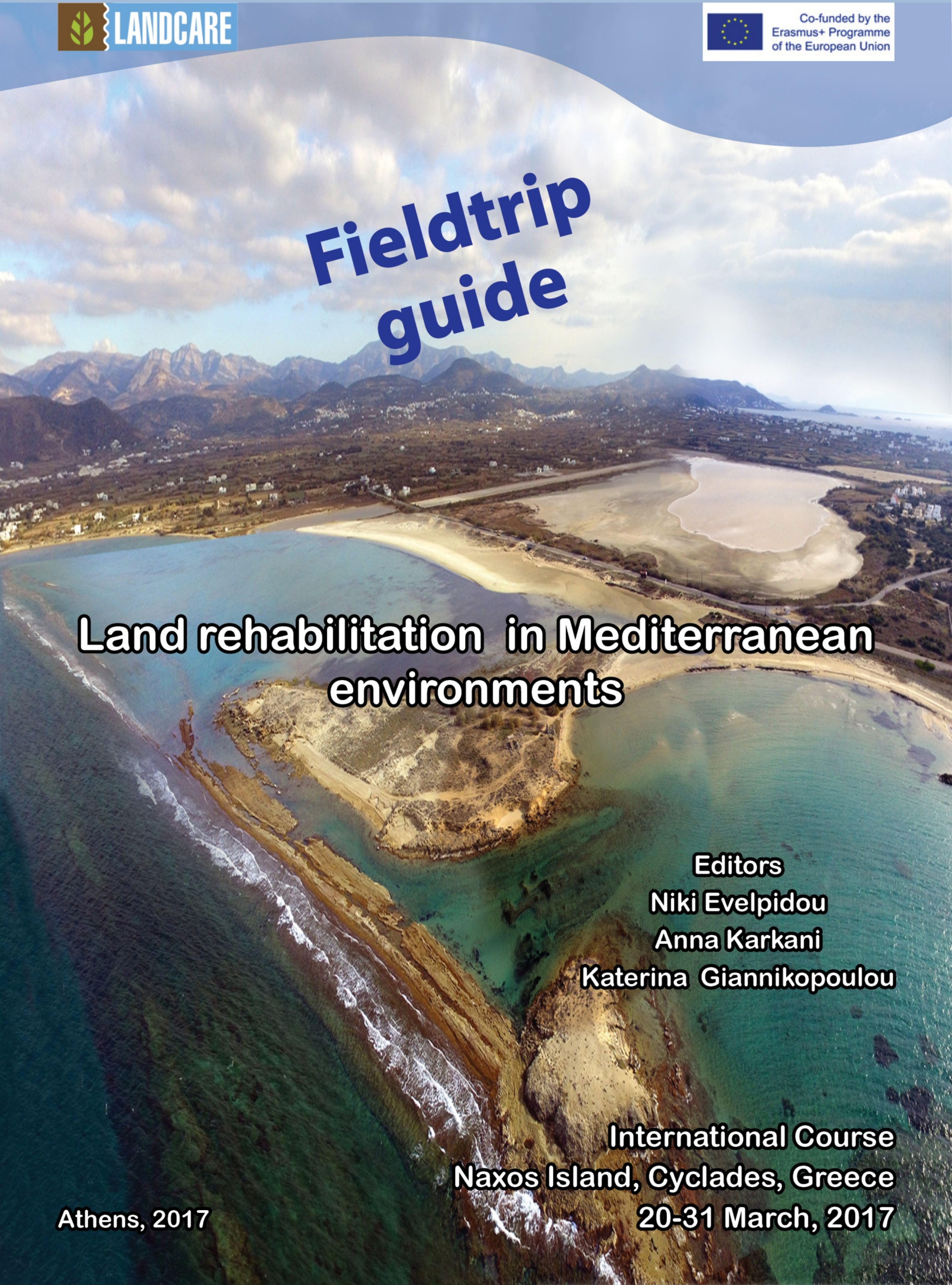


Co-funded by the Erasmus+ Programme of the European Union

Fieldtrip guide

Land rehabilitation in Mediterranean environments

Editors
Niki Evelpidou
Anna Karkani
Katerina Giannikopoulou

International Course
Naxos Island, Cyclades, Greece
20-31 March, 2017

Athens, 2017

Table of Contents

Preface

This fieldtrip guide was developed for the needs of the training school "Land rehabilitation in Mediterranean Environments", which will take place at Athens and Naxos Island, Cyclades, Greece, during 20-31 March, 2017. It was developed in the framework of LANDCARE, an Erasmus+ project with the collaboration of 7 partners: University of Santiago de Compostela (Spain), University of Lisbon (Portugal), University of Athens (Greece), National Research Council/Institute of Ecosystem Study (Italy), Forest Research Centre of Lourizán/Conselleria do Medio Rural – Xunta de Galicia (Spain), West Systems SRL (Italy), Empresa de Desenvolvimento e Infra-estruturas do Alqueva (Portugal), Archipelagos Institute of Marine Conservation (Greece).

At this point, I would like to thank the Municipality of Naxos and Small Cyclades and the Agency of Culture, Sports, Environment, Education, Welfare & Solidarity (NOPPAPPPA) for their continuous support and hospitality during educational activities related to geology and environment and during our research in the Island on Naxos. I would also like to thank Marianna Gatou for editing the English language, Manolis Lykouropoulos for fieldwork and photographic material and Sofia Kagani for providing bibliographic material from local libraries and media. Last but not least, I would like to thank all LANDCARE partners for their collaboration.

For the organizing committee,

Niki Evelpidou

About Landcare

Context / background of the Project

Southern Europe is particularly vulnerable to land degradation, which affects important sectors of the economy (agriculture, fishing, tourism) and the supply of vital services and goods (water, food). Although *"actions to restore ecosystems and biodiversity have significant potential to create new skills, jobs and business opportunities"* ((ED 2011/2307(INI)), there is a considerable shortage of skilled workers in this field, due to the lack of proper training. This is especially important in Southern Europe, where youth unemployment is extremely high.

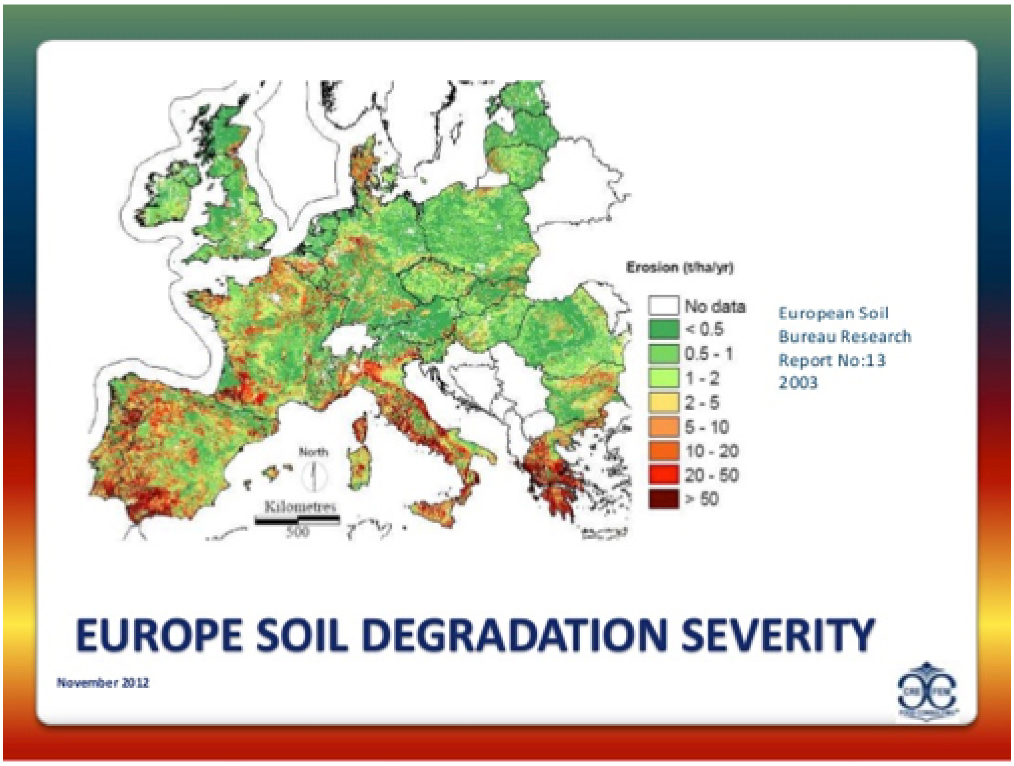


Fig. 1: Soil degradation severity in Europe.

Objective of LANDCARE

The overall objective of LANDCARE is to improve training capacities in relation to Land Degradation and Rehabilitation (LD&R) in Southern Europe, in order to fulfil the demands of an emerging labour market and contribute to the green economy.

LD&R is a field that requires training, involving real study cases and hands-on experience. For this reason, the education path proposed in the project will combine short-term international mobility and innovative online learning (PLEs, SPOCs).

The project will try to recover unemployed skilled people who are useful to encourage employability in this sector. Employability skills will be enhanced by means of personalized training and hands-on practices. To increase the scope of this strategy, the project reinforces interactions between students, educators, researchers, companies/agencies/NGOs and decision-makers.

Description of activities

The main activities proposed focus on training both staff (from academic and professional partners) and students (HEI, company staff and selected unemployed people). The teachers' training will include:

a) intensive training in innovative online learning tools (PLE, SPOCs) and

b) short-term joint events to reinforce training capacities in LD&R.

The students' training will be based on two types of blended mobility:

a) The concepts of Land Degradation and Rehabilitation will be taught by means of an intensive study programme, involving mobility and flexible online training.

b) Practical experience and employment skills will be provided by means of an internship programme combined with solid online and personalised training on employment and entrepreneurship.

Main Outputs of the project

Certain teaching outputs of the project will have a strong multiplier effects: the development of blended mobility to enhance the employability in the "Green Economy", the publication of the first handbook linking Land Restoration and employability opportunities and the launch of a peer teaching network. The main multiplier social effect is the enhancing of the green economy to generate job and development.

INTERNATIONAL COURSE 2017: LAND REHABILITATION IN MEDITERRANEAN ENVIRONMENTS

TRAINING BY

- UNIVERSITIES: University of Santiago de Compostela (Spain), University of Lisbon (Portugal), National and Kapodistrian University of Athens (Greece), National Research Council/University of Pisa (Italy).
- COMPANIES: Forest Research Centre Lourizán (Spain), West Systems (Italy), EDIA (Portugal), Archipelagos (Greece).

COURSE OUTLINE

- Classroom sessions and online teaching within an integrative learning approach

- Field and laboratory practices with case studies and real world projects
- Language of the course: English
- Internship in a company ABROAD

TOPICS

- Freshwater ecosystems
- Coastal areas
- Contaminated soils
- Wildfire areas
- Environmental education
- Employability related with LANDCARE

CERTIFICATES

- ERASMUS Certificate for the International Course (6 ECTS) and for the Internship (1 month)

INTERNATIONAL COURSE 2017 "LAND REHABILITATION IN MEDITERRANEAN ENVIRONMENTS"

When: 20-31 March, 2017

Venue:

- **National and Kapodistrian University of Athens, Greece**
- **Naxos Island, Cyclades, Greece**

The programme of lectures and other activities	
Day 1 **Sunday** **19/03/2017**	Arrival to Athens– All students Ice breaker, from 18:00 to 21:00 *Dinner at guest house of NKUA (Near the main gate of NKUA, check map)*

Session: Employability related with LANDCARE **Responsible University: National and Kapodistrian University of Athens** **Venue: Seminar Room, Faculty of Geology and Geoenvironment 1st floor.**		
Day 2 **Monday** **20/03/2017**	9:00-9:30	Welcome from: Department director, Dr. Gournelos Theodoros *Coordinator, Dr. Agustín Merino* *Local organizer, Dr. Niki Evelpidou*
	9:30–9:45	Presentation of the project and course *Coordinator, Dr. Agustín Merino* *Local organizer, Dr. Niki Evelpidou*
	9:45–10:00	Experiences from the ISP "Analysis and Management of Anthropogenic Natural Hazards and Disasters" in Naxos, McAGENDA ERASMUS+ Project. *A. Hafti, A. Petropoulos, V. Vroustis*
	10:00-10:15	Experiences from participant students of the Training school "Land Rehabilitation of Degraded Environments", in Spain. LANDCARE Erasmus+ project. *Maria Manousaki (OASP/NKUA)*
	10:15-11:45	Student's presentations
	11:45-13:30	Employability in Landcare

		Dr. Michael Stamatakis (NKUA)
	13:30	***Light Lunch***
	17:30	Departure to Naxos with Ferry boat "Blue Star Ferries Naxos"
	22:45	Arrival to Naxos
	23:00	Bus will pick you up from the port and transfer you to the guest houses (Vivlos village)

Session: Soil-water management, Desertification and Rehabilitation ***Responsible University: University of Lisbon and University of Tehran*** ***Venue:* Ursulines Monastery, Old town of Naxos**		
Day 3 **Tuesday** **21/03/2017**	8:20	Bus departure to Naxos
	9:00–10:30	Soil-water management , Desertification and Rehabilitation: Case Studies of your own country *Students*
	10:30–11:00	***Coffee break***
	11:00-12:00	Degradation processes and Rehabilitation of wetland ecosystems *Patricia Rodríguez-González (Ulisboa)*
	12:00-13:00	Degradation processes and Rehabilitation of wetland ecosystems: case studies *Patricia Rodríguez-González (Ulisboa)*
	13:00 – 14:30	***Lunch break***
	14:30-16:30	Desertification *Parvaneh Sayyad-Amin (U. Tehran)*
	17:00	Bus departure to Vivlos village

Session: Industrial degradated areas and waste management ***Responsible Universities:* University: National and Kapodistrian University of Athens** ***Participating Institutes: CNR-ISE, USC***		
Day 4 **Wednesday** **22/03/2017**	9:00 – 13:00	Fieldwork: Industrial degradated areas *Waste Management company* *Marble quarry, Karpontini bros Naxian marble UNL., Kinidaros area* *Serena Doni and Cristina Macci (CNR-ISE)* *Niki Evelpidou (NKUA)*
	13:00 – 13:30	***Lunch break***
	13:30-15:30	Mine degradated area, Emery mine

		Serena Doni and Cristina Macci (CNR-ISE) *Niki Evelpidou (NKUA)*

Fieldwork: Coastal Erosion / Land Degradation / Contaminated areas ***Responsible Universities:*** **University: National and Kapodistrian University of Athens** ***Participating Institutes: USC, ULisbon***		
Day 5 **Thursday** **23/03/2017**	9:00-13:00	Biological treatment station "BIO.KA" (near airport) Ag. Georgios coastal area, palaeogeography, environmental changes.. This stop will be attended by the "1st secondary school of Naxos", *Niki Evelpidou (NKUA), Ioannis Kontopoulos (SSN)* Survey of a Salt pit (near airport) *Niki Evelpidou (NKUA)*
	13:00 – 13:30	Light Lunch break
	13:30 – 17:00	Ag. Prokopios Coastal Erosion, case study "Hawaii beach" *Niki Evelpidou (NKUA)*

Session: Fresh water ecosystems/ Degradated areas ***Responsible Universities:*** **University: National and Kapodistrian University of Athens** ***Participating Institutes: USC, ULisbon, CNR-ISE***		
Day 6 **Friday** **24/03/2017**	9:00-13:30	Field work: Eggares area reservoir Vegetation at rivers, Amitis area *Patricia Rodriguez-González (ULisbon)* *Niki Evelpidou (NKUA)*
	13:30 – 14:00	***Lunch break***
	15:00-17:30	Field work (continue): Dam Faneromenis Wetlands, Glyfada area *Patricia Rodriguez-González (ULisbon)* *Niki Evelpidou (NKUA)*
		LANDCARE project meetings ***All tutors***

Session: Contaminated Areas ***Responsible University: National Research Council/Institute of Ecosystem Study CNR-ISE (Italy)***		
Day 7 **Saturday** **25/03/2017**	8:20	Bus departure to Naxos
	9:00 – 11:00	Contaminated Areas: Case studies from your own country *Students*
	11:00 – 11:30	***Coffee break***
	11:30 – 12:00	Soil contamination *Serena Doni and Cristina Macci (CNR-ISE)*
	12:00 – 12:30	Soil contamination (continued) *Serena Doni and Cristina Macci (CNR-ISE)*
	12:30 – 13:00	Soil rehabilitation technologies *Serena Doni and Cristina Macci (CNR-ISE)*
	13:00 – 13:30	Soil rehabilitation technologies (continued) *Serena Doni and Cristina Macci (CNR-ISE)*
	13:30 – 15:00	***Lunch break***
	15:00-17:30	Laboratory: Soil contamination and rehabilitation of contaminated sites *Serena Doni and Cristina Macci (CNR-ISE)*
	17:45	Bus departure to Vivlos village

Day 8 **Sunday** **26/03/2017**	Free

Session: Coastal Areas and coastal erosion and rehabilitation techniques. *Responsible University: National and Kapodistrian University of Athens*		
Day 9 **Monday** **27/03/2017**	8:20	Bus departure to Naxos
	9:00-11:30	Coastal Areas and coastal erosion Case studies of your own country *Students*
	11:30 – 11:45	***Coffee break***
	11:45–12:30	Coastal System *Niki Evelpidou (NKUA), Vasilios Kotinas (NKUA), Marianna Gatou (NKUA)*
	12:30 – 13:30	Coastal erosion modeling *Vasilios Kotinas (NKUA), Niki Evelpidou (NKUA)*
	13:30 – 14:15	***Lunch break***
	14:15-18:00	Laboratory: Coastal erosion modeling *Vasilios Kotinas (NKUA)*
	18:20	Bus departure to Vivlos village

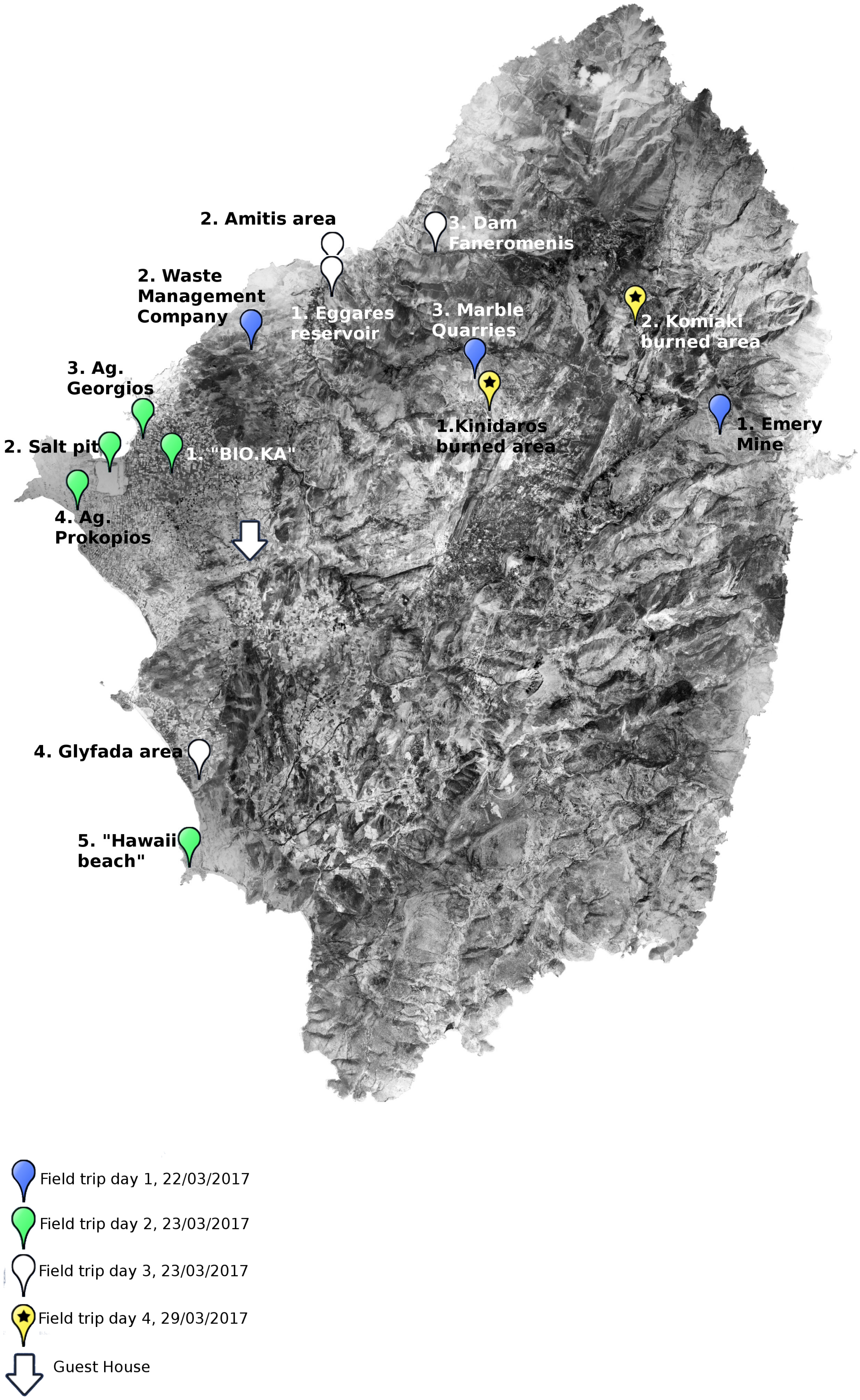
Session: Wildfire areas and reclamation techniques *Responsible University: University of Santiago de Compostela / National and Kapodistrian University of Athens*		
Day 10 **Tuesday** **28/03/2017**	8:20	Bus departure to Naxos
	9:00 – 11:00	Wildfire areas : Case studies from your own country *Students*
	11:00 – 11:30	***Coffee break***
	11:30-13:30	Wildfires: degradation processes and rehabilitation techniques *Agustín Merino (USC)* *Martin Rodríguez-Padorno (USC)*
	13:30-14:30	***Lunch break***
	14:30-16:00	Forest Degradation: definition and quantification *Agustín Merino (USC)* *Miltiadis Athanasiou (NKUA)*
	16:00-18:30	Wildfires: science and management *Miltiadis Athanasiou (NKUA)*

	18:50	Bus departure to Vivlos village

Session: Wildfire areas ***Responsible University: University of Santiago de Compostela / National and Kapodistrian University of Athens***		
Day 11 **Wednesday** **29/03/2017**	9:00 – 14:00	Field work: Rehabilitation after wildfire: Kinidaros area *Agustín Merino (USC)* Miltiadis Athanasiou (NKUA) *Martin Rodríguez-Padorno (USC)*
	14:00 – 14:30	***Light Lunch break***
	14:30 – 17:00	Field work: Rehabilitation after wildfire: Komiaki area *Agustín Merino (USC)* *Miltiadis Athanasiou (NKUA)* *Martin Rodríguez-Padorno (USC)*

Session: Economic impact / **Employability related with LANDCARE** ***Responsible University: National and Kapodistrian University of Athens***		
Day 12 **Thursday** **30/03/2017**	8:20	Bus departure to Naxos
	9:00-11:00	Economic impact and economic cost of Natural Hazards and Disasters. Their relation with the economic development, crisis and international market. *Chara Brachou (Ministry of Environment, Energy and Climate Change)*
	11:00-11:30	***Coffee break***
	11:30-13:30	Entrepreneurship in Land Rehabilitation *Niki Evelpidou (NKUA)* *Eirini Koumoutsea (NKUA)* *Agustín Merino (USC)*
	13:30	***Lunch break***
	18:00	Bus departure to Vivlos village
	20:00	**Certification award party**

Day 13 **Friday** **31/03/2017**	Free day-Travel back



Field trips locations in Naxos Island (aerial photos orthomosaic; Evelpidou, 2001).

Introduction

Niki Evelpidou, Anna Karkani

Geographical and climatological context of the area

Naxos Island is located in the central Aegean, belonging to the south Cyclades complex (Fig. 2). Administratively, Naxos belongs to the South Aegean Region, Prefecture of Cyclades. Naxos is the largest island of the Cyclades (428 km^2).

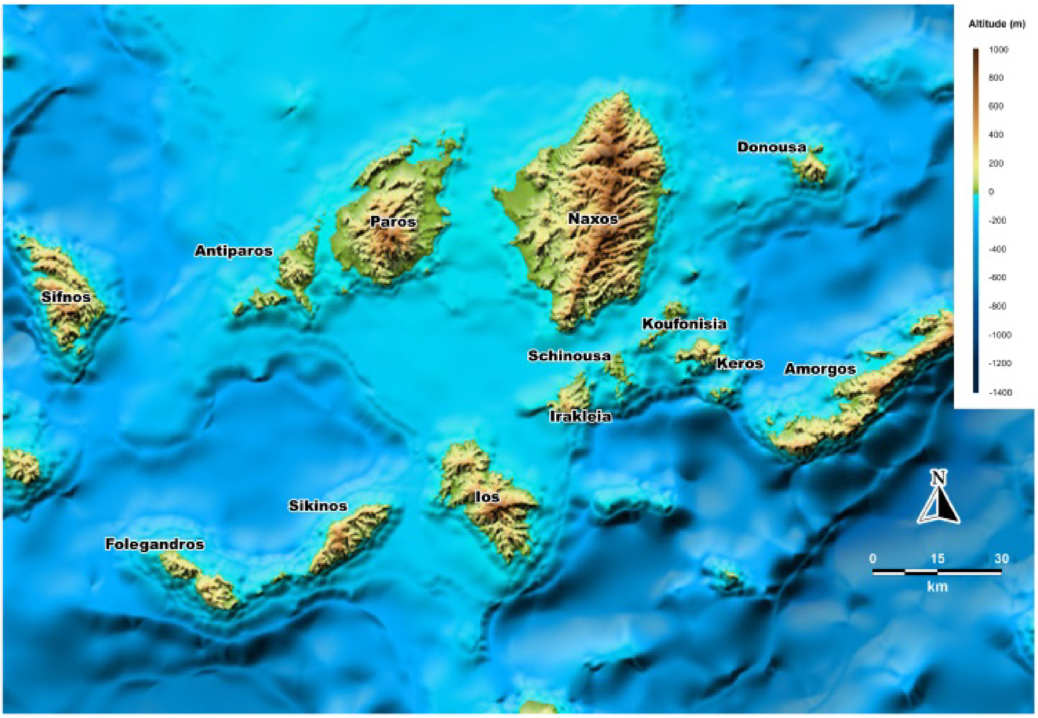


Fig. 2: Naxos Island, located at the center of the Cyclades islands, Aegean Sea (Evelpidou, 2001).

Chora is the capital city of Naxos, and its main port. Mountain Zeus is the highest peak of the island, reaching an altitude of 1004 m. On its south, Naxos borders with the island of Small Cyclades (Iraklia, Schinousa, Koufonisia).

The climate is of Mediterranean type, characterized by long dry summers and mild winters. The winter season is rarely described by frost or snow, while storms are more common. In Naxos Island, the winter is mild, with the lowest temperature reaching 12°C, in February (Table 1; Fig. 3). The mean annual temperature is 18.16°C. The warmest month is August, with the highest mean temperature being 26.6°C.

Table 1: Mean monthly temperatures in Naxos (Source HNMS)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AV
Mean	12.1	12	13.2	16.1	19.3	23.3	24.8	24.7	23	19.8	16.1	13.5	18.16
Mean maximum	14	14.4	14.9	17.6	21.1	25.5	26.4	26.6	25.3	22.4	18.3	15.3	20.15
Mean minimum	10	9.9	10.2	13.8	17.3	21.5	23.2	23.1	20.9	17.6	13.9	10.5	15.99

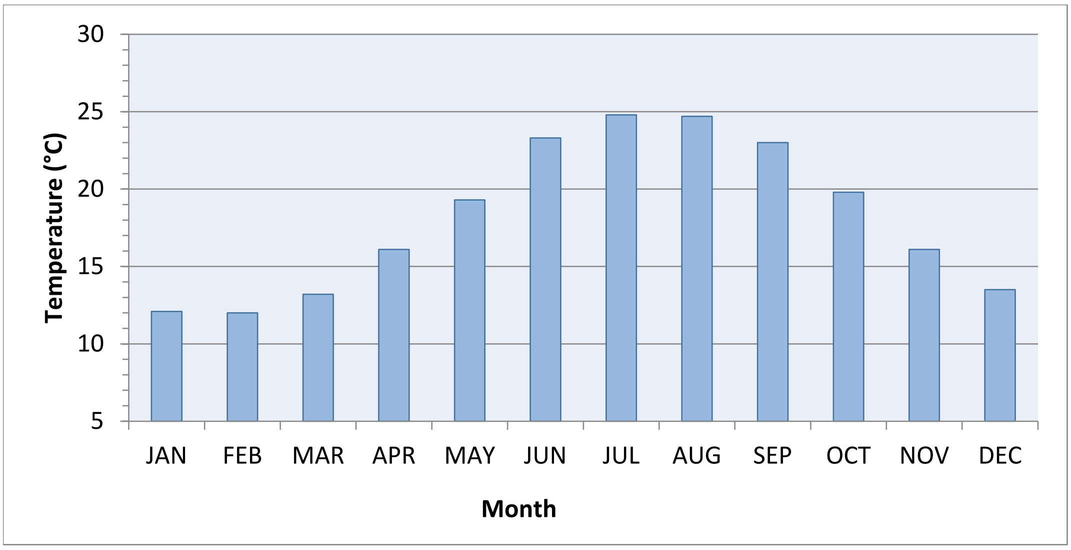


Fig. 3: Mean monthly temperatures in Naxos.

Regarding the wind regime, both islands are characterized by the persistence of the northerly winds. In general, they present a double fluctuation: a primary maximum during winter (December-February), with a secondary maximum during summer (July-August) (Table 2); the latter is also associated with the presence of the Etesians, which persist for extended periods from May to September.

Table 2: Monthly wind velocities in Naxos Islands in knots (Naxos; HNMS)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVER
NAXOS	15.65	15.84	14.77	11.94	10.18	10.41	13.28	13.94	13.91	14.52	13.39	14.82	13.55

Table 3: Wave direction and height expressed in percentage of occurrence (after Athanasoulis and Skarsoulis, 1992)									
Direction	N	NE	E	SE	S	SW	W	NW	Calm
(%)	21.8	8.2	5.7	4.7	3.3	7.6	24.7	20.0	4.0
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

Coastal and submarine geomorphology

The coastal zone of Naxos is diverse, mainly due to the lithological variety and tectonics that have affected the wider region. The north, east and south coasts of the island consist mainly of marbles and schists, while the west coasts are formed mainly on alluvial deposits and granodiorite. The majority of the coastal zone is characterized by low land morphology, while steeper slopes are located in the north and south part of the island (Evelpidou, 2001). Most beaches are found in the west part of the Island and are more extensive comparatively to Paros. More developed coastal dunes are also found in Naxos, often neighbouring with lagoons in the back.

Bathymetrically, although the relief of the Cycladic area is gentle, there is a general slope towards the west from about −100 m down to nearly −200 m. During the LGM, Paros and Naxos islands, along with other neighbouring islands, formed a “mega-island”, 160 km long and 90 km wide (Kapsimalis *et al.*, 2009). The two islands became “autonomous” again around ~8000 BP. Today, the depth between them reaches almost -40 m.

Geological context of the wider area

The convergence between the Eurasian and the African continental plates makes the Aegean a unique environment in terms of active geodynamics, plate movements, ongoing geological processes and dynamically changing landscapes (Sakellariou and Galanidou, 2016). A complicated tectonic structure has been formed, owing to the active subduction processes and the ongoing migration of the continental and oceanic crustal blocks (Le Pichon and Angelier 1979; Angelier *et al.* 1982; Le Pichon *et al.* 1982, 1995; Le Pichon 1982; Meulenkamp *et al.* 1988; Taymaz *et al.* 1991; Jolivet, 2001).

The Cycladic region is presumed to be under an extensional tectonic regime behind the modern volcanic arc at the centre of the Aegean plate and possesses a relatively thin continental crust of about 25-26 km in thickness (e.g. Tirel *et al.*, 2004; Zhu *et al.*, 2006). This is owed to the gravitational collapse of the Aegean crust due to the southward retreat of a subduction front during the Cenozoic and the westwards extrusion of the Anatolian block in the Aegean, during the Neogene (Tirel *et al.*, 2004).

The Central Aegean is characterized by relatively low seismicity and the absence of large earthquakes (Fig. 4) (e.g. Papazachos, 1990). In a recent study Vamvakaris *et al.* (2016), calculated the mean return period values for shallow earthquakes with M>6.0 in the Aegean region and suggested very long return period values (> 200 years) for the broader Cyclades Plateau, amongst other areas. The same authors, also found, that the most probable maximum magnitudes for a return period of 50 yr is expected to be smaller than M=5.0, for low seismicity areas, such as the Cyclades Island plateau.

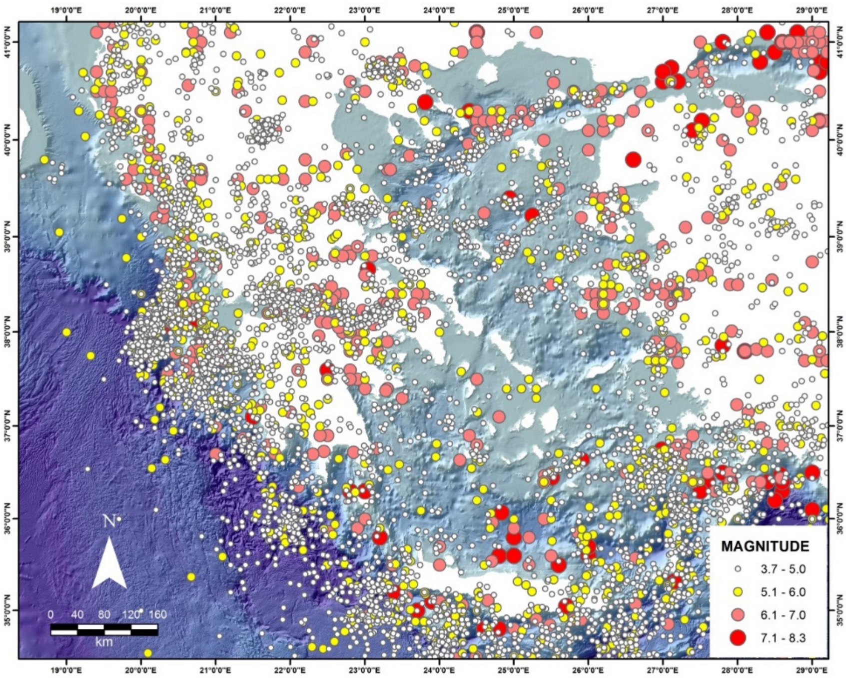


Fig. 4: Seismicity in the Greek region since 550B.C. The distribution of epicenters shows that the study area is characterized by low seismicity and absence of strong earthquakes (from Karkani, 2017).

According to Sakellariou and Galanidou (2016), vertical tectonic movements are of minor significance and the coastal evolution of the central Aegean during Late Pleistocene-Holocene is mostly affected by eustatic sea-level fluctuations and, to a lesser degree, by isostatic movements. They do, however, note evidence of tectonic subsidence considering the work of Desruelles *et al.* (2009). Lykousis (2009) noted a continuous subsidence rate during the last 400 ka, with values of 0.34–0.60 mm/yr for the Cycladic plateau, with a gradual decrease in the magnitude of the extensional tectonic regime. The relative motion of the Cyclades during the Quaternary is toward the south and south-west, with a rate of about 3 cm per year (Peterek and Schwarze, 2004).

Geology of Naxos

Naxos forms an N– S elongate structural dome cored by migmatite (Jansen and Schuiling, 1976; Buick, 1991). The core of the dome constitutes the lower- most structural unit, with migmatized gneissic quartzofeldspathic rocks containing marble, metapelite and amphibolite (Keay *et al.*, 2001). A series of metamorphic rocks, with marbles, schists and metavolcanics (Dürr *et al.*, 1978), surround the dome (Fig. 5): the lower parts consist of highly metamorphosed and folded amphibolites and meta-ultrabasic rocks, while the upper parts of metaconglomerates and metabauxites (Schuiling and Kreulen, 1979). The alternation of schists and marbles is owed to the extensive isoclinal folding (Dürr, 1986) of Eocene age (Andriessen *et al.*, 1979).

Seven metamorphic zones have been distinguished, with temperatures ranging between 300°C and more than 720°C (Wijbrans and McDougall, 1986). Above the metamorphic series, non-metamorphic rocks are found, comprising a mélange of disrupted shallow-water Mio-Pliocene sediments (Jansen, 1973; Angelier *et al.*, 1982).

The metamorphic rock series were later intruded by a range of thin leucogranite sheets and dykes and a large granodiorite body (Keay *et al.*, 2001). The timing of emplacement of the large western granodiorite on Naxos has been investigated by various researches (e.g. Dürr *et al.*, 1978; Andriessen *et al.*, 1979; Pe-Piper *et al.*, 1997). More recently, Keay *et al.* (2001) placed the timing at ~12 Ma.

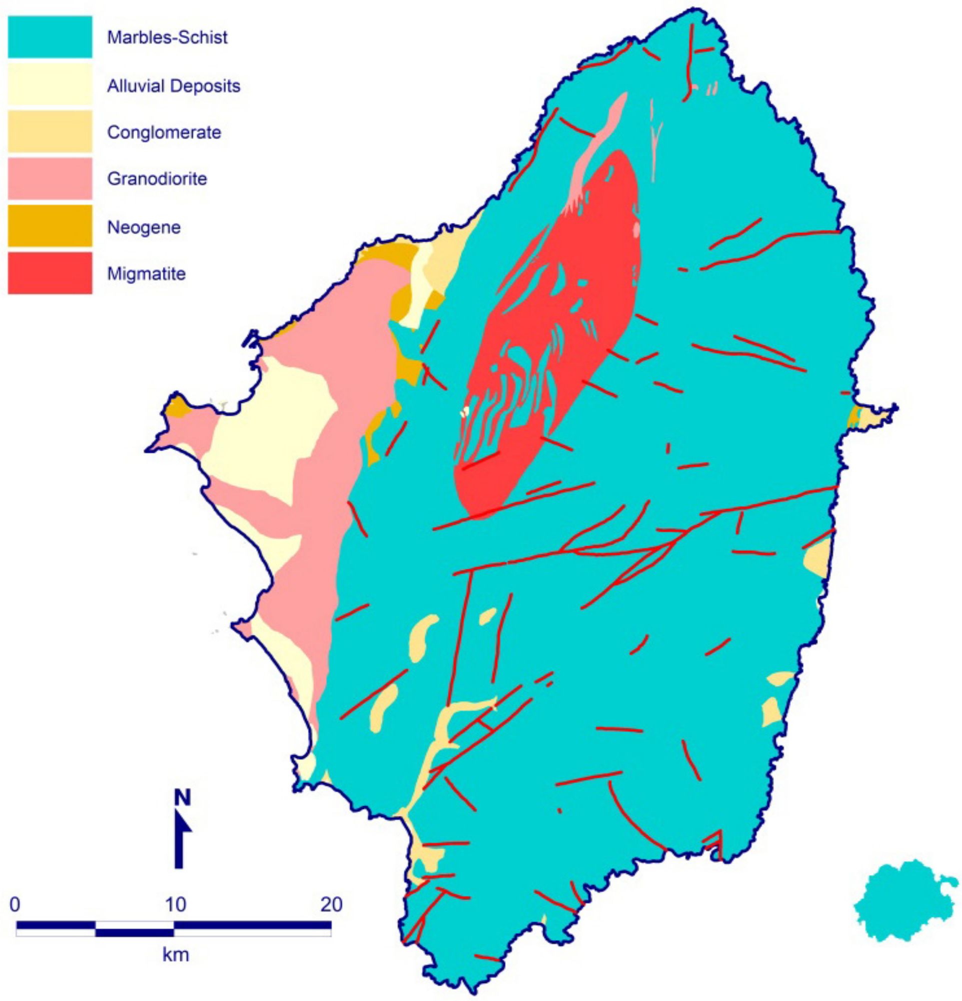


Fig. 5: Simplified lithological map of Naxos with main faults (Evelpidou, 2001).

References

Andriessen, P.A.M., Boelrijk, N.A.I.M., Hebeda, E.H., Priem, H.N.A., Verdurmen, E.A.T., Verschure, R.H., 1979. Dating the events of metamorphism and granite magmatism in the

Alpine orogen of Naxos (Cyclades, Greece). Contributions to Mineralogy and Petrology 69, 215– 225.

Angelier, J., Lyberis, N., Le Pichon, X., Barrier, E., Huchon, P., 1982. The tectonic development of the Hellenic arc and the Sea of the Crete: a synthesis (Mediterranean). Tectonophysics 86, 159–196.

Buick, I.S., 1991. The late Alpine evolution of an extensional shear zone, Naxos, Greece. Journal of the Geological Society of London 148, 93– 103.

Desruelles, S., Fouache, E., Ciner, A., Dalongeville, R., Pavlopoulos, K., Kosun, E., Coquinot, Y., Potdevin, J.-L., 2009. Beachrocks and sea level changes since Middle Holocene: comparison between the insular group of Mykonos–Delos–Rhenia (Cyclades, Greece) and the southern coast of Turkey. Global and Planetary Change 66, 19–33.

Dürr, S., Altherr, R., Keller, J., Okrusch, M., Seidel, E., 1978. The median Aegean crystal- line belt: stratigraphy, structure, metamorphism, magmatism. In: Closs, H., Rodeder, D., Schmidt, K. (Eds.), Alps, Apennines, Hellenides, pp. 455–477. IUCG Sci. Rep. 38.

Dürr, St., 1986. Das Attisch-kykladische Kristallin. In: Jacobshagen, V. (Ed.), Geologie von Griechenland, pp. 116-167. Borntraeger, Berlin.

Evelpidou, N., 2001. Geomorphological and Environmental study in Naxos Island using remote sensing and GIS technology, Ph.D. thesis, University of Athens, Faculty of Geology and Geoenvironment, 226 pp. (in Greek).

Evelpidou, N., 2001. Geomorphological and environmental study of Naxos Island using remote sensing and GIS. PhD Thesis, Department of Geography and Climatology, Faculty of Geology, University of Athens. GAIA, Vol. 13, 226 p.

Jansen, J.B.H., 1973. Geological Map of Greece, Island of Naxos (1:50,000). Institute for Geology and Mineral Resources, Athens.

Jansen, J.B.H., Schuiling, R.D., 1976. Metamorphism on Naxos: petrology and geothermal gradients. American Journal of Science 276, 1225-1253.

Jolivet, L., 2001. A comparison of geodetic and finite strain pattern in the Aegean, geodynamic implications. Earth and Planetary Science Letters 187, 95–104.

Kapsimalis, V., Pavlopoulos, K., Panagiotopoulos, I., Drakopoulou, P., Vandarakis, D., Sakelariou, D., Anagnostou, C., 2009. Geoarchaeological challenges in the Cyclades continental shelf (Aegean Sea). Zeitschrift Für Geomorphologie, Supplementary Issues, 53(1), 169–190.

Karkani, A., 2017. Study of the geomorphological and environmental evolution of the coastal zone of Central Cyclades. PhD thesis, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens.

Keay, S., Lister, G.S., Buick, I.S., 2001. The timing of partial melting, Barrovian metamorphism and granite intrusion in the Naxos metamorphic core complex, Cyclades, Aegean Sea, Greece. Tectonophysics 342, 275–312.

Le Pichon, X. 1982. Land-locked oceanic basins and continental collision. In: Hsü, K. (Ed.), The Eastern Mediterranean as a Case Example, in Mountain Building Processes, pp. 201–211. Academic Press, San Diego, CA.

Le Pichon, X., Angelier, J., 1979. The Hellenic arc and trench system: a key to the evolution of the Eastern Mediterranean area. Tectonophysics 60, 1–42.

Le Pichon, X., Angelier, J., Sibuet, J.-C. 1982. Plate boundaries and extensional tectonics. Tectonophysics, 81, 239–256.

Le Pichon, X., Chamot-Rooke, N., Lallemant, S. L., Noomen, R., Veis, G., 1995. Geodetic determination of the kinematics of Central Greece with respect to Europe: implications for eastern Mediterranean tectonics. Journal of Geophysical Research 100, 12,675–12,690.

Lykousis, V., 2009. Sea-level changes and shelf break prograding sequences during the last 400ka in the Aegean margins: Subsidence rates and palaeogeographic implications. Continental Shelf Research, 29(16), 2037–2044.

Meulenkamp, J. E., Wortel, M. J. R., Van Wamel, W. A., Spakman, W., Hoogerduyn Strating, E. 1988. On the Hellenic subduction zone and the geodynamical evolution of Crete since the late Middle Miocene. Tectonophysics, 146, 203–215.

Papazachos, B.C., 1990. Seismicity of the Aegean and surrounding area. Tectonophysics 178, 287–308.

Pe-Piper, G., Kotopouli, C.N., Piper, D.J.W., 1997. Granitoid rocks of Naxos, Greece: regional geology and petrology. Geological Journal 32, 153– 171.

Peterek, A., Schwarze, J., 2004. Architecture and Late Pliocene to recent evolution of outer-arc basins of the Hellenic subduction zone (south-central Crete, Greece). Journal of Geodynamics 38, 19–55.

Sakellariou, D., Galanidou, N., 2016. Pleistocene submerged landscapes and Palaeolithic archaeology in the tectonically active Aegean region. Geological Society, London, Special Publications, 411, 145–178.

Schuiling, R.D., Kreulen, R., 1979. Are Thermal Domes Heated by CO2-rich Fluids from the Mantle? Earth and Planetary Science Letters 43, 298-302.

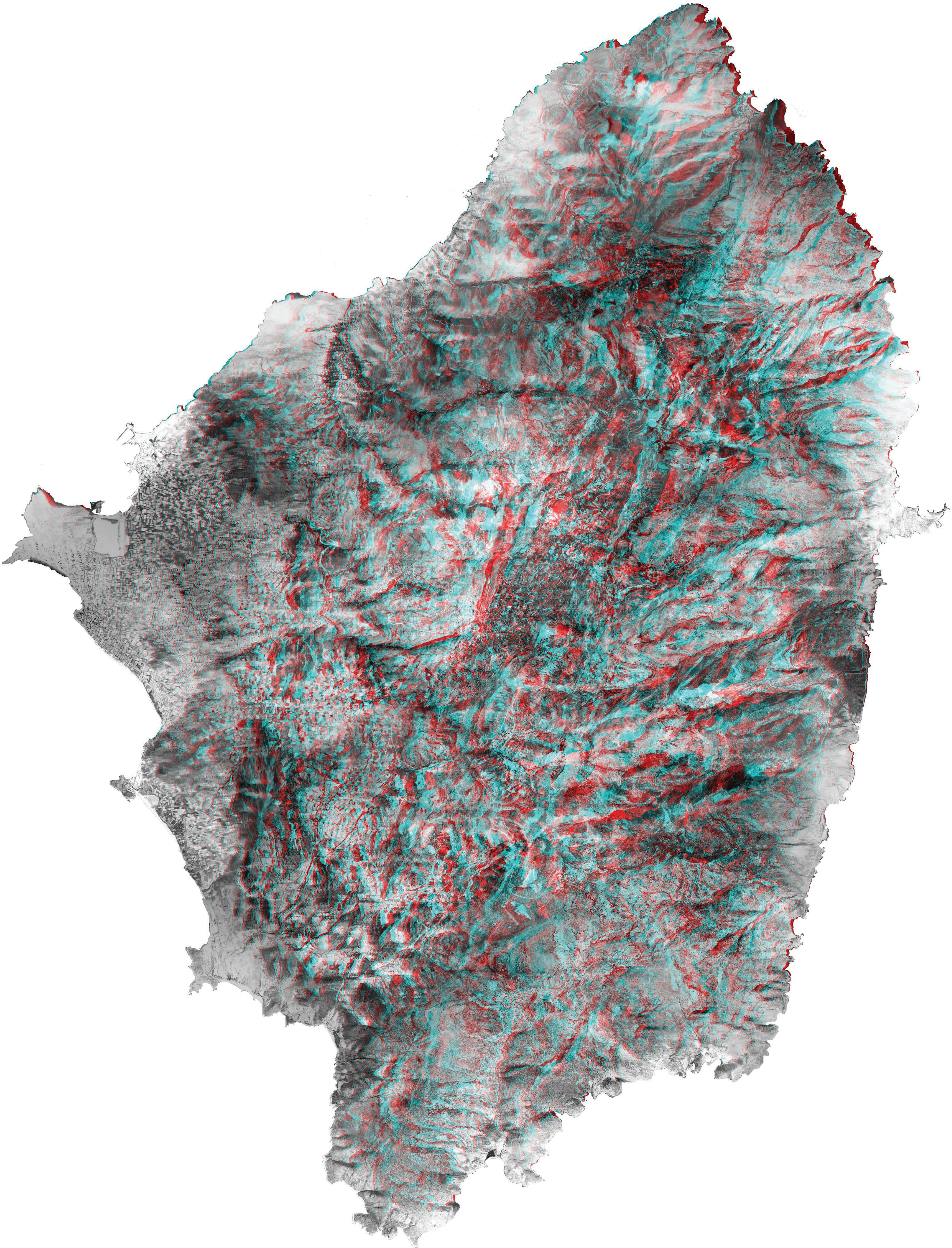
Taymaz, T., Jackson, J., McKenzie, D., 1991. Active tectonics of the north and central Aegean Sea. Geophysical Journal International 106, 433–490.

Tirel, C., Gueydan, F., Tiberi, C., Brun, J.P., 2004. Aegean crustal thickness inferred from gravity inversion. Geodynamical implications. Earth and Planetary Science Letters 228, 267–280.

Vamvakaris, D. A., Papazachos, C. B., Papaioannou, C. A., Scordilis, E. M., Karakaisis, G. F., 2016. A detailed seismic zonation model for shallow earthquakes in the broader Aegean area. Natural Hazards and Earth System Sciences, 16(1), 55–84.

Wijbrans, J.R., McDougall, I., 1986. 40Ar/39Ar dating of white micas from an alpine high-pressure metamorphic belt on Naxos (Greece); the resetting of the argon isotopic system. Contributions to Mineralogy and Petrology 93, 187–194.

Zhu, L., Mitchell, B.J., Akyol, N., Cemen, I., Kekovali, K., 2006. Crustal thickness variations in the Aegean region and implications for the extension of continental crust. Journal of Geophysical Research, 111, B01301. doi:10.1029/2005JB003770.



Field trip day 1, 22/03/2017

Industrial degradated areas and waste management

Responsible University: National and Kapodistrian University of Athens

Participating Institutes: CNR-ISE, USC

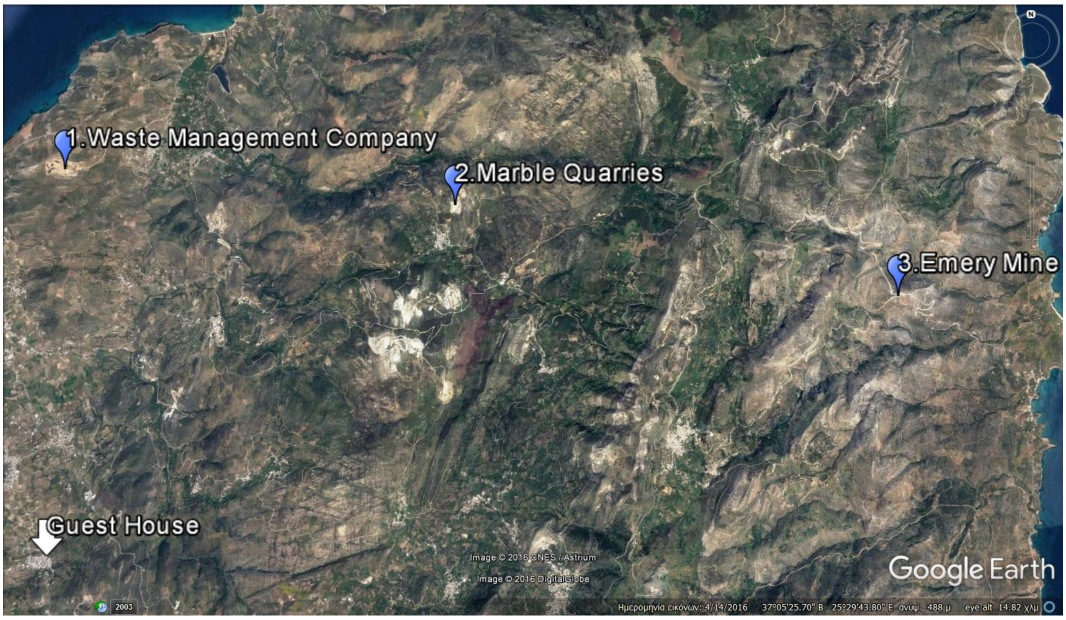


Fig. 6: Field trip locations (Google Earth image).

Stop 1. Mine degradated area, Emery mine

Serena Doni, Manolis Lykouropoulos, Marianna Gatou

Introduction

Emery takes its name from the Emeri Peninsula on the Greek island of Naxos, where the bulk of the emery used in the western world was produced since the classical Greek era. The ancient Greeks called emery “smyris”, after the port city of Smyrna (today Izmir in Turkey, but then part of Greece), which served as the main distribution hub for Naxos emery. The Romans called it “naxium”, naming it from its place of origin (King, 1865). Emery is a metamorphic rock, mainly consisting of the mineral corundum (aluminium oxide-Al_2O_3) mixed with iron oxides, such as magnetite (Fe_3O_4) and hematite (Fe_2O_3). In addition to corundum and iron oxides, emery sometimes contains quartz, diaspore, gibbsite, margarite, chloritoid and sillimanite. It is black, brownish-black or dark gray in color and is the hardest mineral after diamond, making it the second hardest mineral with a Mohs hardness value of 9.

Emery has been worked from very early times on the Greek island of Naxos. The deposits, which occur there as loose blocks and as lenticular or lens-shaped masses or irregular beds in granular limestone or dolomite, are mostly concentrated on the mountains at the northern end of the island. An area of round 250 acres on the slopes of Mt. Amomaxis, in the NE part of Naxos is dotted with hundreds of small emery mines, dated from the antiquity. The most important ones are located in the immediate vicinity of the village of Bothris. The lenticular masses of emery, which are very variable in size, ranging in length from a few feet to upward of 100 yards and in maximum thickness from 5 to 50 yards, are closely associated with the limestones, and as they follow their undulations they vary very much in position, lying at all kinds of slopes, from horizontal to nearly vertical. Seventeen different deposits have been discovered and worked at different times. These range over considerable heights from 180 to 700 meters above sea level. The largest working, that of Malia, is one of the lowest. This important deposit covers an area of more than 30.000 m^2, extending for about 500 meters in length with a height of more than 50 meters. This was worked during the Turkish occupation and it has supplied fully one half of all the emery exported, since the formation of the Greek Kingdom. The highest quality of mineral is obtained from the two comparatively thin, but extensive deposits, at Aspalanthropo and Kakoryakos, which are 435 meters above the sea level. The mineral is stratified in thin bands, from 1 to 2 feet in thickness, crossed by two other systems of divisional planes, so that it breaks into nearly cubical blocks in the working. The floor of the deposit is invariably crystalline limestone and the roof a loosely crystalline dolomite covered by mica schist. The underlying limestones are often penetrated by dykes of tourmaline granite, which probably have some intimate connection with the origin of the emery beds above them (Merrill, 1899).

The arduous procedure of the emery’s mining was carried out in groups of people (5-20), that worked in underground galleries, under really adverse conditions. After carrying the emery on their backs all the way out of the gallery, they were transferring it with animals or with their own hands to the ports of Liona and Moutsouna and, then, they were loading it into the ships.

Crushed or naturally eroded emery (known as black sand) is used as an abrasive, for example on an emery board, as attraction enhancer in asphalt and tarmac mixtures or used in mechanical engineering as Emery cloth.

Aerial Ropeway

Since the 1920s emery production was great, the modernization of its transportation needed to be designed. Thus, 40.000 pounds sterling were spent for the construction of aerial ways of transportation, train tracks with wagons, ramps, buildings, warehouses etc., which helped significantly the exploitation of the product. Aerial ropeway was the main way of transporting emery for 4 decades, from 1930 until 1979 when it stopped working and trucks were used instead. It was one of the greatest public projects of the time and it modernized and improved transfer time, as until then transportation was implemented by mules. It is a work of English art, a typical example would be a cable air transportation system using bogies and consisting of a network of 72 pillars (height up to 40 meters), 2 drive engine rooms, 5 loading stations, supporting building equipment, material storage rooms and loading facilities in Moutsouna. The only moving part of the system is the single rope with a length of 18 kilometres with about 170 hanging bogies. With Pigi in Koroni being the starting position, the project covers an air route of 9 kilometres which ends up at the ''courtyard'' area of the bay of Moutsouna, where the emery was stored in piles and then was transported using wagons on trails to the dock, from where it was loaded into ships that had been driven ashore the harbour.

The design of the project started in 1920 and its construction during the period 1926-1929. The official opening took place in 1930. The construction of stone and metal is of particular interest for the trend calculations and the adjustment to the very specific soil data, and while the technology came from England it has been applied in such a way to the rough Cycladic geophysical bedrock that it has been perfectly incorporated into the landscape. It crosses the emery rich zone which belongs to the Apeiranthos and Koroni communities and extends the range of about 30 square kilometres.

The decline of emery

For many years research to identify deposits has stopped, as the proven quantity is sufficient for several years according to the limited reception and the even smaller disposal to the Greek public. Each mine group extracts and delivers to the state only the amount that is set, and then the product is transferred to public repositories. Unfortunately, while the minimum amount of extraction is 5000 tons per year, the public sector cannot allocate more than 2000-2500 tons. The Greek government, in order to support the mountain villages, subsidizes the insurance cost of the workers and supports a passive mode, without a plan for mineral exploitation. From 1878 to date more than 70 studies (legal and techno-economical) have been written about the exploitation of this precious mineral, but to no avail. The mines are declining and along with them all efforts that were made for their development. About 50 years ago a politician visited a mine and asked ‘’what is in emery?’’ and one of the workers answered ‘’ It contains politics’’.

Mine reclamation

Mine activities impact the environment by contaminating air, water, soil, and wetland sediments from the scattered tailings as well as pollution of groundwater by discharged leachate.

Even when the mining activities cease, the impacts *onsite* and *offsite* continue as a consequence of which all the surrounding compartments of the ecosystem (adjacent vegetation, soils, groundwater, etc.) are exposed to very high concentrations of heavy metals. Potentially toxic heavy metals can be accumulated in plant and animal bodies as a result of direct or indirect consumption. Another endemic problem with abandoned and derelict mines is the generation of large-scale acidic waters. In addition, persisting erosion of abandoned mines can affect land stability and revegetation efforts.

The aims for an effective reclamation of a mined site include:

(a) Removing risks potentially posed upon health and safety of humans and animals;

(b) Stabilizing the site and reduce or remove the impact of erosion and mass movement;

(c) Maintaining or increasing the biological diversity of species in the vicinity;

(d) Removing or ameliorating sources of site contamination by monitoring and documentation;

(e) Improving the visual amenity of the site and its surroundings.

Since the last decade, reclamation of mine degraded lands has been receiving great attention.

Establishment of natural vegetation on the mine degraded lands through succession and the recovery of soil quality similar to natural soil may extend over a long time (50–100 years), likely due to the lack of substrate and adverse soil conditions for plant growth. However, it may be shortened by the anthropogenic intervention, such as reclamation/restoration of degraded sites.

Mines are largely comprised of spoil materials that may have high concentrations of hazardous trace elements, low soil organic carbon (SOC) and nutrient pool and may differ in the ratio of soil nutrients (N, P, K) from undisturbed soils. Mine spoil, also, has very little biological activity and biodiversity.

Increase in nutrient stocks in mine soil plays an essential role in the development of soil horizons and plant growth, during the early stages of reclamation or natural succession. Considering this, one of the most usual practices before revegetation, is to cover the spoil with the original topsoil. Unfortunately, at many sites the characteristics and the enormous volume of spoil make top-soiling unfeasible. In such cases, reclamation requires surface ploughing to reduce compaction, neutralization of acidity and potential acidifiers, fertilization with nutrients, and enrichment with microorganisms and a readily decomposed organic substrate, in order to initiate biogeochemical cycles. Thereafter, tree plantation can be practiced.

Although not all the tree species are able to develop in a harassed mining environment, selection of target species (species that can tolerate a wide range of climatic conditions such as drought, temperature, and contamination) is important for reclamation. Generally, plants tolerant to metals/metalloids, with roots at the contaminated level and able to accumulate high biomass, are suitable for mine reclamation.

At the same time, the recovery of natural vegetation is often preferred. Several examples of spontaneous plants that grow on these degraded and contaminated soils/spoils are known. The plants that survive in such contaminated environments show, in general, no symptoms of toxicity and play an important role in the decontamination and stabilization of degraded soils and mine spoils.

Initially, seeding of grass-legumes mixtures (table 1) on these degraded sites can allow a quick development of a thick vegetation cover, which ameliorate the spoil surface and, then, the desirable tree species can be planted.

Table 4: Preparation and sowing of spoils

Treatment	Amount/procedure
Ploughing and harrowing	
Liming	1 t ha-1 limestone
Hydroseedings	NPK 15:15:15 fertilizer (170 kg ha-1) Seeds (150 kg ha-1) Ryegrass (*Lolium perenne*) Fescue (*Festuca rubra*) Bluegrass (*Poa pratensis*) White clover (*Trifolium repens*)
Mulch	300 kg ha-1 Cellulose Stabilising agents

Stop 2. Waste Management Company

Aikaterini Giannikopoulou, Marianna Gatou

Introduction

The modern approach on waste management, concerning their disposal, integrally includes the concept of public health and environmental safety. One of the methods, in order to achieve that, is by disposing wastes in Sanitary Landfill sites. By applying this method, entrapment of contaminants contained in the waste, into a sealed enclosure is primarily achieved. Then, the contaminants are being processed under controlled conditions. Thus, long-term and environmentally friendly operation of landfills, as well as the protection of public health are ensured.

Landfilling is the process by which the disposed wastes are crossplied in layers of 2-3 m height and, then, they are compressed and covered with a suitable inert material at the end of daily operation. When the disposal site has reached its final capacity, a final layer of inert material is placed and above that, is placed a layer of soil suitable for planting, in order to finally restore the space.

A major issue concerning sanitary landfills is potential groundwater pollution. To ensure that such a problem will be prevented, the landfill location should be carefully selected and the landfill cavity should be properly sealed. A suitable location for a sanitary landfill construction must be characterized by low seismic hazard and low ground permeability.

During the operation of a sanitary landfill, two derivatives are being produced, requiring careful management.

1. **Leachates:** The leachates are liquid residues produced in landfills by the decomposition of the organic part of the waste and by rainwater permeation. As the leachates spread into the waste mass, various substances are dissolved and carried away. This process continues for several years after the closure of the landfill.
2. **Biogas:** Organic materials buried in the landfill, gradually decompose in absence of oxygen (anaerobic digestion). This process generates various gases, known collectively as biogas. Biogas predominantly consists (> 90%) of about equal parts of carbon monoxide and methane, and include small amounts of ammonia, carbon dioxide, hydrogen sulphide, nitrogen and oxygen. The uncontrolled production of biogas may cause explosion and consequently fire. Conversely, if collected with appropriate systems, biogas can be used to produce energy from garbage.

Other pollutants, which can be produced during the operation of a sanitary landfill, are heavy metals and organic and inorganic compounds of calcium, chloride and sodium.

There are certain criteria that should be considered for the construction of a sanitary landfill.

- ✓ Proper stability conditions
- ✓ Fire protection system
- ✓ Settlement of rainwater
- ✓ Management of leachate and biogas
- ✓ Control and monitoring system for timely maintenance of the establishment

The construction and operation of a sanitary landfill can be briefly described by the following steps:

1. Proper formation of the cavity where the wastes are going to be disposed. The amount of waste, predicted to be produced during the operation of the landfill, determines the cavity's size.
2. Proper insulation and waterproofing to prevent groundwater pollution.
3. Installation of drainage pipes for collecting the leachate. The leachate, after being biologically cleaned, is either released into the environment or driven back to the landfill cavity to contribute in moistening and faster disintegration of waste.
4. Waste disposal and compression for reducing their volume.
5. The produced biogas is collected in pipes sunk into the wastes and burned. If the amount of the biogas produced is large enough, it can be used to produce electricity.
6. Once the landfill cavity is filled, the restoration of the landfill begins. The cavity is covered by proper materials and soil and the surface is planted.

The construction of such establishments is of great importance, particularly in Greece, where uncontrolled waste disposal sites, commonly called landfills, are used.

Naxos Sanitary Landfill

Location and physical characteristics

The selected site for the construction of the sanitary landfill of Naxos is located at "Ksidi peak", about 4 km away from the town of Naxos. The area's size is 170.081,75 m^2 and its mean altitude is 165 m.

Fig. 7: Naxos Sanitary Landfill. Photo by Manolis Lykouropoulos.

The area consists partly of rural parts and rocky grassland. The relief of the position is relatively smooth, with slopes of 20-25% eastwards, locally reaching 35%. Drainage of surface water is eastward, through existing stream (of transient flow) that runs through the area. Located approximately 400 m east of the boundaries of the landfill, the stream flows into a creek, also of transient flow.

The geological formation of the entire area is granodiorite, which appears to be relatively healthy, but is characterized by a dense network of discontinuities. In the eastern part of the field, there are alluvial deposits of small thickness, formed by accumulation of waterflow drifted fragments of the bedrock. The greater part of the granodiorite field is covered by a thin soil layer (up to 1 m thickness). This layer may be thicker (up to 2 m) at the stream area. There is no evidence indicating the existence of active faults within the landfill area or the wider area, therefore, according to Greek Antiseismic Regulation, it is characterized as an area of low seismic risk.

Concerning the groundwater pollution risk, the permeability of geological formations was taken into account. Alluvial deposits are highly permeable, while granodiorite is characterized by low permeability, due to its discontinuities network. Hence, the pollution risk of the landfill's location is considered to be low up to moderate.

Technical characteristics - Parts of the establishment

Naxos sanitary landfill was designed so that it will serve the Administrative Unit of Naxos Island and Small Cyclades, including the communities of Naxos, Irakleia, Donousa, Sxoinousa and Koufonisi Island. It was designed for a minimum of 20 year operation.

The selected practice for applying sanitary landfilling, in this case, is the Cell method. According to this method the landfill consists of individual cells, i.e. discrete areas with a specific capacity.

According to permanent (28.500) and seasonal population (28.500 & 17.000) data, the mean annual waste quantity is estimated to be 15.450 tn. Considering that soil covering daily rate will be 20% of the waste volume, the final volume of the sanitary landfill is estimated to be 548.875 m^3.

In order to achieve proper insulation, waterproofing and drainage conditions, the bottom and slopes of each cell are coated by seven layers of different materials (geotextiles, membranes, gravels, soil materials).

Concerning leachate management, a drainage network is designed, suitable for collecting the leachate and transferring it to the processing point. For the process of leachate there are three serially aerobic flow-through type lagoons, without sludge recirculation, where oxygenation is achieved by surface aerators. The processed leachate will recirculate and return in the landfill cell, in order to enable faster disintegration of waste, through a pumping station and pipe network. In addition, is provided a refining and decontamination unit, in case of using part of the processed leachate for irrigation.

Fig. 8: Naxos Sanitary Landfill. Photo by Manolis Lykouropoulos.

Regarding biogas management, the biogas will be pumped and transferred through a suitable pipe network at a burning unit (burning torches).

Other main parts of the sanitary landfill include:

- External and internal road construction works
- Firefighting tank and network
- Flood control channels
- Rainwater drainage network
- Planting and Irrigation works
- Environmental monitoring (drillings)

Finally, an area of approximately 4700 m^2 exists, available for future construction of a waste processing unit.

Stop 3. Marble quarry, Karpontini bros Naxian marble UNL. (Kinidaros area)

Aikaterini Giannikopoulou, Marianna Gatou

Introduction

Marble is a rock consisting of calcite ($CaCO_3$), or of a mixture of calcite ($CaCO_3$) and dolomite ($CaCO_3$, $MgCO_3$) and has been created during the metamorphism of limestones (carbonate sedimentary rocks). In marbles impurities of quartz, micas, chlorite, graphite etc. can be found. The word's origin is the ancient Greek word "marmaros", which means "shiny stone".

In Greece, during the Classical period, marble was widely used, resulting in the prevailing of marble in the ancient Greek architecture and marble quarries existed in various areas (Penteli, Eleusis, Tripoli, Argos, Selinus, Syracuse, Skyros, etc.). The quarries of Paros and Naxos were already famous since the Archaic period (Dworakowska, 1975)

The commercial name "marble" characterizes not only the stones that geology characterizes as marbles, but also a series of other rocks, that can be cut into relatively thin slabs, smoothed and polished. Such rocks are limestones, dolomites, serpentines, some conglomerates, etc.

The quality of marbles depends, to a considerable extent, on the composition of rocks they originate, as well as on the degree of their metamorphism. The color of marbles is, mostly, white – semi-white to grey in different tones, with a zone variation of colors, and in some cases the color can even be black, greenish, pink, reddish, etc., (pure calcite is white, but mineral impurities add color to it). Depending on the granular size of their crystals, marbles can be characterized as fine grained (grain size between 0.01-0.5 mm), average grained (grain size between 0.5-2 mm) and coarse grained (grain size 2-6 mm). Fine grained marbles are considered to have a greater mechanical strength than the ones being coarse grained. However, their strength also depends on their histological features.

The exploitation of marbles takes place, primarily , in the form of opencast exploitation (marble quarries), in which marbles are cut-off with the use of steel wire ropes or special equipment, with the eventual production of the rectangular marble blocks which are very characteristic in quarries.

The marble of each area has its own special features. The marble of Naxos, white and coarse grained, was used both in sculpture and architecture. The commercial name of the Naxos marble is "Crystallina of Naxos" due to the "crystals" formed by the blending of quartz (2%) with calcite (98%). This is where its translucence and shine comes from. For the biggest part, the marble produced in Naxos is channeled to domestic and international markets without processing. Some quantities are processed locally by the four marble factories operating on Naxos.

Karpontini bros Naxian marble UNL

The company “KARPONTINI BROS - NAXIAN MARBLES UNLIMITED” was founded in 1990 and is primarily involved in the extraction and trade of blocks of marbles as raw material. The company is based in Kynidaros, Naxos. The company operates two privately owned quarries in the area of Kynidaros Naxos:

1. **“Psarogremna-Zas”** occupies an area of 50,000 sq. meters and
2. **“Sanidades”** occupies an area of 92,000 sq. meters.

Fig. 9: Marble Quarry in Naxos. Photo by Manolis Lykouropoulos.

The geological formations of the area are migmatite and crystalline marble layers or lenses. Both formations are developed NNE - SSW. The formations’ slopes are mainly large (65° - 90°). The area is heavily cracked and the formations have discontinuities, partly openand red soil is present.

Table 5: Naxos Crystallina. Physical and Mechanical Properties				
Apparent specific weight, kg/m3 (ASTM C-97)	Absorption coefficient, % wt (ASTM C-97)	Compressive strength, MPa (ASTM C-170)	Modulus of rupture, MPa (ASTM C-99)	Abrasion resistance, mm (DIN 52108 - 20 Cycles)
2710	0.09	89	13	8.56

Table 6: Mineralogical Composition, % wt					
Calcite	98,00	**Dolomite**	0	**Quartz**	2,00
Muscovite	0	**Clorite**	0	**Feldspars**	0
Epidote	0	**Chromite**	0	**Fe Oxides etc.**	0
Clay Minerals	0	**Serpentine**	0	**Pyroxeni**	0

Table 7: Chemical Analysis, % wt					
CaO	55,60	**MgO**	0,50	**SiO_2**	0,07
Fe_2O_3	0,14	**Al_2O_3**	0,02	**K_2O**	0,02
Na_2O	0,04	**MnO**	0,02	**LOI**	43,00

References

Dworakowska, A., 1975. Quarries in ancient Greece. Zakład Narodowy im. Ossolińskich, Wrocław, Polland.

KARPONTINI BROS - NAXIAN MARBLES UNLIMITED

King, C.W., 1865. The natural history, ancient and modern, of precious stones and gems. Bell and Daldy, London, 442 p.

Merrill, P. G., 1899. Guide to the study of the collections in the section of Applied Geology- The nonmetallic minerals. Washington Government Printing Office.

Field trip day 2, 23/03/2017

Coastal Erosion / Land Degradation / Contaminated areas

Responsible University: National and Kapodistrian University of Athens

Participating Institutes: USC, ULisbon

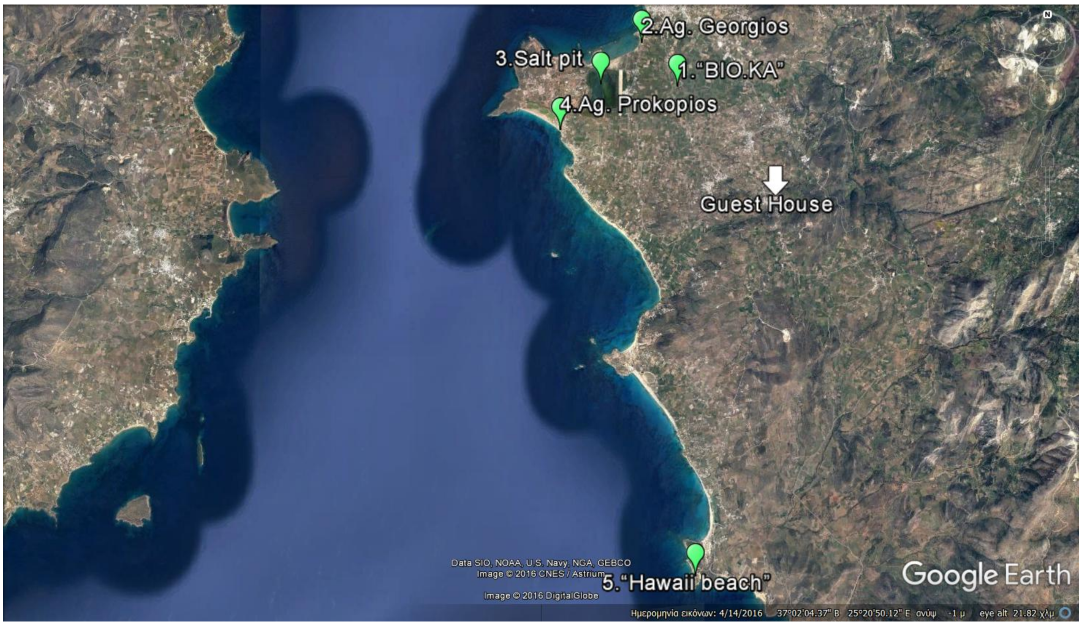


Fig. 10: Field trip locations (Google Earth image).

Stop 1. Biological treatment station “BIO.KA” (near airport)

Aikaterini Giannikopoulou, Marianna Gatou

Introduction

One of the most effective ways of dealing with the pollution of water resources, is by constructing sewage treatment facilities. In these facilities, sewage purification (removal of harmful components) is sought, so that they can be safely disposed into the environment.

Harmful waste components are considered to be bulky solid objects, suspended solids, the organic-natural ingredients (e.g. carbohydrates, protein, and fats), pathogenic microorganisms and nutrients (phosphorus, nitrogen). The disposal of untreated waste to a waterbody creates various problems. Pathogenic microorganisms are responsible for the transmission of diseases in humans and other organisms, while organic components, nitrogen and phosphorus, are mostly responsible for eutrophication situations.

Sewage treatment facilities are characterized by the degree of waste purification, that is determined by which of the above harmful components are removed. Removal of the bulk solids, sand and suspended solids is characterized as primary treatment. Removal of organic components and pathogenic microorganisms is characterized as secondary treatment. Biological treatment is a type of secondary treatment. Tertiary treatment is about nutrients (P, N) removal.

The basic units in primary treatment of a sewage treatment facility are:

- Bar racks (series of metal bars in which the bulky solids are retained)
- Sand traps (Specially designed tanks in which suitable flow conditions are created that cause sedimentation of sand in them)
- Primary sedimentation tanks (where much of the suspended solids and part of the organic components precipitate)

The suspended solids, settling at the bottom of the primary settlement tanks, are called primary sludge.

A sewage treatment facility that includes biological treatment, almost complete removal - by more than 95% - of the organic components is achieved. Biological purification is based on the controlled use of the biochemical disintegration processes, which naturally occurs in the environment.

The processes of the biological treatment in such a facility can be briefly described as followed:

- Suitable tanks are provided, where the conditions necessary for microorganism growth and multiplication (nutrients and oxygen) are ensured. Thus, harmful organic components are replaced by these microorganisms (mainly bacteria), which not only are not harmful, such as pathogens, but are also the cleaning "tool" in the waste purification process. The mixture of microorganisms and nutrients is the so-called "active sludge ", so this method of waste treatment is called activated sludge method.

- The sludge is removed from the mass of waste by being allowed to pass into the secondary sedimentation tank (similar to the primary sedimentation tanks), where the sludge settles in its bottom, forming the so-called secondary sludge.
- Purified waste in the tank overflows. Secondary treatment is followed by decontamination process to eliminate pathogens, usually by chlorination in elongated tanks. Wastes can then be disposed safely in the environment, as long as the deposition destination is not considered to be particularly sensitive (in such case tertiary treatment would follow).

The primary and secondary sludge from the settling tanks go through:

- Condensation (increase in the percentage of contained solids)
- Stabilization (aerobic or anaerobic) (reduce pathogens and odors). In a variation of the activated sludge method, called prolonged ventilation (widely applicable in Greece), aerobic stabilization of sludge takes place in the same aeration tank without using separate aerobic stabilization tanks.
- Dehydration-Drying

Management of the processed sludge (solid wastes) include:

- Disposal in soil
- Disposal in sea
- Burning
- Agricultural usage
- Disposal in landfill

Naxos Sewage Treatment and biological treatment station

Location and physical characteristics

The selected site for the construction of the sewage treatment facility of Naxos is located at the area “Livadi” in northwestern Naxos, near Glynado community, about 1,5 km away from Naxos Town. The size of the station area is 17.500 m^2. Nearby the station area are located the airport of Naxos and Peritsis river.

“Livadi” area is mainly used for agricultural purposes. The biological treatment area is generally flat (northwestern slopes < 20%), covered by sparse shrubby vegetation. The area is covered by alluvial deposits. These deposits derive from disintegrated materials of the adjacent geological formations (schists, amphibolites, migmatites). Mechanical composition of the area’s soil varies from sandy clay loam to loamy sand with pH values of 6,8 – 7,8. Generally, Livadi area’s soils face salinization issues.

Fig. 11: Naxos Sewage Treatment and biological treatment station. Photo by Manolis Lykouropoulos.

Technical characteristics - Parts of the establishment

Naxos sewage treatment facility serve a total population of 45000 of Naxos town and St. Arsenios, Glynado, Galanado, Biblos and Sagri communities. Sewages are driven at the treatment station through a collective sewage network. The facility was designed for an operating duration of 40 years. The design is done in a way that ensures proper operation for the current and future conditions and flexible response to the large variation in population between winter and summer.

Concerning the biological treatment of the facility, the chosen treatment method is the activated sludge method with prolonged ventilation and decontamination of final effluent with chlorine.

The purpose of this facility is to improve the quality of wastewater, by meeting the conditions of hygiene rules ($BOD_5 \leq 20$ gm/lt, suspended solids $\leq$ 25 mg/lt, nitrogen $\leq$ 8 mg/lt, phosphorus $\leq$ 4 mg/lt), so that physical, chemical, biological and microbiological characteristics of the marine recipient will not be compromised.

Naxos sewage treatment facility includes primary, secondary (biological treatment) and tertiary treatment stations. The main treatment units of the facility are:

- Sewage receiving shaft
- Bar racks
- Ventilated sand traps
- Biological treatment

i. Selection - distribution tank
ii. Phosphorus removal
iii. Ventilation tanks

- Final sedimentation tanks
- Recirculation and excess sludge pump station
- Decontamination – chlorination of processed wastewaters
- Sludge treatment (condensation, stabilization, dehydration)

The facility includes, also, water supply, rainwater and electricity network, as well as control and monitoring units.

The processed wastewater is disposed in the marine area of “Mougri” cape via underwater pipeline. In addition, in this facility is provided the ability to reuse treated wastewater, for irrigation of the plain of Naxos and for enrichment of the underground aquifers, in order to reduce the degree of salinity. The processed sludge is disposed in organized landfill.

Adverse effects, concerning the operation of the sewage treatment facility, might be:

- Unpleasant odors and insect gathering
- Droplets escape from the tanks, when strong winds blow, towards the neighboring residential areas.
- Noise Increase
- Pollution of recipient in case of a malfunction
- Problems with by-products disposal

Stop 2. Survey of a Salt pit (near airport)

Niki Evelpidou, Aikaterini Giannikopoulou

Introduction

Salt pits are intertidal, coastal ecosystems that are regularly flooded with salt or brackish water (Fig. 12). They consist areas where seawater gets trapped and in the summer evaporates, leaving salt inside the pit. Evaporation, requires apart from sunshine and strong winds. Salt pits are normally formed in flat coastal areas (altitude low to zero), due to lack of competing land uses and where there are favorable weather conditions (intense evaporation). In nature, zero altitude areas are created as endings of heads of bays and estuaries, where the mild relief continues beyond the waterline.

In such areas a soil layer is created on the ground surface by the precipitation of clay minerals. This occurs when fine grained materials, suspended in the river water (if the speed and turbulence does not allow precipitation), enter the marine environment.

Fig. 12: Close view of “Alyki” salt pit. Photo by Niki Evelpidou.

Hydrologically, the salt pit areas, as plain's endings, accept large water loads corresponding to the run-off of extensive water catchment areas. These areas are also characterized by a labyrinthine natural shallow channel system. This system, depending on the season, either drives water to the recipient or creates flooding conditions. This way, a drainage network is created for the salt pit, through which runoff water flows away, thus preventing the basin’s fresh water mixing with the salty waters of the pit. The water table in the salt pit areas is high and the composition of the groundwater is salty to brackish. Salt pits flooding by salt or fresh water are particularly important for the quality of groundwater in the surrounding areas. The small difference in height between the salt pit and the sea, creates variance in hydrostatic pressure, which prevents the mixing of sea water with upstream aquifers, protecting this way the aquifers from salinization.

Salt pits' sustainability is mainly controlled by the relationship between salt pit's vertical accretion (due to sediment accretion, peat accumulation, belowground decomposition, subsidence) and sea level rise. Other facts that affect their development and structure are tidal, wave and current action, erosion, freshwater influx, nutrient supply and topography.

Since salt pits are characterized by extreme conditions (with high salinity being the most significant), the organisms that survive there, are those who manage to develop proper adaptation characteristics. Salt pit ecosystems are dominated by halophytic and semi-halophytic vegetation (salt-tolerant grasses, herbs and low shrubs). Increase in salinity is proportional to the reduction of diversity. Salt pits are habitat for zooplankton, aquatic insects and worms, fishes of high resistance in high salinity and most importantly avifauna, that uses salt pits for nesting, feeding, breeding or resting. As salinity of a salt pit increases, decomposers' populations decrease and the quantity of organic materials increases.

The most distinctive, economically important, product of a salt pit is the crystalline salt, the organic non-decomposed peat that constantly accumulates at the bottom of the salt pit and waterfowls.

In Greece, the geographical distribution of salt pits highlights their great importance on the preservation and conservation of migratory birds, as they consist intermediaries "stations" in the travel path of birds.

Salt pit "Alyki" of Naxos

Fig. 13: Aerial view of the "Alyki" salt pit. Photo by Niki Evelpidou.

The salt pit named “Alyki” is the largest and most important coastal wetland of Cyclades, in terms of biodiversity and scarcity of birds that find temporary or permanent refuge at its waters. Alyki is a complex of different habitats, spread over a wider area of 1 km^2, right behind St. George’s beach, in “Livadi” area, northwestern Naxos, just 3 km. southern of Naxos Town.

During classical times, Alyki’s area was part of a small bay used as a port (Yria), but the local river’s (Peritsis river) alluvial action caused its decline, as the area gradually transformed. The alluvial action of Peritsis created a variety of wetlands, flood land and abandoned riverbeds in the area behind St. George’s beach. Alyki was used as a saltwork from at least 1421 AC up to 1952 AC, when its use for receiving salt was officially abandoned. After the construction of the coastal road, the communication of Alyki with the sea was interrupted. Also, a large portion of Alyki was drained due to the Naxos airport construction in 1992, the construction of a small dam for irrigation reasons and for turning the lagoon’s land into agricultural ground.

Today Alyki is a residual lagoon system, characterized by a large area of shallow brackish waters, small bays with reefs, shallow estuaries next to sand dunes, salt meadows, marshes with reeds and rushes, seasonal streams and rocky spots with junipers. Alyki’s bottom surface is mostly covered with sandy soils except for the eastern part where it’s covered with clay. The surrounding area is characterized by clay loam soils and artesian groundwater.

Alyki faces intense environmental stress. An example is the case of malfunctioning of the sewage treatment facility in 2010. Poorly treated wastewater was not driven through the marine pipeline at the specified point of deposit, but, having followed surface flow in ditches ended in Alyki, resulting in pollution of the wetland.

Fig. 14: Salt pit “Alyki”. Photo by Manolis Lykouropoulos.

Stop 3. Agios Georgios coastal area

Niki Evelpidou, Anna Karkani, Aikaterini Giannikopoulou

Palaeogeographic reconstruction of Agios Georgios coastal zone (based on Evelpidou *et al.*, 2010; 2012)

St. Georgios coastal zone consists of three concave beach zones, separated by a small headland and being sheltered from a small island, named Manto and a partially merged reef (Evelpidou *et al.*, 2012). Part of the coastal zone landwards to the dune field is characterized by a rectangular low-lying alluvial plain filled with lagoonal deposits (Fig. 15). An elongated drainage basin supplies the study area with fresh water and sediment; the basin extends from the ridge, up to the sandy coast of St. Georgios (Evelpidou *et al.*, 2012).

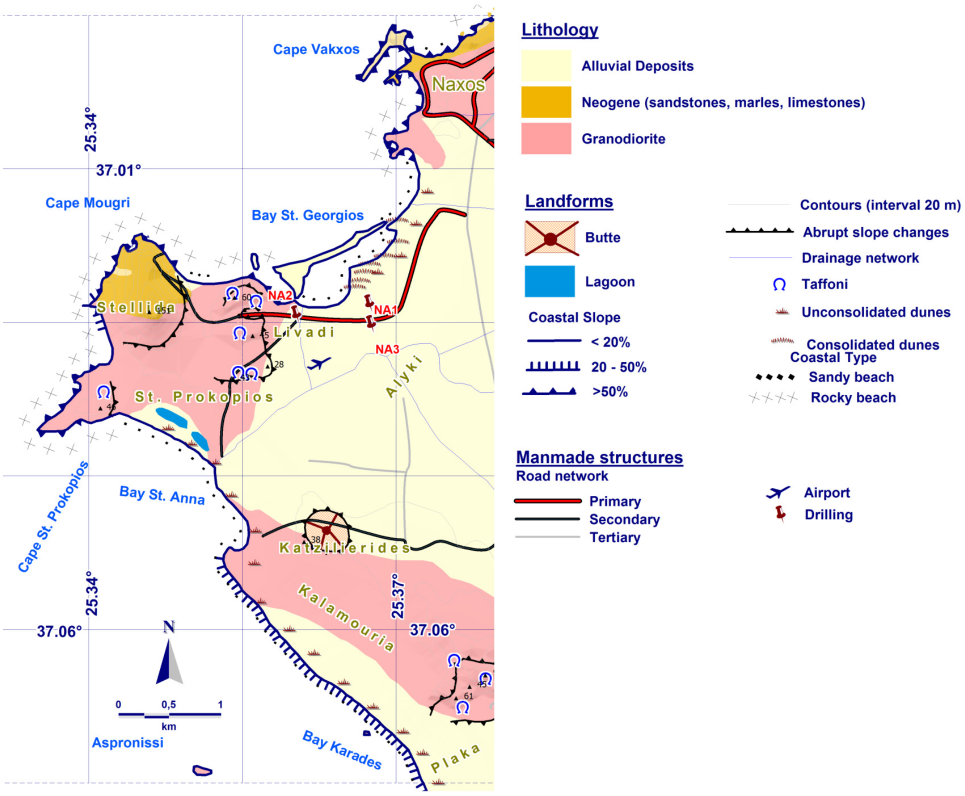


Fig. 15: Geomorphological characteristics of St. Georgios bay (from Evelpidou *et al.*, 2012).

The palaeogeographic evolution of Agios Georgios coastal zone has been studied through the accomplishment of 3 shallow drillings (NA1, NA2, NA3). The cores were opened and studied in detail, while plant, shell, peat and charred material were, also, collected from several layers of the sedimentary sequence for ^{14}C dating.

Lithology-faunal evidence - depositional environment

Borehole NA1 (5.37 m deep) was drilled in the flat sandy coastal area at the north end of the Naxos airstrip (Fig. 16). From 5.37 to 2.70 m depth, sands with silty-clayey layers and pebbles exist. From 2.70 to 1.75 m NA1 borehole is characterized by very dark gray silty clay. Sandy layers with intercalations of silty-clayey layers correspond to the first 1.70 m of the borehole. Between 0.60 and 0.46 m, a silty layer contains a lagoonal assemblage of *Cerastoderma glaucum* valves and many small fragmented *Abra*.

Borehole NA2 (3.24 m deep) was drilled at the mouth of a W-E trending old valley-like depression, created on the granitic basement and filled with alluvial clastic sediments (Fig. 16). From 3.24 to 2 m there is a scarcity of shells. The first 2 m of NA2 are sandy sediments with silty-clayey layers. Borehole NA3 (5.35 m deep), drilled 150 m southwards of NA1, penetrated a similar succession to NA1.

Micropaleontological analyses

The lowermost part of core NA1, during the interval between 5.15 and 4.75 m, is featured only by rare marine, mostly broken, and therefore probably transported, foraminiferal specimens. This evidence indicated this unit as coastal. From 4.75 to 4.50 m depth, the presence of euryhaline small sized *Ammonia* spp. suggests a brackish mesohaline palaeoenvironment (Triantaphyllou *et al.*, 2003; Evelpidou *et al.*, 2010). In the interval from 4.50 to 2.90 m, the euryhaline *Ammonia* spp. is associated with marine miliolids, indicating a shallow marine environment with fresh water input. Above, between 2.90 and 2.60 m, brackish mesohaline conditions are supported by the presence of *Haynensina* spp., a species found in the internal portions of the lagoonal environment (Serandrei Barbero *et al.*, 1997) and mesohaline to oligohaline biofacies (Triantaphyllou *et al.*, 2003; Evelpidou *et al.*, 2010). Continuous fluctuations between marine and euryhaline species characterised the uppermost part of the core (2.60-0.30 m), suggesting an alternating shallow marine environment with fresh water input, to a brackish mesohaline one. Towards the top of the core the presence of broken foraminiferal specimens indicates a coastal environment. Small euryhaline *Ammonia* spp., miliolids (particularly *Quinqueloculina* spp.) and *P. mediterranensis* mark the base of the core NA2 to 2.84 m. Both miliolids and *P. mediterranensis* are evidence of shallow marine environments with algal vegetation and elevated fluxes of neritic carbonates (Murray, 1991). Between 2.84 and 1.80 m, the presence of few broken foraminiferal specimens indicates a coastal environment. The peaks of *Haynesina* spp. and *A. perlucida* mark the uppermost part of the core, suggesting a shallow marine environment with fresh water input that periodically turns to a mesohaline lagoon. The major part of core NA3 has proven to be totally barren of microfauna. Only four levels within the sequence, namely at 3.30-35, 4.50-55, 4.80-85, 4.95-5.00 m depth, contained fragments of probably brackish mollusks. Therefore the sequence could represent a coastal high energy environment, possibly fluvial with occasionally higher inputs of fresh water.

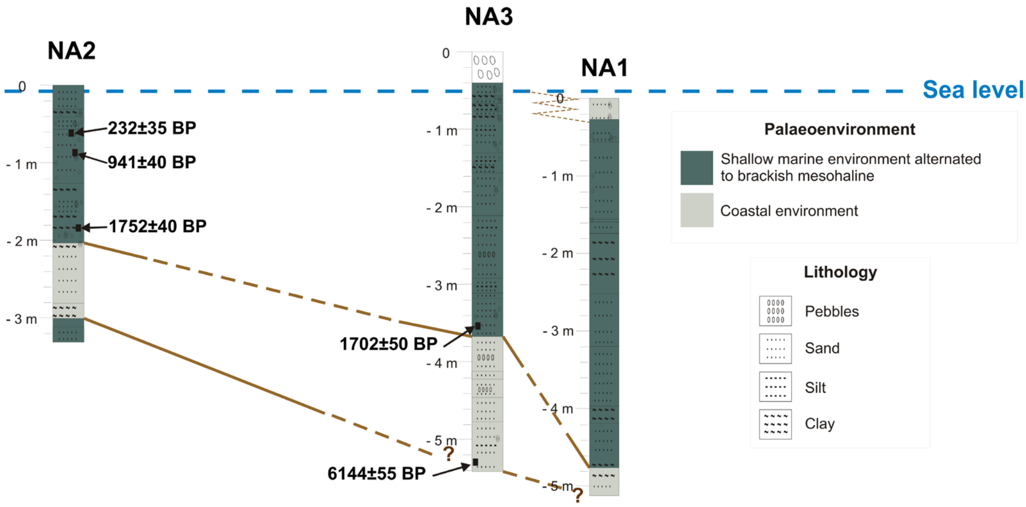


Fig. 16: Stratigraphic columns of the Agios Georgios cores (from Evelpidou *et al.*, 2012).

Paleogeography

In Borehole NA1, the sands with silty-clayey layers and pebbles from the bottom of the core up to 2.70 m indicate deposition in a transitional very shallow marine-coastal to lagoonal-marshy environment. The very dark gray silty clay between 2.70 and 1.75 m indicates a very calm aquatic environment (probably lagoon-marsh). In Borehole NA2, from the bottom up to 2 m the scarcity of shells may indicate a more coastal environment, while the first 2 m of the core characterized by sandy sediments with silty-clayey layers and scattered small fragments of *Cerastoderma glaucum* and *Bittium*, indicate a lagoonal-coastal environment. Borehole NA3 penetrated a similar succession to NA1, but with a predomination of more coastal to lagoonal deposits.

According to Evelpidou *et al.* (2012), around 6000 BP, St. Georgios Bay was protected by the elongated reef, which extends almost parallel to the present day coastline (Fig. 17). The analysis of sediments and microfaunal content revealed that at least from 6144 BP until 232 BP, the area of St. Georgios was an active lagoon (Fig. 18). The embayment was changing from a coastal environment to an environment frequently alternating from shallow marine with fresh water input to a brackish mesohaline one (Evelpidou *et al.*, 2010). Parts of the elongated reef, either at the southern or northern part of the bay during the period, were periodically submerged and seawater was burst into the bay. This could possibly happen during storm events when waves were large enough to overcome the reef and enter the lagoon. After a detailed bathymetric study of the area, it appears that the two edges of the reef represent the only possible periodic passage routes of seawater into the, most of the time, protected lagoon.

Fig. 17: Aerial view of Ag. Georgios coastal zone, with the reef protecting the bay. Photo by Niki Evelpidou

There are signs of high energy environment, especially at the NA3 core, which represents fluvial deposits with occasionally higher inputs of fresh water. The Peritsis River, which was flowing near the Yria site (8^{th} century BC), was possibly crossing the eastern part of St. Georgios Bay, near NA3. It is evident that, due to flood events of the Peritsis River, the site was reconstructed several times (Lamprinoudakis *et al.*, 1987). The existence of the large shallow bay was used as a harbor to access the worship center, and this theory is supported by the remains of a large ancient quarry at Stelida cape.

The environment was, also, dominated by aeolian activity. The drier climate in combination with the coastal marine and aeolian processes has shaped the recent landscape.

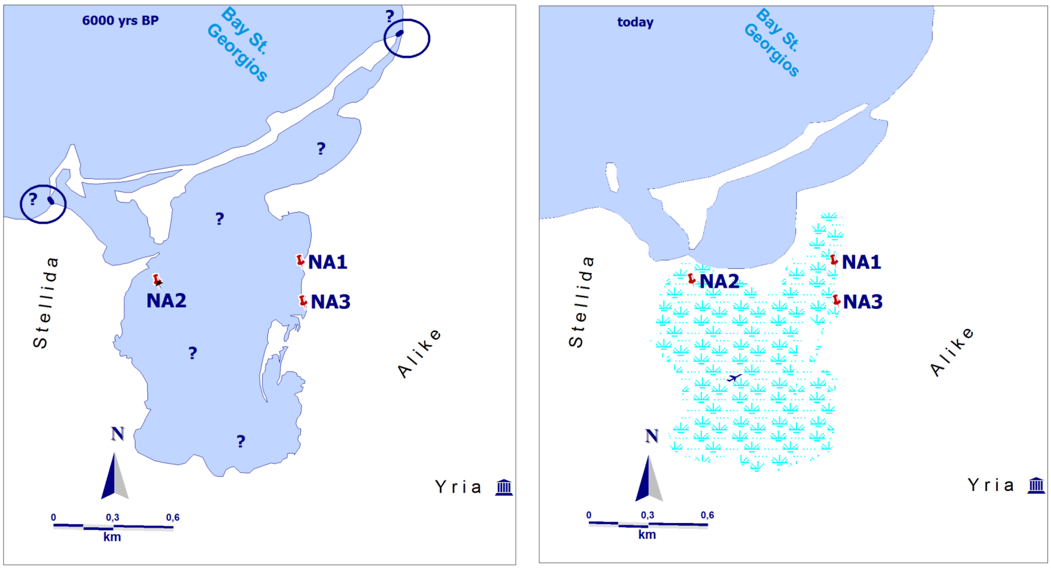


Fig. 18: Palaeogeographical reconstruction of Agios Georgios during ~6000 BP in comparison to present geography. The area that used to be a lagoon during 6000 BP is a wetland nowadays (from Evelpidou *et al.*, 2012).

Beachrocks and shoreline evolution (based on Karkani *et al.*, 2017)

The submarine part of Agios Georgios is characterized by the presence of four successive beachrock slabs, between the present sea level and -6.2±0.5 m, which were dated with luminescence dating (Karkani *et al.*, 2017). The beachrocks extend parallel to the coast, almost continuously, for more than 1 km. Due to their extensive width, they do not maintain the same characteristics along the coast (Fig. 19).

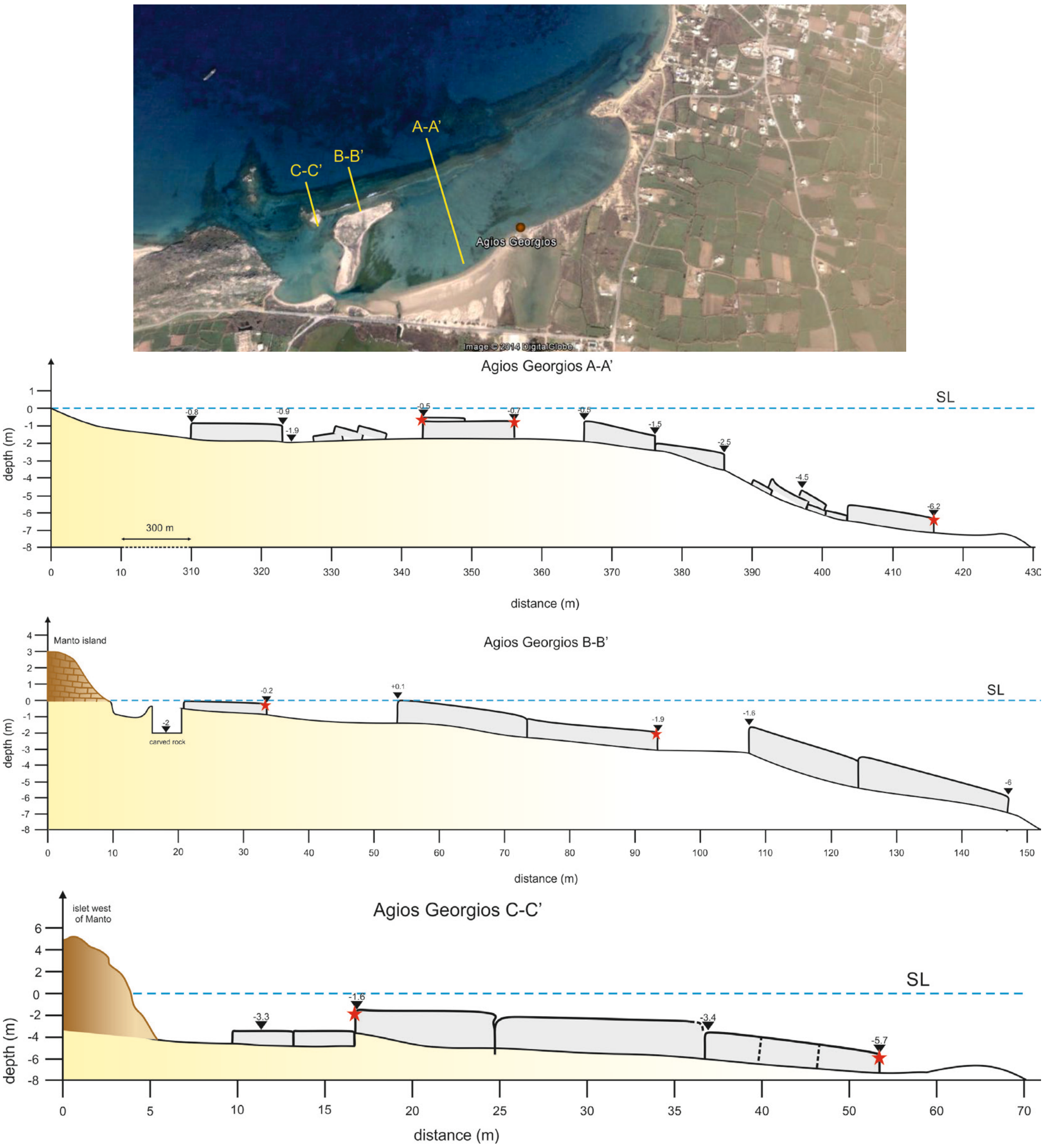


Fig. 19: Submarine transects of beachrocks at Agios Georgios (W Naxos). The beachrocks extend for more than 1 km parallel to the modern coastline reaching a maximum depth of -6.2 m (from Karkani, 2017).

Shoreline evolution

Agios Georgios provides an interesting example of shoreline evolution. The submarine beachrocks were distinguished in three shorelines (Fig. 20). The second shoreline (maximum depth -1.9 m), wider than the youngest one, was dated between 1.38±0.17 ka, using quartz and 1.42±0.09 ka, using K-feldspar (sample 3163). The age of the deepest shoreline was not determined because the sediment amount for gamma spectrometry was too little and therefore the measurement was not possible. This deepest shoreline reaches depths of -5.7 to -6.2 m; therefore it may have been at least older than the age obtained from sample 3169, i.e. 4.48±0.78 ka (quartz) / 3.39±0.57 (feldspar).

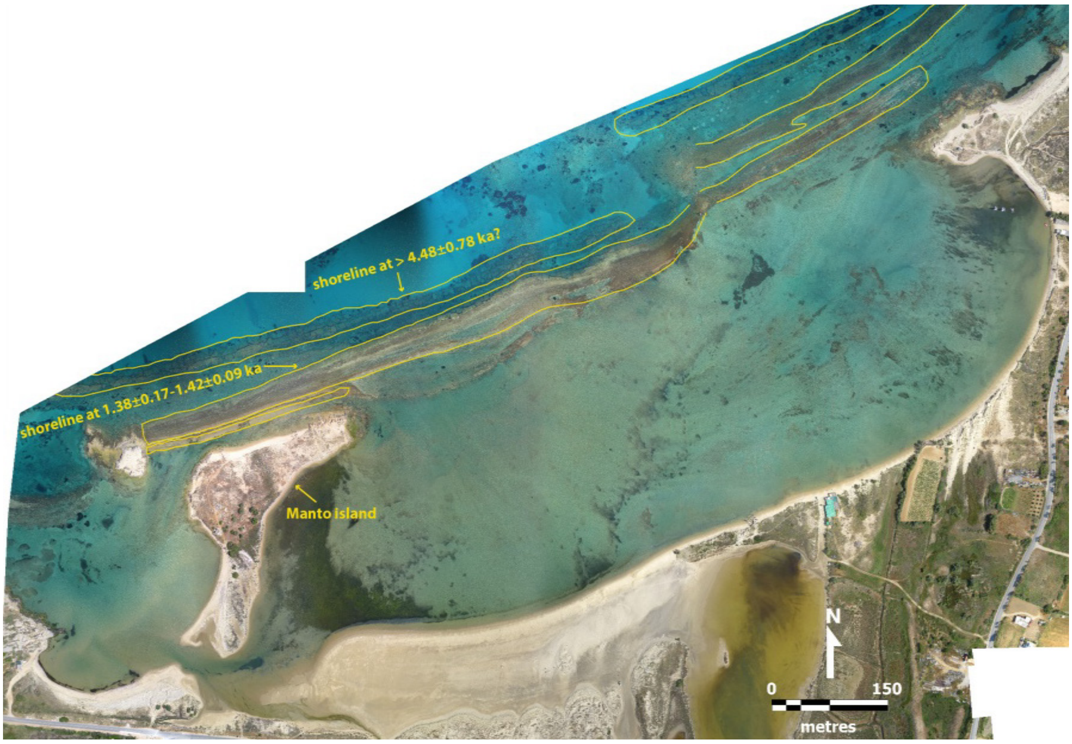


Fig. 20: Palaeoshorelines deduced from submerged beachrocks in Agios Georgios (W Naxos). The beachrock slabs reveal the continuous shoreline regression in the bay of Agios Georgios (from Karkani *et al.*, 2017).

The beachrock slabs, extending almost parallel to the present-day coastline, reveal the continuous shoreline regression in the bay of Agios Georgios. It is also worth noting, that the grain size of the beachrocks is variable amongst the various palaeoshorelines, which may suggest different coastal hydrodynamic settings and the alternation of lower and higher energy coasts. In particular, during the time of the deepest shoreline appears more coarse grained and with more angular, and not well rounded, grains in comparison with the shallower shorelines suggesting a coast with higher energy. The second shoreline consists mainly of well-rounded mineral grains and larger lithoclasts with medium sorting. The shallower shoreline has more well sorted grains, rounded and semi-rounded suggesting a lower energy coast.

The present configuration of the beachrocks suggests that the paleoshorelines were more extensive, reaching probably the two edges of Agios Georgios bay. They did not, however, prevent the incursion of marine water into the bay, as the corings from Evelpidou *et al.* (2012) have reported that this embayment was changing from a coastal environment to a shallow marine with fresh water input and a brackish mesohaline one.

Fig. 21: View of Ag. Georgios beachrocks, reaching a depth of -6.3 m. Photo by Niki Evelpidou.

Erosion

The St. George bay bottom, as well as the beach, consists of loose sediments. The bay is quite shallow, being characterized by depths between 0.20 - 1.50 m, due to the beachrock reef extending parallel to the shore front. The reef is being eroded by strong wave action, caused by the prevailing northern and northwestern winds. This way, the reef supplies the beach with sediment. in addition, the presence of the reef, creating a surf zone approximately 560 m from the coastline, mitigates the effect of the wave action in the beach, thus protecting it from the erosive action of the waves. On the other hand, the outer western side of the ongoing tombolo, is exposed to waves and has undergone corrosion.

Fig. 22: St. George beach. Photo by Niki Evelpidou.

Marine vegetation

The beachrock formations in St. George bay present heterogeneity in their form. A large part of the reef consists of a single beachrock formation with large breadth. The reef exhibits this form in the southwestern part of the bay close to the sea surface or may be above it. On the contrary, beachrocks in the northeastern part of the bay are located in five different beachrock rows, three major and two minor. These formations are found in greater depths relatively to the southwestern half of the beachrock reef. On the whole, the formation acts as a breakwater protecting the coast from wave energy.

The morphological differentiation of beachrock reef has an impact on the marine ecosystem and the type of vegetation. In the shallower half of the reef (depth of 0-1 m.) exists dense arboreal vegetation, including mostly species of *Cystoseira* genus and *Jania sp*. While in the deeper half of the reef there is lower and sparse vegetation and the main species found are *Halopteris scoparia* and *Halopithys incurva*.

The identified algae taxa of St. George beachrock reef are of the typical vegetation of the oligotrophic Mediterranean marine ecosystem.

On the reef there are, also, significant populations of the sea anemone *Anemonia viridis* and of sea urchins (*Arbacia lixula*) that sparsely create barren zones. Also, in the sandy bottom of St. George bay, there are local appearances of the species *Posidonia oceanica*.

Table 8: Algae Taxa identified along Ag. Georgios beachrock reef.		
Phaeophyta	**Rhodophyta**	**Chlorophyta**
Cystoseira sp.	*Jania sp.*	*Dasycladus vermicularis*
Padina sp.	*Laurencia complex*	*Chaetomorpha sp.*
Dictyota sp.	*Geramium*	*Cladophora sp.*
Brown Filamentus Epiphyte	*Halopithys incurva*	*Anadyomene stellata*
Halopteris scoparia	*Amphiroa rigida*	*Caulerpa cylindracea*
Sphacelaria cirrosa		*Caulerpa prolifera*
		Acetabularia sp.

Stop 4. Ag. Prokopios

Niki Evelpidou, Anna Karkani

Introduction

At Ag. Prokopios there are small, coastal wetlands (salt pits). Ag. Prokopios salt pits are located 4.1 km southwest of Naxos Town and have been included in the inventory of WWF Hellas for wetlands Aegean (Katsadorakis and Paragamian, 2007). Their average area is 127.700 m^2. Specifically, there are three seasonal ponds of saltwater (NaCl content of 30,9 g / l, Langangen, 2004) in sandy substrates. The ponds, depending on the height of the water level, are joined or separated. In the past, the ponds were supplied with fresh water from the underground aquifer (there are wells in the area), but today, probably, this is greatly reduced. There is great seasonal water level fluctuation and very often, the two of the three, dry completely in the summer. There is no direct connection between the pits and the sea. The main types of habitat in the wetland are: Lagoons, Annual vegetation with Salicornia, Mediterranean salt meadows, Embryonic shifting dunes, Dunes with sclerophyllous shrub vegetation. There is no aquatic vegetation in the ponds, only in the periphery there is halophytic vegetation of Salicornia and Halocnemum, sand dune annual plants and sclerophyllous shrubs (Corydothymus). During migration periods, the ponds are used by many species of birds. Ag. Prokopios salt pits were once used as saltworks, but salt collection was banned by public authorities, because until 1980 oil was disposed in them causing their pollution in order to prevent illegal trade of the product. Although Ag. Prokopios is considered to be a protected area, it is threatened by polders, building projects and change of land use.

Fig. 23: Ag. Prokopios coastal zone with salt pits. Photo by Niki Evelpidou.

Sand dunes

Dunes or sand dunes are small hills of sand, which are usually found in coastal areas. Coastal sand dunes owe their development to the combined action of aeolian transport of sand and the presence of vegetation covering dunes, in contrast with desert dunes, where vegetation is absent.

They constitute an important habitat in the transitional zone of land and sea and they are owed to erosion processes and the deposition of sand in the coastal zone. Therefore, the sand of the coastline, which is drifted by the wind, is naturally replaced by the sand, which is brought to the coast by waves and currents. This sand comes from the river basins, from eroded rock sediments or from submarine accumulations of sand.

Because dunes consist of sand, they constitute an unstable, but dynamic geomorphological unit of the coastal zone. Their development and preservation depends on the prevailing winds of the area, the wave regime in the coastal zone and the supply-sorting of erosion materials, as well as the supply of erosion material from nearby streams and rivers bring to the coastal zone.

Dunes along with coastal mudflats, salt marshes and sandy beaches, belong to the coastal habitats, they provide a wide spectrum of important functions and they are invaluable for the protection of wild fauna and flora. Dunes and salt marshes in particular absorb wave energy, thereby preventing the erosion of the coastal zone.

Dunes are sensitive, but dynamically evolving ecosystems that host flora and fauna with a high adaptation to unfavorable environmental conditions. Their ecological importance is great and is mainly attributed to the vegetation, which has a key structural role in the development and preservation of dunes, as this vegetation:

- Holds the sand
- Stabilizes the coastline and the soil from the erosive action of the sea and the wind
- Works protectively as a natural barrier (sea water, winds) for the inland.

Besides, dune systems are sensitive and fragile ecosystems that have adapted to the changes caused by natural causes (wind, wave), while, regardless of the sandy deposits (extent, thickness, height), they play an important part in groundwater hydrology of the wider area. This is owed to their substantial storage capacity, concerning the groundwater hosted in their mass.

Formation

Bouncing is the process through which the sand is transported to the land; the movement of grains is accelerating after they are lifted by the wind. It is known that the wind speed increases as we move away from the ground because the soil friction decreases. When a sand cloud passes over an anomalous surface the bouncing is reduced due to the loss of energy, resulting to the deposition of the material transported and therefore the creation of a new dune. The development and stabilization of a dune depends on the growth of vegetation, which is known to trap sand and reduce the effect of wind.

Fig. 24: Sand dunes at Ag. Prokopios coastal zone. Photo by Niki Evelpidou.

After the development and stabilization of a dune, its migration towards inland is possible, as erosion of its seaward part and deposition of material landward is observed. When the wind energy exceeds the cohesion of the sandy layer or the resistance of vegetation, large parts of the dune may be detached.

Coastal dunes, in general, form when the dry sand from the foreshore zone is transferred to the backshore. The material is concentrated above the limit of high tide, particularly when deposition takes place against obstacles, such as woods, or plants (Goldsmith, 1985). The development and shape of dunes are related to the quantity of sand that can be transported by the wind, the erosion and deposition.

Coastal dunes differ from desert dunes, as more processes are involved, such as wave activity and vegetation cover; these processes affect their size, shape, evolution and preservation. In deserts the height of dunes can reach 500 m, while coastal dunes have a height not exceeding 50 m.

The development of dunes in the backshore zone is, also, encouraged by the frequent strong winds and the presence of a sandy beach. In addition, dunes are strengthened by wave processes, particularly when the waves come from storms that transport fine material from the beach towards the sea, thus shifting the boundaries of coastal dunes.

Coastal dunes are most frequently found on extensive beaches with small hills, rather than on steep and narrow beaches. They have a wider development on macrotidal coasts, such as the west coasts of Britain. On the shores of the North Sea, dunes are found behind large shores close to Holy Island and along the Moray Firth shores. They are, also, often in Belgium, the Netherlands, Germany and Denmark.

The development of dunes requires a constant wind direction; otherwise, the formation material is always reworked. The transported sand is deposited when the velocity is reduced to a degree unable to transfer it anymore. Any obstacle on the ground contributes to this process, such as the presence of vegetation (Fig. 25). The presence of moisture is also possible to contribute to the concentration of sand, which will constitute to the beginning of a dune formation.

Fig. 25: Stabilization of dunes by vegetation. Photo by Niki Evelpidou.

The sand deriving from the coast is usually fine and well rounded. The analysis of grain size has shown that desert dunes have better sorted sand in comparison to the coastal dunes.

The winds transport the sand from the coast to the backshore zone. The sand is transported until the wind velocity is reduced, until an obstacle is found or due to the presence of vegetation. Vegetation cover reduces the vertical force of the wind and enables the deposition of sand. This deposition increases the inclination of the backshore zone and as a result a small hill is formed, which blocks the further transport of sand. This small hill is also covered with plants and is known as foredune. Sometimes, strong winds transport the sand above this hill and deposit it as a thin layer or as a small hill landward.

The sand is better sieved on a coastline that consists of well sorted grains of irregular shape. In order to quantitatively investigate the rates of sand transport and the quantity of sediments on the coastlines and the coastal dunes, recurrent field visits are necessary. In general, the quantity of transported sand depends on the wind force and it is constrained by the width of the coast. A larger quantity can be transported from the coast towards a backshore dune by oblique rather than vertical winds.

The morphological characteristics of dunes are associated with the quantity of sand transported by the wind and the cycles of depositions-erosion. Dune dimensions are variable and their diameter ranges from a few meters to several kilometers. Their height ranges from 1-2 m to 20-30 m. They have a steep slope towards the wind blowing side, while their leeward side is smoother, another characteristic that distinguishes them from the desert dunes.

Regarding their shape, it also presents a large variety from very simple to quite complicated forms. So, we may find crescent dunes, linear, pyramidal as well as dunes developed from quite complex combinations.

It is a fact that, in comparison to the vast areas of dunes developed in the desert, coastal dunes occupy a very small area. The last ones are formed when an extended sandy coast exists, which is usually characterized by a large tidal range. It is characteristic that many dunes originate from earlier geological times when the sea level was much lower than today.

Dune types

Primary dunes - Foredunes

Primary dunes are sand hills that are developed in the backshore zone or on sand hill or on a berm, where dune grass has concentrated and has trapped sand transported by the wind. The concentrated vegetation limits the velocity of the wind near the ground and creates a sheltered environment, where the sand is deposited (Goldsmith, 1989). The dunes are reinforced in height and width depending on the quantity of sand transported by the wind and the transgression of the shore.

The vegetation cover traps the sand and a primary dune can start developing along the high tide line, where the vegetation grows due to the concentration of seeds by plant remains.

Primary dunes are formed parallel to the high tide. They may also form along a terrace covered with low vegetation in the backshore or along an area with irregular hilly dunes.

There are geographical variations in the types of plants that contribute to the development of primary dunes. A well-known plant in Europe is the marram (Ammophila arenaria), which is also found in other areas and works as a stabilizer for dunes. Agropyron junceum is usually found in the Mediterranean and in the Black Sea. Ammophila arenaria has the strongest impact and can add up to 2 m of sand in a primary dune during one year.

Backshore cliffing of dunes

As a consequence of the contemporary dominance of coastal erosion along the world's coastlines, the seaward parts of dunes are often eroded/scarped. Dune cliffs therefore, recede due to the undercutting by wave action with the sand collapsing and being transported.

Dune cliffs are vertical when the sand is moist and coherent, however as it dries, it is detached and concentrated to a lower area. This sand concentration, if not removed by the waves or the wind, grows as the cliff recedes, until it turns into a slope with an angle of about 32° with the rest dry dune.

On some coastlines, the formation of dune cliffs caused by storm waves is followed by a new sand concentration, as sand is transported from the beach against the cliffed dune, when the weather is calmer. The earlier dune profile is restored when vegetation begins to cover the new sand accretion. During alternating cycles of erosion-deposition, the margins of coastal dunes may change between dune cliffing and restoration.

Parallel dunes

In certain coastlines there are a number of dunes, usually placed parallel to the shore, which were successively formed as primary dunes behind a sandy transgressive coast.

The seaward side of the primary dune retreats due to storm waves, forming a sandy steep hill. As a consequence, the waves restore the beach and a new primary dune starts forming along the upper tidal berm, in front or parallel to the previous dune; they are usually separated by a zone free of vegetation that becomes a low-lying swamp. Occasionally, the seaward sides of the parallel dunes are steep as a consequence of the formed steep hill. When such hills are absent, the transgression forms a wide area covered with low vegetation at the back of the coast (Bird and Jones, 1988).

The formation of swamps separating the parallel dunes is often supported by swirls acting on the leeward side of the developing dunes.

The height and interval of the parallel dunes depends on the quantity of sand transported on the coast, the deposition-erosion processes and the effectiveness of vegetation in trapping sand. When the concentration of sand increases rapidly in a transgressive beach with often storms, a large number of dense, low height parallel dunes are formed.

Blowouts and Parabolic dunes

On some coastlines, unstable dunes may be found with minimum or no vegetation cover. These dunes are distinguished in parabolic dunes, blowouts and transgressive dunes (Hesp and Thom, 1990). Mixtures of stable dunes with vegetation cover and unstable dunes are developed as a result of stabilization of moving sand with simultaneous plant attachment, or as a result of temporary interruption during the development of dunes with vegetation cover.

Coastal dunes that were stabilized by vegetation may have subsequently been eroded and redeveloped, especially in areas where vegetation was weakened and moved due to natural causes or human interventions. In this way, already shaped dunes may be transformed into thin layers of moving sand. Even parallel dunes may be interrupted by blowouts, which may have no vegetation or present floating sand moving landward (Carter *et al.*, 1990).

Blowouts are, also, formed due to natural processes during dry periods, when the vegetation cover is weakened. In addition, they are formed, when the outer part of the dunes is cut off from the sea during strong storms and sand hills are left with no vegetation cover, exposed to the wind action.

U-dunes or parabolic dunes are called those blowouts that grow until their axial length is more than three times their mean width, have an advancing nose of loose sand (with a slope of 30–33°) and trailing arms of partly fixed vegetated sand on either side of an axial corridor excavated by deflation

Parabolic dunes have parts of sand that are placed in the orientation of the dominant wind. The wind force forms the parabolic shape, which in turn modifies the surface that is affected by the wind. The wind movements derive from the morphology of parabolic dunes, but subsequently they are developed independently.

Transgressive dunes

Along with blowouts and parabolic dunes, there are, also, other moving dunes, which are called transgressive dunes; they are formed by sand moved by the wind and are restrained by vegetation. In other cases, transgressive dunes are developed in locations of older coastal dunes, whose development was interrupted by many blowouts, until they were developed into elongated dunes directed landwards.

Furthermore, there are elongated transgressive dunes that form an angle with the prevailing winds. They usually have a rippled hill, a small inclination to the windward side and a steep one to the leeward side. These concentrations of moving sand with no vegetation have a similar form with the dunes of the dry inland regions.

In some coastlines, early transgressive dunes are stabilized with vegetation, particularly with marram grass that existed in the previous century.

Cliff-top dunes

On some steep coastlines, the winds have transported the sand from the shore against the cliff, forming climbing dunes. Such dunes may grow and move towards cliffed headlands, where, when there is no sufficient sand, they are transformed into relict clifftop-dunes (Bird, 1998).

Dunes located on a steep top may not have formed by sand transported from nearby shores. In arid regions the steep peaks have shifted, due to erosion, towards the area where dunes existed in areas with sparse or no vegetation. In NW Australia there are tops covered with red desert sand or pindan. In the shore of Port Phillip Bay in SE Australia, the grey dunes covering the tops in the SE suburbs of Melbourne constitute a part from a series of elongated parallel dunes developed on the coastal platform of desert dunes during a dry period of the Pleistocene (Bird, 1993).

Dune systems

In a well-developed system of sand dunes, towards inland, we usually find the following sequence:

Primary or embryonic moving sand dunes, which are formed with the help of wind, have sparse or no vegetation and they are facing the sea.

The most significant in terms of the extent and diversity are found in Limnos, Naxos, Rhodes, the Peloponnese, Sithonia, Kassandra, Thrace, W. Greece, Crete, Gavdos and elsewhere.

Moving or white sand dunes, constantly change, as they are always in dynamic evolution, with more stable rooted vegetation. They are developed behind the primary dunes.

Around the plants, more sand is trapped and with the help of the wind, the moving white dunes form. The most significant dune systems, in terms of extent and diversity, are found in Limnos, Naxos, Rodos, Sithonia, Kassandra, Peloponnese, Thrace, Western Greece, Crete (e.g. Elafonisi, Falasarna, and Chrysi).

Dune and wetland habitats, which are formed behind small sand hills along the coast at intermediate lower areas between dunes, are flooded occasionally. The diversity of these habitats, which are dynamic ecosystems, are owed to the inclination and orientation of dunes in relation to the prevailing winds, the water table and the sea water level, the soil composition and the vegetation cover.

The most representative occurrences are found in Limnos, Atalanti, Spercheios, Sourpi, Katerini, Chalkidiki, Peloponnese, Thrace, W. Greece, Elafonisi, Falasarna, S. Crete, Naxos and Gavdos.

Stable or gray dunes with greater cohesion of the sand dunes, more plants and animals and greater water retention.

Some representative examples are found in Limnos, Thassos, Samos, Thrace, Sithonia, Kassandra, W. Greece, Koufonisi, Elafonisi, W. Crete, Gavdos, Peloponnese, Skiathos and Schinias.

A large number of plants and animals live in sand dunes, while in degraded environments the area is colonized from nitrofila, other native or alien species. The first plants colonizing the dunes are usually small with thorny hard, small, hairy leaves and strong, extensive root system, while in more stable conditions herbaceous plants, sclerophyllous shrubs and trees are also found.

Degradation risks and erosion

The current deterioration of many dune systems is attributed to natural causes (beach width, wind and wave intensity, etc.) and human activities (walking on permanent paths, frequent crossing of vehicles, touristic activities, land reclamation). In addition, the plants that make up the dune systems consist of species restricted to this habitat and therefore, due to the general deterioration of the dune populations, plants have an increasing risk of extinction (e.g. Pancratium maritimum).

The main threats for sand dune ecosystems come from:

- The interruption of their continuity (e.g. road construction, various infrastructures)
- The loss of their habitat, due to touristic or other purposes
- Changes in sand supply (e.g. port or other works in the coastal zone, arrangements of rivers and streams, tree planting on the beach, continuous cleaning by mechanical means, sand extraction)
- disposal of garbage and construction debris
- Multiple activities in a limited area (e.g. tourists, vehicles, campings), which exceed the environmental capacity of the area from an ecological point of view and in terms of the offered facilities.

The threats and degradation risks of sand dunes can be addressed through a good management, rational planning, environmental awareness, social consensus and acceptance. Typically, conservation and protection projects of important dune systems begin with studies on their bearing capacity of human activities, while for the design mild interventions and actions are considered.

Previously, erosion of the coastal zone was treated with "hard" technical solutions, such as the construction of marine protection systems and breakwaters. However, although these systems were able to limit coastal erosion in some areas, they intervened in the natural process of sand transport causing erosion in other locations. Nowadays, "soft" practices are preferred, such as the planting of native plants (see more in the following chapter).

For coastal erosion, Europe has adopted the following recommendations:

- Early warning of risks, environmental impact assessment and restoration of damages in the framework of policies on coastal management.
- Increasing the protection of the coasts by restoring the sediment balance with mild and socially acceptable interventions (e.g. sediment transport from areas that have strategic reserves and as long as the physical balance of the system is not compromised)
- Drastical and scheduled management of coastal erosion (better planning in the long term and a regional plan for the management of coastal sediments, also taking into account risks, costs and effects)
- Implementation of best practices individually for each case, with full knowledge of management of coastal erosion

Finally, a guarantee for the preservation and protection of dune ecosystems is the continuous awareness of the local community and their active participation in the sustainable management of these important ecosystems.

Coastal dunes restoration

The main cause for the loss and degradation of coastal dunes is owed to human activities (e.g. Lithgow *et al.*, 2013, Table 2). They could be generally categorized in 6 groups (Martínez *et al.*, 2013; Lithgow *et al.*, 2013): a) housing and recreation, b) industrial and commercial use, c) waste disposal, d) agriculture, e) mining and f) military activities. Such activities typically alter the natural processes on the coastal zone, thus modifying the system's dynamic.

Coastal dunes may vary in shape and form and various types may be found. In general, the foremost dunes located on the backshore are typically foredunes, formed by aeolian deposition of sand. Their size may vary from quite small to very large, while the amount of vegetation also varies. The backdunes are located landward from the foredunes, with variable shape and relief and generally they tend to have a smaller height than the foredunes.

Coastal dune restoration activities include mainly the reshaping of dunes and the recovery of sediment dynamics and dune stabilization by controlling invasive species of plants and animals. Research on coastal dunes restoration has taken place in many areas around the world, including Europe, Africa, Asia and North America. For Europe, in particular, most of the studies concerning coastal dunes restoration are found in the Netherlands (e.g. Vandenbohede *et al.*, 2010; van der Hagen *et al.*, 2008; Arens and Geelen, 2006). In terms of restoration methods, Lithgow *et al.* (2013) noted that there is no best way to restore a dune. Due to the dynamism and diversity of this ecosystem and the various geomorphological and ecological characteristics of dunes around the world, a wide range of activities may be implemented.

Beach nourishment

The formation of dunes could be accomplished through beach nourishment, by providing the necessary sand volume and space for the dunes to develop, however in this case, maintenance is necessary for the preservation of dune integrity and time is of the essence in order for backdune species to colonize (Martínez *et al.*, 2013). However, the restoration of vegetation and morphology can last up to ten years (Woodhouse *et al.* 1977; Maun, 2004). In addition such an action is expensive. However, in the case of Talacre Warren (Wales), beach nourishment had proven successful, when in 2003, 150,000 m3 of dredged sand was pumped on to the foreshore along a section of eroding dunes. The cost was reduced from navigation dredging operations of the material in the nearby Dee Estuary. Some years later, new foredunes are developing and blowouts are now channeling the sand into hind dune areas, creating new mobile dunes.

Use of vegetation

The increase or planting of vegetation can assist the stabilization and development of coastal dunes, as vegetation can trap and stabilize sediments, reduce the wind intensity and provide habitat (e.g. Nordstrom, 2008). It is, however, important which vegetation species will be used, as native species will have a higher survival rate and are easy to propagate, harvest, store, and transplant. In the foredune zone, beach grass (Ammophila sp.) and other species can be planted to trap sand (Craft and Bertram, 2008). With time, the dunes can be increased in size, woody vegetation can colonize and soil can initialize forming.

Most restoration projects are found in the USA (e.g. in Louisiana: Boustany, 2010; New Hampshire: Morgan and Short, 2002). The actions of coastal restoration in the area include various vegetative, hydrological and structural methods, which can be divided in two types of projects: a) marsh creation projects and b) large-scale river diversion projects. In the first type, coastal land is reclaimed rapidly through the mechanical extraction and delivery of dredged sediments (Aust, 2006; LCPRA, 2012; Merino *et al.*, 2011), while the second type aims to mimic the alluvial land building process (e.g. Allison and Meselhe, 2010; LCPRA, 2012; Nittrouer *et al.*, 2012; Simenstad *et al.*, 2006). Both types of projects present disadvantaged and pitfalls. Marsh creation projects are less functional, since ecological restoration aims to restore processes and not structures. Diversion projects have been criticized by stakeholders who have requested more immediate results (Caffey *et al.*, 2014). According to Caffey *et al.* (2014), due to the scale of coastal land loss in Louisiana and the limited funding, these two methods need to be assessed in terms of efficiency and cost-benefit terms in the provision of ecosystem services.

Fig. 26: Vegetation on the coastal dunes of Ag. Prokopios. Photo by Niki Evelpidou.

In Europe, most restoration projects are found in the Netherlands, Germany, U.K, Denmark and other countries, and these activities are mostly funded through LIFE projects with the involvement of authorities and stakeholders. Ecosystem recovery in wetlands can be divided in passive, active, and creative approaches (Simenstad *et al.*, 2006). In the first case, removing barriers or stopping a degrading activity on a disturbed ecosystem can lead to its reinstatement either partly or fully (e.g. Bos *et al.*, 2002). On the other hand, more engineered activities are involved in active restoration approaches, in an attempt to recreate wetland processes and structure. These activities may involve re-establishment of tidal hydrology and/or planting vegetation to facilitate the growth of native marsh vegetation and limit or eliminate invasive species (Bos *et al.*, 2002).

In the framework of LIFE, the ZENO (Zwin dunes Ecological Nature Optimisation) project focused on the area Zwin Dunes and Zwin Polders Flemish nature reserve with a restoration project. After an extensive study of biotic and abiotic factors by Zwaenepoel *et al.* (2007), a management plan was approved, which included a number of ecological engineering interventions such the removal of vegetation (shrub and exotic tree species), the remodeling or creation of ponds and the removal of old infrastructure (war remnants, old horse jumping etc.), hydrogeological interventions, together with a restoration of the micro-topography in the Kleyne Vlakte (advised by Zwaenepoel *et al.* (2007)). What these interventions aimed for was the rewetting of the Kleyne Vlakte with water stored within the nature reserve so that it would no longer drain towards the polder area. The project was completed in 2010, and according to the report the first results were optimistic.

Van der Hagen *et al.* (2008) investigated three restoration projects of coastal dunes in the Netherlands. The three projects were based on the conceptual Model of Dunes (Bakker *et al.*, 1979), with either abiotic or biotic restoration. Hydrological restoration activities included the removal of extraction wells and with small-scale sod-cutting, however pioneer communities did not return as expected. In the areas Van Limburg Stirum and Kikkervalleien, the activities included hydrological and geomorphological restoration, with blowing sand and reduction of the groundwater extraction; according to Van der Hagen *et al.* (2008), the abiotic restoration initiates a promising situation. Future plans need to take into consideration the influence of the remaining vegetation, as well as the ability of seeds of the target species to reach the restored area (Van der Hagen *et al.*, 2008). Another important point raised is the acceptance of the public of such management actions, who show a varying degree of enthusiasm for the aforementioned actions.

The increase or planting of vegetation can assist the stabilization and development of coastal dunes, as vegetation can trap and stabilize sediments, reduce the wind intensity and provide habitat (e.g. Nordstrom, 2008).

In order to understand if the coastal ecosystem is self-sustainable and resilient in the long term, a long term monitoring is required (Lithgow *et al.*, 2013), which is usually difficult and expensive to achieve. The complexity and the many parameters affecting the coastal zone make restoration projects difficult to achieve their goals. According to Hopfensperger *et al.* (2007), chances are increased if concurrent science-based and socially acceptable decisions are taken into account. Any restoration activity should, therefore, primarily focus on recording and understanding the structure and function of the coastal ecosystem, its state of degradation and the possibilities of minimizing the factors contributing to degradation. When selecting coastal sites for restoration multiple criteria should be taken into consideration (e.g. Lithgow *et al.*, 2013; Jackson *et al.*, 2013), deriving from geomorphological and ecological processes as well as from human activities.

Stop 5. Coastal Erosion, case study “Hawaii beach”

Alexandros Petropoulos, Niki Evelpidou

Coastal Erosion. Pocket Beach Hawaii, Naxos Isl., Greece

Hawaii beach is located at the SW part of Naxos Island with an orientation to ESE. The length of the shoreline is estimated at 388 m, with a width close to 5m, the total area of the beach is 4.139 m^2 (Fig. 27). At the backside of the shore, there is a cliff with a height of 6 to 8 m and a length of 442 m.

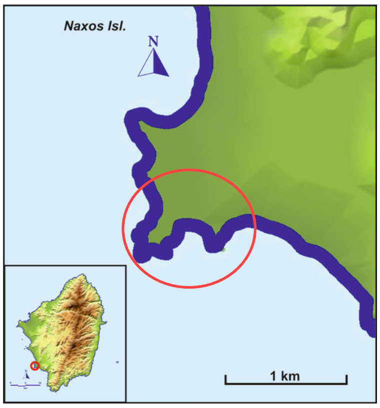


Fig. 27: The location of Hawaii pocket beach at Naxos Isl.

Hawaii beach is characterized as a pocket beach, as it is a small shore with a length less than 1 km and also is bounding by headlands which block any sediment exchange with the neighboring parts of the coast, making them an autonomous and independent ecosystem (Fig. 28).

Fig. 28: Pocket beach Hawaii. Photo by Niki Evelpidou.

The geological formation of the area is characterized by granite, granodiorite, which are very strong materials resistant to the erosion but affected to the fragmentation, and marl which is eroded very easy (Fig. 29).

Fig. 29: Fragmented Granodiorite - Eroded Marl. Photo by Niki Evelpidou.

The creation of Pocket Beaches is based on the process of wave erosion in the surrounding rock formations and at the transport of the sediments which are being produced at the coast, through wave and currents. Their shape is determined by the type of environment rocky formation, while the momentum of the wave, the currents and tides determine the type and quantity of the deposited precipitate.

The pocket beaches are the major ecosystem of the place. Any alternation at the beach affects the morphodynamic evolution of the place, such as geological and sedimentological composition of the bottom, geometrical characteristics, morphological peculiarities, its orientation relative to the prevailing oceanographic conditions and coastline expansion. They are developing significant natural ecosystem with habitats and a variety of plants and animals brittle in any change in the existing conditions.

Coastal erosion is observed since the beginning of the creation of a coastal area, and is influencing and shaping its evolution. However, climate change (sea level rise, extreme weather phenomena) and human interventions in the coastal area and inland, have intensified their effects, which are expected to be even more important in the near future (Maglara, 2011).

The risk assessment of a region of rising sea levels can be based on various factors such as (Papanikolaou et al., 2011):

- The rate and extent of rise
- The relationship between tectonics and eustatic in an area: tectonically active regions counteract or reinforce the rise of sea level depending on the movement of pieces
- The relationship between sea level rise and sediment discharge: the change may be a result of climate change (manmade or natural), through which affected the erosion rate as a result of precipitation and vegetation change, or anthropogenic interference, such as the construction of dams, sand extraction, fires, etc.

Furthermore, there are many local factors that affect coastal erosion, such as (Dukakis, 2005; Papanikolaou et al., 2011): a) the topography of the shore (shore in bay or the open sea), b) the lithology of coast (sandy or rocky), c) the morphology of the coast (gentle or steep slope), d) the prevailing climatic century wave conditions (longitudinal currents, winds, typical wave heights), e) the frequency and intensity of extreme weather and wave phenomena, f) the sediments stocks area (coast near the river or not).

Our current case study of Hawaii is to identify, to study, to compare and to model the coastal erosion processes in this area for a long time. At the end of this research we must be able to have a completely and representatively recording of coastal erosion processes at Hawaii beach and their implementation at standard numerical simulation models of Pocket Beaches.

The ultimate goal is to table proposals for management measures and actions that will yield positive results with the least possible interference with the natural environment, and the correlation of these areas with their development - in relation to human activities (tourism, fisheries, construction). This survey will be applied in other coastal areas of Greece and Mediterranean, with the same geomorphological interest.

Methodology

For the study of coastal erosion in a region, three stages can be distinguished:

1. The first stage includes the collection and study of bibliographic material on earlier scientific approaches in the region (e.g. hydrographic network, climate, vegetation). The processing of these data will produce valuable conclusions about the evolution of the coast.
2. The second stage includes field research with repeated interceptions. At the field we can join topographic / sedimentological sections from the marine section to the boundaries of the beach, perpendicular to the coastline. These sections are depicting the morphology of the area and, based on the prices of sedimentological analysis, it is possible to identify the mechanisms of action of one or more combined factors (e.g. wave, wind, and river). Moreover, by determining the feed mechanisms (e.g. river) and settlement (e.g. wave) may be assessed an annual balance sediments that help morpho-dynamics development of the region. Finally, with repeated mapping of the area and the time monitoring, is imprinted a detailed mapping of the area where is recognizing any change of it.
3. The third stage includes the implementation of a standard numerical simulation models which are going to focus at the eroded parts of the field. The composition of thematic maps will lead to that direction.

The equipment that will be used is (Fig. 30):

- Side scan sonar. This method has the ability to scan large areas of the sea bed, contributing to the mapping of landforms, the background types and marine habitats.
- Sub-bottom profiler. This method determines the geological substructure of the seafloor, while giving information about the physical and geotechnical properties of sediments, the morphology of the bottom along the section.

- GPS. The Global Positioning System (GPS) is a space-based radio-navigation system that determines the precise location in space and time.
- Tape measure/stakes/paint. For the composition of the topographic sections.

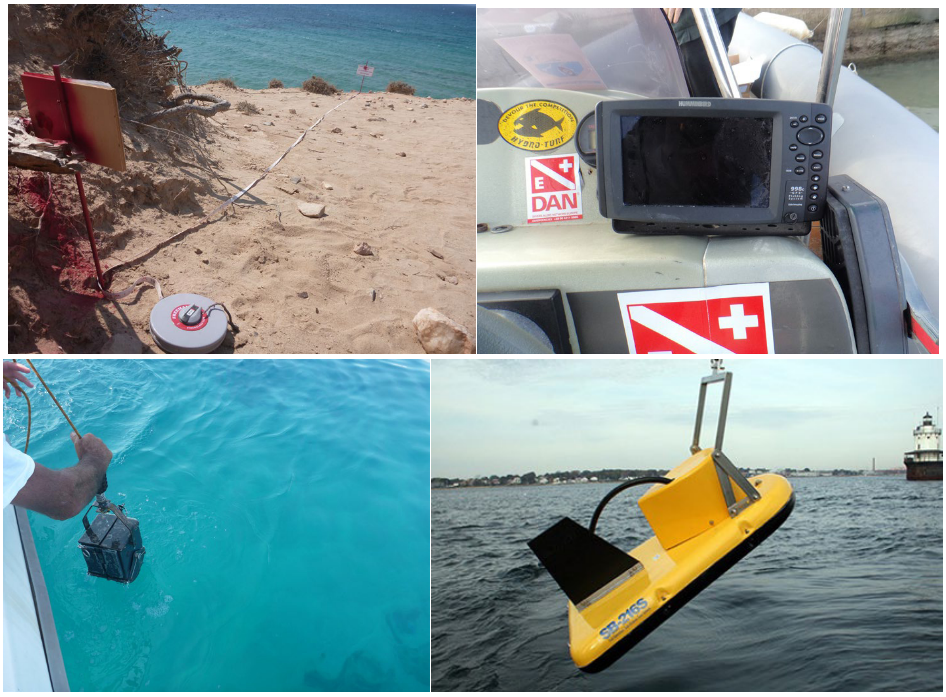


Fig. 30: a. Topographic sections, b. Side scan sonar, c. Sand samples, d. Sub bottom profiler. Photos by Alexandros Petropoulos.

References

Allison, M.A., Meselhe, E.A., 2010. The use of large water and sediment diversions in the lower Mississippi River (Louisiana) for coastal restoration. Journal of Hydrology 387 (3), 346–360.

Arens, S.M., Geelen, L.H.W.T., 2006. Dune landscape rejuvenation by intended destabilization in the Amsterdam water supply dunes. Journal of Coastal Research 225, 1094–1107.

Aust, C., 2006. Cost-efficacy of Wetland preservation and Restoration in Coastal. Thesis, Louisiana State University, Baton Rouge.

Bakker, T. W. M., Klijn, J. A., Van Zadelhoff, F. J., 1979. Duinen en duinvalleien, een landschapsecologische studie van het Nederlandse duingebied. Pudoc, Wageningen. (with English summary).

Bird, E.C.F, Jones, D.G.B., 1988. The origin of foredunes of the coast of Victoria, Australia. Journal of Coastal Research 4, 181-192.

Bird, E.C.F., 1993. The Coast of Victoria. Melbourne University Press, Melbourne.

Bird, E.C.F., 1998. The Coasts of Cornwall. Alexander, Fowey.

Bos, D., Bakker, J.P., de Vries, Y., van Lieshout, S., 2002. Long-term vegetation changes in experimentally grazed and ungrazed back barrier marshes in the Wadden Sea. In: Bos, D. (Ed.), Grazing in Coastal Grasslands, pp. 111–130.

Boustany, R., 2010. Estimating the Benefits of Freshwater Introduction into Coastal Wetland Ecosystems in Louisiana: Nutrient and Sediment Analyses. Ecological Restoration 28 (2), 160–174.

Caffey, R.H., Wang, H., Petrolia, D.R., 2014. Trajectory economics: Assessing the flow of ecosystem services from coastal restoration. Ecological Economics 100, 74–84.

Carter R.W.G., Hesp, P.A., Nordstrom, K.F., 1990. Erosional landforms in coastal dunes. In: In: Nordstrom, K.F., Psuty, N., Carter, R.W.G. (Eds.), Coastal dunes: forms and process, pp. 129-157. John Wiley & Sons, Chichester.

Craft, C.B., Bertram, J., 2008. Coastal Zone Restoration. In: Jørgensen, E.V., Fath, B. (Eds.), Encyclopedia of Ecology, p. 637-644. Academic Press, Oxford.

Doukakis, E., 2005. Development of the coastal zone. Athens: NTUA, Master of Water Resources Science and Technology (in Greek).

Evelpidou, N., Pavlopoulos, K., Vassilopoulos, A., Triantaphyllou, M., Vouvalidis, K., Syrides, G., 2012. Holocene palaeogeographical reconstruction of the western part of Naxos island (Greece). Quaternary International, 266, 81–93.

Evelpidou, N., Pavlopoulos, K., Vassilopoulos, A., Triantaphyllou, M., Vouvalidis, K., Syrides, G., 2010. Yria (western Naxos island, Greece): Sea level changes in Upper Holocene and palaeogeographical reconstruction. Geodinamica Acta, 23(5–6), 233–240.

Goldsmith, V., 1985. Coastal dunes. In: Davis, R.A. (Ed.), Coastal Sedimentary Environments, pp. 171–236. Springer-Verlag, New York.

Goldsmith, V., 1989. Coastal sand dunes as geomorphic systems. Proceedings of the Royal Society of Edinburgh B96, 3-15.

Hesp, P.A., Thom, B.G., 1990. Geomorphology and evolution of active transgressive dunefields. In: Nordstrom, K.F., Psuty, N., Carter, R.W.G. (Eds.), Coastal dunes: forms and process, pp. 253–288. John Willey & Sons, Chichester.

Hopfensperger, K. N. 2007. A review of similarity between seed bank and standing vegetation across ecosystems. Oikos 116, 1438-1448.

Jackson, N.L., Nordstrom, K.F., Feagin, R.A., Smith, W.K., 2013. Coastal geomorphology and restoration. Geomorphology 199, 1-7.Maglara, M., 2011. Estimation of exposure of Elafonisos coast on coastal natural hazards. Athens: Harokopion University, Department of Geography, MSc ‘Applied Geography and Spatial Management’ (in Greek).

Karkani, A., 2017. Study of the geomorphological and environmental evolution of the coastal zone of Central Cyclades. PhD thesis, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens.

Karkani, A., Evelpidou, N., Vacchi, M., Morhange, C., Tsukamoto, S., Frechen, M., Maroukian, H., 2017. Using beachrocks to track the millennial shoreline evolution in central Cyclades (Greece). Marine Geology, in review.

Katsadorakis, G., Paragamian, K., 2007. Inventory of wetlands of the Aegean Islands: identity, ecological status and threats. WWF Greece (in Greek).

Lamprinoudakis, V., Korres, M., Bournia, E., Ohnesorg, A., 1987. Excavation of an ancient sanctuary in Yria of Naxos. The research during 1982, 1986 and 1987. Archaiognosia 1-2, 133-134, 143-145, 162-163, 185, 190 (In Greek).

Langangen, A., 2004: Charophytes from four Cyclade Islands (Mykonos, Naxos, Paros and Antiparos) in Greece. Journal of Biological Research 1, 31-38.

Lithgow, D., Luisa Martínez, M. Gallego-Fernández, J.B., 2013. Multicriteria Analysis to Implement Actions Leading to Coastal Dune Restoration . In: Martínez, Luisa M, Gallego-Fernández, Juan B., Hesp, Patrick A. (eds.), Restoration of Coastal Dunes. Springer Series on Environmental Management, DOI: 10.1007/978-3-642-33445-0_17.

Louisiana Coastal Protection and Restoration Authority (LCPRA), 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority of Louisiana, Baton Rouge, LA.

Martínez, Luisa M, Gallego-Fernández, Juan B., Hesp, Patrick A. (Eds.), 2013. Restoration of Coastal Dunes. Springer Series on Environmental Management, XIV, 347 p. Springer, the Netherlands.

Maun, M.A., 2004. Burial of plants as a selective force in sand dunes. In: Martínez, M.L., Psuty, N.P. (Eds.), Coastal dunes, ecology and conservation, pp. 119–135. Springer, Berlin.

Merino, J., Aust, C., Caffey, R.H., 2011. Cost efficacy of wetland restoration projects in coastal Louisiana. Wetlands 31, 367–375.

Morgan, P.A., Short, F.T., 2002. Using functional trajectories to track constructed salt marsh development in the Great Bay estuary, Maine/New Hampshire, USA. Restoration Ecology 10, 461–473

Murray, J.W., 1991. Ecology and Paleoecology of Benthic Foraminifers. Longman Publisher, Harlow, 397 p.

Nittrouer, J.A., Best, J.L., Brantley, C., Cash, R.W., Czapiga, M., Kumar, P., Parker, G., 2012. Mitigating land loss in coastal Louisiana by controlled diversion of Mississippi River sand. Nature Geoscience 5, 534–537.

Nordstrom, K.F., 2008. Beach and dune restoration. Cambridge University Press, Cambridge, 187 p.

Nordstrom, K.F., 2008. Beach and dune restoration. Cambridge University Press, Cambridge, 187 p.

Papanikolaou, M., Papanikolaou, D., Vasilakis, E. E., 2011. Changes in sea level and Impacts on the coast. Committee for the Study of Climate Change impacts, BANK OF GREECE, Athens (in Greek).

Serandrei Barbero, S.R., Albani, A.D., Zecchetto, S., 1997. Paleoenvironmental significance of a benthic foraminiferal fauna from an archaeological excavation in the Lagoon of Venice, Italy. Palaeogeography, Palaeoclimatology, Palaeoecology 136, 41-52.

Simenstad, C., Reed, D., Ford, M., 2006. When is restoration not? Incorporating landscape scale processes to restore self-sustaining ecosystems in coastal wetland restoration. Ecological Engineering 26 (1), 27–39.

Triantaphyllou, M.V., Pavlopoulos, K., Tsourou, Th., Dermitzakis, M.D., 2003. Brackish marsh benthic microfauna and paleoenvironmental changes during the last 6.000 years on the coastal plain of Marathon (SE Greece). Rivista Italiana Paleontologia et Stratigafia 109 (3), 539-547.

van der Hagen, H.J.M.L., Geelen, L.H.W.T., de Vries, C.N., 2008. Dune slack restoration in Dutch mainland coastal dunes. Journal of Nature Conservation 16, 1–11.

Vandenbohede, A., Lebbe, L., Adams, R., Cosyns, E., Durinck, P., Zwaenepoel, A., 2010. Hydrogeological study for improved nature restoration in dune ecosystems — Kleyne Vlakte case study, Belgium. Journal of Environmental Management 91, 2385–2395.

Woodhouse, W.W. Jr, Seneca, E.D., Broome, S.W., 1977. Effect of species on dune grass growth. International Journal of Biometeorology 21, 256–266.

Zwaenepoel, A., Cosyns, E., Lambrechts, J., Ampe, C., Langorh, R., Vandenbohede, A., Lebbe, L., 2007. Integrale gebiedsvisie en beheerplan voor het Vlaamse Natuurreservaat “De Zwinduinen en-polders” te Knokke-Heist, met aandacht voor het recreatief gebruik. (Integrated perspective and management plan for the Flemish nature reserve ‘The Zwindunes and Zwinpolders’ at Knokke-Heist, with attention to recreational joint use). WVI, Aeolus & Universiteit Gent.

Field trip day 3, 24/03/2017

Fresh water ecosystems/ Degradated areas

Responsible University: National and Kapodistrian University of Athens

Participating Institutes: USC, ULisbon, CNR-ISE

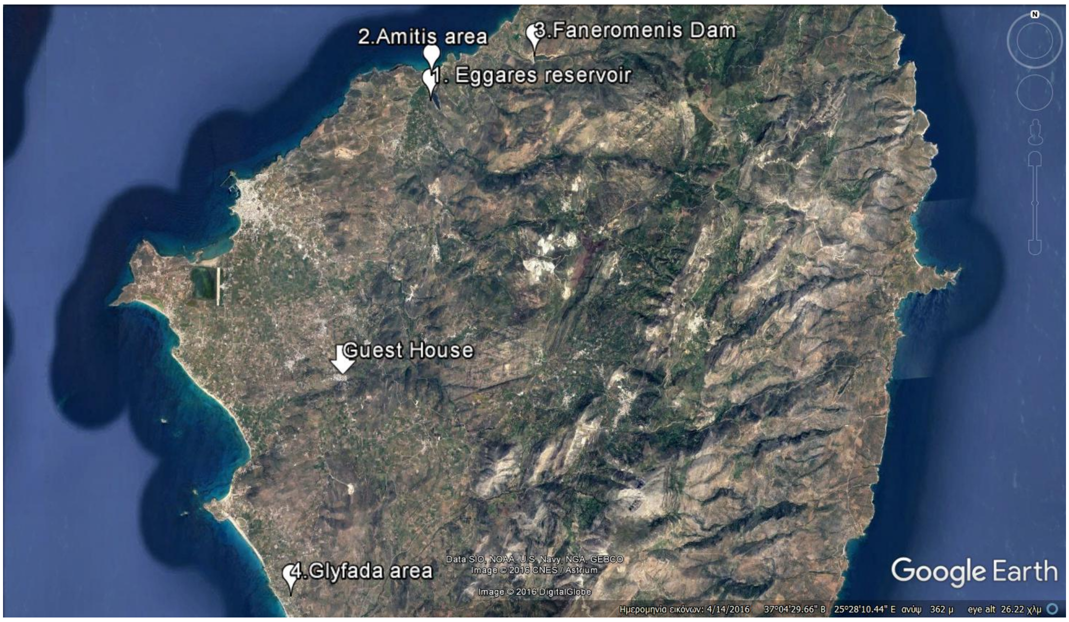


Fig. 31: Field trip locations (Google Earth image)

In this field trip we will go through different sectors of a Mediterranean river basin, and relate riparian changes with observed pressures, by combining aerial images with field assessment, making use of the QBR index of riparian quality (Munné *et al.*, 2003).

Stop 1. Eggares area reservoir

Patricia Rodríguez González, Aikaterini Giannikopoulou

Location and physical characteristics

The selected site for the construction of the reservoir is located at the foot of hills extending to the northwest coast of Naxos, about 8 km from the town of Naxos, 1.5 km north of Eggares community and 650 m from the sea. Geomorphologically, the site of the reservoir, is a valley of northern exposure, relatively flat (slopes 0,5% - 2%) and is surrounded by hills characterized by gorges and steep slopes. To the north, the valley opens to the sea. The water intake site is located 2,5 km south of Eggares community. The site of the embankment of the reservoir is to the sea and is covered by dunes. The whole project's area is characterized by brushwoods and includes rural ground.

Fig. 32: Eggares reservoir. Photo by Manolis Lykouropoulos.

The reservoir has been designed so that, through the water intake, it concentrates the surface runoff of the particular location's catchment area. This basin has an area of 14.82 km^2 and an average altitude of 507 m. The hydrographic network of the basin includes many small streams, that contribute to the basic torrent of Eggares (non-permanent flow).

From a geological point of view, the basin consists of 80-85% of schists and gneisses (impermeable rocks) and 15% of marbles (semi-permeable rocks). The area of the reservoir consists of alluvial sediments and the surrounding hills are composed of tertiary age conglomerates.

Technical characteristics - Parts of the establishment

The reservoir of Eggares was designed and constructed, in order to meet the irrigation needs of the Eggares plain and for providing water supply in the surrounding areas. The reservoir has the following characteristics:

- It occupies an area of 40.000 m^2
- Its net capacity is 585.500 m^3
- It is coated with a sealing membrane
- It includes an embankment of 15 m height

There are also included the following structures:

- Drainage Network
- Perimeter trenches for collecting rainwater
- Trapezoidal section spillway
- Water supply shaft

Surface runoff collection (water intake) is achieved by diverting water with a small dam (1m high), that leads the water from the stream in the supply shaft of the reservoir.

In this downstream section of the basin local pressures, due to land use, (river constrained by surrounding agriculture, channelization) and, also, the effect of upstream changes, are visible when comparing google earth pictures from 2003 and 2016.

Application of QBR index

In this stop we will make observations of vegetation, habitat structure and lateral connectivity with terrestrial ecosystems in a less disturbed section of the hydrographic basin. We will also identify existing pressures (water diversions? any artificial structure? exotic species? erosion from upland?)

Weir – hydrologic regime alteration from 2003 to 2016

Observations regarding hydromorphological changes and effects on surrounding riparian vegetation will take place. Comparison of google aerial pictures, 2003 to 2016, and in-situ vegetation/habitat indicators will be examined.

Fig. 33: Top image: 2003 –Weir seems to enable some overflow. Bottom image: 2016 – Weir seems to have become a stronger barrier - new regime use.

Channelization in river

In this downstream section of the basin local pressures, due to land use, (river constrained by surrounding agriculture, channelization) and, also, the effect of upstream changes, are visible when comparing google earth pictures from 2003 and 2016.

Fig. 34: Top image: 2003 – Narrowed channel but some dynamics in certain sections, water visible. Establish relationship with the weir upstream enables water flow, maintaining some dynamics. Bottom image: 2016 – Less fluvial dynamics, vegetation encroachment due to upstream regulation (weir).

Stop 2. Vegetation at rivers, Amitis drainage system

Patricia Rodríguez González, Aikaterini Giannikopoulou

The mouth of the creek in Amity Beach is 2.1 km. north of Engares community in Naxos. The wetland's area is 52.500 m^2. This wetland is supplied by the water of the creek that originates in Skoulikaria springs, located in Eggares, and by groundwater. The wetland is also influenced by the sea (salinity 4,47 g / l, in the spring of 2002 Langangen, 2004). The alluvial ground of the wetland have been expropriated long ago due to extensive farming. In the agricultural areas there are currently abundant natural windbreaks of trees and the reed *Arundo donax*. Its importance for migratory birds is remarkable. The main habitats found are: Shifting dunes along the shoreline with *Ammophila arenaria*, Mediterranean salt meadows (*Juncetalia maritimi*), embryonic shifting dunes, reeds and hard oligo-mesotrophic waters with benthic vegetation. The extensive sandy beach is covered by sand dune vegetation *Otanthus maritimus*, *Euphorbia maritima*, *Porobolus pungens* and *Matthiola tricuspidata*. On the banks of the estuary grows the reed *Phragmites australis,* few *Arundo donax*, arboreal vegetation (*Tamarix sp.*) and *Juncus sp.* The wetland's basin is covered by intensive and extensive crops of vegetables, cereals and vineyards. The wetland protected by the PD small island wetlands of Greece (Y422NAX006, GG 229 / SSO / 2012). (Field data collection: 4/2005. INVENTORY: C. Katsadorakis).

Fig. 35: Amitis, Creek mouth. Photo by Manolis Lykouropoulos.

Riparian vegetation in Mediterranean regions

Riparian corridors in Mediterranean-climate regions are resource-rich habitats within water-limited landscapes. Plant species are adapted to multiple abiotic stressors, including dynamic flooding and sediment regimes, seasonal water shortage, and fire. Yet, long term impacts have severely degraded these ecosystems from land-use conversion to agriculture, streamflow regulation, nutrient enrichment, biological invasions and climate change, making them extremely vulnerable (Stella *et al.*, 2013).

Riparian vegetation as plant community is the main structural component of riparian ecosystems and thus its structure and change provide useful information on the underlying changes in the fluvial system. For this reason, it is a reliable tool for monitoring riparian ecosystems state and related services (Rivaes *et al.*, 2013). Particularly in arid and semi-arid regions, riparian areas host high local plant diversity and a greater proportion of the biome's tree species than their counterparts in temperate or tropical regions. They also host a large proportion of the surrounding biome's wildlife species for some portion of their life history (Stella *et al.*, 20131).

Riparian plants display a tight association with fluvial processes and their physical drivers in Mediterranean regions. Riparian physical drivers in Mediterranean regions can be divided into five principal categories: (1) flood magnitude and hydraulics; (2) flood timing; (3) streamflow and water table dynamics; (4) sediment dynamics and texture; and (5) fire. In this association, plants are not only passive but active components as river system engineers (Gurnell, 2014). The influence of plants on river systems is significant across space scales from individual plants to entire forested river corridors role particularly in stabilizing banks, modulating sediment dynamics and through its contribution to hydraulic roughness. These processes in turn affect the rate and spatial pattern of floodplain development, and influence recruitment success of seedling cohorts through seedbed availability, water table depth, and sediment texture.

Recent research is providing increasing understanding over riparian vegetation pattern and functioning as a basis for rational resource management in Mediterranean regions. Yet, multiple historical and current impacts jeopardize their sustainability. Globally, human pressure will increase in Mediterranean regions (Underwood *et al.*, 2009) and climate change is reducing the water supply in most of them. Specific strategies for riverine and riparian management need to take into account future changes. For this purpose, limiting further degradation and developing rehabilitation approaches, that increase their resilience, are urgently needed.

QBR INDEX

The QBR index was initially developed in Mediterranean rivers in Spain (Munné *et al.*, 2003), and has already been applied in several countries, including Greece (Chatzinikolaou *et al.*, 2011). Calculation of the QBR index in the field is made using a two-sided sheet, which is completed by a field surveyor. The index is based on four components of riparian habitat: total riparian vegetation cover, cover structure, cover quality and channel alterations. It also takes into account differences in the geomorphology of the river from its headwaters to the lower reaches. These differences are measured in a simple, quantitative way. The index score varies between 0 and 100 points.

Field site:

Site width: Before the QBR calculation, the main channel and floodplain zone should be differentiated (see the figure at the top of the field sheet) identifying the bankfull zone. Although the delimitation of the riparian zone is not always easy, the observer should use all the available indicators of the riparian area, such as fluvial terraces, presence of riparian vegetation and evidence of the effects of large floods. In highly modified areas, a compromise is made between the true riparian area, lacking of human impact, as well as the present situation, where extensive agriculture or forest plantations may exist. For index determination, the river is divided into two sections: the main channel and the riparian area. The former is subdivided into two: the area permanently covered with flowing water (which is not considered in the scoring process), and the channel zone between the permanently flowing reach and the bankfull state (see the figure at the top of the field sheet).

Site length: The index must be calculated in river or stream lengths of 50m (upstream areas) or 100m (middle and lower reaches).

Field sheet structure:

1-Total vegetation cover. This is assessed both for the riparian and channel areas and includes any kind of tree, bush, shrub or helophyte. Grasses are excluded because they are annual plants and their cover may vary very much, depending on the year and the hydrological conditions.

2-Vegetation cover structure. An assessment of the structural complexity of the riparian environment is made, that may increase the bio-diversity of the fluvial ecosystem, both for animals and plants.

3-Cover quality. The number of tree species, present in a stream reach, will vary depending on river geomorphology and stream type. Three stream types are defined according to the total geomorphological score, depending on the form and slope of the riparian environment (field sheet).

4-River channel alterations. Man-made river channel alterations are included in the index because they consist one of the main disturbances to the riparian habitat too (channelization, rigid structures, alluvial terraces, embankments, weirs, river crossings, wells for water abstraction…).

Classes of riparian quality

After completing the analysis, the sum of the four parts gives the final QBR index. The index varies between 0 and 100. There are five quality classes of riparian habitat, which broadly correspond to those suggested in the Water Framework Directive (European Commission, 2000).

Table 9: Quality classes according to the QBR index

Riparian habitat quality class	QBR	Colour
Riparian habitat in natural condition	≥95	Blue
Some disturbance, good quality	75–90	Green
Disturbance important, fair quality	55–70	Yellow
Strong alteration, poor quality	30–50	Orange
Extreme degradation, bad quality	≤25	Red

Stop 3. Dam Faneromenis

Sofia Kagani

The Faneromeni Dam is located in the NW part of Naxos, in the torrent of Skinos and a few hundred meters away from the sea. This is a recovery project of the torrent Skinos water or Faneromeni, for irrigation, initially, purposes and additionally for the water supply of Naxos Town. The construction of the dam was completed in 2001. During the study for the construction of the dam, the underground water level was detected in the depth of 7,50m. The location of the dam is characterized by a strong morphological relief, as the slopes are steep on both abutments and range from 40-50%, while the valley of Skinos has a general orientation E-W. The Faneromeni Dam is LAPS type (rockfill with upstream plate concrete), height 48.5 m, crest width of 5m, crest length of 260m and embankment volume 451.500 m3, with a physical barrier (gneisses, schists).

Fig. 36: View of the Faneromeni Dam, in the NW part of Naxos. Photo by Manolis Lykouropoulos.

The lack of sufficient amount of clay material did not allowed the construction of a rockfill dam with clay core. Its capacity and usable volume reaches 1.467.000 m3. Because of the bad conditions of stability in the left abutment, additional measures were required, by removing the loose cover materials. The water supply of the Faneromeni dam is made by three independent sources, arranged on the slope of the right abutment. Furthermore, the water of the dam through reduced pressure is guided in the water refinery and the reservoir

Eggares, and then, through the irrigation pump is driven in the balancing tank and the irrigation network.

However, the water intake from the bottom was creating turbulence problems and high refining cost. To address the above problems, as well as for the functional rehabilitation of the networks, it was conducted a floating abstraction construction and reconstruction, modernization and automation of the operation of the distribution block valves and of the water reservoir and the dam.

Fig. 37: Downstream area of Faneromeni dam. Photo by Manolis Lykouropoulos.

Stop 4. Wetlands, Glyfada area

The wetlands of Glyfada area are located 12,5 km South of Naxos and are included in the inventory of WWF Hellas for wetlands Aegean (Katsadorakis and Paragamian, 2007). They occupy an area of 149.300 m^2. The wetlands are nearly three distinct coastal ponds, forming a type of lagoon, with their water ranging from fresh to hypersaline. The inflow of fresh water is the discharge of the aquifer and salt water enters from the sea. Right next to the lakes, from the land side, there are old wells. Perhaps it is the best preserved wetland on the west coast of Naxos, which is largely characterized by the exceptional beauty of the landscape and includes a priority habitat, coastal dunes with Juniperus spp. Also, the following habitats are included: Lagoons, Mediterranean salt meadows, shifting dunes with Ammophila arenaria, hard oligo-mesotrophic waters with Characeae, and reeds. The wetland is an important station for many species of migratory birds and the presence of fishes is probable. The wetland's basin is dominated by rocky hills with brushwoods and it is sparsely built. Glyfada wetlands are located within the boundaries of the Special Area of Conservation (GR4220014) and the Wild Life Refuge (Government Gazette 857 / B / 2004) but they are threatened by further building, dune encroachment by bathers and perhaps pollution. [Visit the census: C. Katsadorakis 4/2005 K. Paragamian 12/2005].

Fig. 38: Wetlands, Glyfada. Photo by Manolis Lykouropoulos.

References

Chatzinikolaou, Y., Ntemiri, K., Zogaris, S., 2011. River riparian zone assessment using a rapid site-based index in Greece. Fresenius Environmental Bulletin 20, 296-302.

Gurnell, A.M., 2014. Plants as river system engineers. Earth Surface Processes and Landforms 39, 4-25.

Langangen, A., 2004. Charophytes from four Cyclade Islands (Mykonos, Naxos, Paros and Antiparos) in Greece. Journal of Biological Research 1, 31-38.

Munné, A., Prat, N., Solà, C., Bonada, N., Rieradevall, M., 2003. A simple field method for assessing the ecological quality of riparian in rivers and streams: QBR index. Aquatic Conservation: marine and freshwater ecosystems 13, 147-163.

Rivaes, R., Rodríguez-González, P.M., Albuquerque, A., Pinheiro, A., Egger, G., Ferreira, M.T., 2013. Riparian vegetation responses to altered flow regimes driven by climate change in Mediterranean rivers. Ecohydrology 6, 413-424.

Stella, J.C., Rodríguez-González, P.M., Dufour, S., Bendix, J., 2013. Riparian vegetation research in Mediterranean-climate regions: common patterns, ecological processes, and considerations for management. Hydrobiologia 719, 291–315.

Underwood, E. C., Viers, J. H., Klausmeyer, K. R., Cox, R. L., Shaw, M. R., 2009. Threats and biodiversity in the Mediterranean biome. Diversity and Distributions 15, 188–197.

Field trip day 4, 29/03/2017

Wildfire areas

Responsible University: University of Santiago de Compostela / National and Kapodistrian University of Athens

Fig. 39: Field trip locations (Google Earth image).

Stop 1. Kinidaros area

Agustin Garcia Merino, Miltiadis Athanasiou

Introduction

Causes of wildfire in the Mediterranean region

In Mediterranean regions the climate and vegetation found promote naturally wildfires of special intensity and fast-spreading. These climatic conditions favours the accumulation of fuel load during autumn to spring, which became dry in summer, when the high temperatures and low air humidity promotes fire ignition. From the 60's a dramatic increase in fire activity has taken place, as a consequence of afforestation schemes with flammable plantations, the encroachment of shrubs after rural depopulation. In addition, the global warming favours the occurrence of fires.

Characteristics of the wildfires

Fire behavior is the manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuel, weather and topography.

Fire managers use various fire behavior descriptors such as rate of spread, flame length, fire line intensity, spotting, the onset of crowning (or crowning initiation and/or propagation), etc. The term Rate of Spread (ROS, km/h or m/min) refers to the linear rate of advance of a wildfire either it is a head fire or not (Fig. 40). Head of the fire is the segment of the fire perimeter oriented in the direction of maximum spread (fanned by the wind or/and burning upslope) whereas heel of the fire is that segment of the fire perimeter that spreads against the wind or/and burning downslope (Fig. 40).

Flame length (FL, m), has been used to describe suppression difficulty (Alexander, 1982; Anderson *et al.*, 2006). Flame size is directly related to the frontal fire intensity (Forestry Canada Fire Danger Group, 1992) or fire line intensity (Byram, 1959; Albini, 1976) (I, kW/m) which is defined as the energy output rate per unit length of fire front. Depending on the fuel biomass which is available for consumption, the general weather conditions and the time of the year, the fire intensity may vary, influencing the heat per meter of fire line that the soil is subjected to.

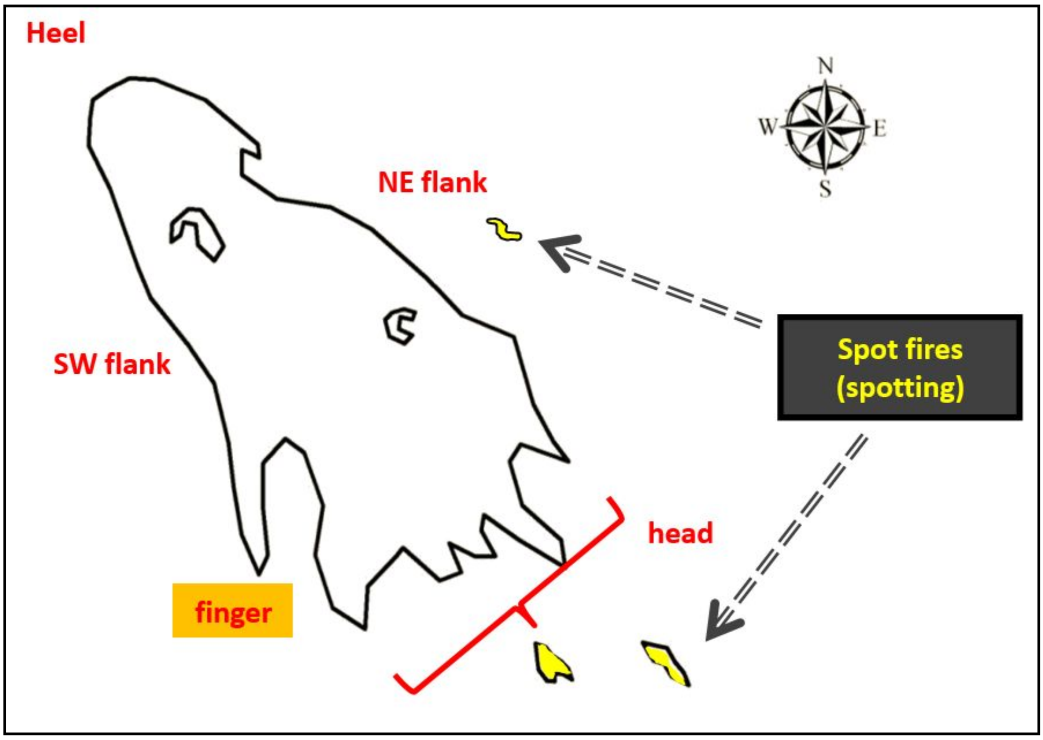


Fig. 40: The anatomical parts (segments) of a wildfire.

Effects of fire on soil properties and soil conservation

Soil burn severity

Wildfires can significantly perturb soil properties, thus affecting plant growth and having important implications for ecosystem recovery. The term "soil burn severity" is often used to describe the level of perturbation caused by fire in soil. The burnt area is a spatially complex mosaics of burned soil patches with a wide range of soil burn severities.

Evaluation of this parameter is a critical step in the decision making process for soil rehabilitation tasks.

Table 10: Soil burn severity classes containing five levels, including an unburned state, through the immediate post-fire soil and duff visual characteristics (modified version of Ryan and Noste's, 1985).

LEVELS OF SOIL BURN SEVERITY	FOREST FLOOR	MINERAL SOIL (A HORIZON)
0	No evidence of fire	No evidence of fire
1	Oa layer (lower duff) partially or totally intact.	Undisturbed
2	Oa layer totally charred and covering mineral soil. There may be ash.	Undisturbed
3	Forest floor completely consumed (bare soil). There may be ash.	Undisturbed. Soil structure unaffected. SOM not consumed. Surface fine roots not burned.

4	Forest floor completely consumed (bare soil). There is no charred residue. Thick layer of ash.	Soil structure affected. SOM consumed in the upper layer. Surface soil colour altered (grey). Surface fine roots burned.
5	Forest floor completely consumed (bare soil). There is no charred residue.	Soil structure affected. SOM consumed in the upper layer. Surface soil colour altered (reddish). Surface fine roots burned.

Changes on soil properties related to erosion and vegetation recover in burned areas

Wildfires affect soil properties, which are important for soil conservation and subsequent rehabilitation. In the moderate and high severities, SOM content is decreased, affecting soil aggregate stability and infiltration. Remarkable increases in soluble base cations (Ca, Mg and K) and phosphorus is often found. One of the most common effects of the fire is the increase in soil pH. After rainfall, this feature implies a net loss of elements from the system, leading to decreased soil fertility.

As a consequence of the higher soil erodibility, the erosion rates in these environments can be extreme. Erosion rates of more than 50 t ha-1 are usually recorded in fire of high intensities. In several studies high erosion rates are recorded, even after the third year of the wildfire.

Land rehabilitation after wildfire: Erosion control and revegetation of burned areas

Natural regeneration

In the lowest burn severities a high number of plant species can regenerate after fire. This effect favours the revegetation in many areas, especially in acidic soils. However, when the severity of the fire is high, the natural regeneration can be difficult due to the lack of seeds, the soil degradation and high erosion rates.

Mulching

Mulching provides immediate ground cover and protects soils from erosion and nutrient capital loss. This practice can reduce runoff volumes in 50 % and soil erosion in 90 %. Mulching methods include aerial and ground application using straw, woodchips, or fiber materials.

Erosion barriers

The trunks and rock barriers placed in steep hillslopes create small barriers where flow of water is reduced and sediments trapped. Other similar materials, such fiber rolls, or sandbags, are commonly used.

Channels treatments

Channel treatments are dam structures made of straw bales, stones, sticks or even sandbags, can be installed to stabilize channels and retain sediments. The dams can, also, done with trunks. They are more resistant than those of straw bale. They are implemented to avoid gully erosion and to stabilize the channel gradient.

Seeding

It is the establishment of fast growing vegetation species, in order to provide ground cover until native vegetation get recovered. Seeding application can be both aerial or manual. Previous effectiveness results of seeding alone showed poor results the first year and variable results in subsequent years. The efficiency of this technique depends highly on rainfall intensity. In addition, seeded grasses usually compete with the native vegetation.

History of wildfire in Naxos

In Naxos, the vegetation species vary, mostly depending on the geologic formation of the island areas; where the bedrock is schist, the dominant phryganic species is *Genista acanthoclada*, whereas in limestone (southern Naxos), the dominant species is *Coridothymus capitatus*. There are, also, scattered shrubs, such as juniper trees and oaks (*Quercus coccifera, Acer sempervirens,* etc.). Moreover, close to the peak of Za - the mountain that stands roughly 13.5 km to the southeast of Naxos town (Chora) and 7.7 km to the south of Kinidaros area - there is a last clump of oaks (*Quercus ilex*), which grow for hundreds of years and are still standing as a reminder of the ancient forests of Naxos.

Fig. 41: A typical landscape of Naxos, covered by a Mediterranean vegetation mosaic of phryganic species and maquis. Photo by Miltiadis Athanasiou.

Phrygana (*Sarcopoterium spinosum, Phlomis fruticosa, Cistus spp., etc.*) are low, often thorny, xeric shrubs up to 0.5 m height which are adapted to high fire frequency and occupy lower elevation areas. They are fine, quite flammable, flashy fuels and respond very quickly to changes of the environmental conditions (Xanthopoulos 2007). Fire in phryganic areas is characterized by low to medium fire intensity and can reach very high rates of spread under high wind conditions.

Maquis (*Arbutus unedo, Pistacia lentiscus, Pistacia terebinthus, Phillyrea latifolia, Quercus coccifera, etc.*) are tall or short typical Mediterranean evergreen shrublands. Those shrublands consist of drought-resistant broadleaved species, their fuel height ranges from 0.5 to more than 2.5 m and fuel load varies accordingly. Fire behavior varies significantly and depends on species composition, site characteristics, fuel loads, intensity of livestock grazing, etc.

Most of the phryganic (e.g. *Sarcopoterium spinosum, Phlomis fruticosa*) and maquis species (*Quercus coccifera, Pistacia lentiscus, Arbutus unedo, Phillyrea sp. Erica arborea*) re-sprout vigorously after the fire, while some phryganic species (e.g. *Cistus spp.*) are obligate seeders.

The effects of fire on soil depend on the temperature and the residence time of the fire, as well as the soil moisture content (Canu *et al.*, 2007). The degree of change in both the chemical and biological properties of soil are strongly linked with fire intensity (Flinn *et al.*, 1984). Exposure of the mineral soil may lead to loss of nutrient (Chesterfield, 1984) and organic matter. Some of these events may be further aggravated by the weather conditions following fire (Canu *et al.*, 2007).

In the past, people terraced the sloping land of the island and created plateaus, in order to support the so-called terrace cultivation. The steep slopes have been cut into a series of terraces with the construction of dry stone walls, to stop soil erosion and consequently create space for cultivation. Quite often, many of those low and dry stone walls are being revealed after bushfires.

Abandonment of rural areas, fire-prone ecosystems, that consist of species which are highly flammable and the poor fuel management, have increased fire hazards, during the last decades in Greece. It could be argued, that forest fire risk (a function of the wildfire hazard agent, the exposure of the forest areas or structures, reduced by the capacity of the responsible organizations to mitigate and recover from loss) is growing in Naxos, mostly as a result of the complexity of the Rural Urban Interface (RUI).

Kinidaros wildfire

The weather conditions (mostly the strong wind), the landscape (topography), the forest fuels, as well as the interactions among them, affected the behavior of "Kinidaros" wildfire. It was a surface fire (it burned through surface fuels, the maximum height of which was roughly 2.5 meters) of medium to high intensity.

Fig. 42: Kinidaros wildfire burn scar.

Kinidaros wildfire was fanned by a south wind (Fig. 42) and spread through a rough landscape (steep slopes, ravines, gorges, narrow valleys, saddles, ridges and spurs), threatening many structures).

Stop 2. Komiaki area

Merino Garcia Agustin, Miltiadis Athanasiou

Komiaki wildfire

The weather conditions (mostly the strong wind), the landscape (topography), the forest fuels, as well as the interactions among them, affected the behavior of "Komiaki" wildfire. It was a surface fire (it burned through surface fuels, the maximum height of which was roughly 2.5 meters) of medium to high intensity.

Fig. 43: Komiaki wildfire, threatening a structure in the Rural Urban Interface, (Komiaki wildfire, November 9, 2016). Photo by Manolis Lykouropoulos.

Fig. 44: Flame length describes suppression difficulty, visualizing and being directly related to the fire line intensity (Komiaki wildfire, November 9, 2016). Photo by Manolis Lykouropoulos.

Komiaki wildfire was driven by a strong southeast wind and spread through a rough landscape (steep slopes, ravines, gorges, narrow valleys, saddles, ridges and spurs), threatening many structures (Fig. 43). The interaction between the general wind, the terrain and the energy that was released by the latter fire, affected its propagation, leading to erratic fire behaviour and made firefighting very difficult and dangerous (Fig. 44).

References

Albini, F.A., 1976. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: USDA, Forest Service, Intermountain Forest and Range Experiment Station, 92 p.

Alexander, M.E., 1982. Calculating and interpreting forest fire intensities. Canadian Journal of Botany 60, 349-357.

Anderson, W., Pastor, E., Butler, B., Catchpole, E., Dupuy, J.L., Fernandes, P., Guijarro, M., Mendes-Lopes, J.M., Ventura, J., 2006. Evaluating models to estimate flame characteristics for free-burning fires using laboratory and field data. In: Viegas, D.X. (Ed.), ‘Proceedings, V International Conference on Forest Fire Research’, 27–30 November 2006, Figueira da Foz, Portugal. (CD-ROM). Forest Ecology and Management. 234S. S77.

Byram, G.M., 1959. Combustion of forest fuels. In: Davis, K.P. (Ed.), Forest fire: Control and use, pp. 61-89. McGraw-Hill, New York.

Byram, G.M., 1959. Forest fire behavior. In: Davis, K.P. (Ed.), Forest fire: Control and use, pp. 90-123. McGraw-Hill, New York.

Canu, A., Arca, B., Ghiglieri, G., Pittalis, D., Deroma, M., Ventura, A., Arca, A., 2007. Fire intensity in moderate drought conditions: effect on topsoil properties in Mediterranean shrubland vegetation. Seventh Symposium on Fire and Forest Meteorology, Bar Harbor, ME American Meteorological Society.

Chesterfield, E.A., 1984. Effects of Fire on the Flora of dry Sclerophyll Forest. In: Ealey, E.H.M. (Ed.) Fighting Fire with Fire, pp.129-145. Proceedings of Symposium on Fuel Reduction Burnibg, Monash University, Victoria, September 17-18, 1983.

Flinn, D.W., Farrell, P.W., Steward, H.T.L., Leitch, C.J., Hopmans, P., 1984. The Effects of Fire in Eucalypt Forest on Soil, Nutrient Cycling, Tree Growth and Catchment Hydrology: a Review with Particular Reference to Fuel reduction Burning. In: Ealey, E.H.M. (Ed.) Fighting Fire with Fire, pp. 146-185. Proceedings of Symposium on Fuel Reduction Burnibg, Monash University, Victoria, September 17-18, 1983.

Forestry Canada Fire Danger Group, 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Forestry Canada Information Report ST-X-3, 66 p.

Xanthopoulos, G., 2007. Forest fire related deaths in Greece: confirming what we already know. Book of abstracts of “IV International Wildland Fire Conference”, May 13-17, 2004, Seville, Spain, p. 339. Full paper on the CD accompanying the book of abstracts.