
REMTECH EXPO
FERRARA FIERE
17-19
SETTEMBRE 2025

LE DUNE COSTIERE
Valore ambientale, paesaggistico ed economico.
Risorsa da proteggere e preservare

VENTI ANNI DI INNOVAZIONE PER LO STUDIO E LA MITIGAZIONE DEGLI IMPATTI SULLE DUNE COSTIERE

Dr. SERGIO CAPPUCCI

Ferrara, 18 settembre 2025

Progetti di ricerca
(nazionali ed internazionali)

CNR, ENEA, ISPRA, Univ. di Camerino, Cagliari, Sassari, La Sapienza Univ. di Roma

Reg Lazio, Marche, Prov. Latina, Comuni S.B.Tronto, Sabaudia, Sassari, P.Naz.le Circeo, Ris Nat.le Sentina

COAUTORI

Acciarri A., Amodio M., Andreucci S., Bisci C., Bovina G., Cantalamessa G., Callori C., Conti M., Cucco A., De Luca M., Di Pancrazio G., Filipponi F., Innocenti C., Pascucci V., Quattrocchi G., Santonastaso A., Screpanti A., Spagnoli F., Taramelli A., Valentini E., Nguyen Xuan A.

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OUTLINE

INTRODUZIONE

BEACHMED - POSIDUNE

CONVENZIONE ENEA-ISPRA-REGIONE LAZIO

TASK FORCE COMUNE DI ALGHERO

CASI STUDIO

USO DI NUOVE TECNOLOGIE REMOTE AND PROXIMAL SENSING

CONSIDERAZIONI CONCLUSIVE

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DUNE – COME CARATTERIZZARLE

ELEMENT	TYPE	ATTRIBUTES	CLASSES
Dune	Polygon	State of activity	Active or re-activated dune
			Dormant dune
		Vegetation	Arboreal vegetation
			Shrub vegetation
			Herbaceous vegetation
			Arboreal sparse vegetation (<20%)
			Shrub sparse vegetation (<20%)
			Denuded
		Anthropization	Urban area
			Urban patches
			Human alterations
		Evolutionary trend	Accreting shore
			Stable shore
			Eroding shore
		Beach Width	0–20 m
			20–60 m
			>60 m
Dune crest	Line		
Crest height	Point		
Accesses	Point/ Line		Ways and walk-Paths
			Natural accesses
Wind	Point		
Protection scheme	Line		Nourishment
			Attached groynes
			Nourishment and hard structures
Use of the Beach	Line		Temporary seaside resort
			Permanent seaside resort

2004-2006

2006-2008

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www.beachmed.it/posidune

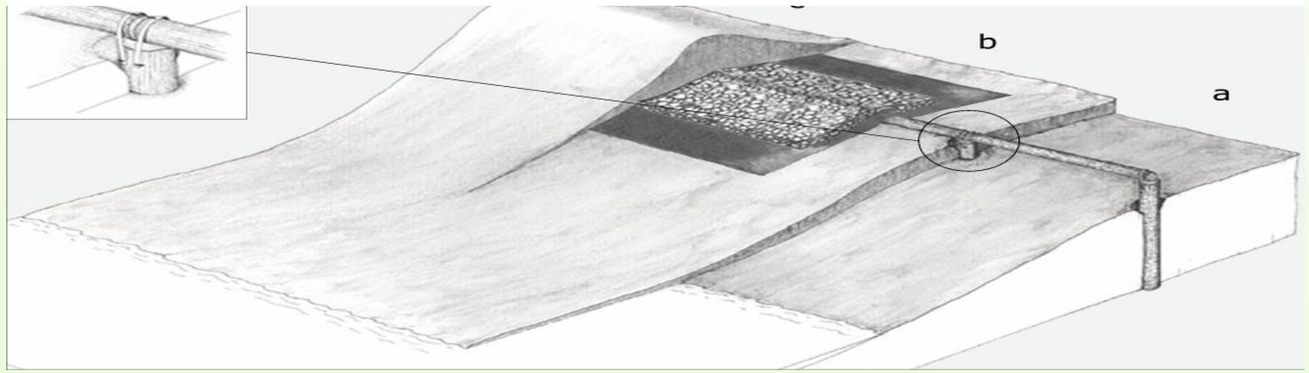
DUNE RESTORATION

www.beachmed.it/posidune

WIND FENCES

CONSOLIDATION THROUGH PLANTING

RECONSTRUCTION



MANAGEMENT OF ACCESS

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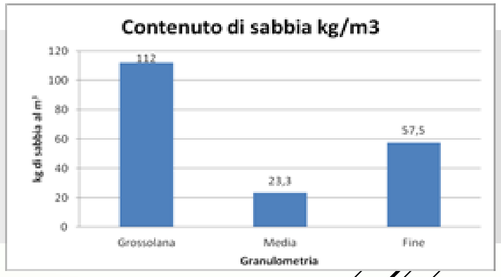
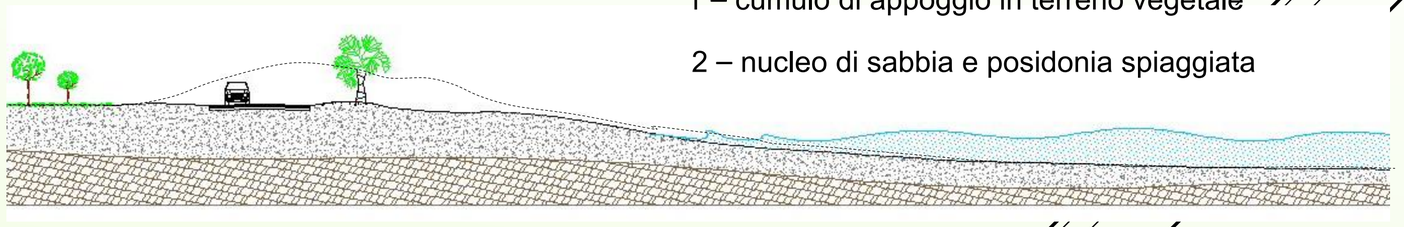
www.beachmed.it/posidune

Task Force antierosione: Alghero 2009-2010

- **Localizzazione dell'area oggetto di interesse**
- **Dinamica del sistema dunale**
- **Metodologia di intervento**



Stato attuale

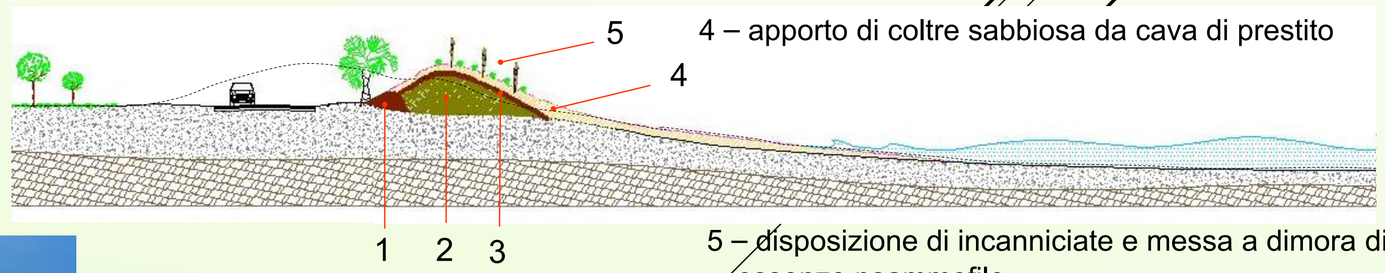


1 – cumulo di appoggio in terreno vegetale

2 – nucleo di sabbia e posidonia spiaggiata

3 – biostuoia in fibra di cocco di contenimento

Ricostituzione della duna e del profilo di spiaggia



4 – apporto di coltre sabbiosa da cava di prestito

5 – disposizione di incanniciate e messa a dimora di essenze psammofile

2009-2010

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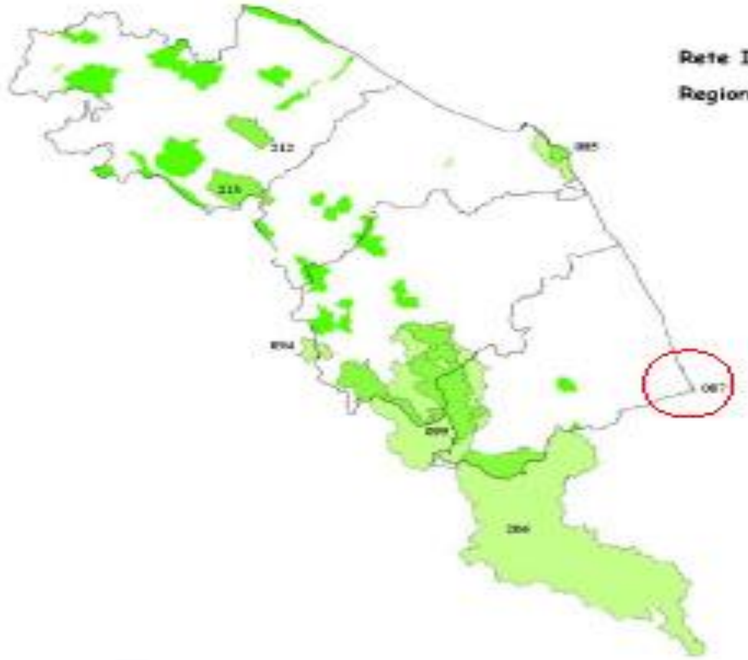
UNISS
UNIVERSITÀ
DEGLI STUDI
DI SASSARI

RISERVA NATURALE DELLA SENTINA



Name and IBA code 1998-2000: Sentina - 087
Italian Region: Marche
Extension: 122 ha
Description and reason of selection: residual coastal wetland stepping stone for migrating avifauna

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ADATTAMENTO E MITIGAZIONE

GRAPHICAL ABSTRACT

Ocean and Coastal Management 201 (2021) 105472

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: http://www.elsevier.com/locate/ocecoaman

Metrics for short-term coastal characterization, protection and planning decisions of Sentina Natural Reserve, Italy

A. Acciarri [a], C. Bisci [a], G. Cantalamessa [a], S. Cappucci [b,*], M. Conti [c], G. Di Pancrazio [a], F. Spagnoli [d], E. Valentini [d]

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[b] ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Rome, Italy
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ARTICLE INFO

Keywords:
Beach erosion
Sediment transport
Coastal evolution
Coastal dunes
Dredging

ABSTRACT

Geomorphological and sedimentological surveys of the emerged and submerged beach-dune system are fundamental for a successful management and protection strategies for coastal planning and development. In particular, these surveys can reveal if coastal areas are affected by erosion, pollution and loss of habitats under the seasonal anthropic pressure related to tourism, leisure and professional fishing, urbanisation and/or other activities impacting the coastal marine resources.

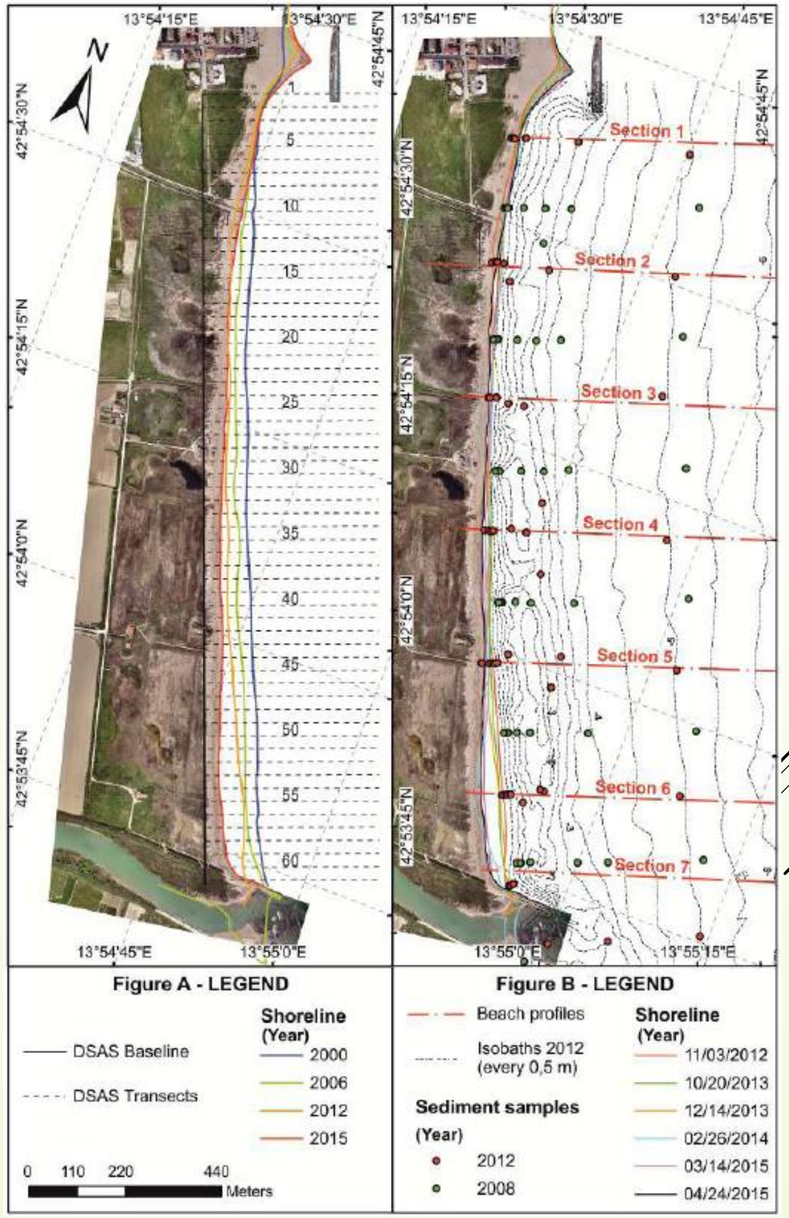
In the present study we discuss the results of the multidisciplinary monitoring activities carried out within the Sentina Natural Reserve (Municipality of San Benedetto del Tronto, Adriatic side of Central Italy, at the south-eastern end of the Marche Region) proposing an exportable methodological approach. Due to the absence of buildings, the study area has not been considered in the coastal protection plan by regional and local authorities and, as a consequence, it is currently exposed to severe coastal erosion, the rate of which has been more precisely determined during the present study. This monitoring testifies that most of the seaward surface of the beach disappeared resulting in a general set back of the whole beach environment. In the last decades, several restoration strategies have been adopted to protect and restore the dunes and the back dunes habitats and the municipality also carried out an emergency action to nourish the beach, including the use of sand dredged from the nearby city harbor.

With this sediment management approach, a tradeoff between safety of navigation of harbor inlet and habitat conservation of Natural Reserve have been reached, since beach nourishment can reduce coastal vulnerability and risk, even though its sustainability in the long term is still debated.

ACCIARRI A., BISCI C., CANTALAMESSA G., CAPPUCCI S.*, CONTI M., DI PANCRAZIO G., SPAGNOLI F., VALENTINI E., (2021). *Metrics for short-term coastal characterization, protection and planning decisions of Sentina Natural Reserve, Italy*. Journal of Ocean and Coastal Management, 201, 105472.

VARIABILITÀ STAGIONALE DELLE DUNE

		Unit	03-nov-12	20-ott-13	14-dic-13	24-apr-15	Total ΔV	Beach Profiles
Section 1	V up to shoreline	(m^2)	134	140,9	138,9	130,1	---	SECTION 1
	ΔV on previous survey	(m^3/ml)	---	+6,9	-2	-8,8	-3,9	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	+690	-200	-880	-390	
Section 2	V up to shoreline	(m^2)	211,8	265,3	277,5	222,5	---	SECTION 2
	ΔV on previous survey	(m^3/ml)	---	+53,5	+12,2	-55	+10,7	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	+16.050	+3.660	-16.500	+3.210	
Section 3	V up to shoreline	(m^2)	163	162	142,2	114,8	---	SECTION 3
	ΔV on previous survey	(m^3/ml)	---	-1	-19,8	-27,4	-48,2	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	-300	-5.940	-8.220	-14.460	
Section 4	V up to shoreline	(m^2)	184	202	162,5	99,3	---	SECTION 4
	ΔV on previous survey	(m^3/ml)	---	+18	-39,5	-63,2	-84,7	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	+5.400	-11.850	-18.960	-25.410	
Section 5	V up to shoreline	(m^2)	151,1	132,2	78,1	68,2	------	SECTION 5
	ΔV on previous survey	(m^3/ml)	---	-18,9	-54,1	-9,9	-82,9	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	-5.670	-16.230	-2.970	-24.870	
Section 6	V up to shoreline	(m^2)	174	147,2	131	7,7	---	SECTION 6
	ΔV on previous survey	(m^3/ml)	---	-26,8	-16,2	-123,3	-166,3	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	-8.040	-4.860	-36.990	-49.890	
Section 7	V up to shoreline	(m^2)	139	118,6	110,1	5,8	---	SECTION 7
	ΔV on previous survey	(m^3/ml)	---	-20,4	-8,5	-104,3	-133,2	
	Total ΔV on previous survey	(m^3 x 100 ml)	---	-3.672	-1.530	-18.774	-23.976	
Total volume loss from nov-2012 to apr-2015 (m^3)							135.399,9	03-nov-12 20-ott-13 14-dic-13 24-apr-15



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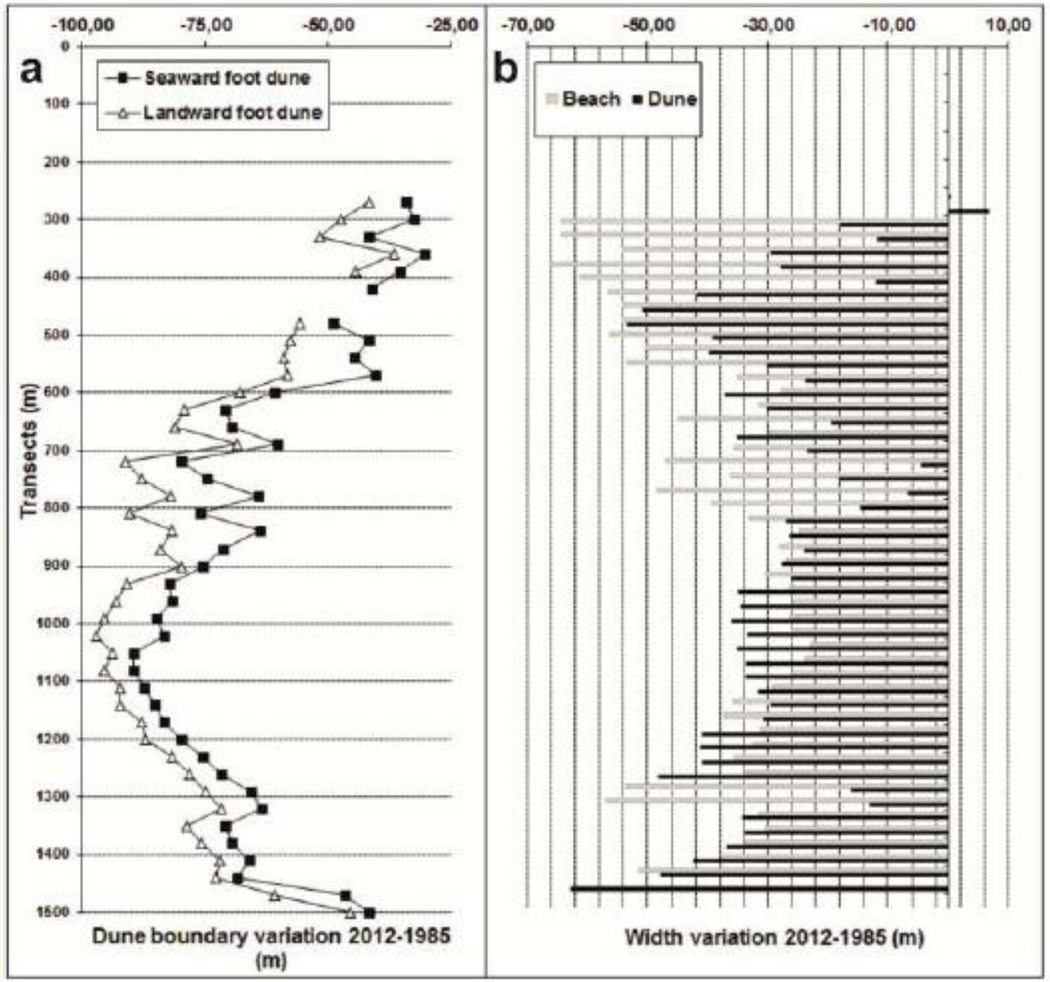
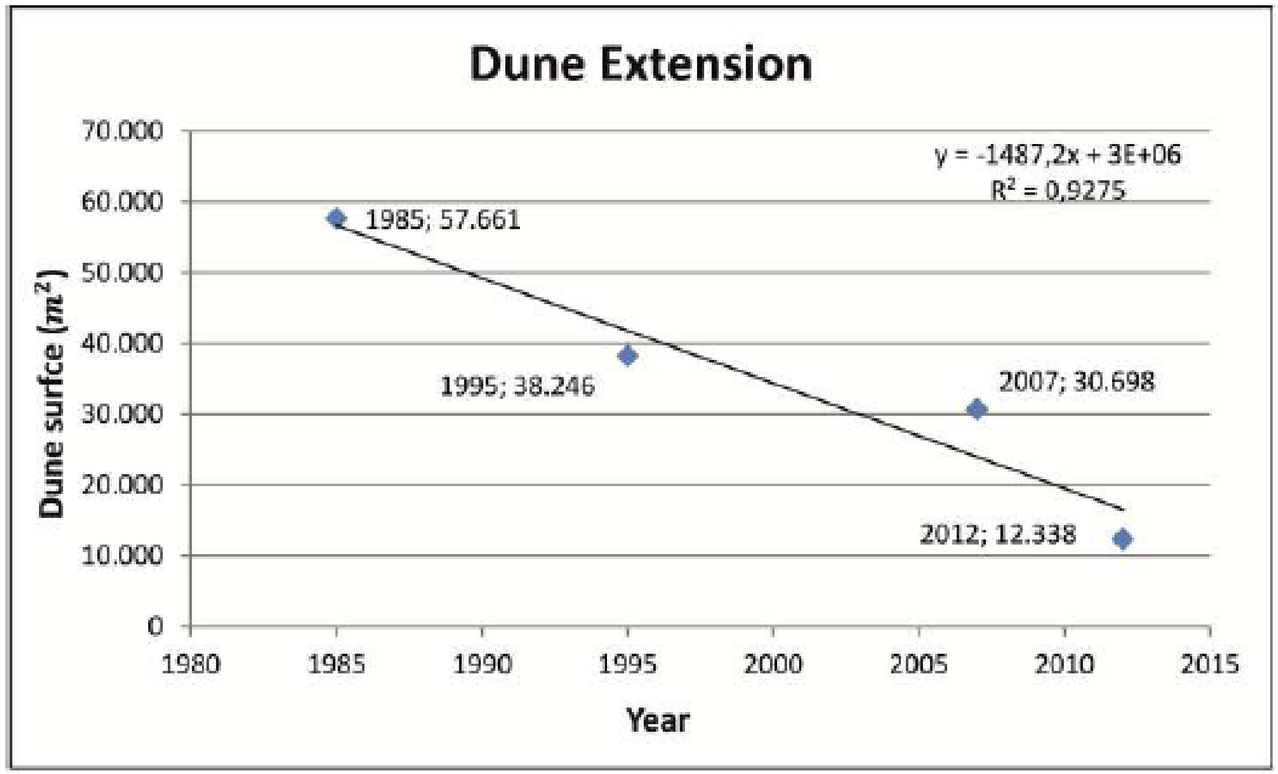
TENDENZA EVOLUTIVA



Element	Unit	1985	1995	2007	2012
Surface of dune polygon	m^2	57,661	38,246	30,698	12,388
Average dune width	m	40.27	23.21	23.60	9.00
Surface of vegetated areas	m^2	34,576	21,898	18,920	3,921
Number of gates	No.	9	8	10	14
Length of walkpaths	m	2,197	2,262	1,907	1,670
Surface of wetland	m^2	10,021	Absent	Absent	33,700*
Defence structures	–	Absent	Absent	Absent	Absent



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AZIONE DI EMERGENZA A PROTEZIONE DELLA DUNA

10,000 m^3 of sand dredged from
San Benedetto del Tronto Harbor
were used for nourishent to protect the Dunes

BISCI C., BOVINA G., CANTALAMESSA G., **CAPPUCCI S.**, CONTI M., SINATRA A., VALENTINI E. (**2011**). *Caratteristiche sedimentologiche e morfologiche, tendenza evolutiva della Riserva Naturale di Sentina (Marche) e ruolo dell'Habitat dunale per la riqualificazione ambientale*. Studi Costieri (ISSN: 1129-8588), 17: 147-162.

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DUNE NELLO STRETTO - INQUADRAMENTO DELL'AREA

A shallow-water dunefield in a microtidal, wind-dominated strait (Stintino, NW Sardinia, Italy)

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2002-2022

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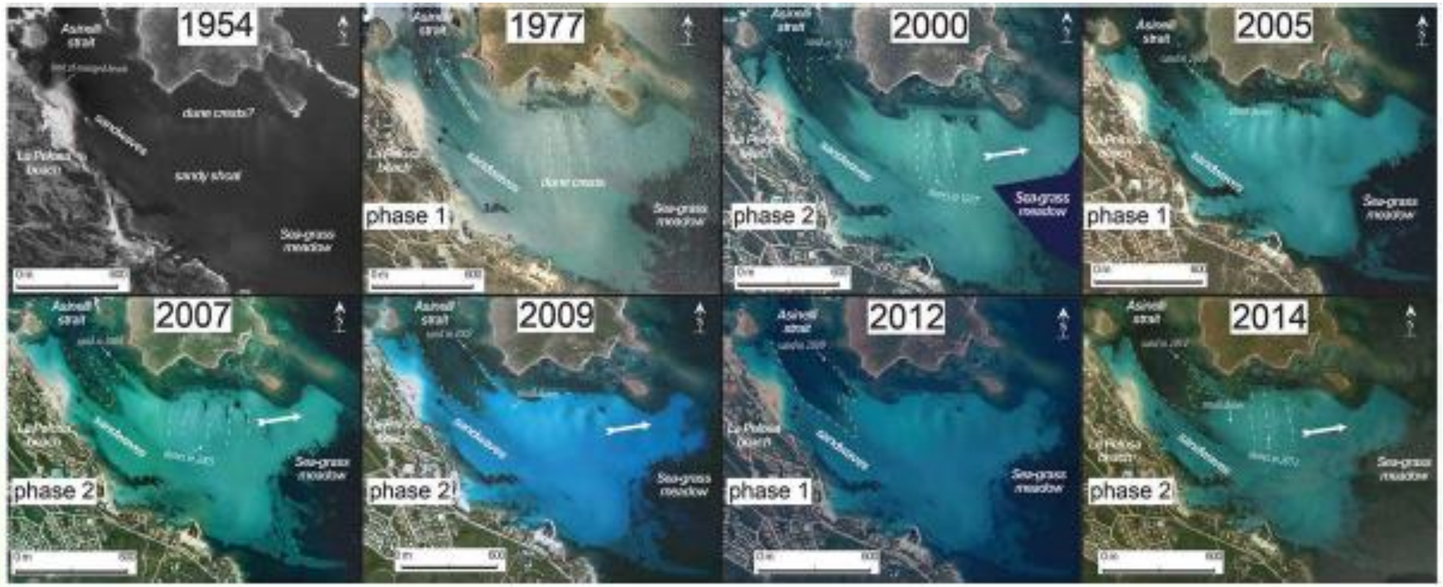
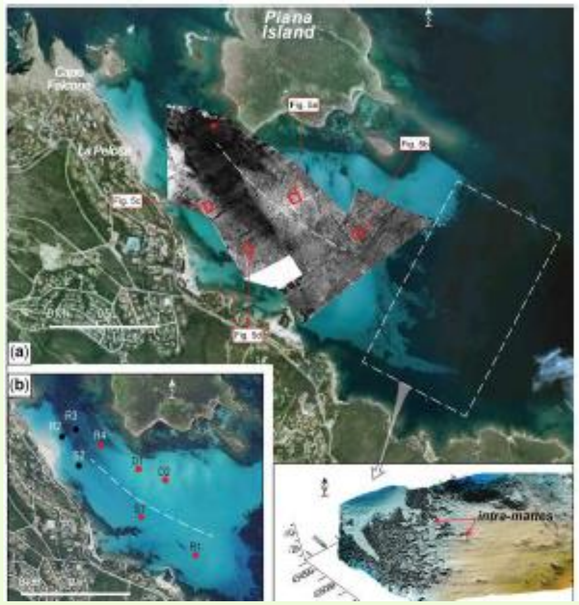
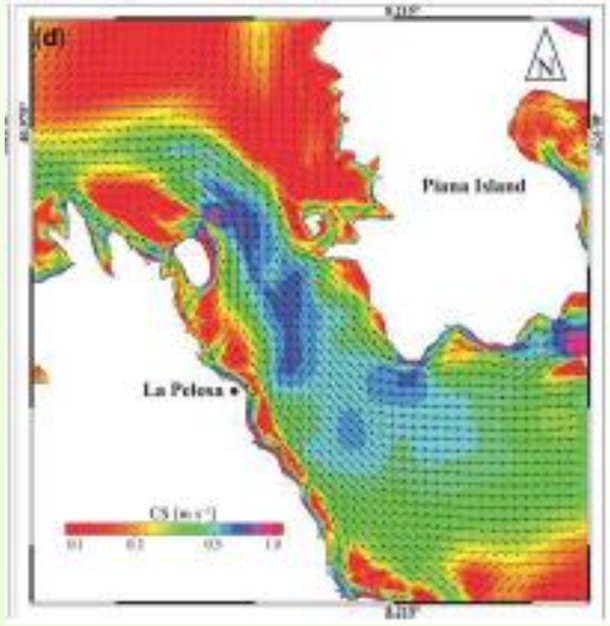
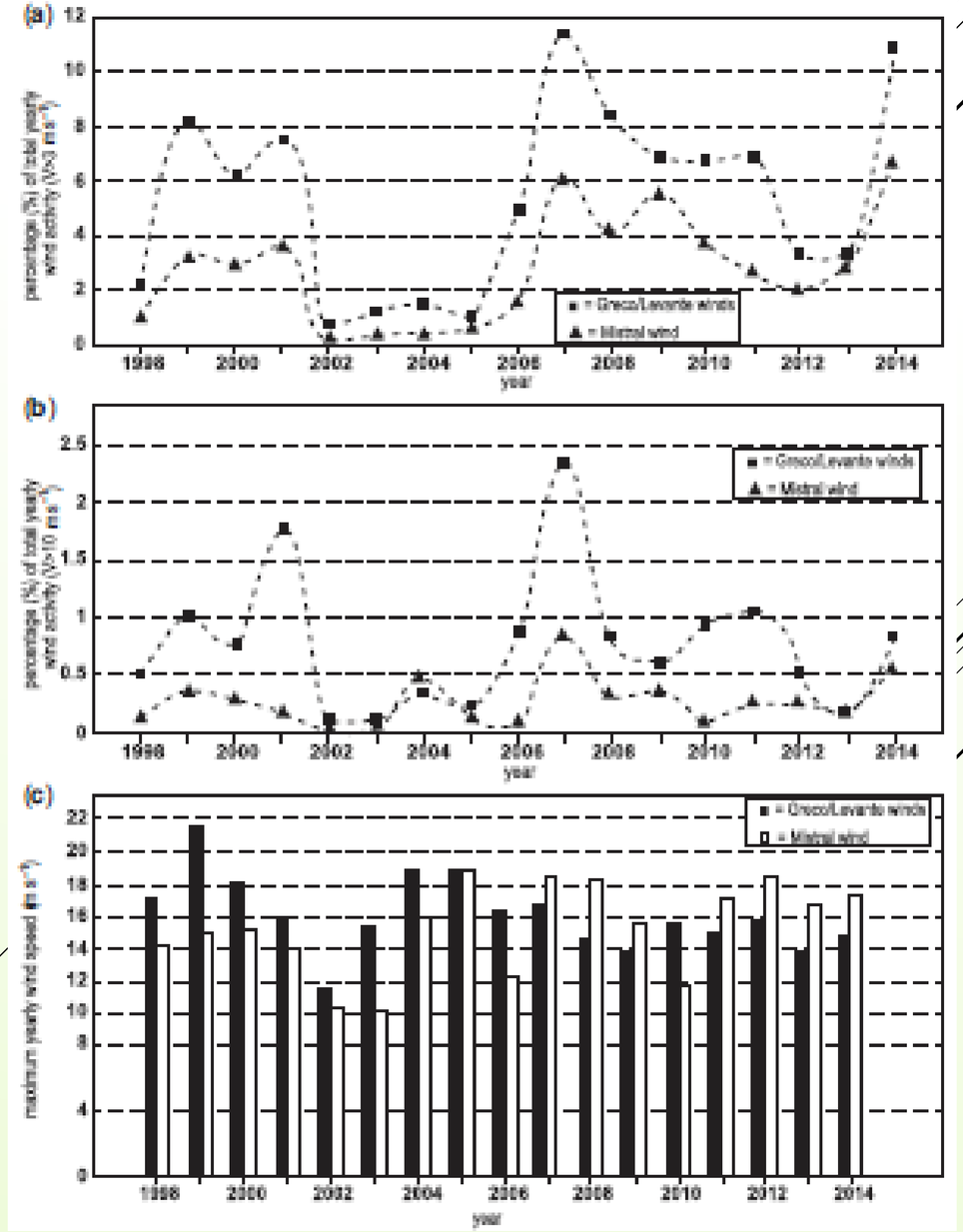
METODO









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EVOLUZIONE E PROCESSO DI SPILL OVER

2002-2022

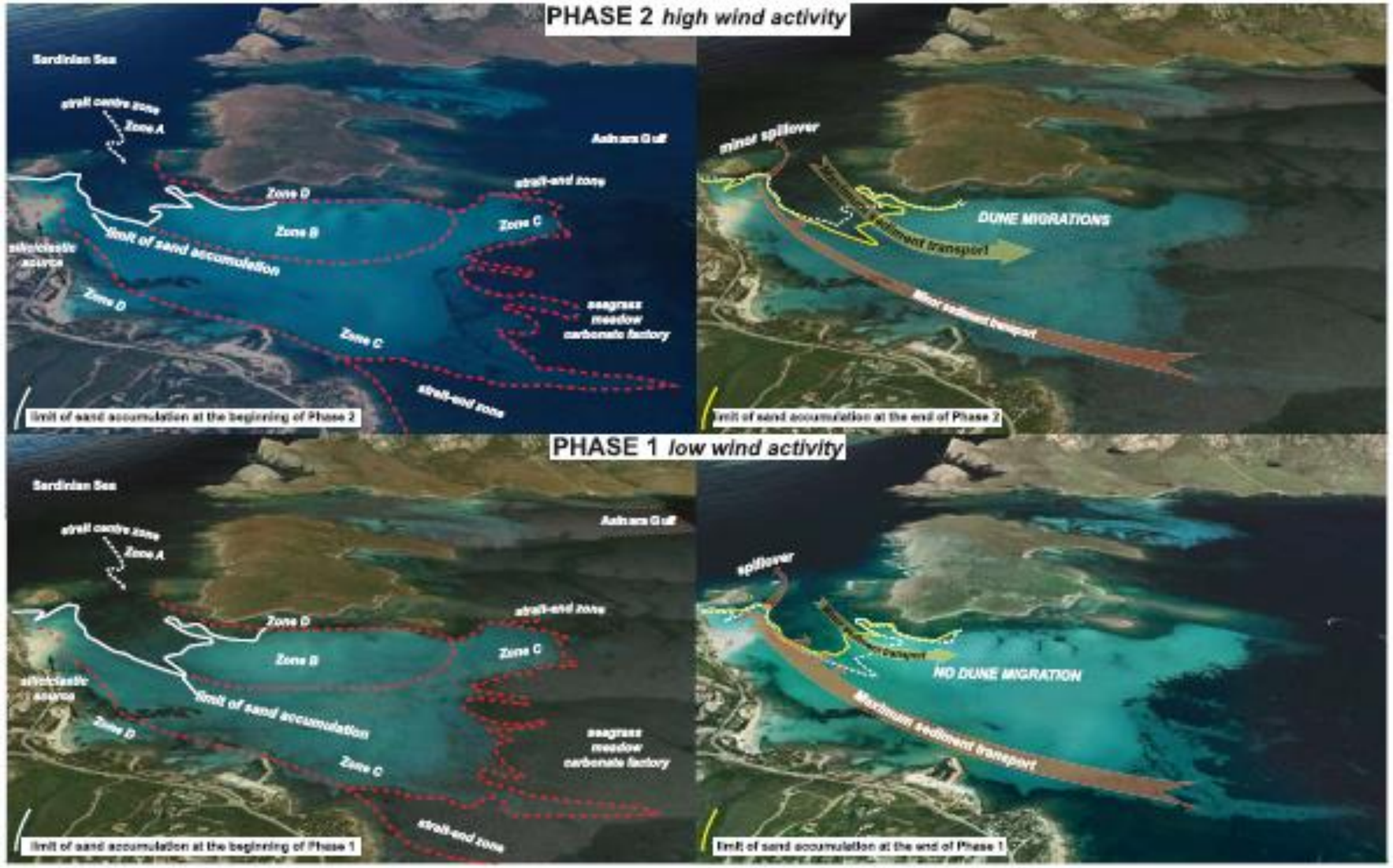

Fig. 10. Conceptual sediment-circulation model for the wind-dominated Asinelli Strait based on the numerical model, bedform migration directions and multi-annual wind persistence cyclicity (4–6 years). Phase 1: low wind activity with sand accumulation at the strait centre, erosion of La Pelosa Beach (emerged part) and important spillover below the depth of closure. Phase 2: high wind activity with complete remobilization of the sand accumulated at the strait centre, dunefield system migration and minor spillover.

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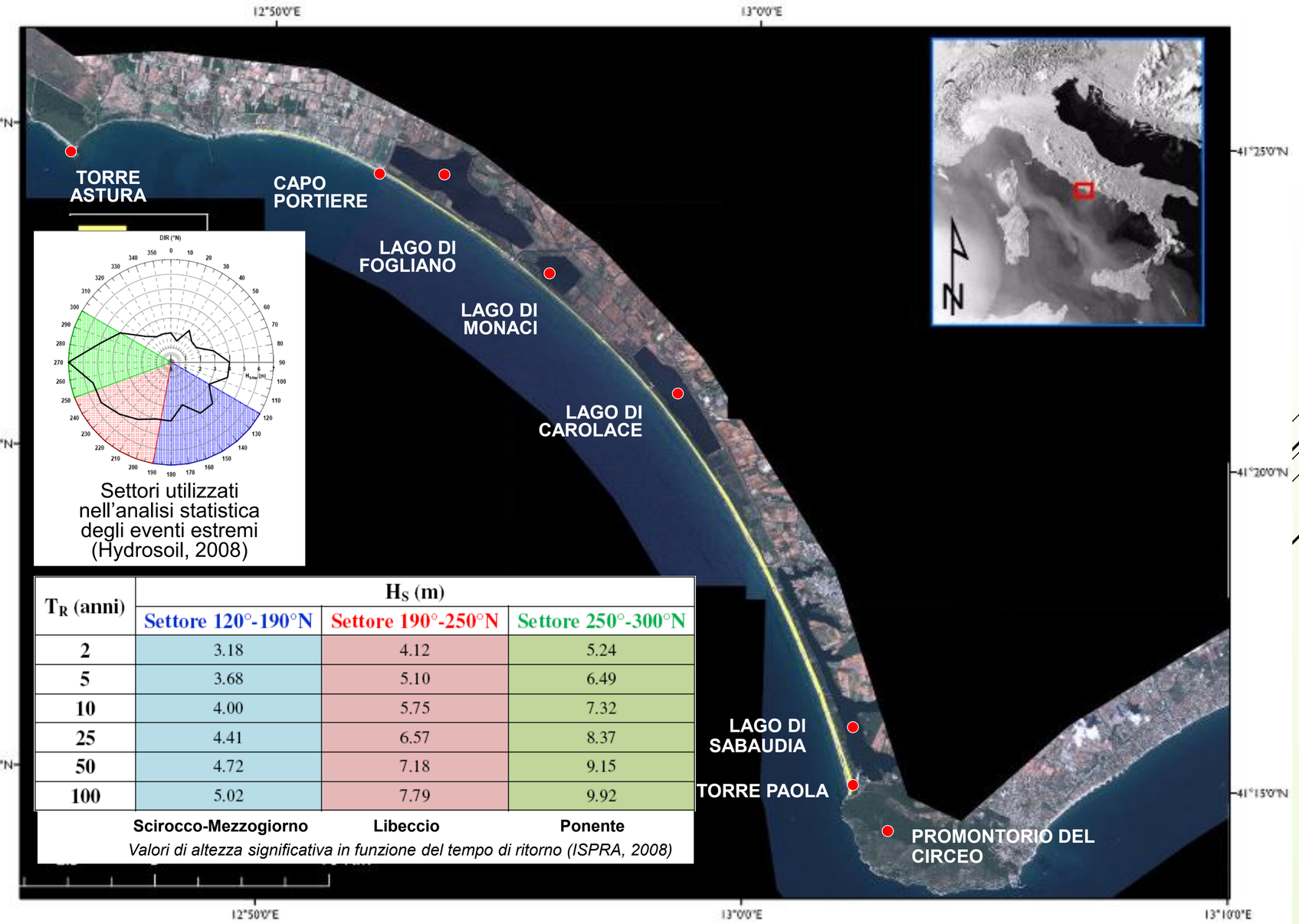
DUNE DEL PNC - INQUADRAMENTO DELL'AREA



Settori utilizzati nell'analisi statistica degli eventi estremi (Hydrosoil, 2008)

T_R (anni)	H_S (m)		
	Settore 120°-190°N	Settore 190°-250°N	Settore 250°-300°N
2	3.18	4.12	5.24
5	3.68	5.10	6.49
10	4.00	5.75	7.32
25	4.41	6.57	8.37
50	4.72	7.18	9.15
100	5.02	7.79	9.92
	Scirocco-Mezzogiorno	Libeccio	Ponente

Valori di altezza significativa in funzione del tempo di ritorno (ISPRA, 2008)

2006-2011

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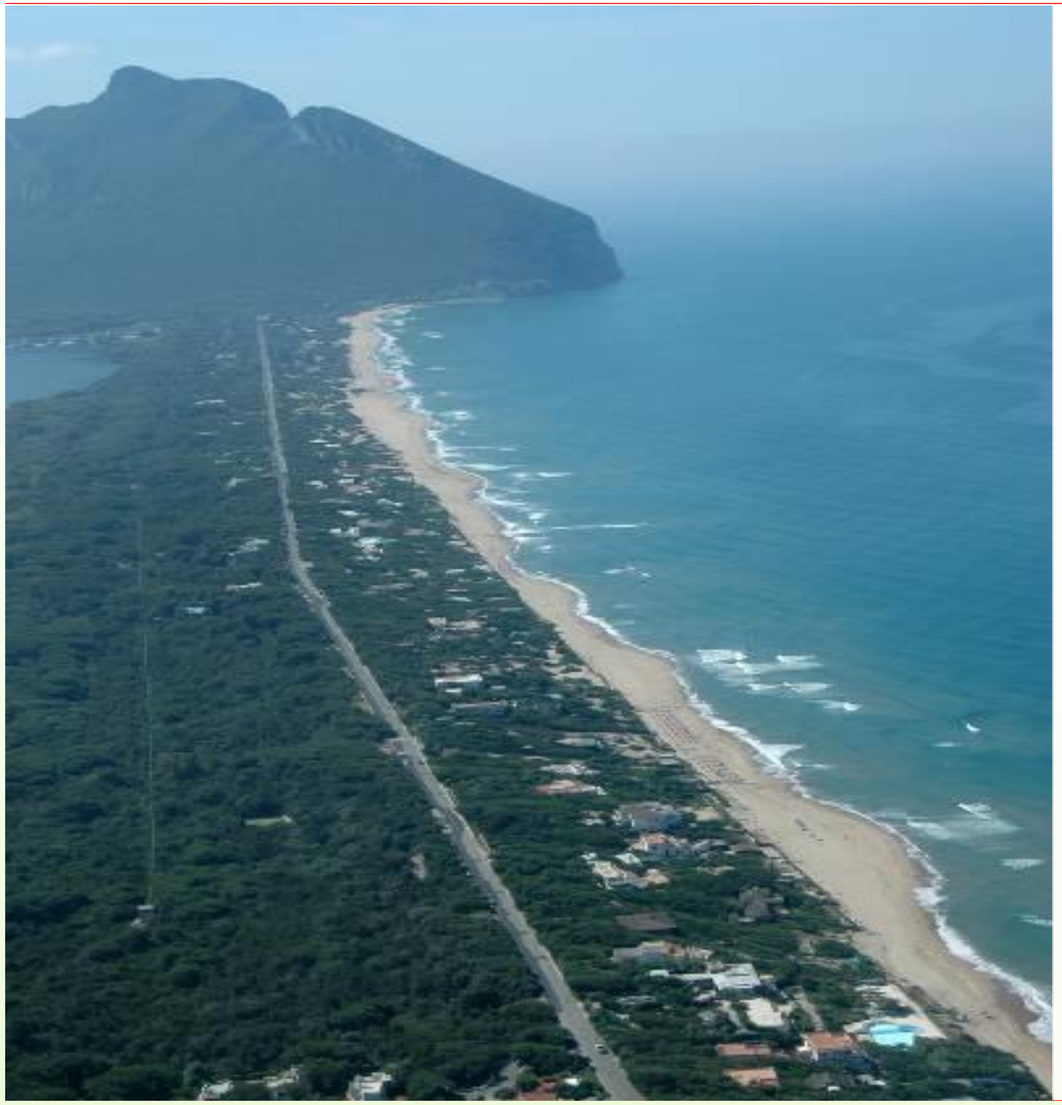
CARATTERISTICHE MORFOLOGICHE E PRINCIPALI CRITICITA’



Dal punto di vista **morfologico**, le **dune** tra il Capo Portiere e Torre Paola mostrano:

✓ una variazione areale si traduce in **decremento (dal ‘77 al ’99)** e **incremento (dal ‘99 al ’05)**.

✓ uno **sviluppo lineare subparallelo alla linea di riva**.

✓ **Ampiezze variabili**, 7÷9m (Laghi di Fogliano e Monaci) e 113÷108 m (Torre Paola) (*lato mare*).

✓ **Quote** comprese tra i 5-6m (Nord) e 20-25 m (Sud).

✓ Allo stato attuale si presentano **attive.**

La **spiaggia antistante** presentaVA valori per lo più compresi tra i 20 e i 60 m

I **cambiamenti** avvenuti negli ultimi 30 anni sono ascrivibili soprattutto all’**IMPATTO ANTROPICO** i cui effetti, diretti (aree urbanizzate, presenza di strutture turistiche sul litorale, ecc.) e indiretti (calpestio, pulizia degli arenili, ecc.), hanno modificato profondamente il sistema dunale, **in maniera sempre più intensa con il passare degli anni e procedendo da NW a SE**.

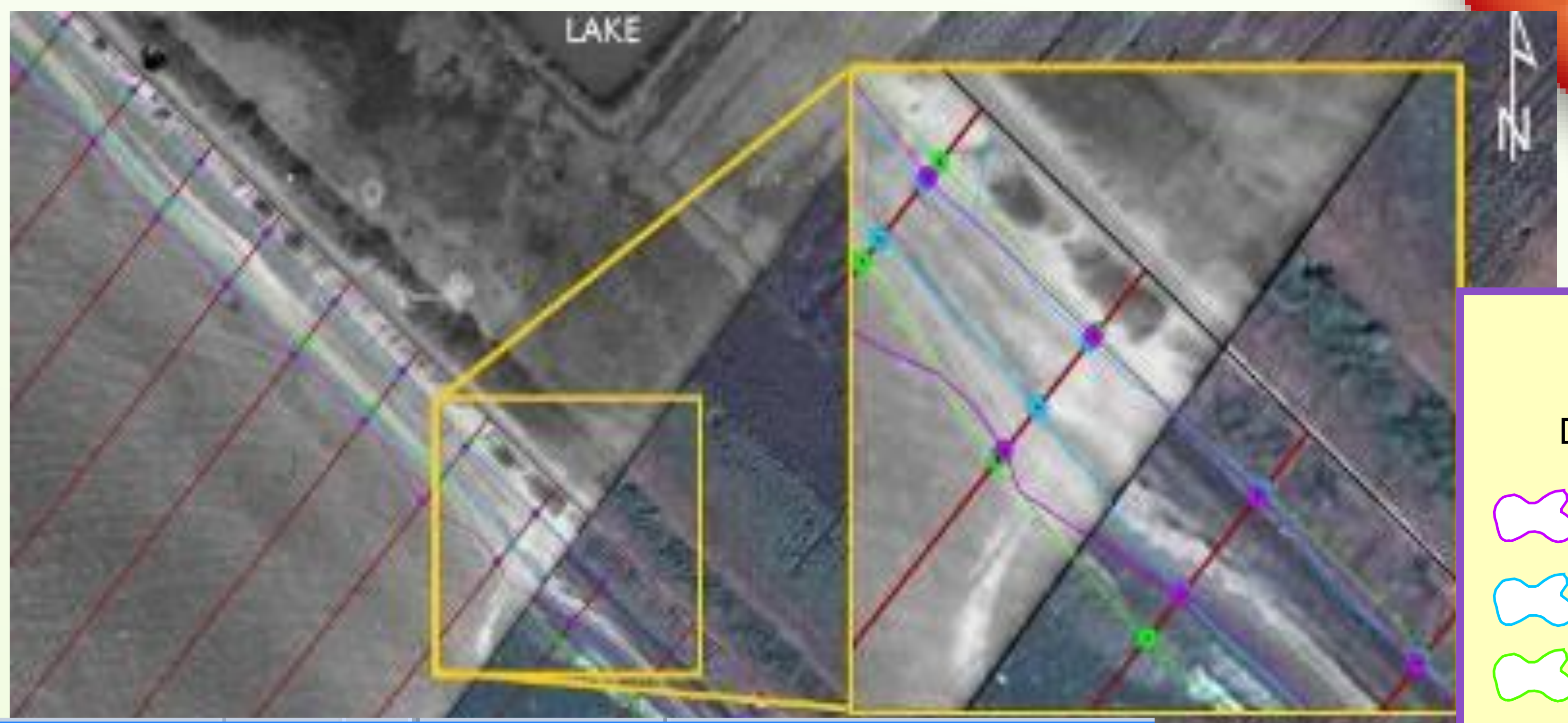
Analisi morfologica del sistema spiaggia-duna
Digital Shoreline Analysis System (DSAS®)

➢ Calcolo della variazione lineare della linea di riva e del piede della duna

METODOLOGIA

INPUT
- Baseline
- Shapefiles

OUTPUT
- Transetti
- Punti di intersezione
- Distanza (in m)



Attributes of TRANSECT_DUNE_TREND_99_05_Intersect

object identifier	TransectId	BaselineId	ShorelineId	Distance	IntersectX	IntersectY
155	122	1	03/04/1999	33.870023	322896.3862	4585515.342
156	123	1	03/04/2005	35.674251	322939.5489	4585485.378
157	123	1	03/04/1999	34.960149	322940.4834	4585485.791
158	124	1	03/04/2005	33.515271	322983.0478	4585460.452
159	124	1	03/04/1999	34.862269	322982.3057	4585459.328
160	125	1	03/04/2005	34.177276	323024.4154	4585432.380
161	125	1	03/04/1999	35.021717	323023.5098	4585430.968
162	126	1	03/04/2005	33.822316	323066.3377	4585405.121
163	126	1	03/04/1999	39.858259	323062.9582	4585400.002
164	127	1	03/04/2005	34.223441	323107.7989	4585377.232

LEGEND

DUNE	SHORELINE
2005	2005
1999	1999
1977	1977

BASELINE — TRANSECT

- 2005
- 1999
- 1977

Intersect points

PRODOTTI FINALI
- Ampiezza della duna
- Ampiezza della spiaggia
- Ampiezza del sistema
- Variazione della linea di riva
- Variazione del piede della duna

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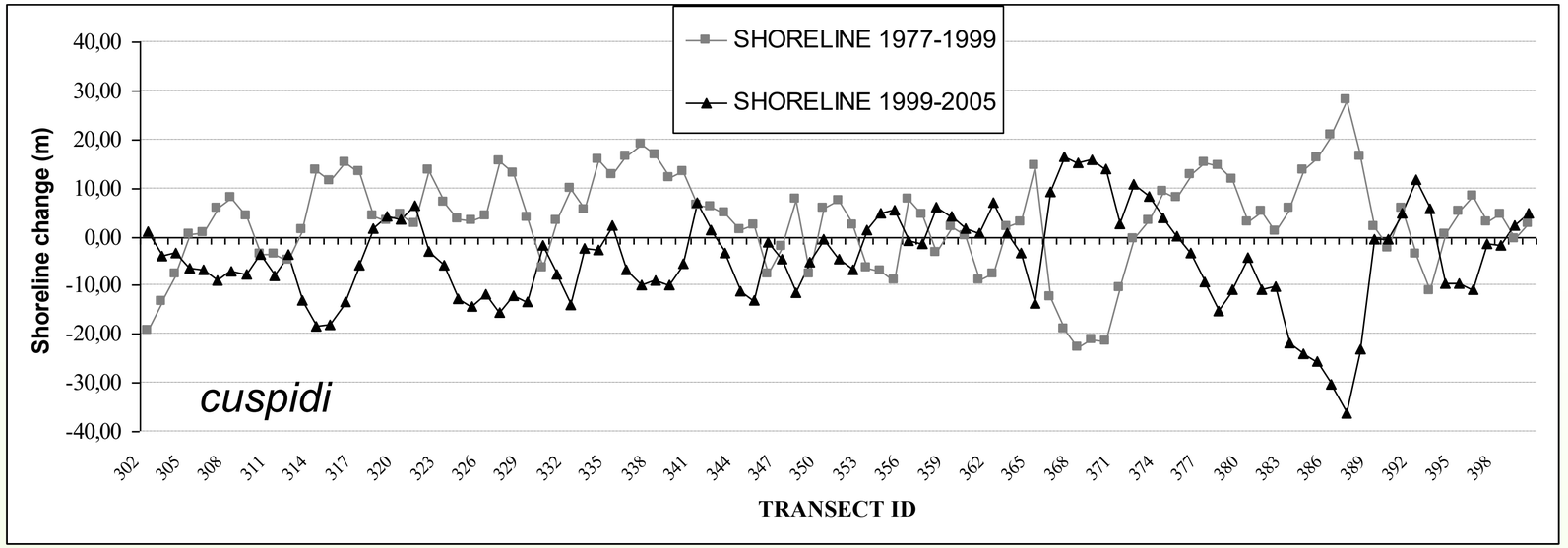
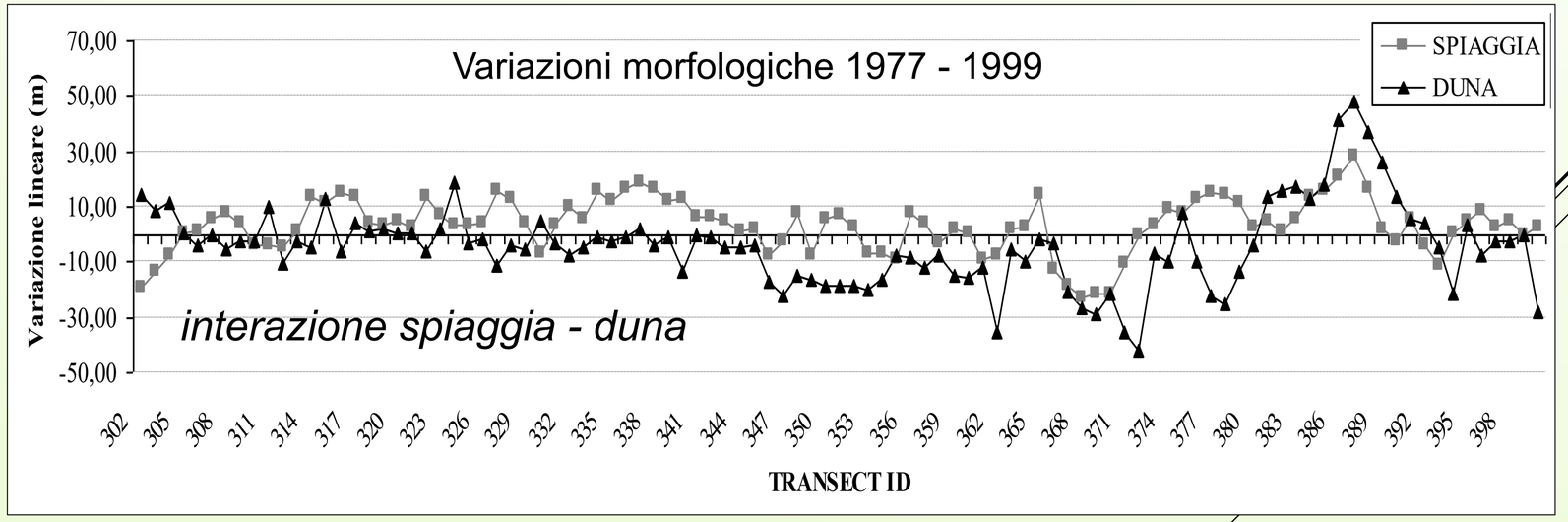
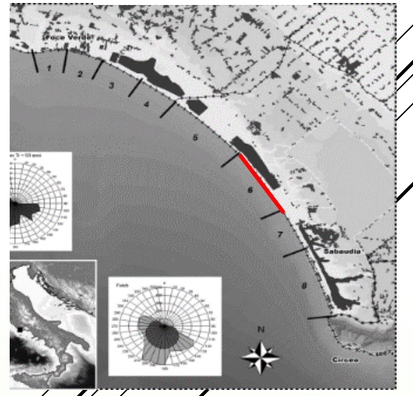
SETTORE 6

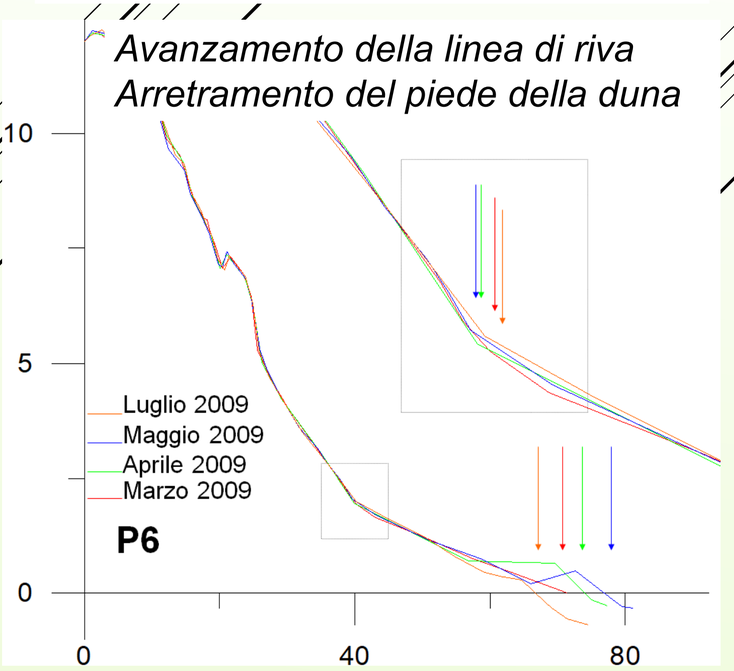
ANALISI A MEDIO TERMINE







ANALISI A BREVE TERMINE



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RISULTATI E PUBBLICAZIONE

Studi costieri 2010 - 17: 105-124

Variazioni morfologiche stagionali del sistema spiaggia-duna del Parco Nazionale del Circeo

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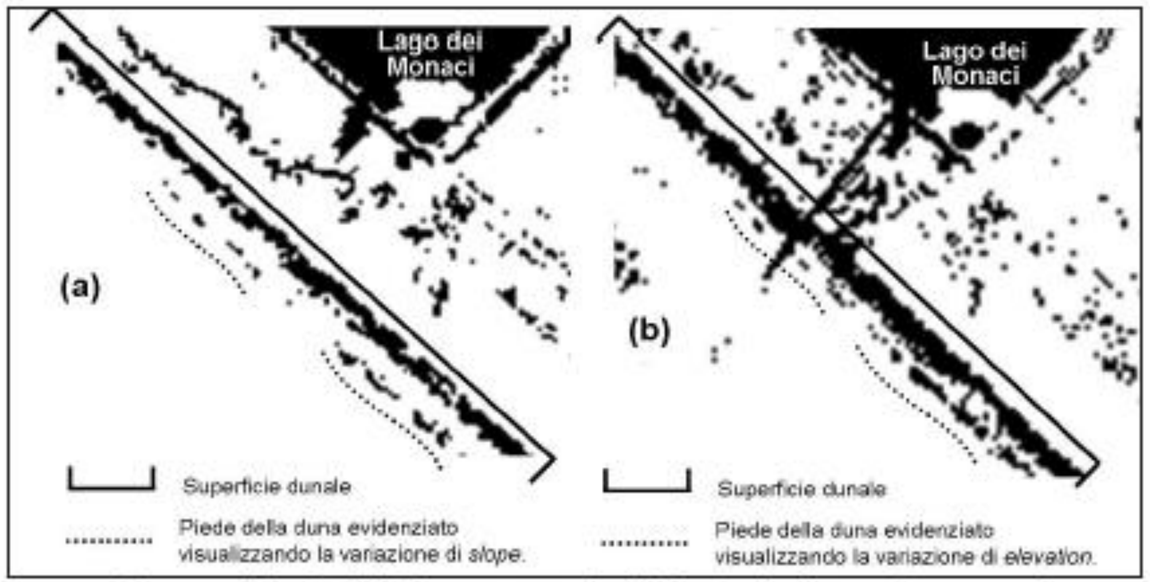
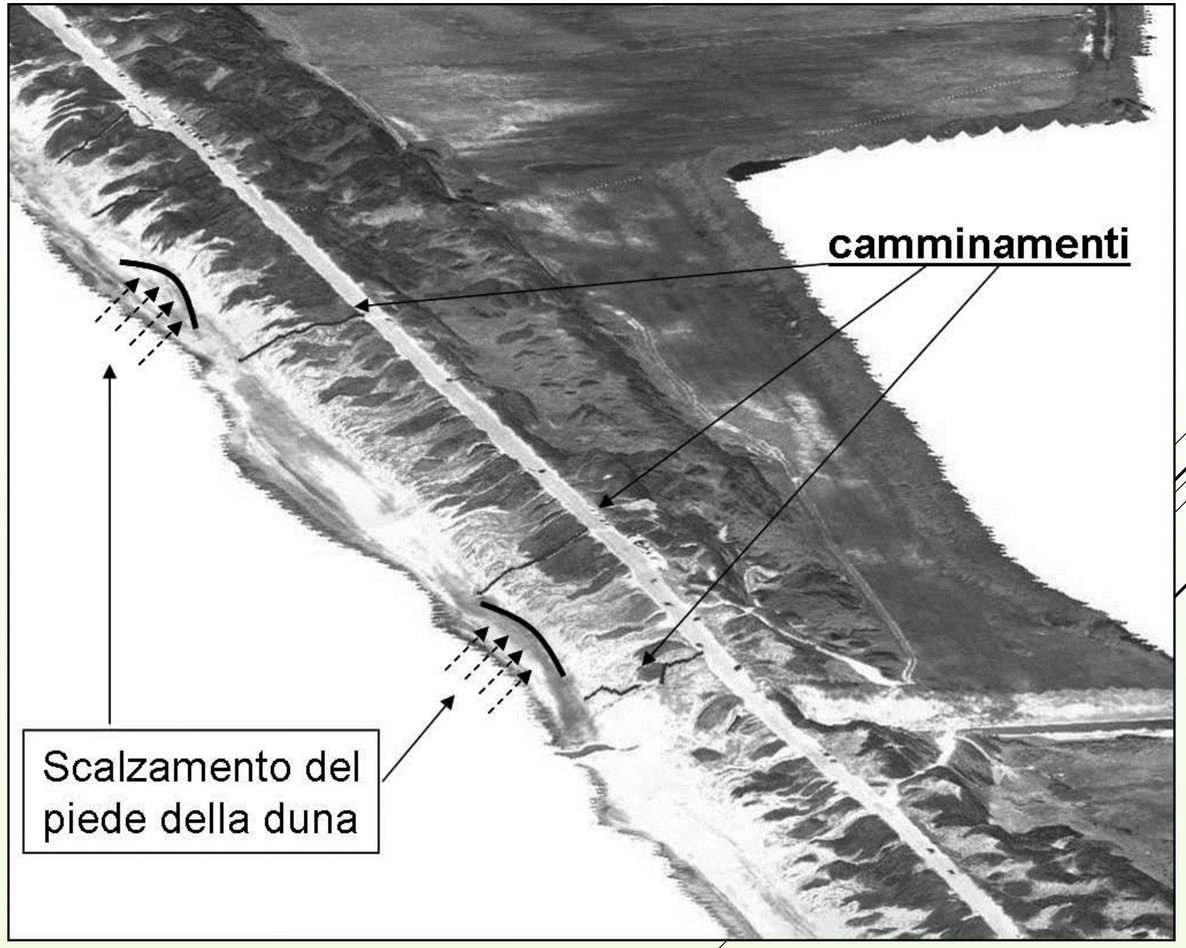


Figura 2 - Visualizzazione del piede della duna tramite i valori di *slope* (a) e di *elevation* (b) associati al DSM LiDAR.



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PNC REMOTE SENSING

remote sensing

MDPI

Article

Exploring the Dunes: The Correlations between Vegetation Cover Pattern and Morphology for Sediment Retention Assessment Using Airborne Multisensor Acquisition

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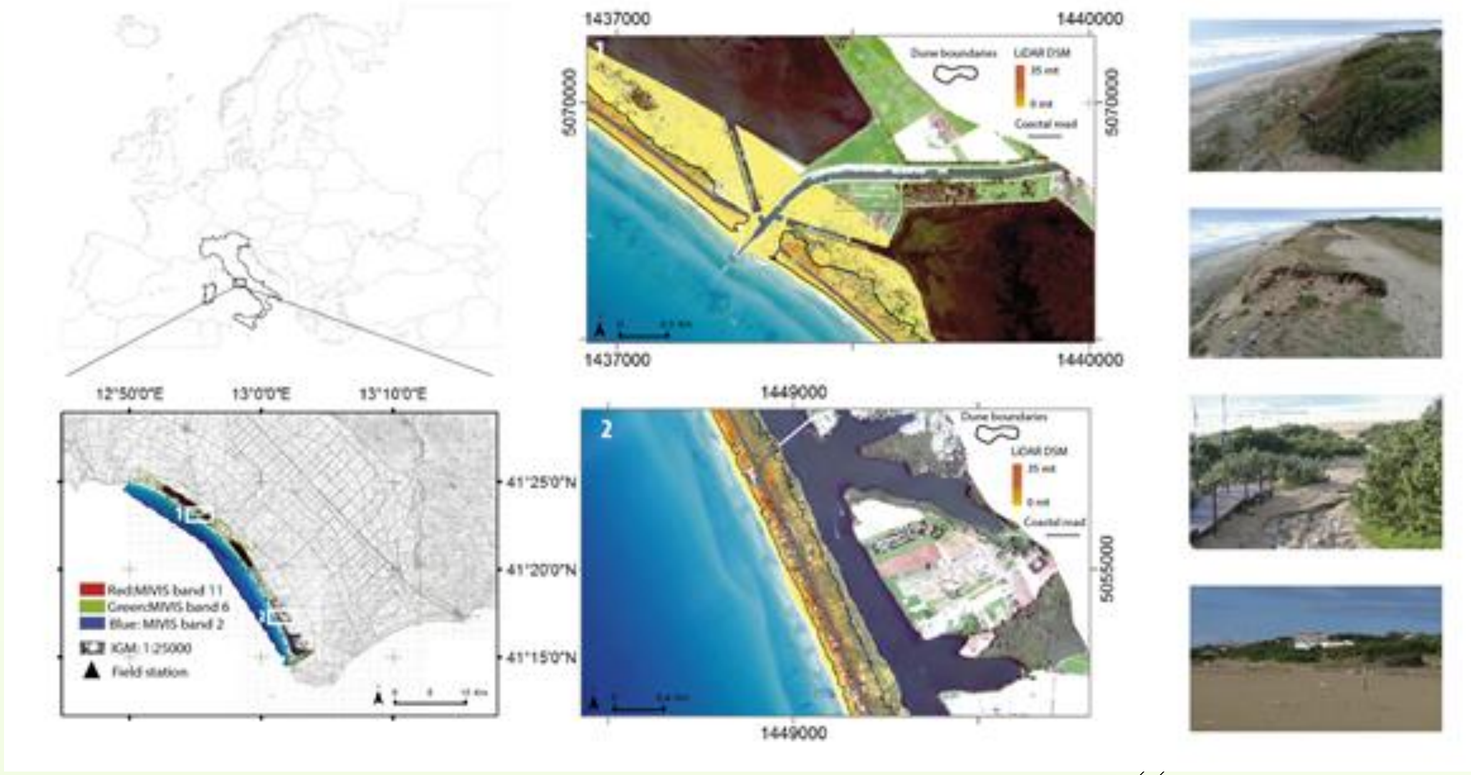
check for updates

2010-2020



Study area location with basic cartography and the hyperspectral MIVIS data coverage (left); miniature 1 and 2 are two zooms from the study area with the LiDAR DSM on MIVIS true colour imagery;
pictures of the area taken in May 2009 (right).

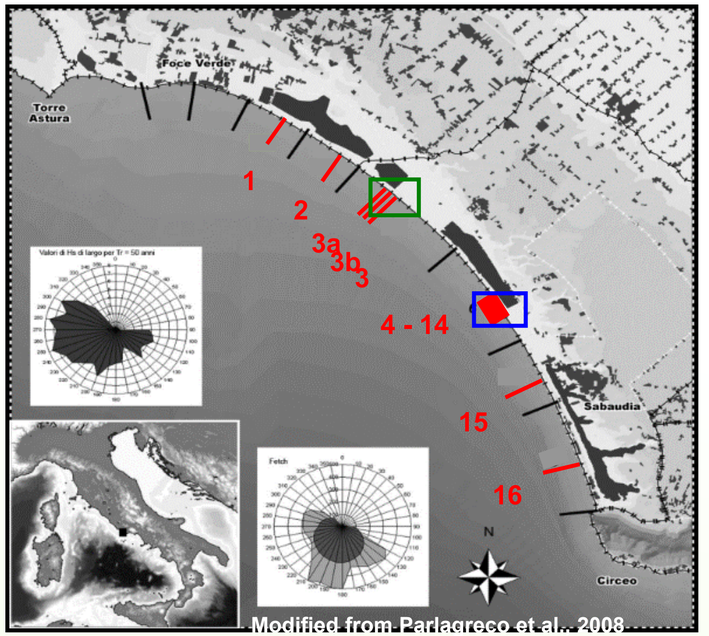
Ferrara, 18 settembre 2025

ANALISI A BREVE TERMINE - METODOLOGIA

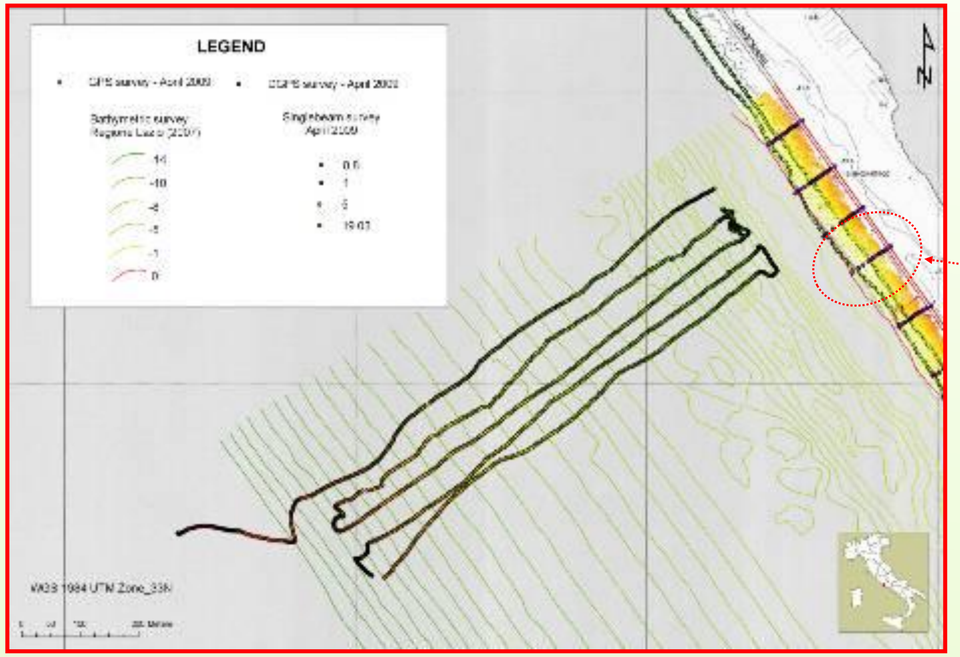
Rilievi topografici stagionali

PARAMETRI:

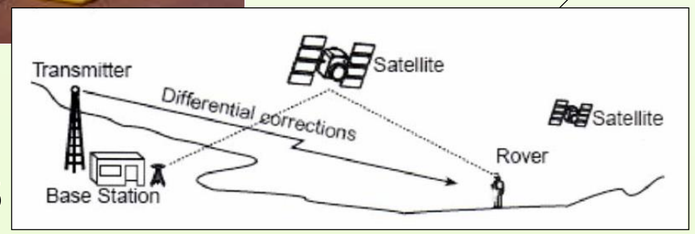
- Ampiezza duna e spiaggia
- Quota cresta duna e retrospiaggia
- Slope
- Volumi
- Variazioni stagionali



Modified from Parlagreco et al., 2008



Strumentazione mediante **DGPS** a doppia frequenza Trimble modello 5700 in modalità cinematica (**RTK**)



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CONFRONTO PROFILI ED ACCURATEZZA

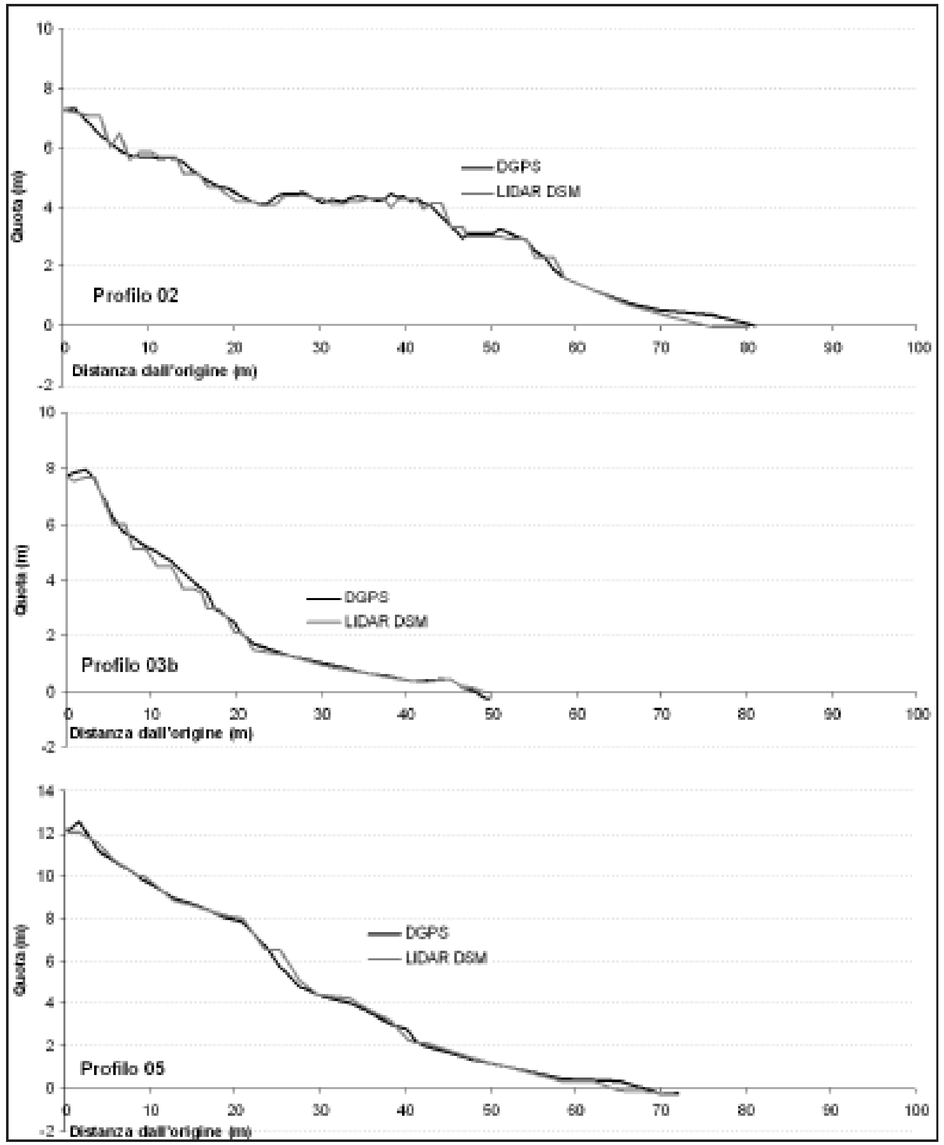
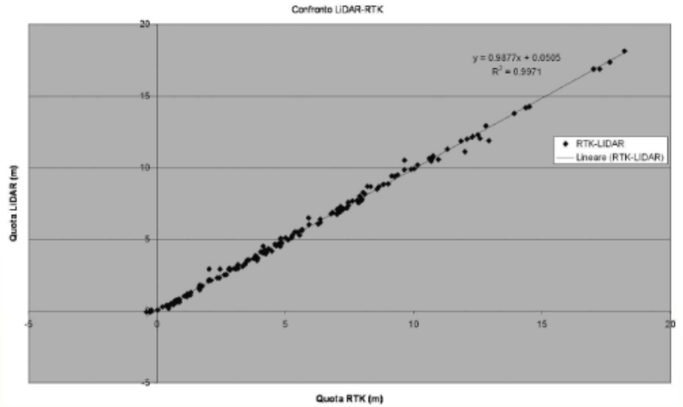
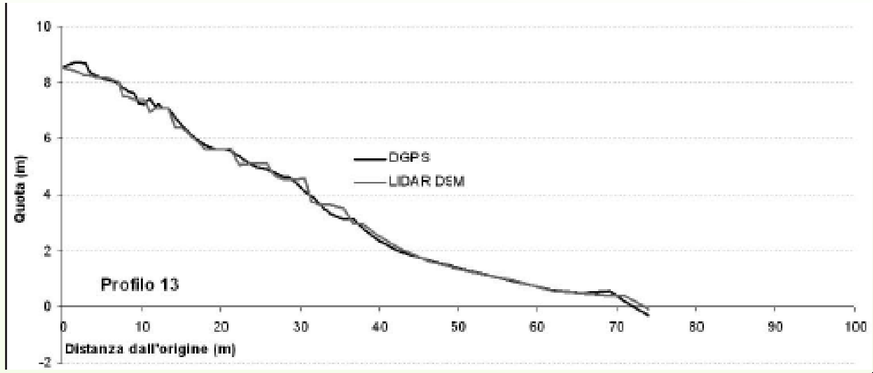
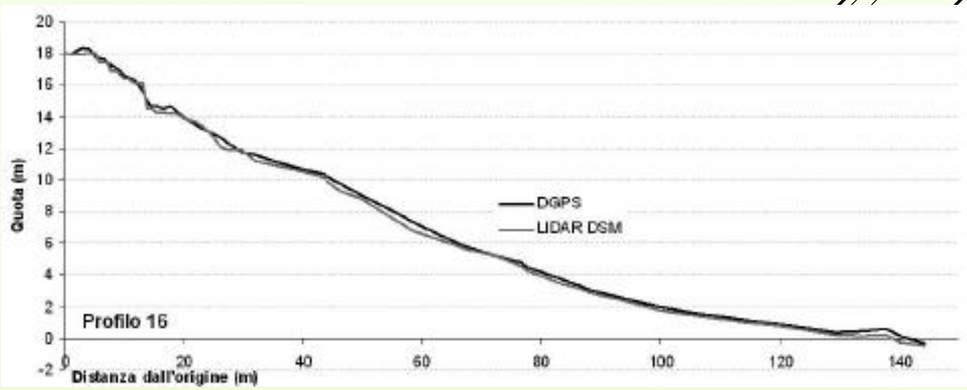


Figura 9a, b, c - Sezioni di alcuni profili spiaggia-duna significativi, elaborati a partire dai dati DGPS e dal DSM LiDAR. (a) Profilo 02, (b) Profilo 3b, (c) Profilo 05.







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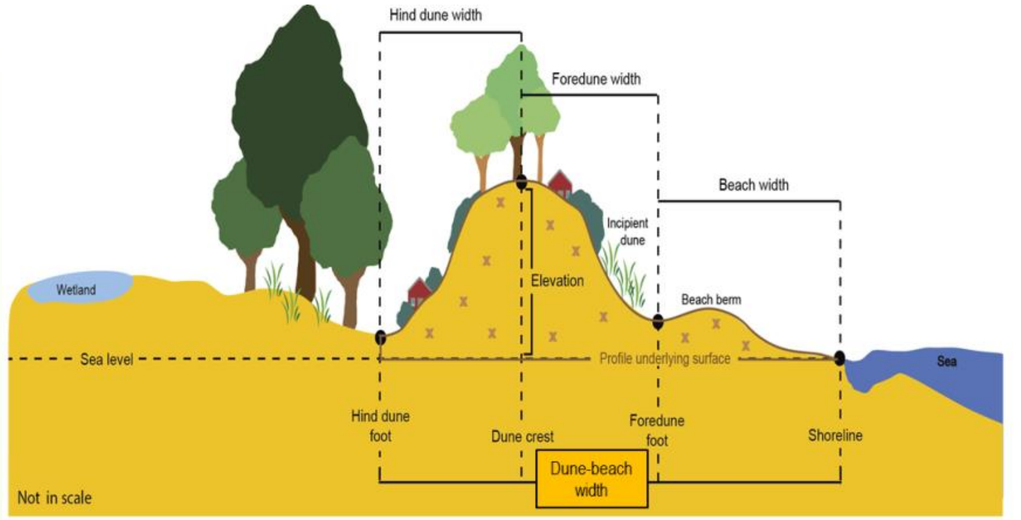
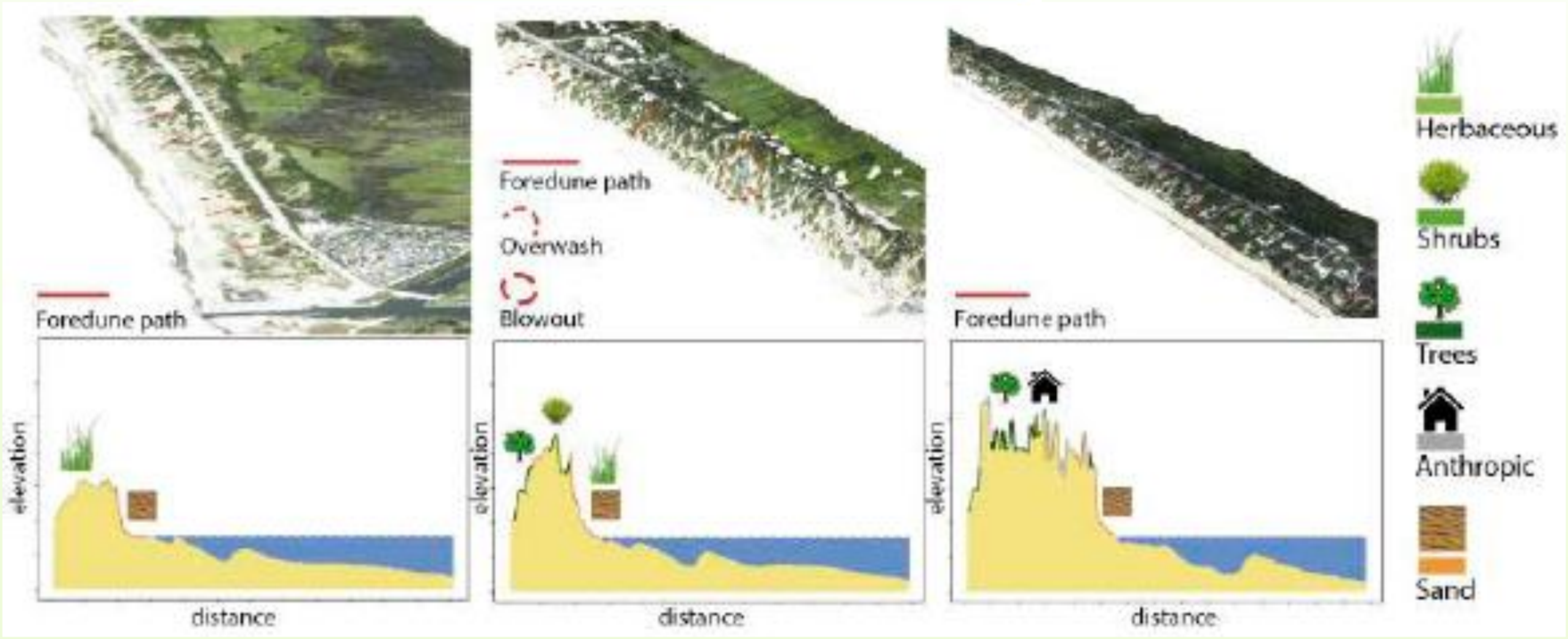
SCHEMA DI CARATTERIZZAZIONE



LiDAR HawkEye II	
Topographic Frequency	64,000 Hz
Altitude	From 250 to 500 m
Swath	From 100 to 330 m
Topographic point density	From 1 to 4 points for m²
Accuracy of Topographic survey	Horizontal: ± 0,5 m Vertical: ± 0,15 m

2018-2020



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METODO

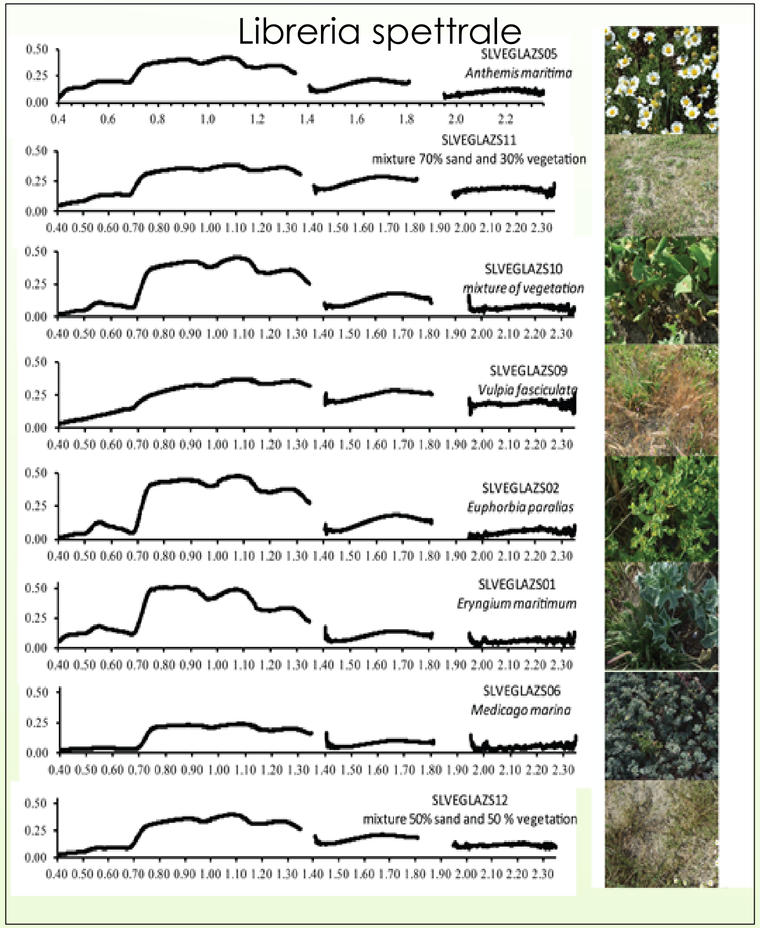
Sinuosità piede della duna

$$s = l/L\ ,$$

Superficie sottesa al profilo

$$S = \int_L^0 hdL\,/\,L,$$

Libreria spettrale



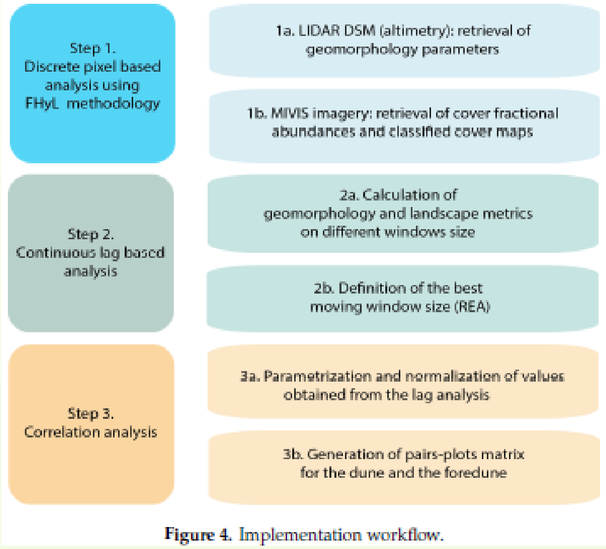


Figure 4. Implementation workflow.

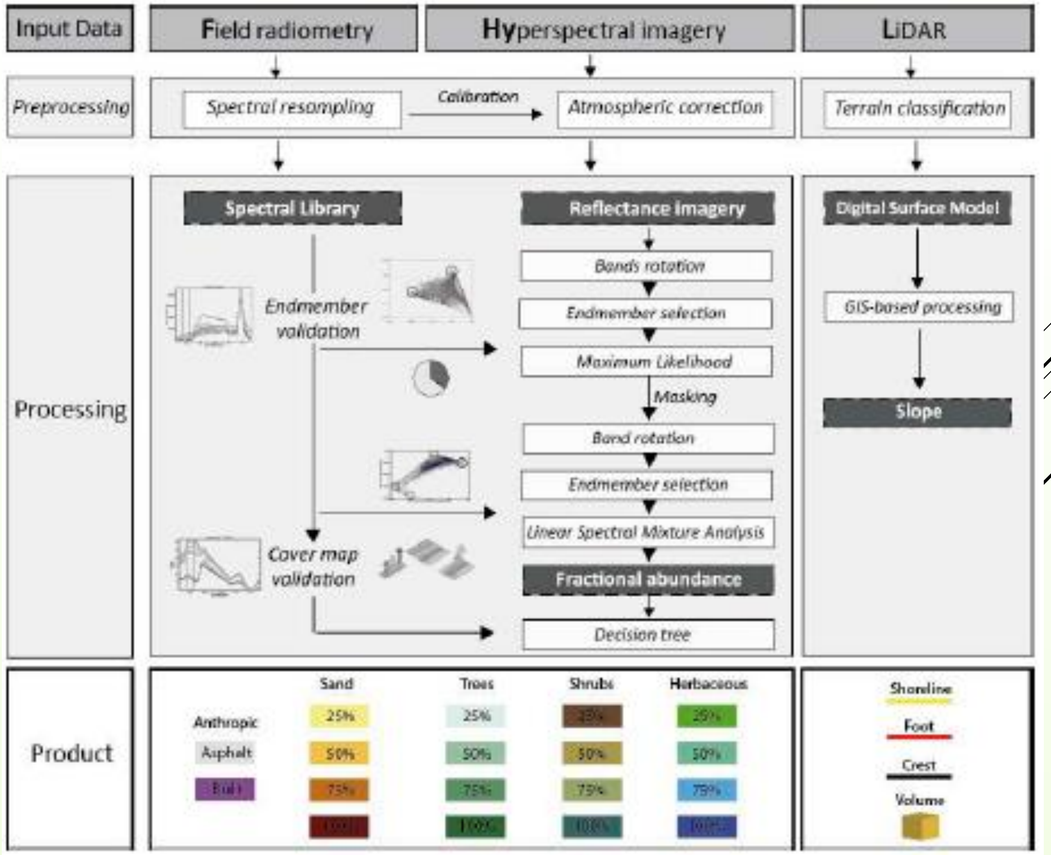


Figure 5. Description of **step 1** in Figure 4: The processing algorithm used is named 'Field, Hyperspectral and LiDAR (FHyL) module 3'.

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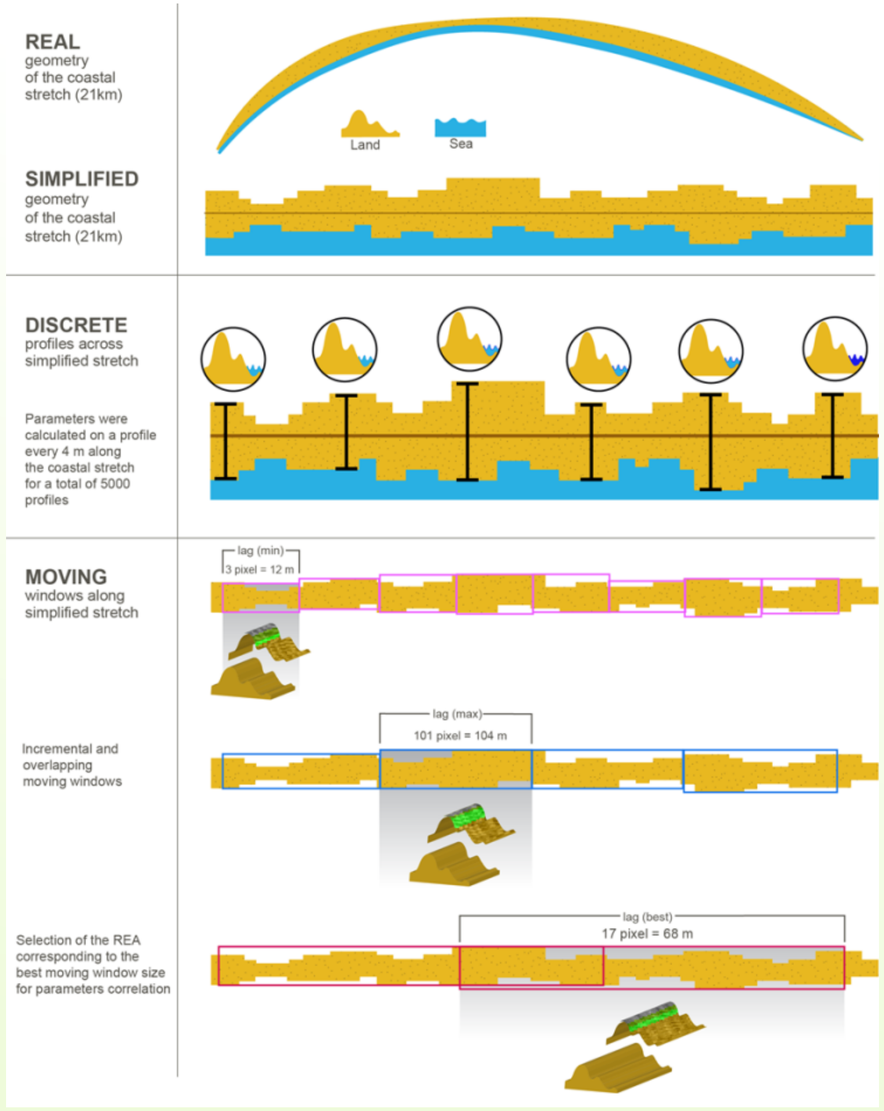
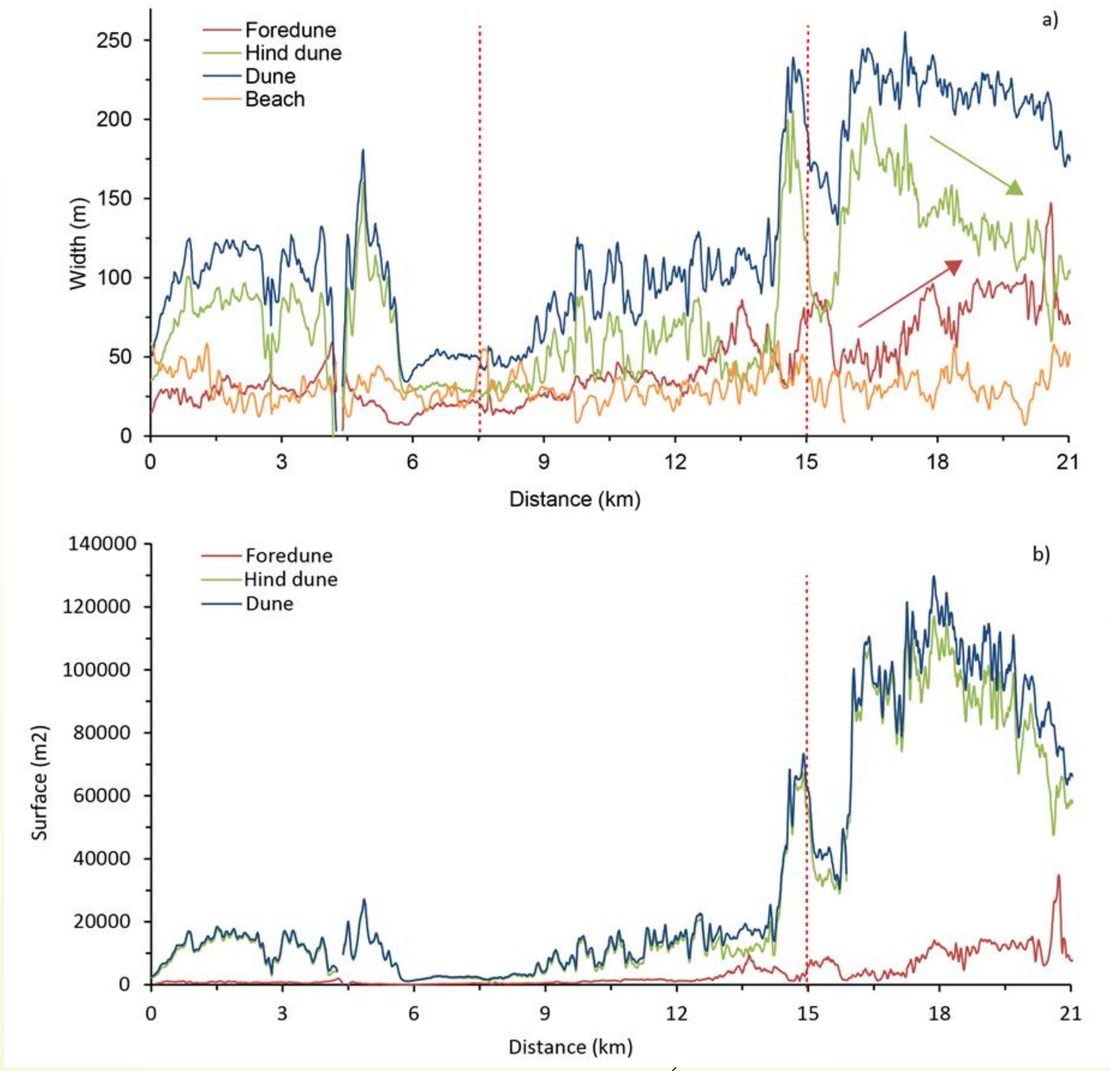
RISULTATI





Description of the morphological main behaviour moving from North to South: a) width vs distance; b) profile underlying surface vs distance. Parameters referred to the 68 m moving window

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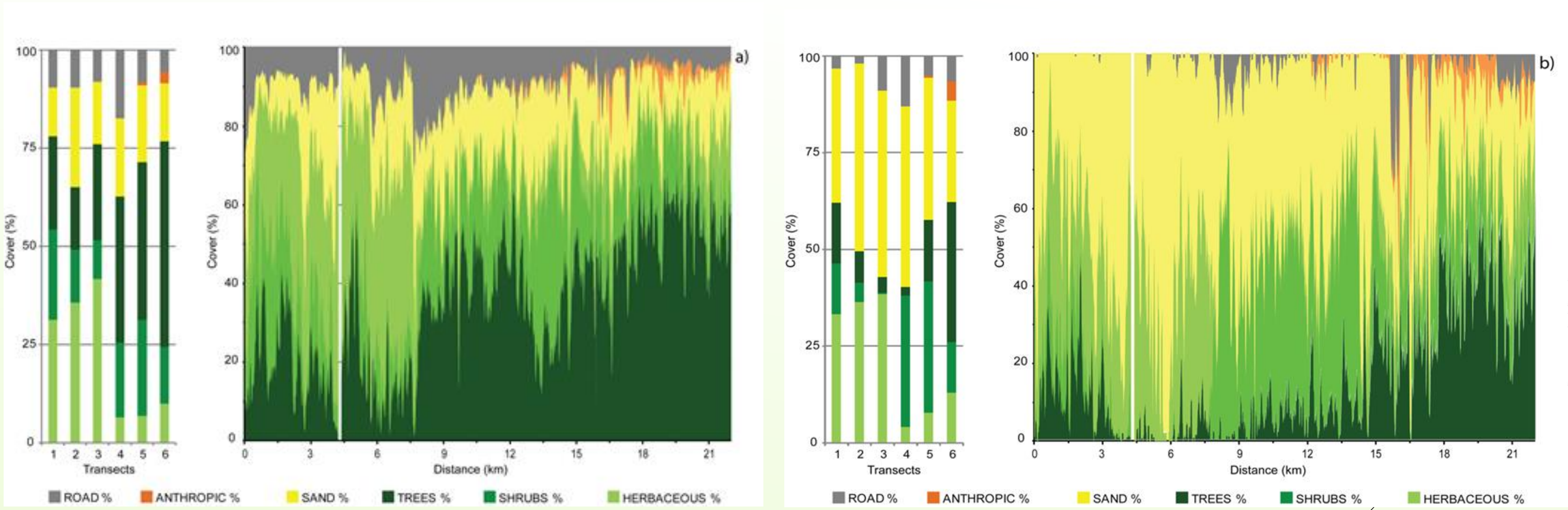
RISULTATI



Cover typologies abundance in six transects (left side) and along the stretch (right side) for (a) the dune and (b) the foredune

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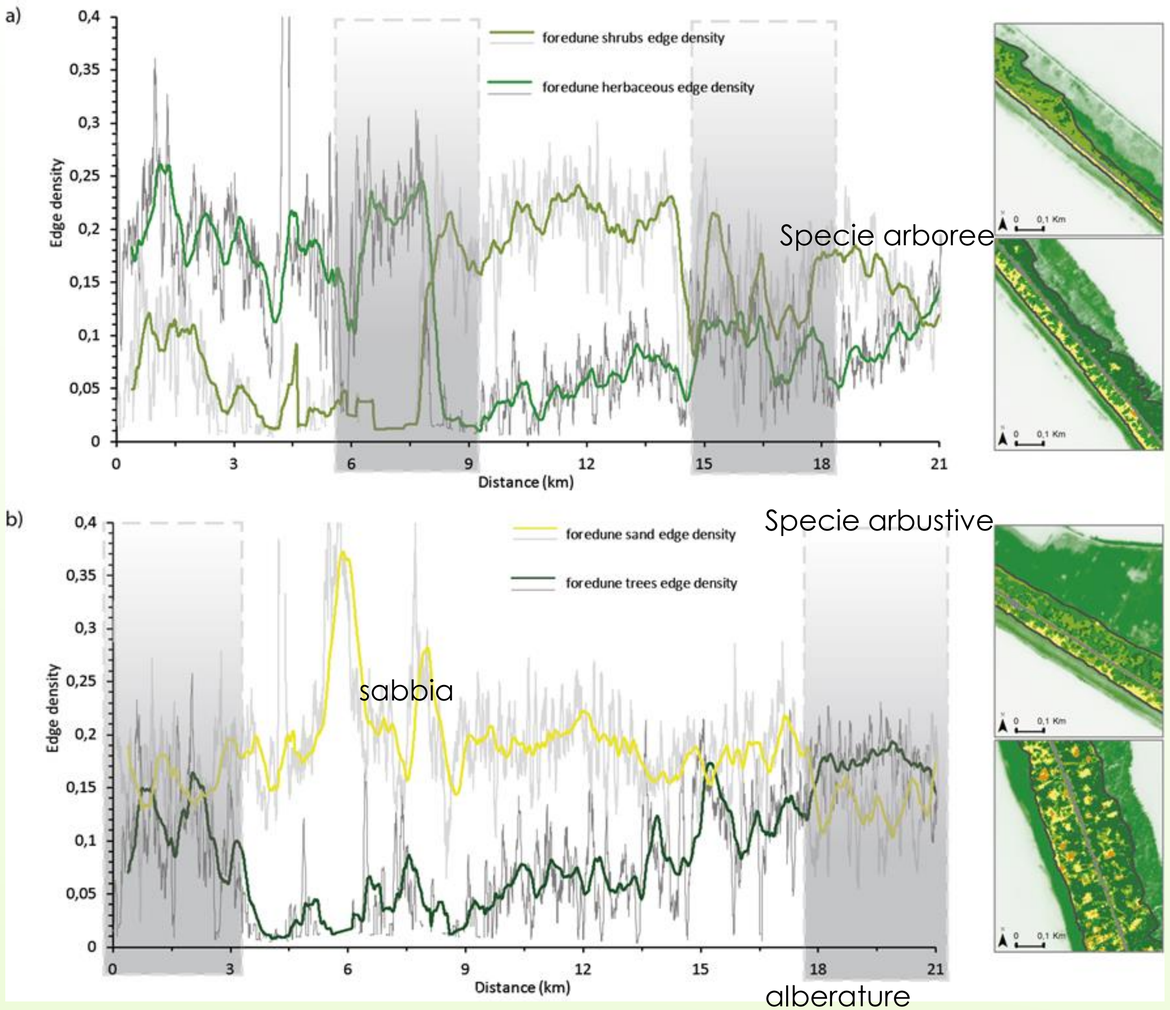

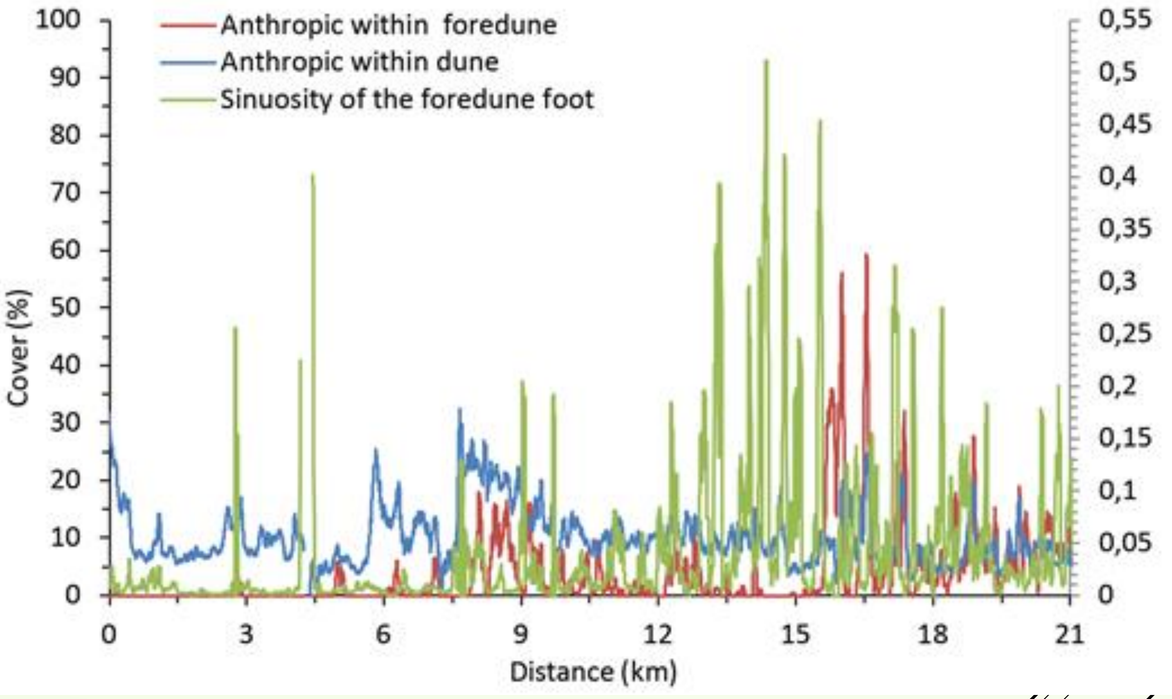

Foredune foot sinuosity (green) and dune anthropic cover (blue)
Foredune (red) shows and increasing presence moving to south from km 7 onward

a) Foredune herbaceous and shrubs edge density values: two main change in trend are detectable at km 7.5 and km 14.5.
b) Foredune sand and trees edge density values: reversed trend between 0 and 2.5 km and after km 15.
Gray lines represent all the data points and the colored bold lines, are the moving averages of data points (average of 100 data points interval).
On the right side the miniatures show the dune cover map of grey windows (note that the orange colour is the anthropic cover class not showed in the foredune ED trends).

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Foto del Dott. M.Amodio


Foto del Dott. M.Amodio


Foto del Dott. M.Amodio
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FUNZIONALITA'
PASSERELLA

Foto del Dott. M.Amodio

Foto del Dott. M.Amodio

RECINZIONE ASSOCIATA A FRANGIVENTO

Foto del Dott. M.Amodio

Marzo 2004