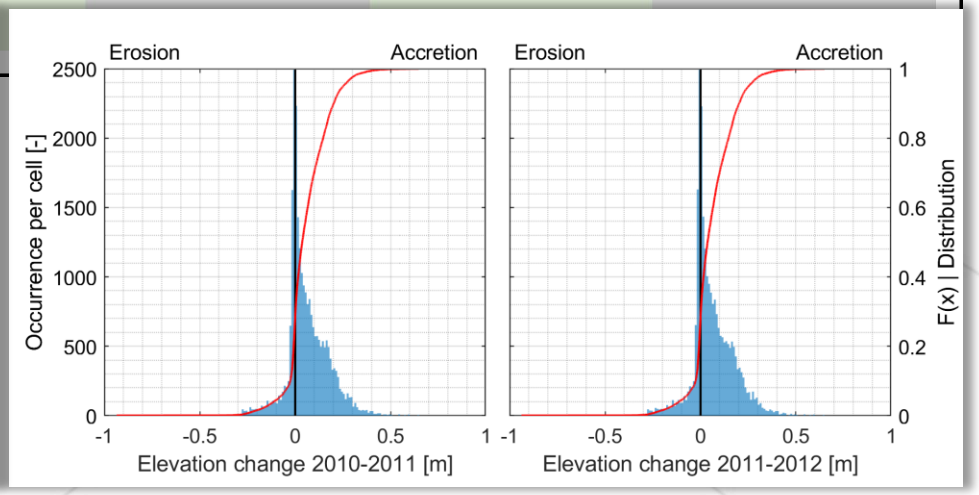
AI CNN application

- 5 matching data sets
- Detection of Erosion / Accretion for dune shape area with vegetation
- All 5 data sets show accreting trend
- **Vegetation coverage & density maps**









CNN_vegetation

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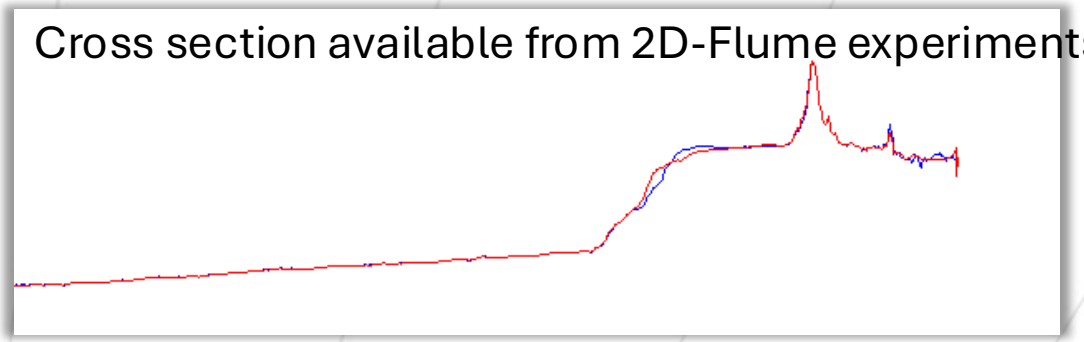
WP11.1: Numeric Demonstrators

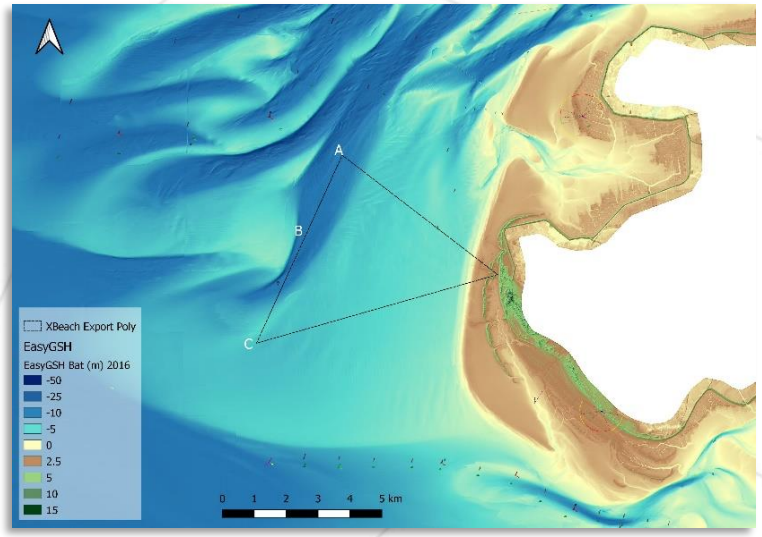
Numerical demonstrators

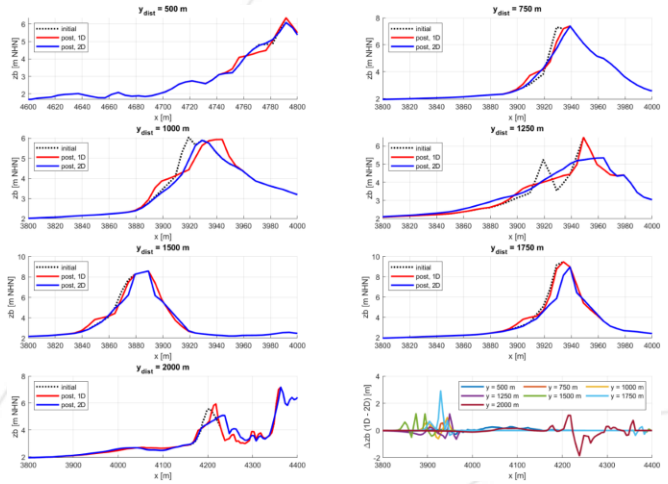
- XBeach – Storm induced dune erosion
- DEM data from demonstrator – 20 years

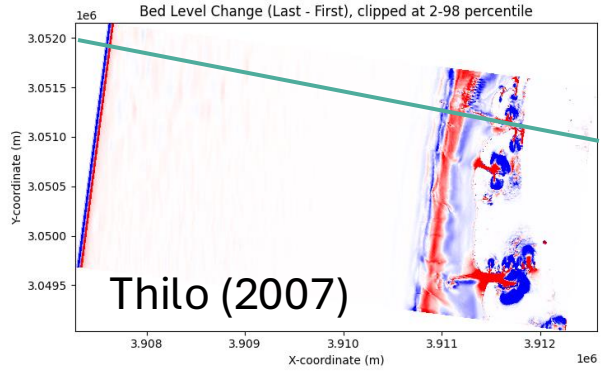
Calibration of 1D model

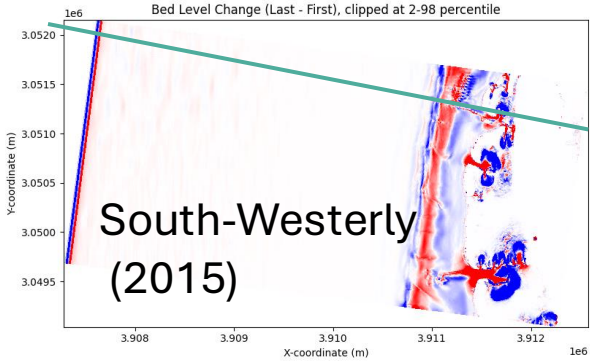
- Used > 200 flume experiments
- Brier Skill Score > 0.87 (very good agreement)
- Upscaled 1D model to 1:1 (<10% variance)
- 2D Storm simulations

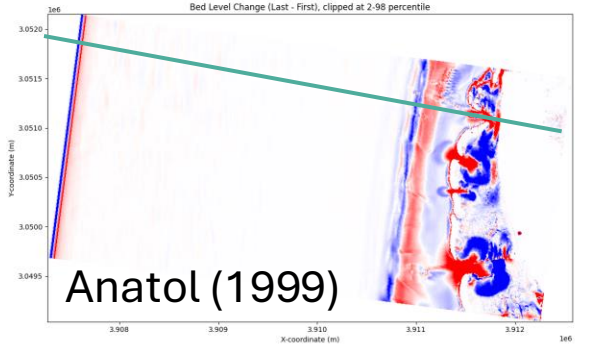












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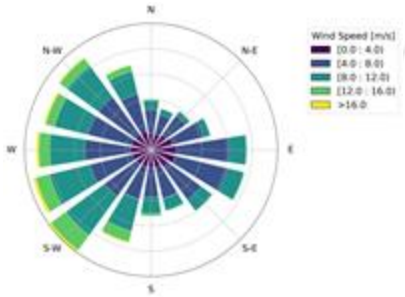
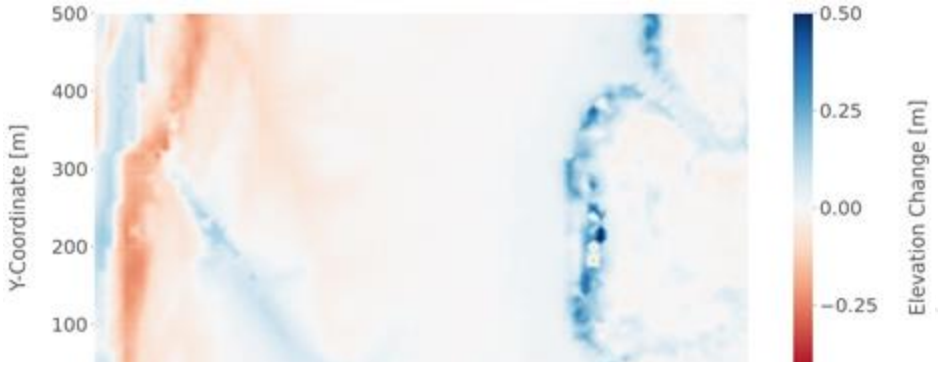
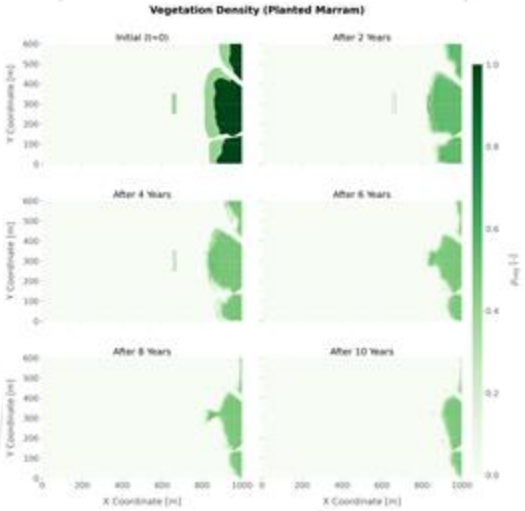
WP11.1: Numeric Demonstrators

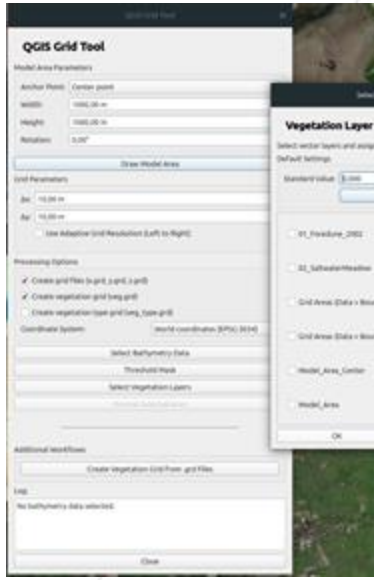
Numerical demonstrators

- AeoLiS model – wind driven transport & dune growth
- 01.1995 – 08.2019 (hourly)
- W/SW direction dominant
- Mostly 4-12 m/s









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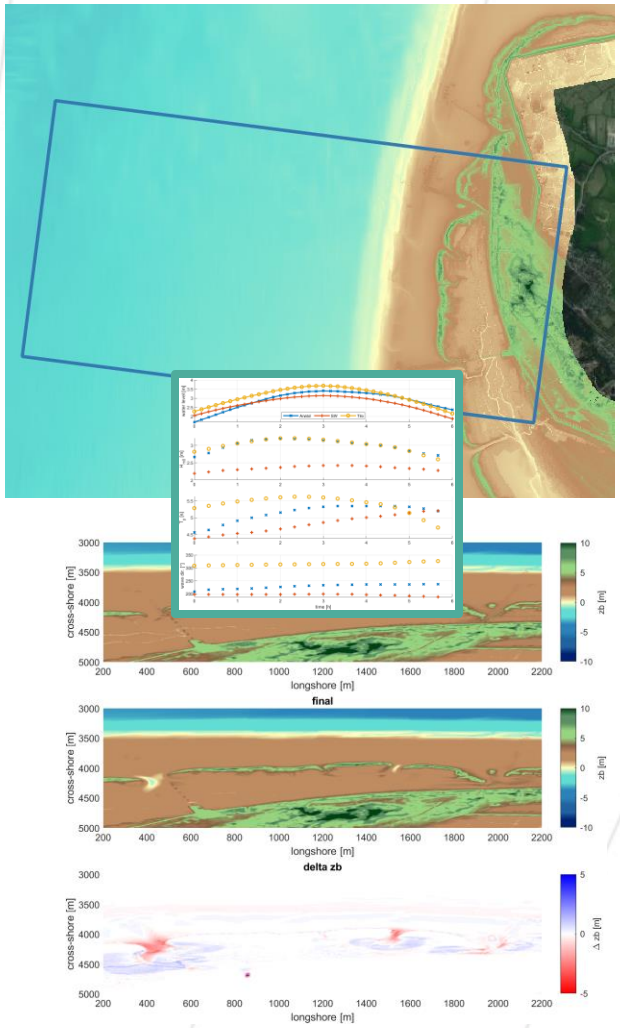
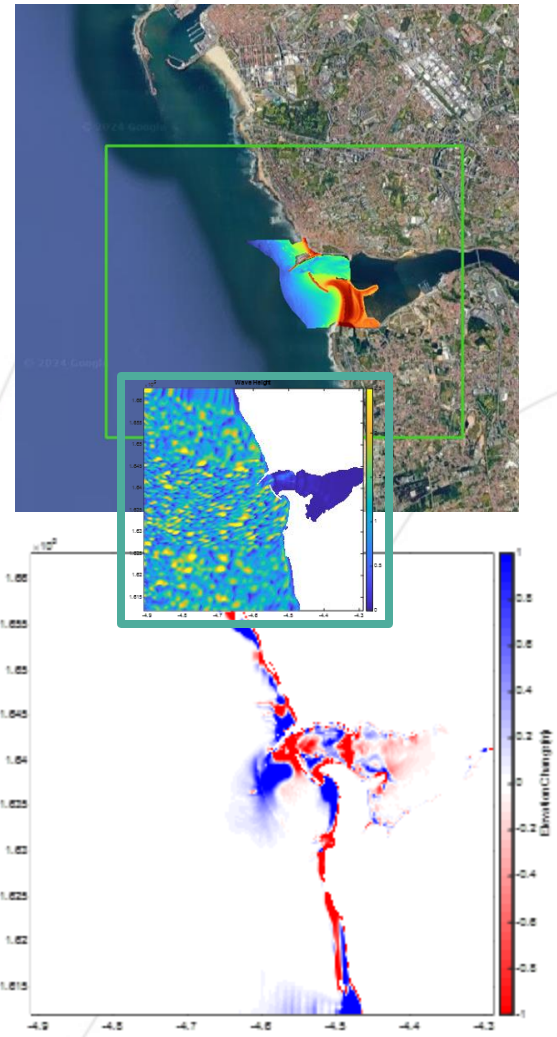
WP11.1: Numeric Demonstrators

- **Xbeach models**

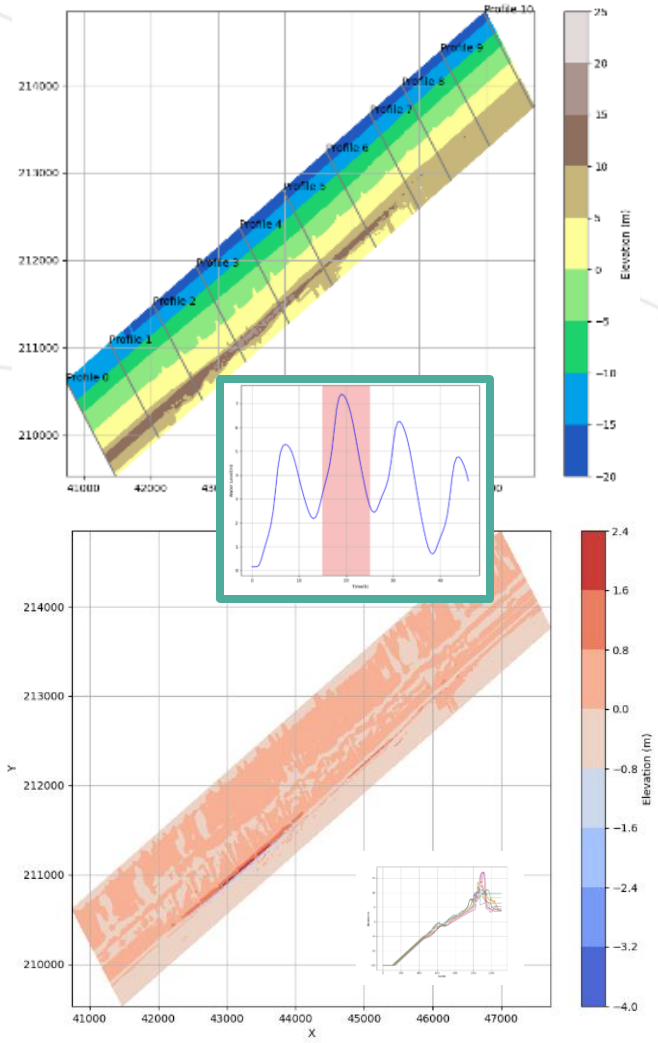
Sankt Peter-Ording, Germany



Duoru River, Portugal



Oostende/ Raversijde–Mariakerke, Belgium



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- **AeoLiS models**

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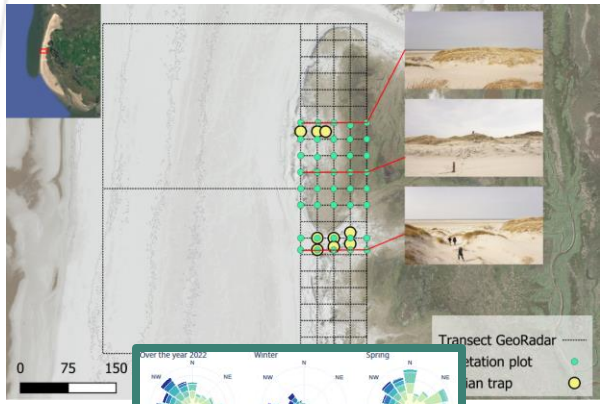
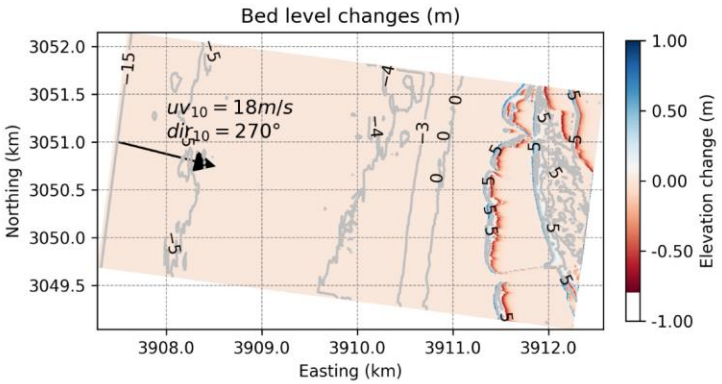
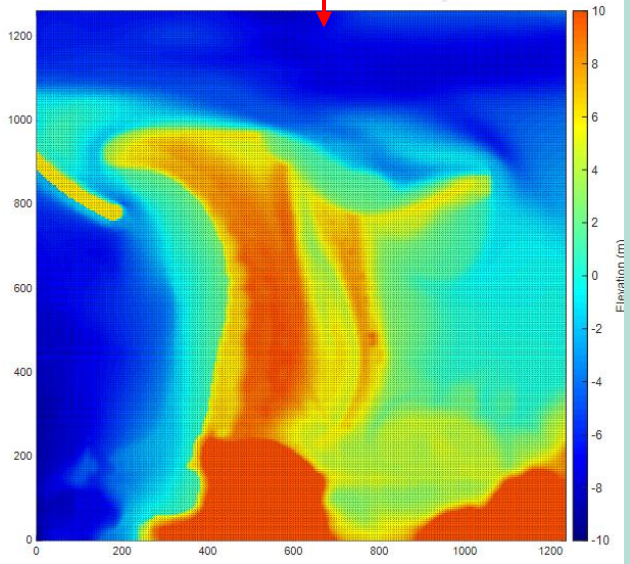




Duoru River, Portugal



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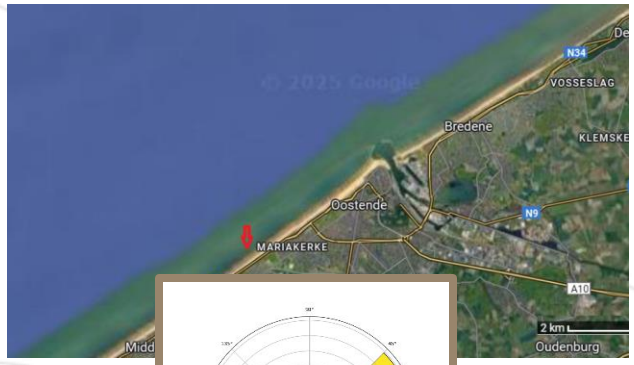

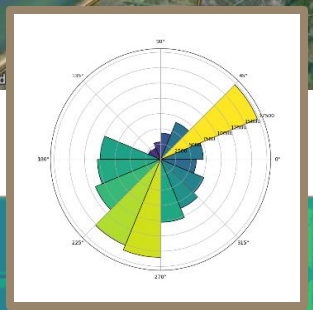

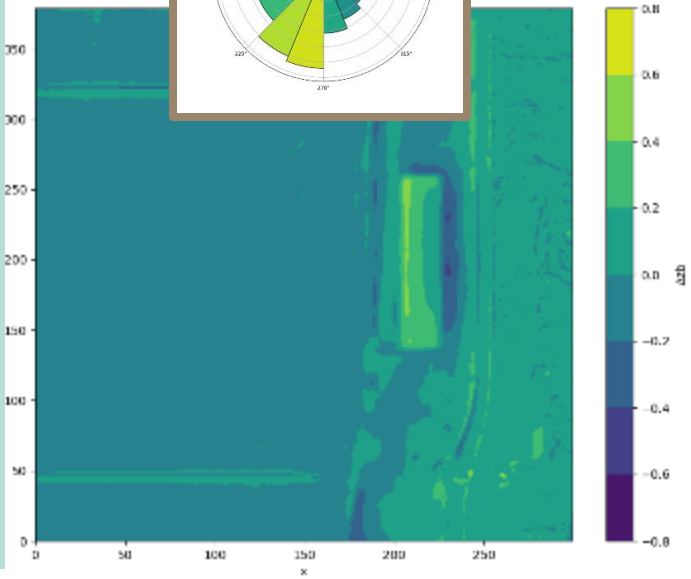

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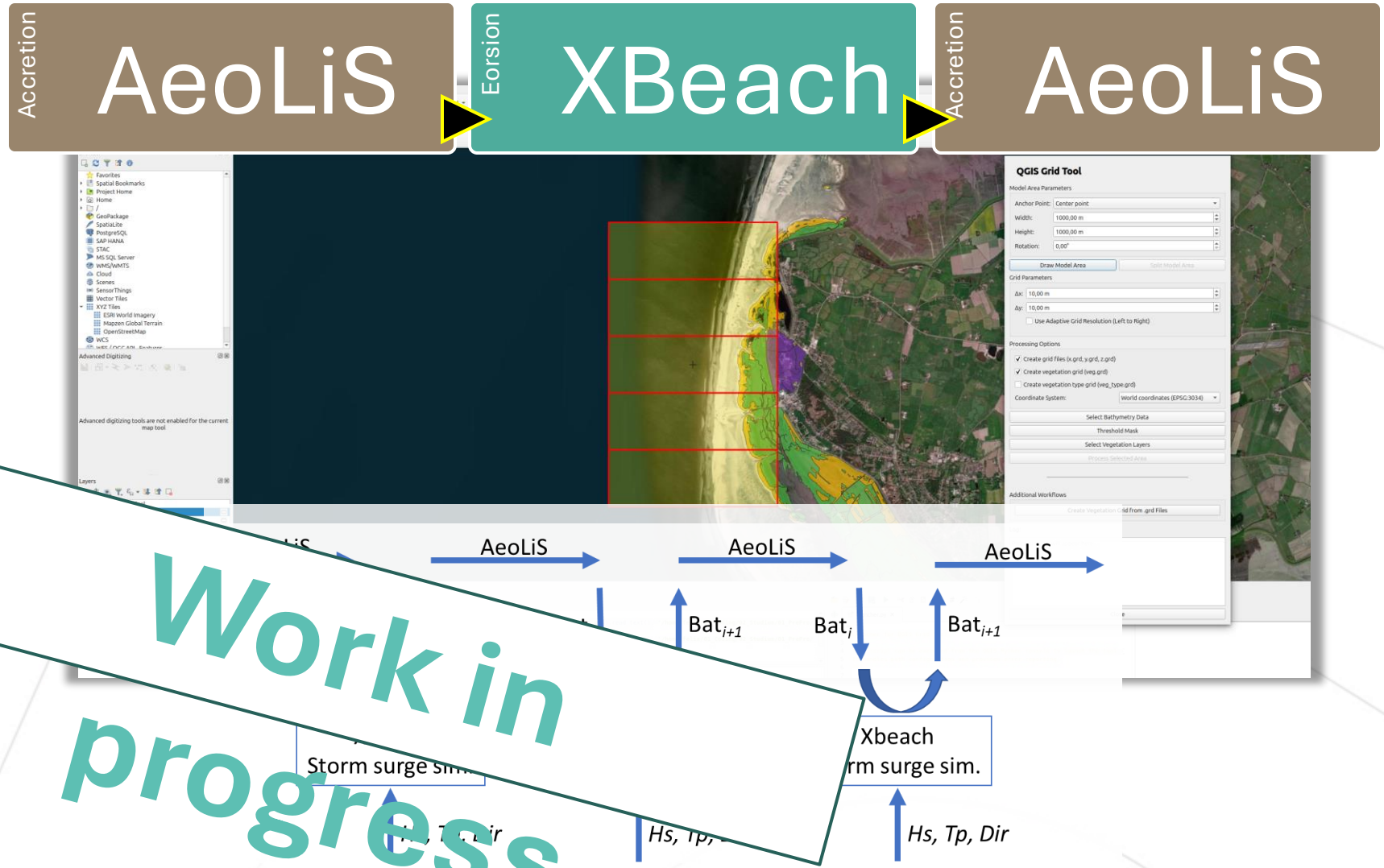
WP11.2: Hindcast Modelling

- Years 2000 – 2020
  - 20 years
- QGIS grid generator
  - AeoLiS
  - XBeach

- <u>AeoLiS | Dune growth</u>
  - Year around
  - 10 yrs simulation time
  - 1 km² on 1 x 1 m
  - Runtime 11 days
- <u>Xbeach | Dune erosion</u>
  - Stormevents ~5 d
  - 1 km² on 10 – 1 m (variable)
  - Runtime 12 h
- **Switch-back-mode**



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DuneFront

WP12: Physical modeling

- **TU Delft, NE**
  - Dune + Dike
  - Fixed bed
  - Completed
- **Flanders Hydraulics, BE**
  - Dune + Dike
  - Live bed
  - Running
- **TU Braunschweig, DE**
  - Dune
  - Live bed
  - Vegetation
  - In preperation

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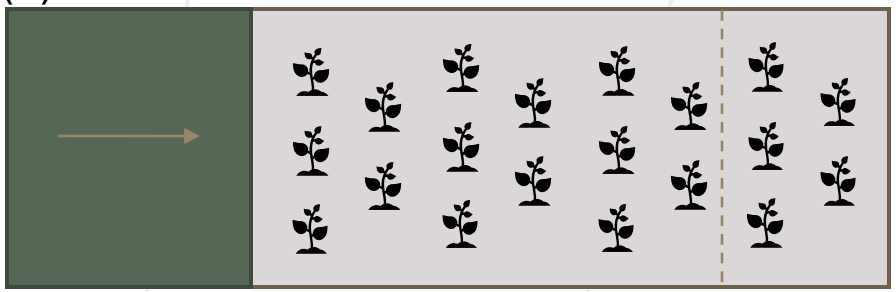
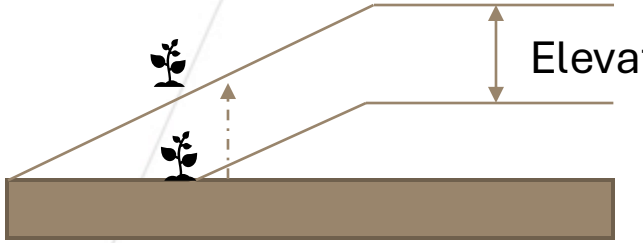
DuneFront

WP12: Physical modeling

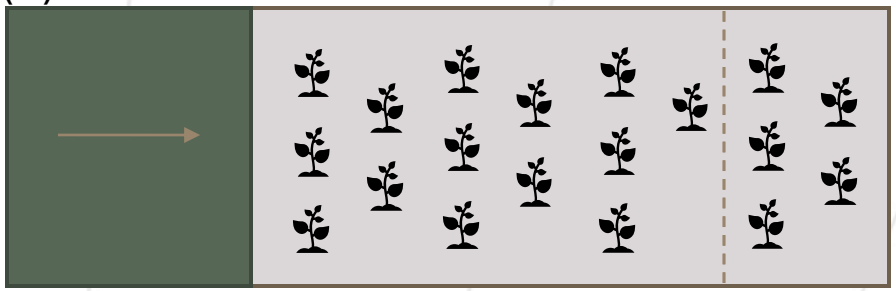
(a) x 3 2025 / 4 months

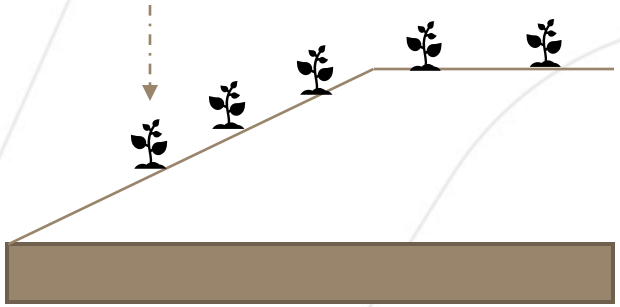




Elevation difference based on time / 0.05 m / month

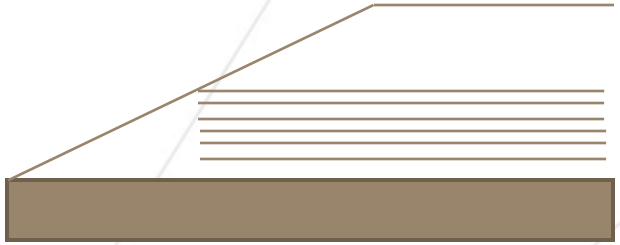
(b) x 3 2025 / 4 months



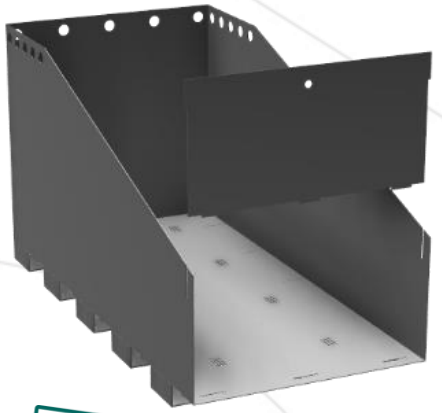


Top planted approach with full crate

(c) x 3 2026 / 12 months



2 layered sand only
1 sand built only full
No plants



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DuneFront

WP12: Physical modeling

- 9 Dune crates
- 3 sets of 3
- Vegetation growth
- Layered built up

~ 2 m^3 / crate
0,2 m below profile line
14 plants / crate
6 plants / m^2

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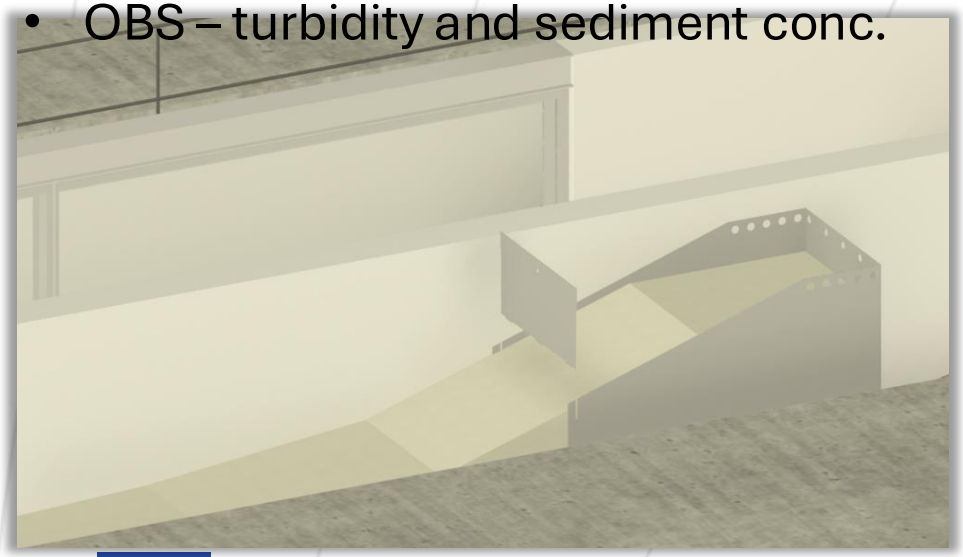
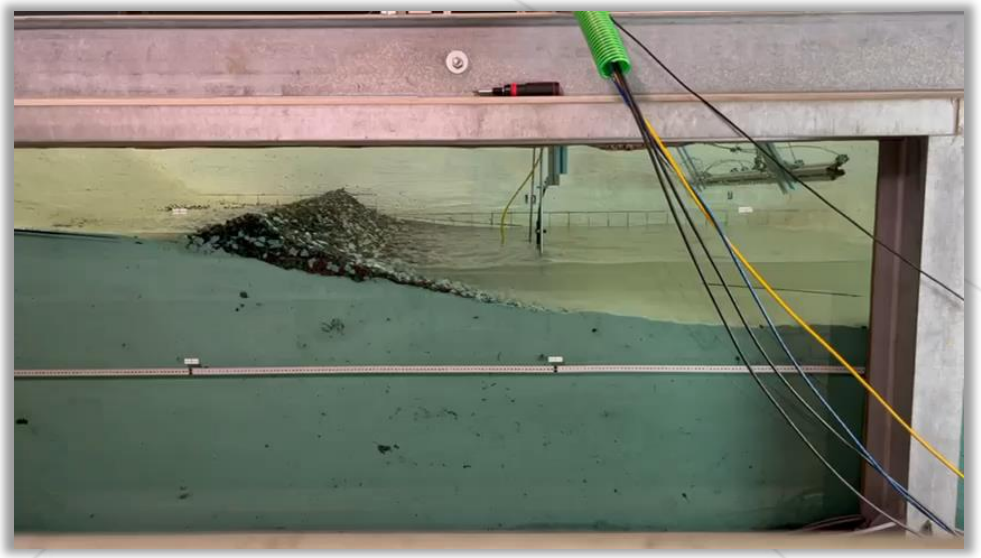
DuneFront

WP12: Physical modeling

- Ultrasonic wave gauges - reflection
- Pressure transducers – waves on beach
- Lidar - Above water dune profile
- Camera – observation
- Trolley | Echosounders – UW profile
- ADV – velocity X,Y,Z
- OBS – turbidity and sediment conc.





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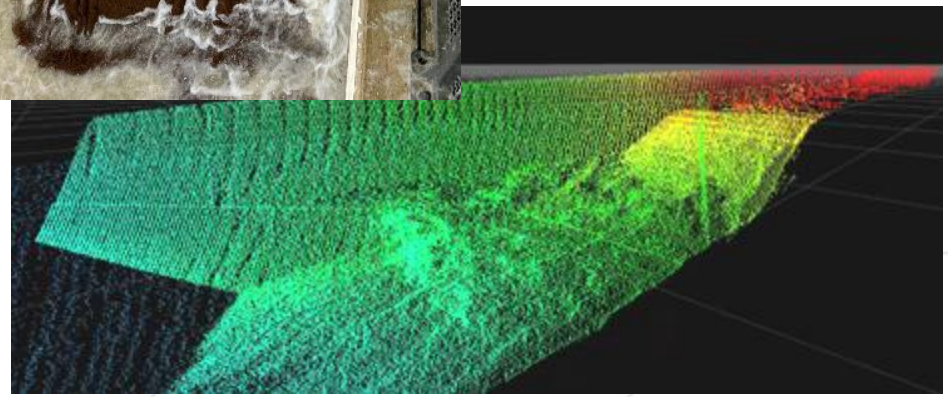
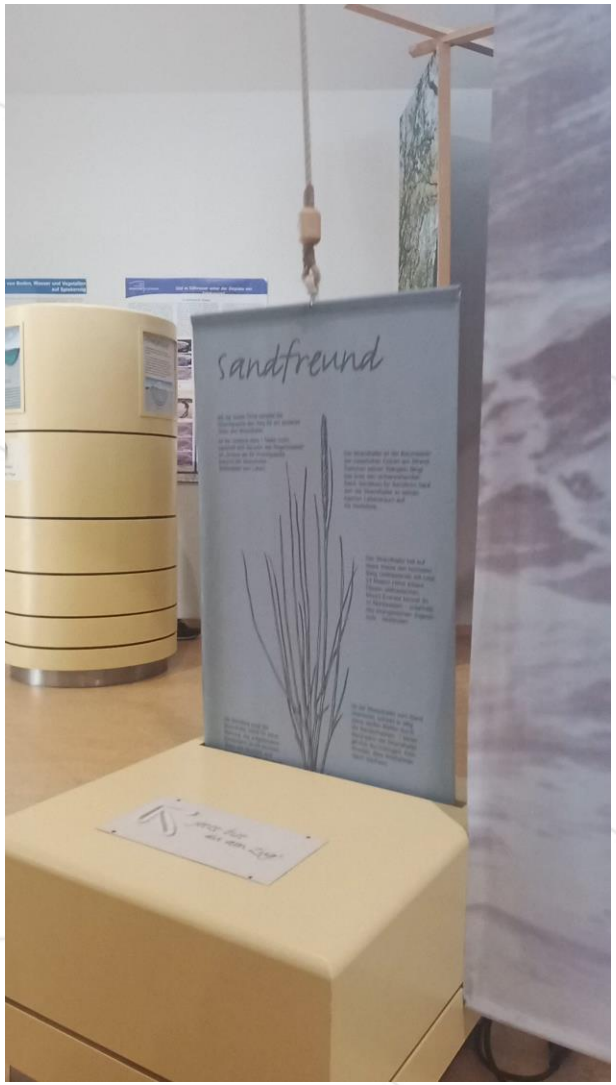
WP12: (Why) Physical modeling

- Marram gras develops terrace like roots
- **Knowledge gaps:**
  - Root influence
  - Model approaches
  - Erosion reduction
- **Applicability:**
  - Decision support for coastal agencies





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DuneFront

Thanks !

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WP12.3: Previous experiences

- Burial increases rhizome development
- Root length density increase
- Interlock of plants
- Above ground development increase

- But was planted in wooden boxes
- Left alone for >12 months in total
- Only 3 plants / crate

Top planted

Buried

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Notes & To Do‘s

For 2025

- Organize large fork lift/loader with 3+ t capacity and driver
- Traverse for the portal crane to lift the crates safely
- Bed for crates in flume needs to be elevated 30 cm
- Latch for sealing off crate bottom from beach area to avoid seepage and sediment loss
- Marking of the vegetation before erosion to track in the waves

- For 2026
  - Soil loggers
  - Vegetation setup with different approaches
    - Staggered
    - Clustered
  - Keep 3 crates after experiments for post-storm recovery study

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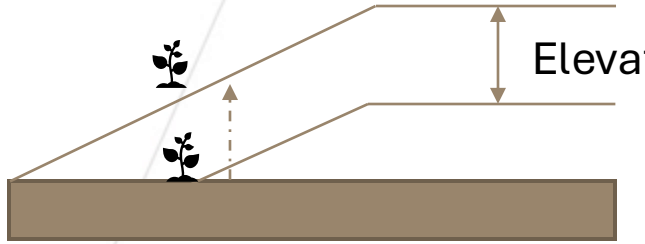
WP12.3: Dune erosion experiments 2026

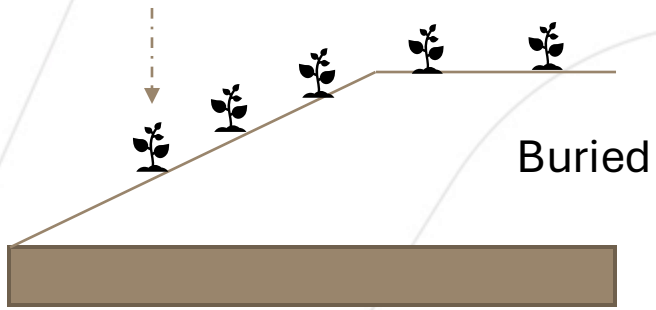
(a) 2026 / 12 months



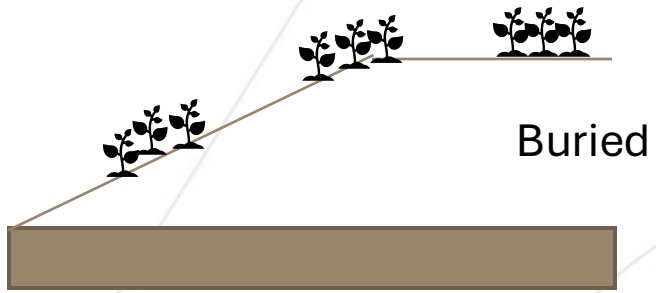
*check for maximum/optimum increase

EAK guideline for planting density & distance
-> scaled down 1:5

(b) 2026 / 12 months



(c) 2026 / 12 months



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WP12.3: Boundary conditions

1:7	Scenario A	Scneario B	Scenario C	Scenario D
	HW200	HW200	HW200	HW50
	-	M100	G100	G100
D (m)	0,50	0,56	0,56	
Hs (m)	0,18	0,14	0,18	
Tp (s)	2,8	2,3	2,8	
T (min)	113	113	113	

1:5	Scenario A	Scneario B	~~Scenario C~~	~~Scenario D~~
	HW200	HW200	~~HW200~~	~~HW50~~
	-	M100	~~M100~~	~~G100~~
D (m)	0,66	0,76		
Hs (m)	0,25	0,20		
Tp (s)	3,13	3,13		
T (min)	134,2	161		

Scenario C is overwash
Scenario D resulted in destruction of dune

Both not feasible with crates due to vertical back wall

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WP12.3: Hydrodynamic scaling

Scale:	5

Deep-wat Approximated wavelength:

$L_o = gT^2/(2$ $L_{app} = L_o\,[\tanh(2\pi\, d/L_o)^{3/4}]^{2/3}$

Prototype (real scale)											Model (m)								
HW scenario	SLR scenario	storm surge water level	SLR	water level	mean beach height	duration	sig. Wave height	peak period	deep water wave lengt	app. Wave length	water level at dune toe	duration	sig. Wave height	peak period	deep water wave lengt	app. Wave length	rel. water depth	breaker index	wave steepness
#	#	h_{Sturm}	h_{SLR}	h	#	t_N	$H_{s,n}$	$T_{p,n}$	$L_{0,n}$	$L_{app,n}$	d_m	t_m	$H_{s,m}$	$T_{p,m}$	$L_{0,m}$	$L_{app,m}$	$d / L_{app,m}$	H_s / d	$H_s / L_{app,m}$
[-]	[-]	m. ü. NHN	{m]	m. ü. NHN	m. ü. NHN	[h]	[m]	[s]	[m]	[m]	[m]	[min]	[m]	[s]	[m]	[m]	[-]	[-]	[-]
HW50	-	4,85	0	4,85	1,9	5	0,8	8	99,9	53,2	0,59	134,2	0,16	3,58	20,0	8,46	0,070	0,271	0,019
HW100	-	5,05	0	5,05	1,9	6	1	6	56,2	38,8	0,63	161,0	0,20	2,68	11,2	6,38	0,099	0,317	0,031
HW200	-	5,2	0	5,2	1,9	5	1	7	76,5	47,2	0,66	134,2	0,20	3,13	15,3	7,73	0,085	0,303	0,026
HW50	M50	4,85	0,2	5,05	1,9	6	0,8	7	76,5	46,6	0,63	161,0	0,16	3,13	15,3	7,56	0,083	0,254	0,021
HW50	M100	4,85	0,5	5,35	1,9	6	1,25	7,5	87,8	51,7	0,69	161,0	0,25	3,35	17,6	8,50	0,081	0,362	0,029
HW50	G50	4,85	0,3	5,15	1,9	6	1	7	76,5	47,0	0,65	161,0	0,20	3,13	15,3	7,67	0,085	0,308	0,026
HW50	G100	4,85	1,2	6,05	1,9	6	1	7	76,5	50,2	0,83	161,0	0,20	3,13	15,3	8,56	0,097	0,241	0,023
HW100	M50	5,05	0,2	5,25	1,9	6	1	7	76,5	47,4	0,67	161,0	0,20	3,13	15,3	7,78	0,086	0,299	0,026
HW100	M100	5,05	0,5	5,55	1,9	6	1	7	76,5	48,5	0,73	161,0	0,20	3,13	15,3	8,09	0,090	0,274	0,025
HW100	G50	5,05	0,3	5,35	1,9	6	1	7	76,5	47,7	0,69	161,0	0,20	3,13	15,3	7,89	0,088	0,290	0,025
HW100	G100	5,05	1,2	6,25	1,9	6	1	7	76,5	50,8	0,87	161,0	0,20	3,13	15,3	8,74	0,100	0,230	0,023
HW200	M50	5,2	0,2	5,4	1,9	6	1	7	76,5	47,9	0,70	161,0	0,20	3,13	15,3	7,94	0,088	0,286	0,025
HW200	M100	5,2	0,5	5,7	1,9	6	1	7	76,5	49,0	0,76	161,0	0,20	3,13	15,3	8,24	0,092	0,263	0,024
HW200	G50	5,2	0,3	5,5	1,9	6	1	7	76,5	48,3	0,72	161,0	0,20	3,13	15,3	8,04	0,090	0,278	0,025
HW200	G100	5,2	1,2	6,4	1,9	6	1	7	76,5	51,3	0,90	161,0	0,20	3,13	15,3	8,87	0,101	0,222	0,023

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WP12.3: Sediment scaling

Sediment

Retailer	product name	mean grain size	Bulk density / type		Uniformity	spec. Surface	fines	AFS
-	-	d50 [mm]	t/m³		in %	cm²/g	<0,063 mm [%]	-
Schlingmeier	G00	0,139	-		55	202	8	110
	G0	0,19	1-1.2		66	135	1	76
Strobel	**QS 711, GS 11, BCS 211**	**0,119**	**1,32**	**kiln dried**	**70**	**211**	**5,5**	**115**
	QS 713, GLS 13-150, GS 13, BS 613, BCS 213	0,136	1.32 - 1.37	kiln dried	87	175	0.5 - 0.9	97
	QS 715, GS 15, BCS 215	0,146	1,34	kiln dried	75	165	0,5	91
	QS 717, GS 17, BS 617, BCS 217	0,171	1,37	kiln dried	71	144	0,5	80
	GLS 14	0,13	0,8	bulk dried	80	171	1	94
	GLS 018, GLS 025, GS 14 RP, GS 15 RP, BCS 312, BCS 313	0,13	1,37	kiln dried	84	180	1	100
	GLS 19/040, GLS 050	0,15	1,37	kiln dried	20	160	0,1	90
	GS 09	0,103	1,3	kiln dried	68	244	3	133
	GS 09 RP	0,107	1,3	kiln dried	68	216	0,5	122
	GS 17 RP	0,165	1,37	kiln dried	73	145	0	81
	BCS 307	0,08	1,32	kiln dried	80	310	21,4	166
	BCS 310. BCS 410	0,09	1,32	kiln dried	86	236 - 263	9	146
	BCS 315	0,15	1,34	kiln dried	76	162	0,5	90
	BCS 411	**0,12**	**1,32**	**kiln dried**	**81**	**188**	**1,2**	**104**
	BCS 412, BCS 413	0,125	1,32	kiln dried	89	187	0,5	104
	BCS 415	0,15	1,32	kiln dried	93	146	0,1	83

Thresholds surpassed (d50, Re oder Ω)

Not suited

Suitable range

the smaller the grain size, the closer we get to the WS or Re limit (laminare current)
the bigger the grain size, the closer we get to the Dean limit (sinking velocity)

**requires information of available sediments*

Dissipative or reflective beach/dune conditions?

		Limit: < 5 (Reflection profile)				Limit: < 5 (Reflection profile)				Limit: < 5 (Reflection profile)	
				influence Hs				influence Tp			
Hs	Tp	Dean_Soulsby	Dean_Stokes	Hs	Tp	Dean_Soulsby	Dean_Stokes	Hs	Tp	Dean_Soulsby	Dean_Stokes
m	s	-	-	m	s	-	-	m	s	-	-
1,5	**7**	13,99	14,29	**1**	**7**	9,33	9,52	**1,5**	**5,00**	19,59	20,00
0,300	3,13	3,96	5,04	0,200	3,13	2,64	3,36	0,300	2,24	5,54	7,06
0,300	3,13	4,31	5,51	0,200	3,13	2,87	3,67	0,300	2,24	6,03	7,71
0,300	3,13	4,72	6,10	0,200	3,13	3,15	4,07	0,300	2,24	6,61	8,55
0,300	3,13	5,22	6,80	0,200	3,13	3,48	4,53	0,300	2,24	7,30	9,52
0,300	3,13	5,82	7,61	0,200	3,13	3,88	5,07	0,300	2,24	8,14	10,65
0,300	3,13	6,56	8,63	0,200	3,13	4,37	5,76	0,300	2,24	9,18	12,09
0,300	3,13	7,48	9,58	0,200	3,13	4,98	6,39	0,300	2,24	10,47	13,42
0,300	3,13	8,64	11,41	0,200	3,13	5,76	7,61	0,300	2,24	12,10	15,97
0,300	3,13	10,15	13,50	0,200	3,13	6,77	9,00	0,300	2,24	14,21	18,90
0,300	3,13	12,14	16,24	0,200	3,13	8,09	10,83	0,300	2,24	17,00	22,74
0,300	3,13	14,84	20,39	0,200	3,13	9,89	13,59	0,300	2,24	20,78	28,55
0,300	3,13	18,63	25,22	0,200	3,13	12,42	16,81	0,300	2,24	26,09	35,31
0,300	3,13	24,19	31,94	0,200	3,13	16,12	21,30	0,300	2,24	33,86	44,72
0,300	3,13	32,76	45,63	0,200	3,13	21,84	30,42	0,300	2,24	45,86	63,89
0,300	3,13	47,01	68,45	0,200	3,13	31,34	45,63	0,188	2,24	41,13	59,89

discarded due to threshold

adapt Hs & Tp for different scenarios, scaling factor B1 applies

**requires adaptation of Hs, Tp according to planned/observed conditions*

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WP12.3: Sensors & Data acquisition

- SeaTek Echosounders
- 2 ADVs
- 2 OBS
- 5 Pressure gauges inside the beach
- 8 ultrasonic wave gauges
- 1 lidar
- 1 camera
- 1 gopro
- 1 HBM
- 1 PC
- 2-3 Screens

- Experimental runs list
- Folders for data storage
- Consistent naming
- Procedure manual
  - 1 …
  - 2 …
  - …

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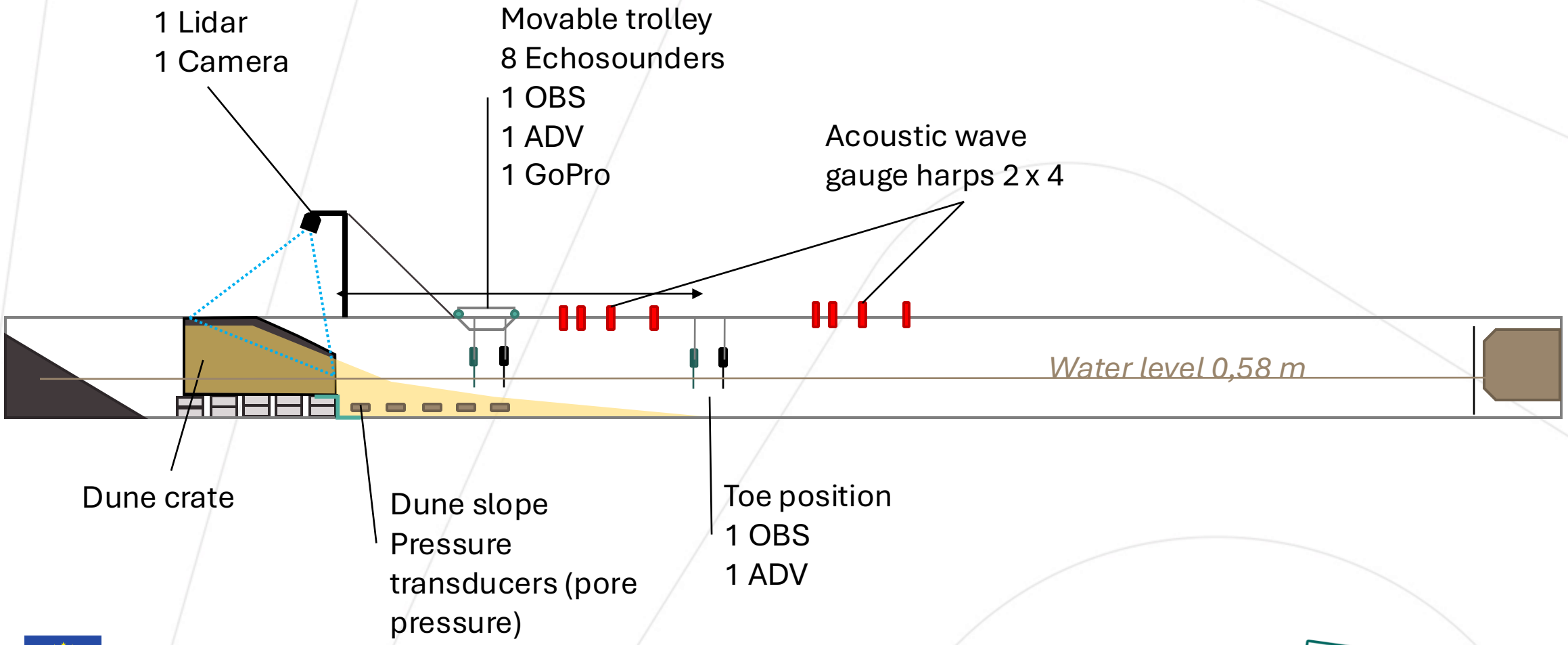
WP12.3: Section of setup and sensors



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WP12.3: Limitations

- WP11 -> TU Berlin has Deliverable by end of 2025 regarding plant traits
  - Requires plant trait data
  - Lidar slope development

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