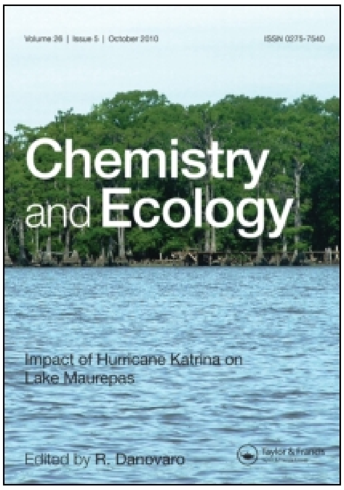

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The evolution of the dune fields of Platamona–Marritza (northern Sardinia): Application of remote-sensing methods

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The littoral of Platamona–Marritza is an example of a Mediterranean coastal environment with a marked heterogeneous dune system. Morphological studies, based on remote-sensing methods and on field surveys, have been carried out in order to trace the diachronic evolution of the aeolian deposits and to understand the current condition of this area. Aerial photographs have allowed us to analyse the evolution of the coastline, the dune fields and the anthropic development of the coastal strip over the period 1955–2002. The field surveys were undertaken in September 2003 and September 2004 to verify the data acquired by the elaboration of the aerial photographs and to identify and map the vegetation of the dune belt. A relationship between vegetative species found on the Platamona–Marritza dune field and the retreat of the coastline was then established.

Keywords: Coastal dunes; Remote sensing; Landscape changes; Platamona–Marritza; Sardinia

1. Introduction

The reconstruction of the evolution of the coastline between Platamona and Marritza has been the subject of a study within the MIUR-COFIN 2002 project ‘The aeolian deposits of the Italian coast and the flux of beach-dune sediments’.

The national project, co-ordinated by the University of Genoa, studied the aeolian deposits of the highly touristed areas of the north-western coast of Sardinia, using remote-sensing methods, as part of a regional development programme.

The incorporation of the digitized material and the bibliographical data in a GIS with suitable legends reflecting the entire national situation enabled us to produce a user-friendly instrument for better territorial management.

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2. Study area

2.1 *Morphological aspects of the coastal area*

The littoral of Platamona–Marritza, situated in northern Sardinia (figure 1) and belonging to the sub-region known as 'Sassarese', from the name of the province in which it lies, is an example of a Mediterranean coastal environment with a notably heterogeneous dune system [1, 2].

The area, fronting the sea to the north and bordered by the municipalities of Castelsardo to the east Porto Torres to the west and Sorso to the south, mainly consists of a low sandy beach lying between the Rio Pedras de Fogu (figure 2) to the east and the Torre di Abbacurrente to the west.

The morphology of the littoral is poorly articulated and characterized by a long sandy beach (about 17 km) fringed by a belt of longitudinal and parabolic dunes, mainly oriented NW–SE, some of which reach a height of 32 m [3].

The aeolian deposits extend along the entire coastal strip, and it is possible to distinguish the Pleistocene aeolian sands from the Holocene and present-day sands [4].

The oldest sandy deposits crop out, above all, along the coast west of Marritza, where they are incorporated in a cliff several metres high. The actual dune field borders the beach for about 15 km; the longitudinal and parabolic dunes are oriented between N 110 and N 140, with a mean orientation of about N 125, clearly due to the action of the Mistral [4].

The hydrographic network (figure 2) consists of minor torrents subject to a meteorological regime, which carry little water for most of the year.

2.2 *Climatic situation*

Meteorological data from the weather station of Porto Torres indicate that the littoral of Platamona has a 'semi-arid' climate, characterized by hot summers with very little rain, but

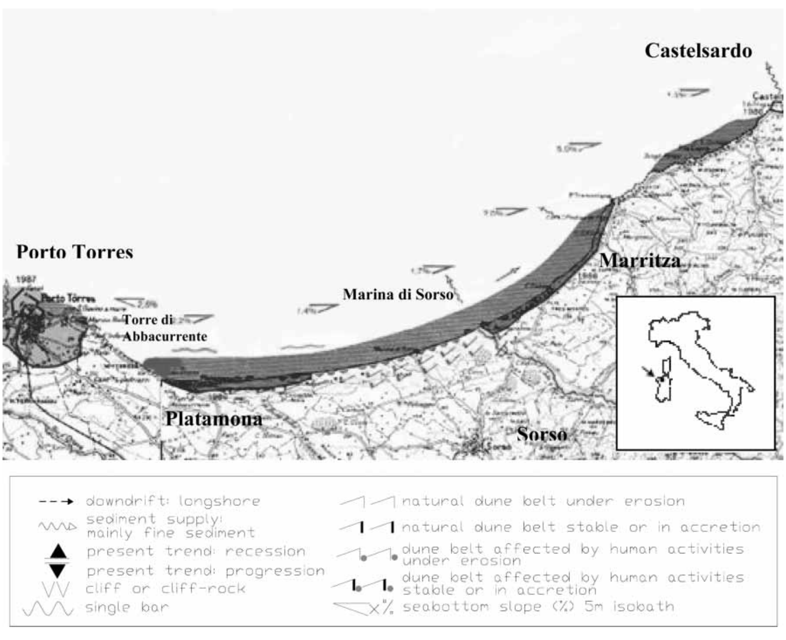

Figure 1. Sector of Map 180 – Sassari. The information reported highlights the principal morphologies of the area and the evolutive trend of the littoral (from [1], modified).

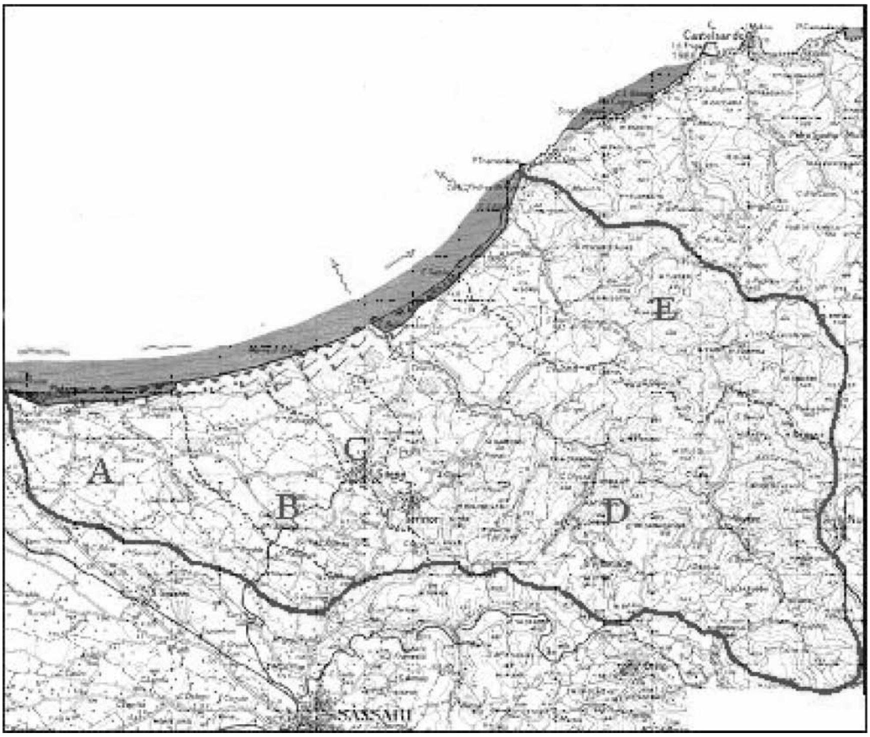

Figure 2. Hydrographic basins of the watercourses flowing into the littoral of Platamona-Sorso-Marritza. A: Rio di Buddi Buddi; B: secondary watercourses that flow into the Holocene dune field; C: Rio Predugnano; D: Silis River; E: Rio Pedras de Fogu (from [1], modified).

with maximum temperatures moderated by the sea, modest rainfall between October and January, and an almost non-existent cold period with a consequent reduction in deciduous vegetational species [5].

The most important winds influencing the littoral dynamics of the beach and dune system of Platamona–Marritza come from Quadrants I and IV, that is to say the Grecale and Mistral respectively. Despite the fact that the Libeccio, coming from Quadrant III, is the most frequent and strongest wind, those coming from the marine sectors are the most important in modelling the littoral dune field.

The anemological conditions remain invariable for most of the year, meaning that the littoral is subject to the same winds in an almost constant proportion in all seasons.

The data on the solid transport from the south-west to the north-east have been obtained from the *Atlante delle Spiagge Italiane* [1].

2.3 *Vegetational features*

Vegetation has a key role in coastal dune building and stability. Immediately behind the swash zone, but still in the intertidal zone, there are species that increase the ruggedness of the terrain and so slow the velocity of the wind, playing a pioneering role in the deposition and stabilization of the sand. Such species contribute to the construction of what is conventionally called an incipient dune [6].

Psammophilous or sand-loving vegetation is adapted to an arid environment, to the extreme mobility of the soil particles and the wind action that carries sand and encrusts the plants with

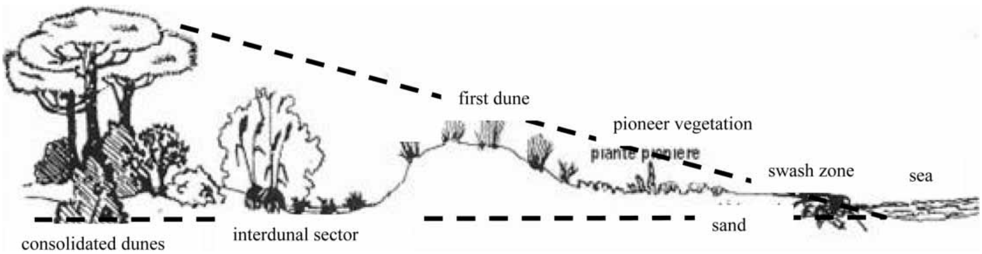

Figure 3. Wedge-like formation of the coastal vegetation (from [5], modified).

salt. In general, these plants develop both deep, and superficial roots and stems that have the special function of anchoring the plant to the sand. These plants are extremely well adapted to the environment they inhabit; in fact, dune ecosystems are environments where numerous factors act to limit all life forms [5].

An easily observed phenomenon is the presence, in a certain habitat, of a determined combination of plants belonging to diverse species. In a simplified scheme of the beach–dune system, consisting of beach, foredune, dune, back dune, interdunal zone, and consolidated dune, it is interesting to note how, morphologically, the vegetation is disposed to form a wedge, with the vertex towards the coastline and the plants with longer stems at the back protected by the progressively higher landward vegetation (figure 3).

3. Materials and methods

3.1 *Remote sensing*

The principal aim of the project was the production of a thematic chart, on the scale of 1:10 000, on a GIS platform, where the most important features for describing the evolution of the dune apparatus and its state of conservation could be reported.

To visualize the aerial photographs and data, ESRI ARCGis 8.2 software was used with specific routines especially developed for the project.

In order to follow the evolution of the coastline and the dune fields, three sets of aerial photos of the beach of Platamona–Marritza, collected in 1955 (scale 1:30 000), 1977 (scale 1:10 000), and 2002 (scale 1:10 000), were analysed.

Correction and georeferencing of digitized images of the photos were performed using a geographic geometry transformation program (ERDAS Imagine Version 8.4). A Transverse Mercator Projection based on 32 °N was used to transform the data (UTM, Datum: WGS 84). The control points (buildings, roads, etc.) were selected from IGM maps (*Istituto Geografico Militare*) to geometrically correct and minimize the residual error between the transformation model and the reference coordinates.

After compiling three aerial mosaics from the photo sets mentioned above, the files were uploaded to the ESRI ARCG is 8.2. The three mosaics were coordinated and superimposed to allow the analysis of the evolution of the littoral over the 1955–2002 time period.

It was then necessary to include new features; the limits of the dune field (clearly visible before reforestation in the 1955 photographic mosaic), the present-day coastline and the main road network.

Moreover a series of specific parameters, useful for representing the entire national territory, were incorporated in the database to provide a complete synoptic view of the dune area studied and highlight its evolutive, morphodynamic, sedimentological vegetational and anthropic characteristics. The parameters that describe the morphological features are 'Duna/*Dun*e' and 'Linea di cresta/*Crest line*'.

'Dune' is a polygonal element that represents the entire dune area (incipient dune, foredune, and secondary or inactive dune). This element also includes other information on the evolutionary trend and vegetational characteristics of the dune field and provision for subdivisions according to: type (two classes: active and inactive, AT/NA), beach width (three classes: 0–20 m, 20–60 metres, >60 m), beach trend (three classes: prograding, retreating, stable) and type of vegetation (six classes on the basis of the visually dominant types: AL = pioneering species, AR = shrubbery, ER = herbaceous, ALR = sparse pioneering species, ARL = sparse shrubbery, ASS = absence of vegetation). 'Crest line' is a linear element that graphically indicates the mean trend of the crests of the active and inactive dune belts. Anthropic features are represented by 'Antropizzazione/*Anthropic*', 'Opere/*Works*', 'Uso spiaggia/*Beach use*', and 'Varchi/*Openings*'. 'Anthropic' is a polygonal element that defines the extent of the urban areas, sparsely settled areas and areas of anthropic use (intended as areas used by man but without the construction of buildings). 'Works' is a linear element that is conventionally positioned at the limit of the swash zone. It can distinguish between various types of works: artificial nourishment (RI), attached works (OR), and artificial nourishment associated with attached works (RO). 'Beach use' is a linear element positioned near the incipient dunes. To indicate the various uses of the front beach, it is defined as: activity associated with temporary occupation (TE), activity associated with permanent occupation (PE). 'Openings' is a point element positioned inside the Dune polygon near an opening towards the sea. It is possible to distinguish between: pathways (SE), roads (SR), and natural openings (VN).

The most important winds influencing the dynamics of the littoral and dune system were also described with 'Vento/*Wind*', a point element that indicates the geographical location of significant meteorological stations, also including those not directly monitoring the coastal area. It contains the following information: name of station; height above mean sea level; observation period.

3.2 *Fieldwork*

The field studies were carried out to determine the most important morphological features indicative of the morphosedimentological dynamics of the foreshore, the backshore, the foredunes, and the dune fields [7, 8].

The study, conducted in September–October 2003, February 2004, and September–October 2004, involved surveying:

- the morphological profiles (figure 4);
- the vegetation along the dune belts.

The morphological profiles (figure 4) were acquired using a SOKKIA:SET6 Electronic Total Station theodolite, and the vegetational species found along each profile were identified and indicated.

To study the state of health of the environment, recourse was made to phytosociology, the science that makes it possible to evaluate biocenotic diversity through the identification and classification of associations [6]. This biotest is more effective than the study of a single species to demonstrate possible anomalous stress situations.

Once all the characteristic and differential species in an association and their ecological and seasonal needs are established, it is possible to determine and evaluate the quality of the phytocenosis through, for example, the presence of an alien species in the community, the disappearance of a characteristic species, the anomalous coverage of specific vegetational

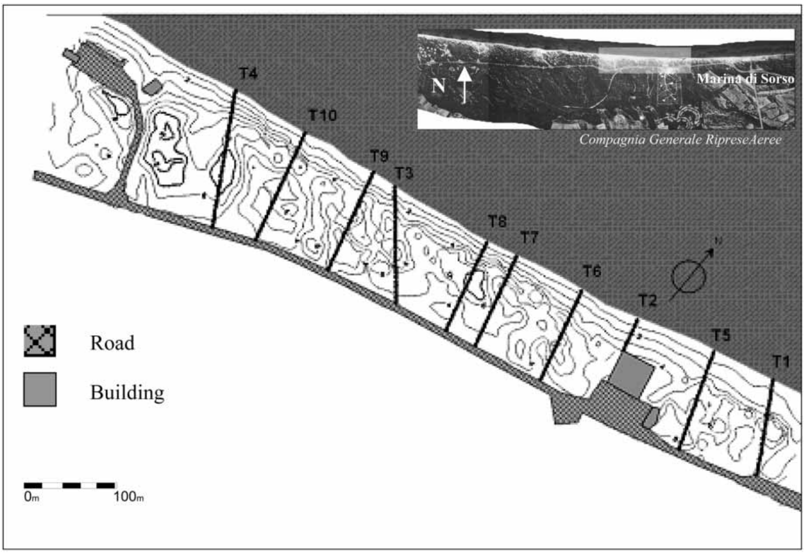

Figure 4. Location of the morphological profiles.

types that indicate particular ecological conditions, and even anthropic interference. In the case of a littoral with a series of dune belts, the beginning of vegetation follows a precise scheme; if the dune field is considered to be divided into distinct sectors (foredunes, incipient dunes, dunes) each can be associated with different vegetational species. The absence of specific species or the distribution of certain associations found during the fieldwork can be considered as an indication of the erosion of the beach.

The littoral of Platamona–Marritza contains all the vegetational tracts typical of a dune environment: near the shore line, it is possible to find species that colonize sandy environments, while on the other side of the main road, Highway 81, the area is populated by a thick pine grove planted by the Forest Service in the 1960s. The aerial photographs of 1955, predating the spread of the woods, and those of 1977 and 2002 demonstrate these two different stages, the direct consequence of which is that the innermost dune belts are well stabilized.

The theoretical series (figure 5) that should exist on this tract of the littoral is strongly influenced by the morphology of the zone: the dune field of Platamona–Marritza is a more or less elevated erosion slope that affects the secondary dunes. In this case, secondary dunes have the same role as the primary dunes and host *Sileno-Elymetum*, at the expense

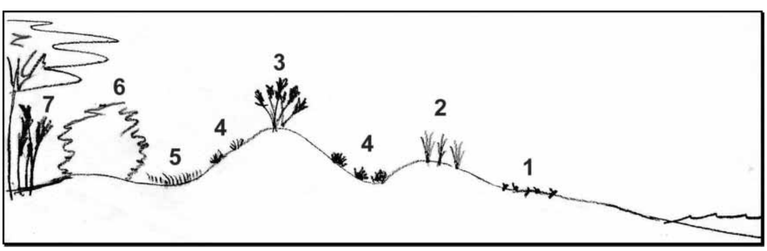

Figure 5. Theoretical transect of the vegetation in the area studied. 1: *Salsolo kali–Cakiletum maritimae*. 2: *Sileno corsicae–Elytrigetum junceae*. 3: *Sileno corsicae–Ammophiletum arundinaceae*. 4: *Crucianello–Helichrysetum microphylli*. 5: *Ephedro–Helichrysetum microphylli*. 6: *Asparago acutifoli–Juniperetum macrocarpae*. 7: Very tolerant perennial species of *Holoschoenus romanus*, *Juncus maritimus*, and *Equisetum ramosissimum*, and reforestation with *Pinus pinaster*.

of *Sileno-Ammophyletum*, which has almost disappeared. An anomalous contact between *Sileno-Elymetum* and *Crucianelletum* may be observed or, in the worst-case scenario, where the erosion is very extensive, between *Sileno-Elymetum* and *Juniperetum*.

4. Results

The study of the diachronic evolution of the dune deposits was made using aerial photographs taken in 1955, 1977, and 2002.

During this period, the morphology of the area changed considerably. From the photographic mosaic of 1955, it can be established that the aeolian deposits were in a natural state: the dunes undisturbed and predominantly colonized only by pioneer vegetation. The only anthropic intervention visible was agricultural activity in the central-southern portion of the dunes and the road linking Sorso and the modern Marina di Sorso.

The Forestry Commission began dune stabilization work in the 1960s, establishing a *Pinus pinaster* forest, principally to arrest the landwards advance of the sand. The analysis of the 1977 photographic mosaic reveals an area entirely covered with vegetation. The anthropic intervention in those years radically altered the appearance of the dune field: a dense network of roads was built in the area as far as the foredunes, and building became increasingly evident along the entire coastline.

The situation in 2002 was not radically different from that of 1977: the *Pinus pinaster* forest still covered a large part of the dune field, and the road network had been extended in some areas, above all to serve new tourist–recreational structures erected in the 1980s and 1990s.

The causes of the sedimentary disequilibrium affecting this stretch of the coast are to be found in the urban development that took place from the 1970s to the 1990s (figure 6), which altered the delicate dynamic equilibrium of the beach–dune system.

The high concentration of tourist attractions along this coastal tract exacerbated the degradation of the area, specifically along the foredunes; a visible consequence of the summer season

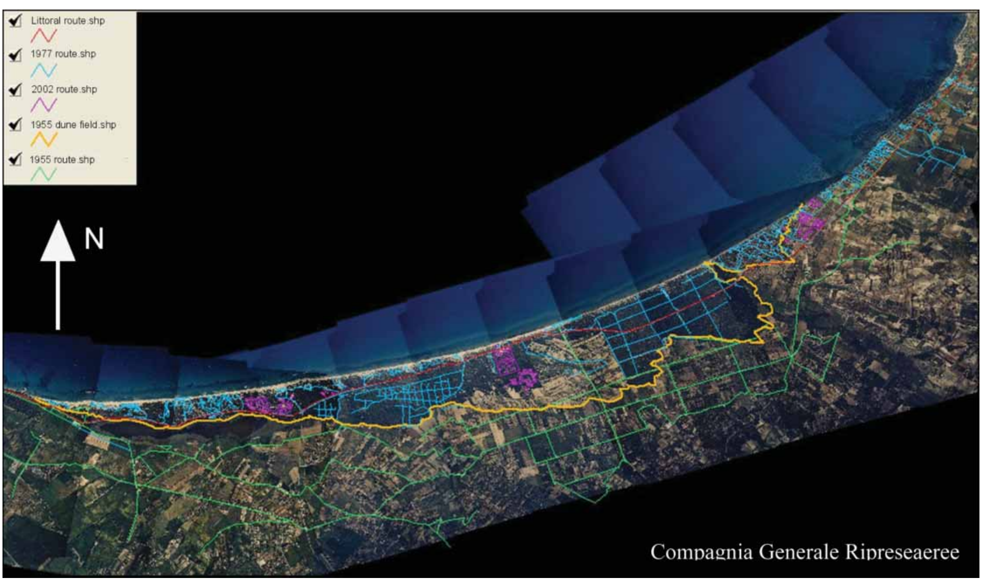

Figure 6. Urban developement from 1970s to 1990s.

Figure 7. Evolution of the coastline between the 1955 and the 2002 (based on aerial surveys of 2002).

is the abandonment of rubbish and the destruction of the pioneer vegetation on the incipient dunes, and their consequent weakening.

The morphological assessment indicates that the most critical zone is the dune front. However, there is also a notable vegetational stress in the interdunal sectors that are colonized by vegetational species considered delicate; those species were found to be compressed between the pioneer vegetation that is retreating with the shoreline and the back dune vegetation.

The analysis of the evolution of the coastline between 1955 and the 2002 reveals that it underwent a general retreat, with the erosive process occurring with different degrees of intensity: to the east, near Marritza, there are notable signs of retreat, with variations up to 25–35 m (figure 7).

Along the littoral of Platamona, the morphodynamic situation is generally analogous with that of a dissipative state where the waves break progressively closer to the back beach because of the presence of well-defined submerged barriers parallel to the coast; the slope is, in general, very gentle (1–2%). In the innermost areas of the surf zone, the beaches are characterized by the increased importance of longitudinal bottom currents [9]. However, some deviations from this morphodynamic condition have been noted in the arc of only a few days during the surveys taken in September–October 2004, with conditions changing to a state more similar to that of a long shore trough barrier, depending on the wind–wave conditions along the coast (figure 8).

The morphological profiles of the backshore were parameterized according to the method proposed by Carobene and Brambati in 1975 [10]. Assuming the parameter '*pvd*' (angle of

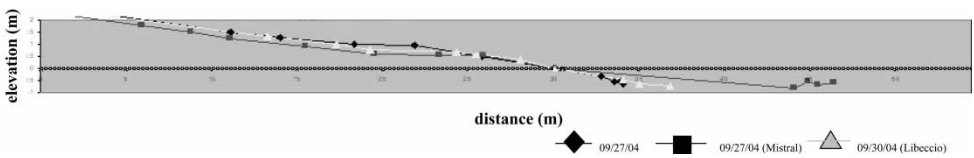

Figure 8. Morphological variation to Transect T2, depending on different wind–wave conditions encountered during the fieldwork (see location in figure 4).

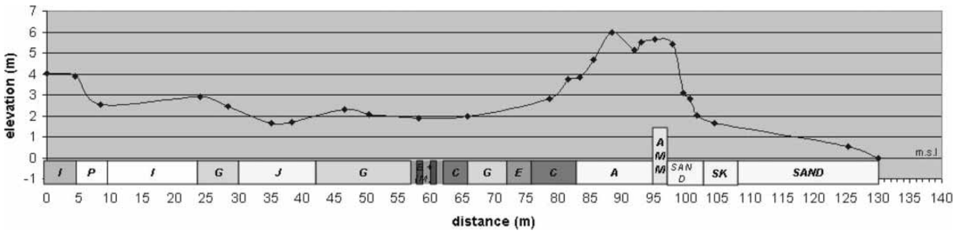

Figure 9. Morphometric profile of Transect 10 (see figure 4 for the location and table 1 for the legend).

the upwind slope of the primary dune, intended as the inclination and expressed in degrees) as the index of erosive stability for the study area, and expecting to find higher values where the erosion is more marked, it is possible to divide the morphometric profiles obtained into two classes, depending on whether the values are above or below the average (=23.88°). The majority of the profiles cross the dunes perpendicularly, and only those near tourist structures show a gentle slope. This conformation can be imputed then to human activity, particularly influential during the swimming season. In fact, the dune sectors with lower slope angles are found in areas less accessible to beach goers and, for this reason, are not subject to any further acceleration of the natural destruction of the dunes that is already under way.

Profile T10 (figure 9) presents a very unusual trend: 82% of this transect lies at an average height of less than 3 m above sea level, while the dune crest reaches a height of 6 m.

In fact, it is possible to see a vast, almost flat, back dune depression and an exposed beach with a slope of 4.9° in line with the average measured during the survey. A dune body, lying between the beach and the back dune depression, presents a flattened morphology recognizable in many other profiles: irregular sections, somewhat flattened at the top, and with a small crestal hollow. The main difference between the profiles is found, however, along the exposed beach and the seaward slope of the dunes. Although the *dPd* values (distance between the foot of the dune and the swash zone) fall within the average limits, the ordinary and storm berms are notably close to the foot of the dune. With the minimum value for this parameter here, it is not surprising to find the highest slope values of the fore (and only) dune: the erosive action

Table 1. Legend of the distribution of the vegetational species.

Abbreviation	Type of association
SAND	Plantless zone
SK	*Salsolo kali–Cakiletum maritimae*
A	*Sileno corsicae–Elytrigium juncae*
AMM	*Sileno corsicae–Ammophiletum arundinaceae*
E	*Ephedro–Helichrysetum microphylli*
C	*Crucianello–Helichrysetum microphylli*
E + C	Mosaic of E and C
Me	*Ephedro–Helichrysetum microphylli* var. *Carpobrotus acinaciformis*
Mc	*Crucianello–Helichrysetum microphylli* var. *Carpobrotus acinaciformis*
PANCR	*Ephedro–Helichrysetum microphylli* var. *Pancratuim maritimum*
G	*Asparago acutifolii–Juniperus macrocarpae*
P	Reforesting with *Pinus pinaster*
J:	Clumps of *Juncus maritimus* and *Holoschoenus romanus*
ACACIA	Clumps of *Acacia cyanophilla*
CANNETO	Formation of *Phragmites australis*
I	Uncultivated

coming from the direction of the waves has eroded the base of the dune, exporting material even during mild storms. It can be expected that in a short time, the frontal part of the dune crest will collapse, with consequent exportation and deposition of new material on the beach at the foot of the dune. An increase in the '*psp*' (slope of the exposed beach, intended as the slope of the straight line between the crest of the maximum storm berm and the foot of the dune) as the result of reworking of sediments by waves and an internal rearrangement based on a new equilibrium, might also occur.

Transect 10 has similar characteristics to the other profiles in terms of vegetation (table 1): ***SK*** is found where the waves lose energy, which typically occurs when there is a change in the slope (foot of the dune as in T 10) or close to a shore subject to direct wave action (as in other transects). In general, the proximity of the foredune belts to the swash zone can cause the presence of ***SK*** up to 2 m above the average sea level; above this line, we can still find sand, where there is a sloping cliff or formations of *Agropyron* of the *Sileno corsicae–Elytrigetum junceae* association (table 1).

In a crisis situation, as exists along the littoral of Platamona, it is not surprising to find a great abundance of pioneer species, often protected by species that prefer completely different environmental conditions, such as a greater quantity of water, a less sandy substratum, a greater concentration of humus, etc. Among the pioneer species, the most important is *Agropyron junceum*. Its association, *Sileno corsicae–Elytrigetum junceae*, is common to varying degrees along the entire littoral: along the profiles studied, it varies from 25 m to 2 m and is also found in large clumps in isolated transects. Instead, where the foredune is still extant, ***A*** is found at the crest, as in the case of Transect 10 (figure 9).

The greatest extensions of these association are in the zones in which the profiles have a 'natural' trend, that is where the dunes grow progressively higher with a gentle slope. Instead, where there is major erosion, particularly on the very steep upwind slopes of the foredune, as in the case of T10, it is possible to find sandy faces of a few metres, depending, above all, on the width of the crest.

The association *Sileno corsicae–Ammophiletum arundinaceae* exists in an extremely fragmented and reduced form, never more than a few square metres, in every part of the dune field, and its spatial collocation is obvious in only a few transects; in T10, it is restricted to a narrow band of 2 m on the outer edge of the foredune, and its situation is not so much linked to its substitution by *Agropyretum junceum* as natural erosion depositing it at the foot of the dune.

G indicates an association characterized by the presence of *Asparago acutifolii–Juniperus macrocarpae* with the notable presence of young forms of *Pinus*, growing in an anomalous situation given the environment preferred by this species, its seeds obviously coming from the landward areas of reforestation. Where the maximum extension of the foredune creates a windbreak, there is a more extensive cover of ***G*** behind the dune itself, as in the case of the transect shown in figure 9.

The *pine grove* (***P***) and the *uncultivated land* (***I***) associations, far from the shoreline, are deeply affected by anthropic activity and are located on the other side of the coastal road system; no useful information for understanding the coastal dynamics can be deduced from these associations.

In general, the vegetational analysis reveals a general retreat from the shoreline, with the transfer of a considerable quantity of sediment incoherent with the zones previously restored, placing the theoretical succession of vegetational associations in crisis. The succession still visible today presents tracts of the preceding arrangement, but in many sectors of the dune field the equilibrium has been definitively compromised, and the trend revealed by all the profiles is towards a new equilibrium spatially moved several tens of metres landwards.

5. Conclusions

The beach and dune fields of the littoral sector studied show signs of a notable erosive trend. The erosive processes, which were exacerbated in the 1970s and 1980s, have caused waves to break at the foot of the dunes, which have consequently assumed a steeper frontal slope. This erosion has caused vegetational stress, highlighted by the phytosociological analysis carried out, which revealed an overlapping of pioneer species and those that normally occupy interdunal and consolidated dune zones.

The research has provided useful data for a specially created user-friendly database that also includes data on all the major national dune fields. It should be noted that, apart from the advantage of having a simple, user-friendly instrument, the database can easily be updated with data from subsequent monitoring programmes of sectors of interest.

References

[1] CNR, MURST. *Atlante delle Spiagge Italiane, Foglio n° 180 – Sassari. Scala 1:100 000* (1999).
[2] CNR, MURST. *Regione Autonoma della Sardegna. Atlante delle spiagge della Sardegna. Scala 1:100 000* (2000).
[3] P.R. Federici, S. Ginesu, G. Oggiano. Genesi ed evoluzione della pianura turritana (Sardegna settentrionale). *Geogr. Fis. Dinam. Quat.*, **10–11**, 103–121 (1987–88).
[4] A. Ozer, Géomorphologie du versant septentrional de la Sardaigne. Ph.D. thesis, University of Liège (1976).
[5] E. Biondi, R. Filigheddu, E. Farris. Il paesaggio vegetale della Nurra. *Fitosociologia*, **38**(Suppl. 2), 3–105 (2001).
[6] E. Biondi, La Geobotanica nello studio ecologico del paesaggio. *Ann. Acc. It. Sc. Forestali*, **XLV**, 3–39 (1996).
[7] K.F. Nordstrom, N. Psuty, R.W.G. Carter (Eds). *Coastal Dunes: Form and Process*, Wiley, New York (1990).
[8] K.F. Nordstrom. *Beaches and Dunes of Developed Coasts*, University Press, Cambridge (2000).
[9] R.W.G. Carter. *Coastal Environments. an Introduction to the Physical, Ecological and Cultural Systems of Coastlines*, Academic Press, London (1988).
[10] L. Carobene, A. Bramati. Metodo per l'analisi morfologica quantitativa delle spiagge. *Boll. Soc. Geol. It.*, **94**, 479–493 (1975).