

Electronic Supplemental Material

Article title: Vegetation patch-level characteristics as key drivers of coastal dune elevation: optimizing nature-based coastal defences

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Estuaries and Coasts

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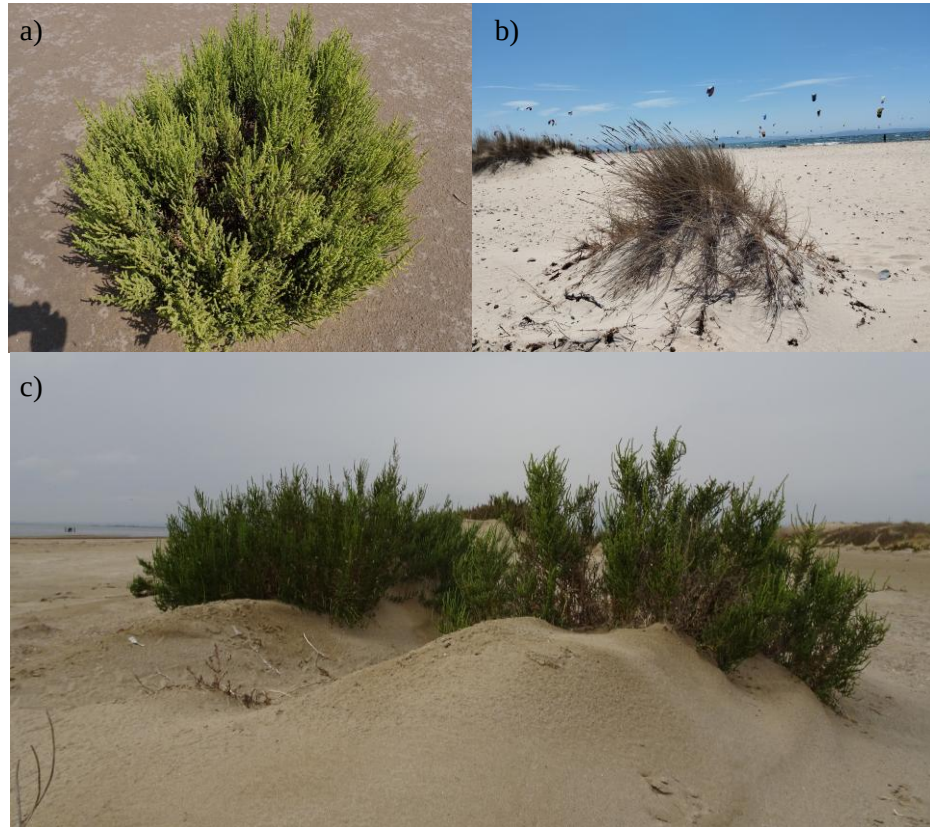


Figure S1. Sandy systems sampled: a) Garxal, Ebro Delta – Protected dunes, Mediterranean coast; b) Los Lances, Cádiz – Non-protected dunes, Atlantic coast; c) La Marquesa, Ebro Delta – Non-protected dunes, Mediterranean coast.

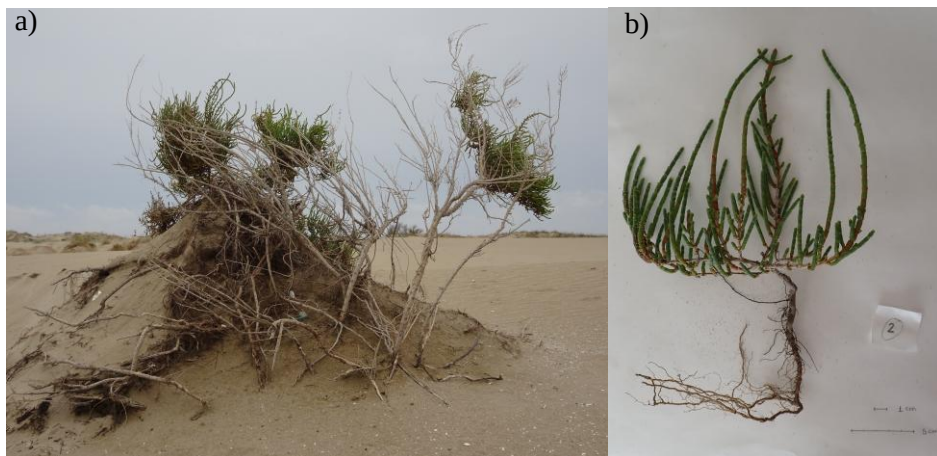


Figure S2. *Sarcocornia fruticosum* a) in the field, Ebro Delta, and b) in the laboratory for trait measurements.

Table S1. A total count of dominant species (n=12) across all sampled patches (n=480)

Dominant plant species	n (patch)
<i>Ammophila arenaria</i>	112
<i>Cakile maritima</i>	76
<i>Echinophora spinosa</i>	19
<i>Euphorbia paralias</i>	23
<i>Limoniastrum monopetalum</i>	9
<i>Limonium vigoii</i>	13
<i>Salicornia europaea</i>	80
<i>Salsola kali</i>	61
<i>Sarcocornia fruticosum</i>	51
<i>Sporobolus pungens</i>	11
<i>Suaeda maritima</i>	13
<i>Xanthium strumarium</i>	12

Table S2. Description of the four plant communities across habitats used in this study:

Community type	Strandline	Pioneer dunes	Dunes	Dune depressions and backdunes
Description	Annual halonitrophilous vegetation occupying accumulations of drift material and gravel, exposed to wind action and occasionally to breaking waves.	Pioneer, perennial, and halophilous community of the low embrion dunes, forming the first dunes and usually exposed to wind, salt spray, and occasionally flooding.	Perennial herb community assemblages growing on dunes-stabilized dunes. Communities of the inland side of dunes are dominated by chamaephyte herbaceous and rhizomatous species.	Herbaceous wet communities of the dune slacks. Formations of annuals and ephemeral plants occupying deep sands in dry interdunal depressions, and located in the clearings of perennial vegetation.
Most abundant species	<i>Cakile maritima</i> <i>Salsola kali</i>	<i>Ammophila arenaria</i> <i>Euphorbia paralias</i> <i>Sporobolus pungens</i> <i>Polygonum maritimum</i> <i>Suaeda maritima</i> <i>C. maritima</i> <i>S. kali</i>	<i>A. arenaria</i> <i>Crithmum maritimum</i> <i>Echinophora spinosa</i> <i>Medicago maritima</i> <i>Xanthium strumarium</i>	<i>Salicornia europaea</i> <i>Sarcocornia fruticosum</i> <i>Limoniastrum monopetalum</i> <i>Limonium vigoi</i>
Plot number	16	224	136	104

Table S3. Functional traits were used to calculate the models and multivariate analysis for 14 psammophilous species. Data represent the means $\pm$ SE of 3 replicates.

Plant specie	Family	Phenology	Plant life-form	Total Length (cm)	CAN-H (cm)	Root Spread (cm)	Leaves Spread (cm)	Maximum Root Length (cm)	Mean Root Length (cm)	Total Root Length (cm/m ²)	Shoot Density (m ²)	Root Density (m ²)
<i>Ammophila arenaria</i>	Poaceae (Gramineae)	Perenne	hemicryptophyte	39.90 $\pm$ 2.26	31.03 $\pm$ 0.99	15.63 $\pm$ 1.32	8.20 $\pm$ 0.61	13.93 $\pm$ 1.54	35.29 $\pm$ 26.54	8480.73 $\pm$ 3286.94	396.12 $\pm$ 198.73	452.71 $\pm$ 142.41
<i>Cakile maritima</i>	Cruciferae (Brassicaceae)	Annual	therophyte	36.75 $\pm$ 8.97	25.00 $\pm$ 7.82	18.38 $\pm$ 3.73	12.47 $\pm$ 4.60	17.75 $\pm$ 2.99	12.00 $\pm$ 1.51	3706.54 $\pm$ 1482.73	155.62 $\pm$ 42.44	325.38 $\pm$ 116.37
<i>Echinophora spinosa</i>	Apiaceae	Bienal/perenne	geophyte	14.07 $\pm$ 5.24	8.77 $\pm$ 3.60	14.80 $\pm$ 10.87	13.00 $\pm$ 1.53	23.67 $\pm$ 3.71	15.49 $\pm$ 1.99	3755.59 $\pm$ 364.64	565.88 $\pm$ 32.67	245.22 $\pm$ 18.86
<i>Euphorbia paralias</i>	Euphorbiaceae	Annual	chamaephyte	59.33 $\pm$ 3.84	42.33 $\pm$ 2.73	13.00 $\pm$ 0.87	14.00 $\pm$ 0.58	24.50 $\pm$ 0.76	11.29 $\pm$ 1.24	2084.34 $\pm$ 61.85	547.02 $\pm$ 37.73	188.63 $\pm$ 18.86
<i>Limonium vigoii</i>	Plumbaginaceae	Perenne	therophytic	9.62 $\pm$ 1.48	1.88 $\pm$ 0.31	12.75 $\pm$ 3.17	4.88 $\pm$ 1.03	11.10 $\pm$ 2.43	6.41 $\pm$ 0.57	2225.34 $\pm$ 511.41	14.15 $\pm$ 14.15	353.68 $\pm$ 87.59
<i>Salicornia europaea</i>	Chenopodiaceae	Annual/perenne	therophyte	34.33 $\pm$ 2.91	18.00 $\pm$ 1.73	9.17 $\pm$ 0.60	8.63 $\pm$ 0.61	16.33 $\pm$ 1.20	16.33 $\pm$ 2.91	1339.26 $\pm$ 272.04	150.90 $\pm$ 37.73	94.31 $\pm$ 37.73
<i>Salsola kali</i>	Amaranthaceae	Annual	therophyte	36.27 $\pm$ 11.44	23.50 $\pm$ 8.10	13.03 $\pm$ 3.31	17.37 $\pm$ 2.58	11.73 $\pm$ 3.29	8.93 $\pm$ 1.45	4036.64 $\pm$ 809.78	377.26 $\pm$ 49.91	471.57 $\pm$ 99.81
<i>Sarcocornia fruticosum</i>	Chenopodiaceae	Perenne	therophyte	25.33 $\pm$ 2.96	13.67 $\pm$ 1.20	11.50 $\pm$ 3.55	11.33 $\pm$ 1.76	12.40 $\pm$ 1.78	16.18 $\pm$ 5.12	1552.41 $\pm$ 228.94	264.08 $\pm$ 37.73	113.18 $\pm$ 32.67
<i>Suaeda maritima</i>	Chenopodiaceae	Annual	therophyte	12.53 $\pm$ 0.76	5.47 $\pm$ 1.07	7.90 $\pm$ 0.74	11.03 $\pm$ 0.97	12.80 $\pm$ 1.03	6.21 $\pm$ 1.24	1754.24 $\pm$ 257.44	381.97 $\pm$ 48.32	297.09 $\pm$ 35.60

Plant specie	Specific Root Length (SRL, cm/g)	Root Length Density (DLR, cm/cm³)	Root Length Ratio (RLR, cm/g)	Root Tissue Density (RTD, g/cm³)	Relative Root Weight (RWR)	Root to shoot ratio (RS)	Root biomass (g/m²)	Stem biomass (g/m²)	Leaves biomass (g/m²)	Aboveground biomass (AGB, g/m²)	Above: Belowground ratio
<i>Ammophila arenaria</i>	48.69 ± 8.97	0.02 ± 0.01	21.46 ± 3.47	$4.33 \cdot 10^{-4} \pm 1.46 \cdot 10^{-4}$	0.31 ± 0.04	0.56 ± 0.12	176.14 ± 60.30	190.21 ± 46.41	182.61 ± 40.82	372.82 ± 86.38	2.33 ± 0.42
<i>Cakile maritima</i>	20.41 ± 6.55	0.01 ± 0.00	5.28 ± 1.63	$4.25 \cdot 10^{-4} \pm 2.5 \cdot 10^{-5}$	0.22 ± 0.04	0.30 ± 0.06	168.18 ± 14.90	201.78 ± 32.13	538.06 ± 205.63	739.84 ± 236.32	4.24 ± 1.21
<i>Echinophora spinosa</i>	19.71 ± 6.18	0.01 ± 0.00	13.05 ± 2.53	$7.33 \cdot 10^{-4} \pm 3.84 \cdot 10^{-5}$	0.43 ± 0.13	1.16 ± 0.66	287.13 ± 154.08	124.27 ± 6.02	178.57 ± 45.69	302.84 ± 48.29	1.79 ± 0.84
<i>Euphorbia paralias</i>	11.59 ± 0.62	0.01 ± 0.00	1.94 ± 0.07	$4.33 \cdot 10^{-4} \pm 3.33 \cdot 10^{-5}$	0.14 ± 0.01	0.25 ± 0.01	180.33 ± 4.99	446.25 ± 42.36	632.24 ± 24.89	1078.49 ± 66.74	6.01 ± 0.52
<i>Limonium vigoii</i>	27.03 ± 3.49	0.01 ± 0.00	7.17 ± 2.14	$2.00 \cdot 10^{-4} \pm 4.08 \cdot 10^{-5}$	0.20 ± 0.04	0.43 ± 0.10	80.57 ± 16.99	192.20 ± 58.92	154.71 ± 50.39	346.92 ± 101.24	4.48 ± 1.05
<i>Salicornia europaea</i>	7.00 ± 0.86	0.00 ± 0.00	2.22 ± 0.43	$4.33 \cdot 10^{-4} \pm 3.33 \cdot 10^{-5}$	0.24 ± 0.01	0.42 ± 0.03	187.93 ± 15.82	437.16 ± 22.25	168.69 ± 17.37	605.86 ± 32.57	3.26 ± 0.25
<i>Salsola kali</i>	31.14 ± 6.37	0.01 ± 0.00	4.59 ± 0.34	$3.00 \cdot 10^{-4} \pm 0.00$	0.13 ± 0.01	0.17 ± 0.02	129.78 ± 1.05	154.30 ± 7.66	709.62 ± 121.01	863.92 ± 114.59	6.66 ± 0.91
<i>Sarcocornia fruticosum</i>	8.21 ± 1.00	0.00 ± 0.00	1.75 ± 0.25	$4.67 \cdot 10^{-4} \pm 8.82 \cdot 10^{-5}$	0.18 ± 0.03	0.34 ± 0.04	194.34 ± 33.12	618.27 ± 20.04	267.02 ± 25.86	885.29 ± 5.95	4.87 ± 0.94
<i>Suaeda maritima</i>	9.80 ± 1.35	0.00 ± 0.00	6.68 ± 1.39	$4.75 \cdot 10^{-4} \pm 4.79 \cdot 10^{-5}$	0.40 ± 0.03	0.99 ± 0.08	180.42 ± 16.97	148.94 ± 26.02	128.84 ± 7.81	277.78 ± 33.14	1.56 ± 0.18

GLMM results:

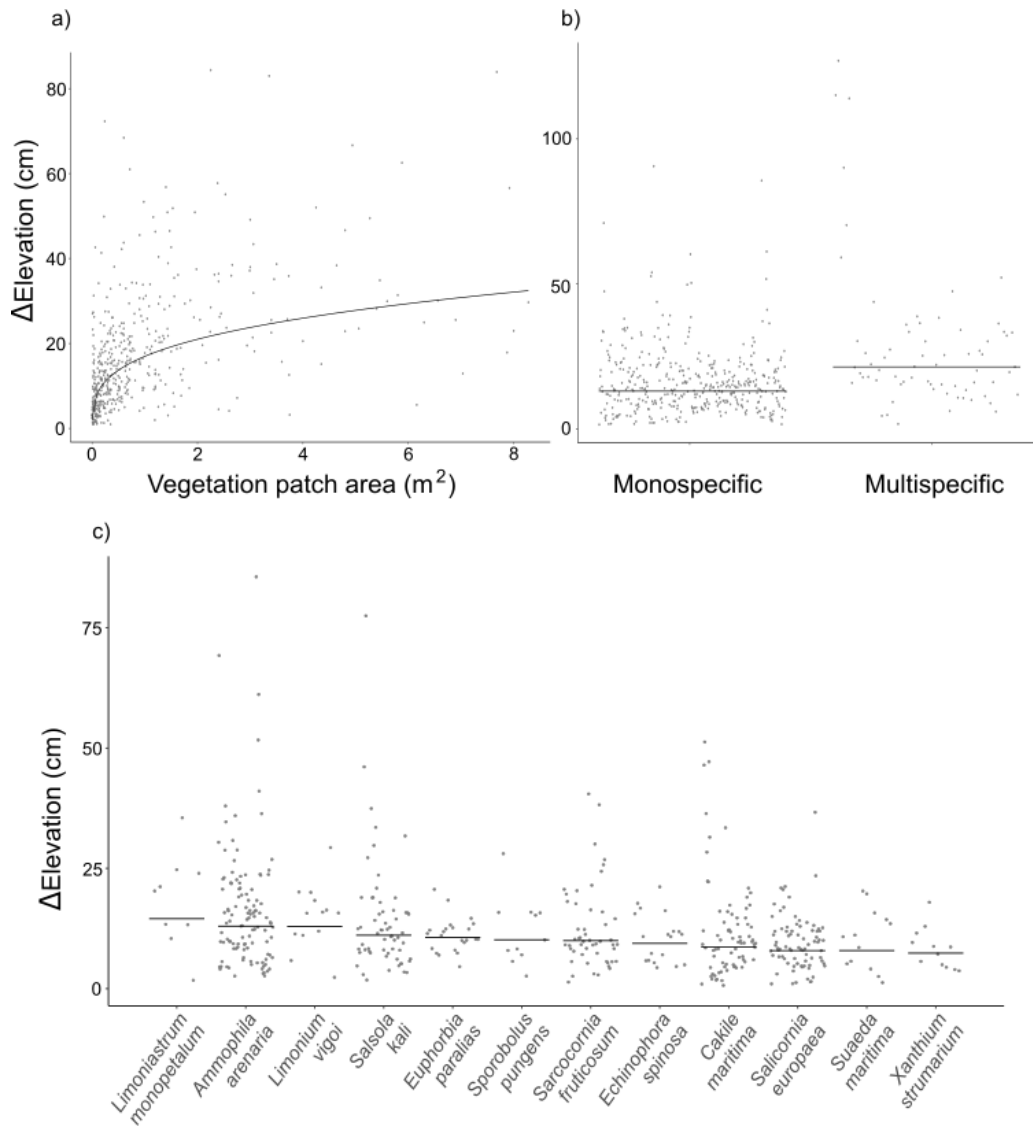


Figure S3. GLMM results of the relationship between: a) the vegetation patch area (in square meters) and the elevation change (in centimeters); b) vegetation patch composition (monospecific vs. multispecific) and elevation change; c) plant species across vegetation patches and elevation change. Data points represent the distribution of standardized partial residuals of the fitted linear mixed model, where continuous lines represent the model fit through the data. Points represent partial residuals using “visreg”.

Table S4. Results from the stepwise linear mixed-effects model (GLMM) for the main drivers of sediment elevation.

Response	Fixed effects	Estimate	Std. Error	d.f.	t value	p value
Sediment elevation	patch area	0.306207	0.023545	464.302	13.005	< 2e-16 ***
	species composition	-0.249035	0.051692	465.752	-4.818	1.97e-06 ***
	specie1	0.367094	0.239307	457.005	1.534	0.12572
	specie2	0.253562	0.082965	465.997	3.056	0.00237 **
	specie3	0.250589	0.212798	464.370	1.178	0.23956
	specie4	0.097010	0.106117	460.162	0.914	0.36110
	specie5	0.054089	0.163748	418.897	0.330	0.74132
	specie6	0.007015	0.212444	465.796	0.033	0.97367
	specie7	-0.009296	0.117448	429.215	-0.079	0.93695
	specie8	-0.068774	0.219336	175.180	-0.314	0.75423
	specie9	-0.155430	0.094807	459.299	-1.639	0.10181
	specie10	-0.242820	0.096623	435.785	-2.513	0.01233 *
	specie11	-0.241162	0.214934	438.626	-1.122	0.26247

Edaphic properties:

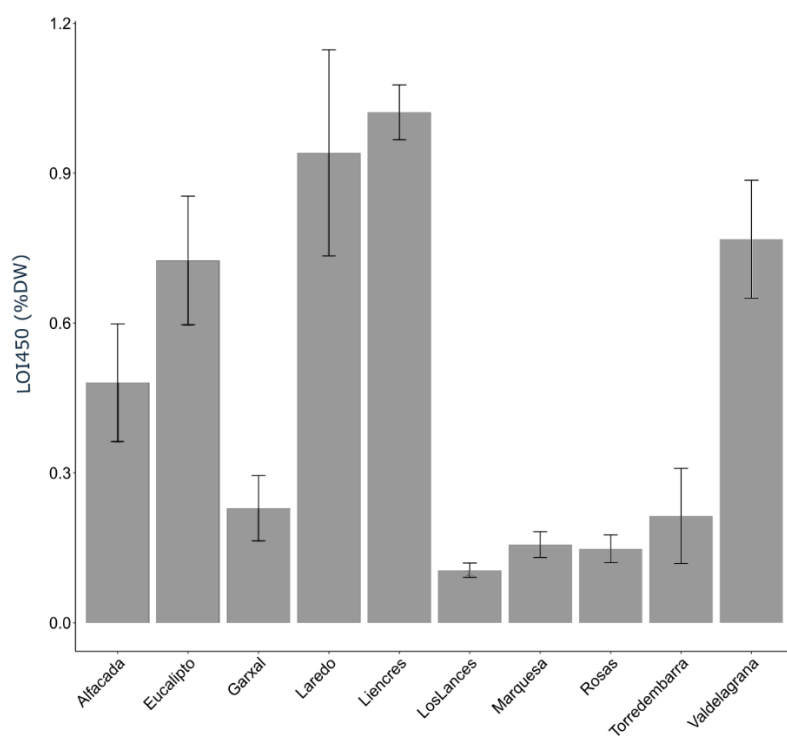


Figure S4. LOI450 (%DW) in bulk sediment samples.

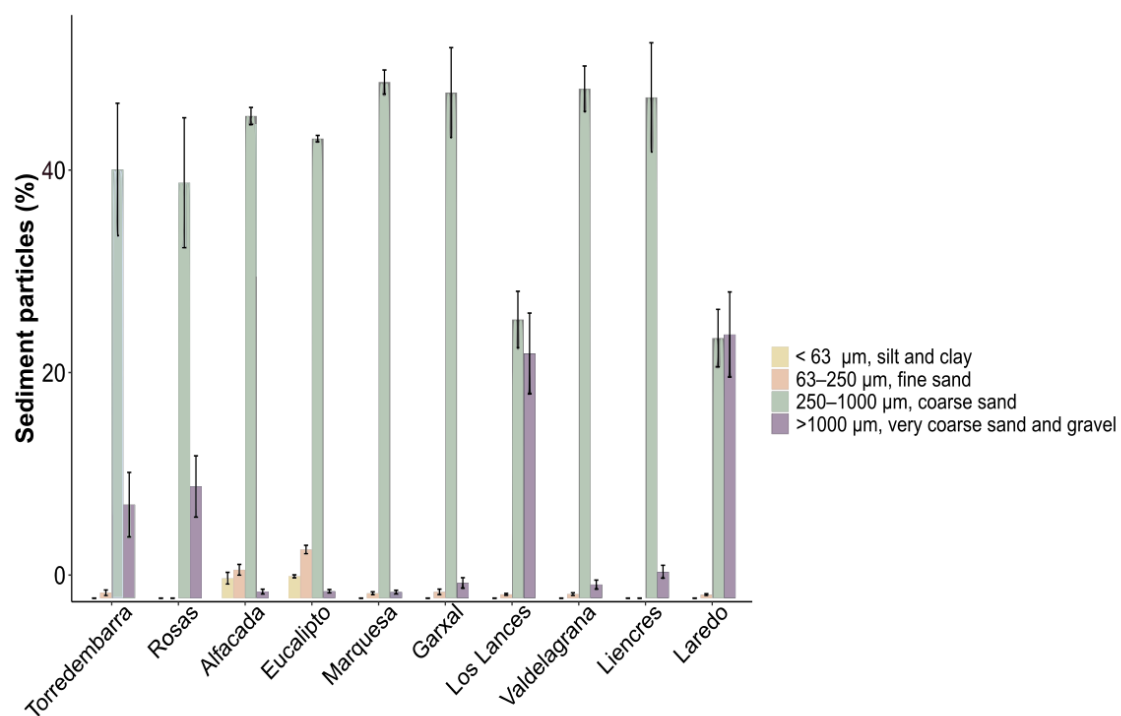


Figure S5. Sediment grain size distribution across the sampled localities, classified according to the Udden–Wentworth scale: silt and clay (<63 µm), fine sand (63–250 µm), coarse sand (250–1000 µm), and very coarse sand and gravel (>1000 µm).