

THE ROLE OF CLIMATE VARIABILITY AND HUMAN ACTIVITIES IN THE DUNE FIELD EVOLUTION IN NAXOS ISLAND, GREECE

P.T. NASTOS¹, N. EVELPIDOU² and A. VASSILOPOULOS²

¹Laboratory of Climatology and Atmospheric Environment, Department of Geology and Geoenvironment, University of Athens, Panepistimiopolis, 157 84 Athens, Greece

²Laboratory of Remote Sensing, Department of Geology and Geoenvironment, University of Athens, Panepistimiopolis, 157 84 Athens, Greece
e-mail: evelpidou@geol.uoa.gr

ABSTRACT

This study focuses on the phenomenon of erosion regarding the coastal dune system in Naxos island (Cyclades), Greece. In the western coastal zone of Naxos, several dune fields are observed. Despite the fact that erosion on the inland has become more intense during the last years, providing thus sufficient material for the development of new dune fields, the current dunes are retreating.

Climate variability and prolonged human activities are the major components that lead to the dunes' modification, which is a sign of desertification that comes in accordance with the recent climate change. The climatic factors that are probably involved in the dunes' erosion are the aeolian blow and the precipitation, which may act in counterbalance to the dunes formation. The climatic data that were used in the analysis include daily values of precipitation and wind speed, acquired from the Hellenic National Meteorological Service, for the period from 1955 to 2003.

This study results in the main reasons for the retreat of the dune fields, namely anthropogenic constructions, whose intensity increases because of the touristic development on the western coastal zone, climatic conditions and wave processes.

KEYWORDS: Dune fields, climate variability, Naxos Island, Cyclades, Greece

1. INTRODUCTION

Naxos is the biggest island in the Cyclades island group in the Aegean with a surface of 430 km² (Fig. 1). The principal factors that lead to the formation of the study area's landforms are tectonics and lithology in combination with the prevailing climatic conditions. Naxos' various lithological formations resist differently to erosion, which combined to the drainage network's activity has lead to the different landforms development (Sabot, 1978; Evelpidou, 2001). The study area is situated in western Naxos where are mostly found mica-shists, gneiss and marbles (Fig. 2). Granodiorites appear on the western part of the study area (Jansen, 1977), forming a number of small headlands which are connected in most cases with barrier beaches overlaid by sand dunes.

The mean annual precipitation for the city of Naxos (west Naxos) is 366.8 mm, the mean annual temperature is 18.18°C and the prevailing winds are of northern and southern directions.

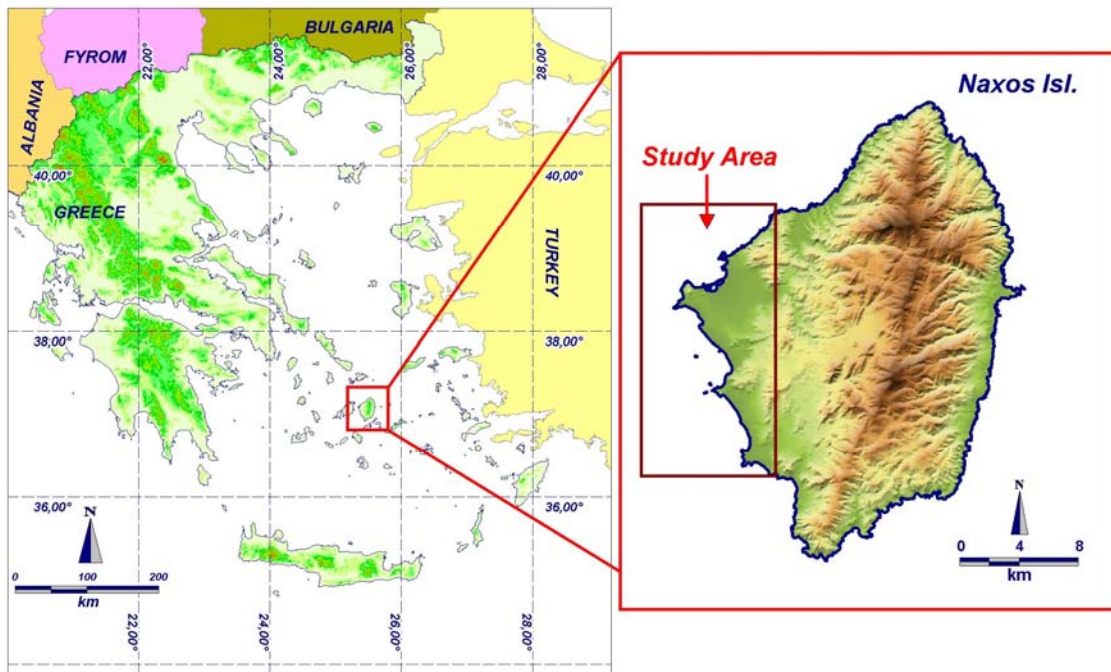


Figure 1. Naxos island and the study area

Information for the region's offshore wave climate was gathered from the Wind and Wave Atlas of the north-eastern Mediterranean Sea (Athanasoulis and Skarsoulis, 1992) and is presented on Table 1.

Table 1. Offshore wave direction and height expressed in percentage of occurrence (Athanasoulis and Skarsoulis, 1992)

Direction (%)	N	NE	E	SE	S	SW	W	NW	Calm
Height (m)	0-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	>5
(%)	36.6	24.1	17.1	9.3	5.8	3.3	2.6	0.8	0.4

The objective of this study is to determine the reasons for the dunes' retreat on the western shores of Naxos, taking into account lithological, geomorphological, anthropogenic and climatic criteria.

2. DATA AND ANALYSIS

The meteorological data concerning daily precipitation totals, mean daily wind speed and daily prevailing wind direction were acquired from Naxos meteorological station of the Hellenic Meteorological Service, for the period 1955-2003. The simple daily intensity index (SDII), as defined by the joint CCI/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI), is also estimated. The steps that were followed during the study are stated below:

First a detailed coastal geomorphological mapping was carried out in scale 1:5.000. Then two sets of aerial photographs, in scale 1:33.000 taken in 1960 and 1986, were interpreted for the determination and mapping of the coastal dunes extend. Sampling was carried out during fieldwork with the combined use of GPS technology, so as to provide a more accurate position recording. The samples were granulometrically analysed and the mean size, sorting, skewness and kurtosis were determined according to Folk and Ward

(1957). Finally, all the above mentioned data were introduced into a GIS and produced an informational database that was categorised in different information layers, forming a geospatial and descriptive database.

3. RESULTS AND DISCUSSION

The coastal part of the study area is characterised by a number of small headlands with sandy beaches and dunes among them. The presence of small lagoons at several locations is an indication of previous recent coastlines. From the bay of Agia Anna up to Agali cape, a number of barrier beaches have been developed with well formed sand dunes on their top. Three sets of dune fields were observed in western Naxos as shown in developed coastal geomorphological map (Fig. 2). The inner set is the older one, several hundred years old, is also well preserved and vegetated with dwarf cedars.

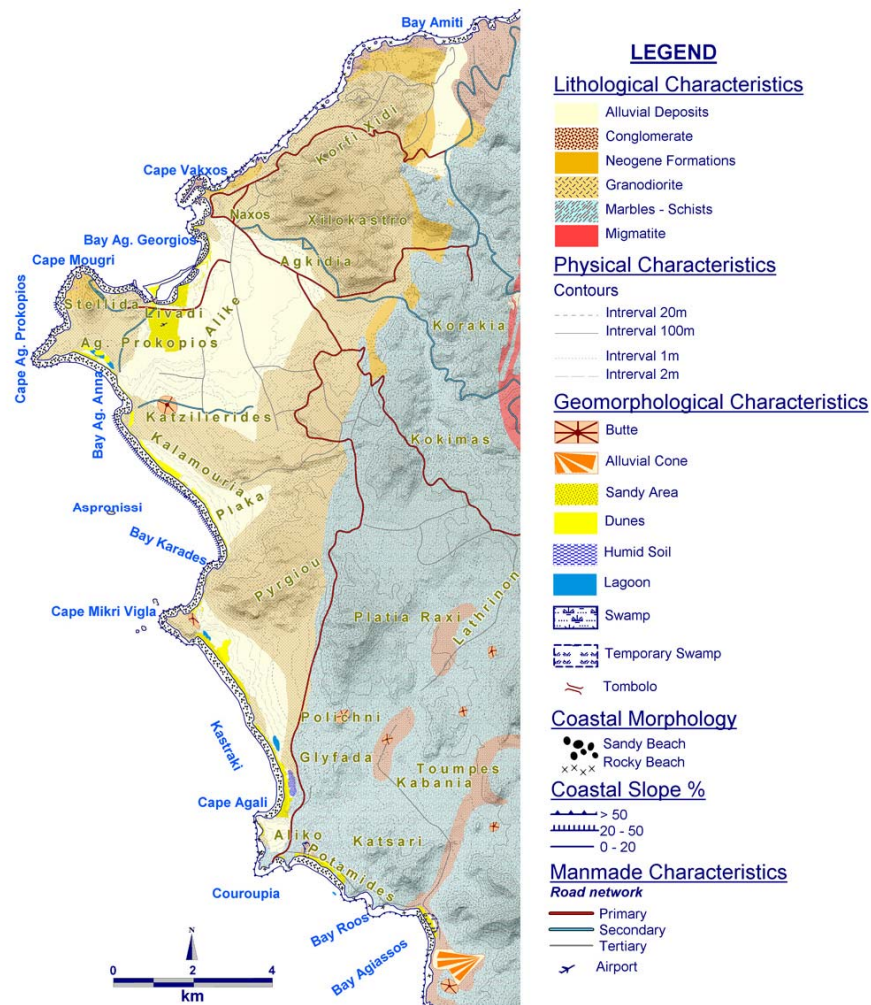


Figure 2. Geomorphological map of the study area

The first dune field is the most susceptible to natural and human interventions. It is also the one that retreats rapidly due to the combined action of humans and waves (Fig. 3a, b). The second dune field which reaches elevations up to 3.85 m (Ag. Prokopios area) is slightly vegetated and doesn't endure the same wave intensity, thus consider more protected than the first one. The third dune field, the older one, is situated behind the second, is stabilised, forested with dwarf cedars and reaches up to 20 m (Fig. 3c). Sand dunes in the southern part of the study area, are sometimes deposited on fluvial-torrential

deposits and mica schists and gneisses forming a coastline with cliffs 10 m high, which are intensely eroded because of the rapid coastline retreat.

The scatter plot between mean daily wind speed and daily prevailing wind direction during the period 1955-2003 (Fig. 4, upper graph) indicates that strong north-westerly winds dominate and this is well exemplified by the presence of aeolian sand accumulation reaching elevations up to 25 m. Besides, south westerly to south easterly strong winds also appear, but they did not influence the dunes formation due to existed topography. The precipitation analysis showed that the simple daily intensity index time series (annual rain totals (mm)/annual number of rain days) show an increasing trend within the examined period but these trends are not statistically significant (C.L. 95%) (Fig. 4, lower graph).



Figure 3. a, b) The first dune fields in the western part, rapidly retreating due to combined action of human activities and wave processes. The first dune field is more susceptible to the natural and human interventions. It retreats rapidly due to the combined action of the waves and man. Figure 3a shows the first field of dunes in 2005, while in 3b the same in 2007, c) the third dune field is the well stabilised and vegetated with dwarf cedars

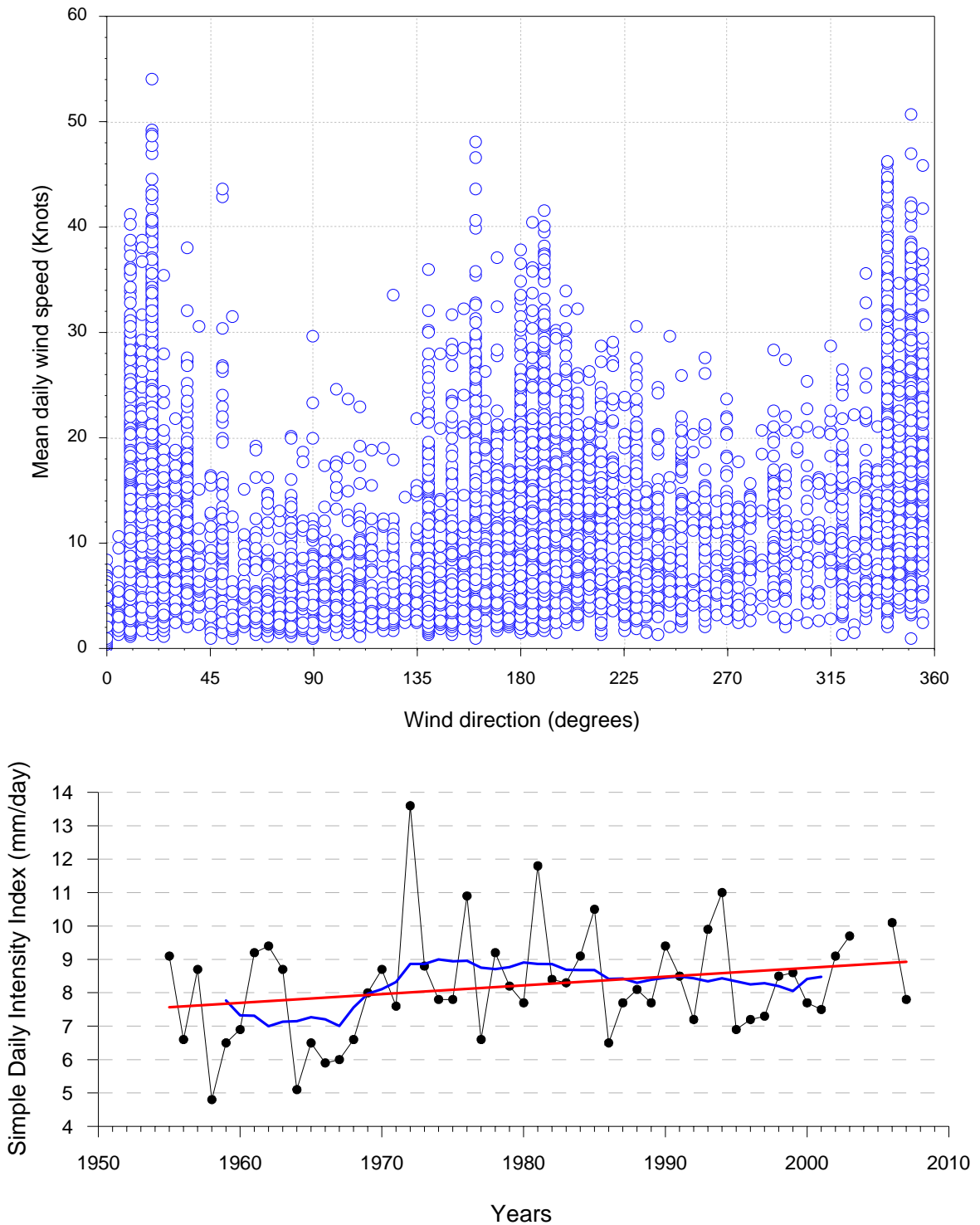


Figure 4. Scatter plot between mean daily wind speed and daily prevailing wind direction (upper graph) and daily intensity index (lower graph)

The rocks of the wider area are fractured with many discontinuities. This fact combined with the rainfall's intensity leads to the rocks' erosion during run-off. This is how material gets transported from the inland to the beach, which under the appropriate conditions could have been used for the dunes' reconstruction. During the last few decades these dune fields are systematically retreating due to several factors. Man has played an important role in the evolution of the dunes, by interfering with their fragile ecosystem

through building residencies, tourist accommodations etc. These interferences have mainly been established at the second and third dune sets. So, despite the fact that erosion on the inland has become more intense during the last years, providing thus sufficient material for the development of new dune fields, the current dunes are retreating, as the eroded material in many cases do not reach the coastline.

Climatic conditions expressed mainly through wind and precipitation, assist the erosion of the first and second set of dunes. The third dune group is also under erosion due to run off because of high daily intensity episodes, which are more frequent and hazardous in the recent years (Fig. 4). Although the precipitation trend is decreasing from 1980's, the erosion processes of the area are very intense, since the high slope relief, the differential lithology and the absence of important land cover are the major factors that contribute to the formation of the present denudated morphology, mainly because of the intense run off, due to high rain intensity. Finally, the wave action has severely affected the first set of dunes, which retreats rapidly, especially during the last decade.

4. CONCLUSIONS

Three sets of coastal dunes were recognised, located in the south-western part of the island, reaching an elevation of 4 m, 8 m and 20 m high respectively. The stabilised and well forested dune fields, located near the peninsula of Couroupia, seem to be older than the rest of the dune fields since they are composed of particles whose size is much coarser than the rest of the samples. This is explained by aeolian reworking or weathering as well as by sheet-fluvial erosion. During the last few decades these dune fields are systematically retreating due to several factors. Man has played an important role in the evolution of the dunes, by interfering with their fragile ecosystem through building residencies, tourist accommodations etc. These interferences concern mostly the second and third dune fields. The third dune field is also under erosion due to run off and intense precipitation. Climatic conditions expressed mainly through wind and precipitation assist the erosion of the first and third set of dunes. Finally, the wave activity has severely affected the first set of dunes, which retreats rapidly, especially during the last decade.

REFERENCES

1. Athanasoulis G. and Skarsoulis E., (1992), Wind and Wave Atlas of north-east Mediterranean Sea, Laboratory of Nautical and Marine Hydrodynamics, NTUA, Athens.
2. Folk R.L. and Ward W.C., (1957), Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology* 27:3–26.
3. Evelpidou N., (2001), Geomorphological and Environmental study in Naxos island using remote sensing and GIS technology, PhD Thesis, University of Athens, Geology Department, Geography and Climatology sector, p. 226.
4. Jansen J.B.H., (1977), The geology of Naxos, *Geol.Geophys.Res.*, Vol. 19, p.100.
5. Sabot V., (1978), La geomorphologie et la geologie du Quaternaire de l'île de Naxos, Cyclades-Greece, PhD Thesis, Brussels.