

An Example of a Detailed Beach Inventory at an Island Scale: The Case of Chios, Greece

Monioudi I.N.¹, Andreadis O.P.¹, Chatzistratis D.¹, Chalazas Th.¹, Hasiotis T.*¹, Velegrakis A.F.¹, Monioudis E.N.², Mettas C.³, Koutsantonaki Ch.¹

¹Department of Marine Sciences, University of the Aegean, University Hill, 81100 Mytilene, Greece

²Department of Financial and Management Engineering, University of the Aegean, 41 Kountouriotou Str., 82100 Chios, Greece

³Department of Civil Engineering and Geomatics, Cyprus University of Technology, 3036 Limassol, Cyprus

*corresponding author: T. Hasiotis

e-mail: hasiotis@aegean.gr

Abstract This contribution presents an example of a detailed beach inventory that can provide a comprehensive understanding of beach characteristics, using as a case study the island of Chios. The inventory was assembled using various sources, such as satellite imagery, optical information/tools provided by the Google Earth Pro application, online resources, and local information sources, including interviews with locals. The ‘dry’ beaches were digitized as polygons on the satellite imagery. Metadata production from the digitized polygons was carried out in GIS. Geospatial information (e.g., width, area, orientation), environmental characteristics (e.g. sediment texture, coastal dunes, cliffs, rivers), socio-economic parameters (e.g. beach development, touristic activity) and human intervention features (e.g. coastal defenses, port facilities) were included in the database. The spatial characteristics and other attributes of the island beaches stored in the database were statistically analyzed, to identify underlying relationships. The geographical distribution of the beach characteristics along the coastline of Chios was also analyzed. This database serves as a vital management tool, facilitating the fulfilment of relevant legal obligations of Greece regarding coastal management. Its comprehensive and detailed information supports effective decision-making and aids in the sustainable management of the island’s beaches.

Keywords: Beach inventory, Chios, Geo-spatial characteristics, Statistical analyses

1. Introduction

Beaches play a crucial role in protecting important coastal habitats (Katsanevakis et al., 2015) and the valuable assets and infrastructure (Neumann et al., 2015) that exist in the backshore, since they serve as a natural buffer against coastal flooding. Also beaches are critical economic resources, being the focus of the 3S (Sea-Sun-Sand) tourist industry. However, the intensification of climate change in recent decades has exacerbated the existing challenges of erosion and flooding, posing a significant threat to beaches (Vousdoukas et al, 2020) and the benefits they offer.

Island beaches are particularly susceptible to erosion due to their limited size and reduced sediment supply (Velegrakis et al., 2008). The increasing use of these beaches and the development of urban areas in the backshore further contribute to their vulnerability. To ensure the sustainable management of touristic beaches, particularly on islands, it is essential to develop integrated management plans at both regional and national levels.

One of the immediate priorities of environmental policy and spatial planning should be the comprehensive documentation of beaches. This involves creating detailed beach inventories that provide a comprehensive understanding of beach characteristics. This contribution presents an example of such a detailed beach inventory, focusing on the island of Chios. By conducting a thorough assessment of the island's beaches, valuable insights can be gained to inform effective management strategies and promote the long-term sustainability of these important coastal resources.

2. Methodology

A beach inventory of the island of Chios was assembled using various sources, such as satellite imagery, optical information/tools provided by the Google Earth Pro application, online resources, and local information sources, including interviews with locals. Qualitative and quantitative information was collated about the physical and socioeconomic attributes of the beaches. The ‘dry’ part of the beaches was digitized as polygons with their onshore boundary set to be the stabilized (vegetated) dunes/coastal cliffs and/or human infrastructure (coastal roads, seawalls and buildings), whereas the shoreline was the sea boundary. The lateral extent of the beaches was delimited by promontories, rocky coasts, or coastal works. The digitization process followed standard rules for the polygons delimitation and data entry to ensure consistency. Metadata were produced from the digitized polygons in a GIS environment.

The recorded attributes of the Chios database include:

1. General information: each beach has a unique ID and name, and the date of the satellite imagery acquisition.
2. Quantitative geospatial characteristics: the database captures beach dimensions such as area, length, and maximum width (BMW). It also includes the location and orientation of each beach.
3. Environmental characteristics including: (i) sediment texture which is qualitatively classified as sand, a mixture of coarse sand, gravel/pebbles, or pebbles; (ii) beachrock existence; (iii) the presence of river or stream mouth near the beach which suggests a potential sediment supply; (iv) special environmental protection regime, such as Natura 2000 or Small Island wetlands; (v) backshore features that include the presence of coastal dunes, cliffs, lagoons, swamps, farms, and cultivation areas in the immediate backshore; (vi) vegetation coverage at the immediate backshore measured as a percentage of the beach length.
4. Socio-economic parameters, such as: (i) beach development which indicates the presence of organized facilities like umbrellas, lifeguards, and water sports activities; (ii) touristic activity, i.e. information on nearby restaurants and accommodation places, which reflects the level of tourism in the vicinity of the beach; (iii) the number and frequency of the visitors (traffic) at the beach based on interviews from the locals and optical information from web resources; (iv) accessibility which indicates the quality of the road network and connectivity to the main road network; (v) Blue Flag awards, which signify high environmental and safety standards, (vi) backshore assets (urbanization), i.e. the coverage of frontline backshore assets/infrastructures measured as a percentage of the beach length.
5. Human intervention features at the beach or its vicinity that include coastal defences such as breakwaters, groynes, and jetties and also port facilities distinguished between fishing ports, marinas, and passenger ports.

The spatial characteristics and other attributes of the island beaches stored in the database were statistically analysed, to identify underlying relationships. The geographical distribution of the beach characteristics along the coastline of Chios was also analysed.

3. Results

3.1. Statistical analysis

The database of Chios contains information for 153 beaches, with a total area of approximately 0.43 km². The total carrying capacity (the number of users that can be simultaneously accommodated) is calculated to be around 19,363 visitors, based on an accommodation space of 22 m² per visitor (Chen and Teng, 2016).

The maximum width of the beaches is considered a significant indicator of their vulnerability to sea-level rise, and as seen from the statistical analysis, the majority of Chios' beaches are narrow, with 81% of recorded maximum "dry" beach widths being less than 50m and 99% of less than 50m; only 2 beaches exceed 60m in width (Figure 1a).

In terms of the sediment type, 6% of the beaches are sandy, 73% are composed by mixed sediments (coarse sand/gravel/pebbles), while the remaining beaches consist of pebbles (Figure 2c).

Regarding the backshore features, coastal dunes are present at only 4 sites, and about 19% of the beaches are partially backed by coastal cliffs. Also, more than 48% of the beaches are directly backed by coastal infrastructures/assets, indicating a high risk of coastal squeeze from increasing sea levels. The coverage of frontline backshore assets is higher than 5 % for about 25% of Chios' beaches, and higher than 75% for about 18% of the beaches (Figure 1b, Figure 2i).

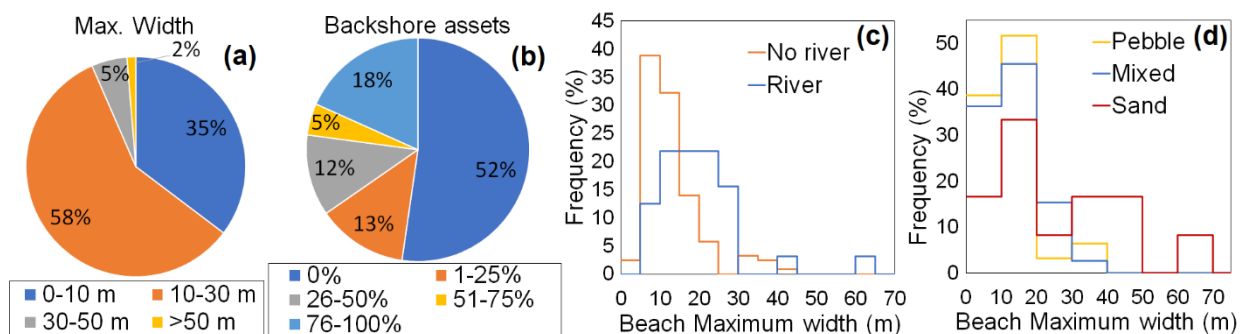


Figure 1. Statistics of Chios' beaches. Pie diagrams of (a) max. width and (b) backshore assets; (c) relationship between beach maximum width (BMW) and the presence of river/stream; (d) Relationship between BMW and sediment type

Port facilities are hosted on 16% of the beaches, with the majority being fishing ports (14%), along with two passenger ports in the city of Chios and Mesta village. Coastal defences are present on 21% of the beaches with groynes being the dominant structures.

Beaches facing the SW sector are wider with mean BMWs exceeding 20m, beaches facing the N, NW and S sectors recorded mean (per direction) BMWs of more than 16m, whereas mean BMWs for the other directions were less than 13m.

Chios is characterized by scarcity of freshwater and only 21% of the beaches were found to be associated with river or (mostly) stream mouth. However, the presence of rivers/streams appears to influence beach width; beaches with rivers/streams at their vicinity are more likely to be wider than those without them (Figure 1c). Beaches with rivers/streams have an average BMW of 20m, compared to an average BMW of 13.6m for beaches without rivers/streams. There is also a correlation between sediment type and maximum width; beaches with finer sediments are associated with larger maximum widths (Figure 1d).

2.2. Geographical distribution

The beaches of Chios are characterized by excellent bathing water quality, however only 15 have been awarded with 'Blue Flag' certifications, mainly due to lack of specific facilities/services. As far as the environmental protection regime is concerned, almost all beaches in the northern part of the island are included in NATURA 2000 sites, while isolated beaches in the rest of the island, such as Kontari (ID: 60), Komi (ID: 90) and Kato Fana (ID: 99) beaches, have wetlands protected by presidential decree 229/AAP/2012 (Figure 2d).

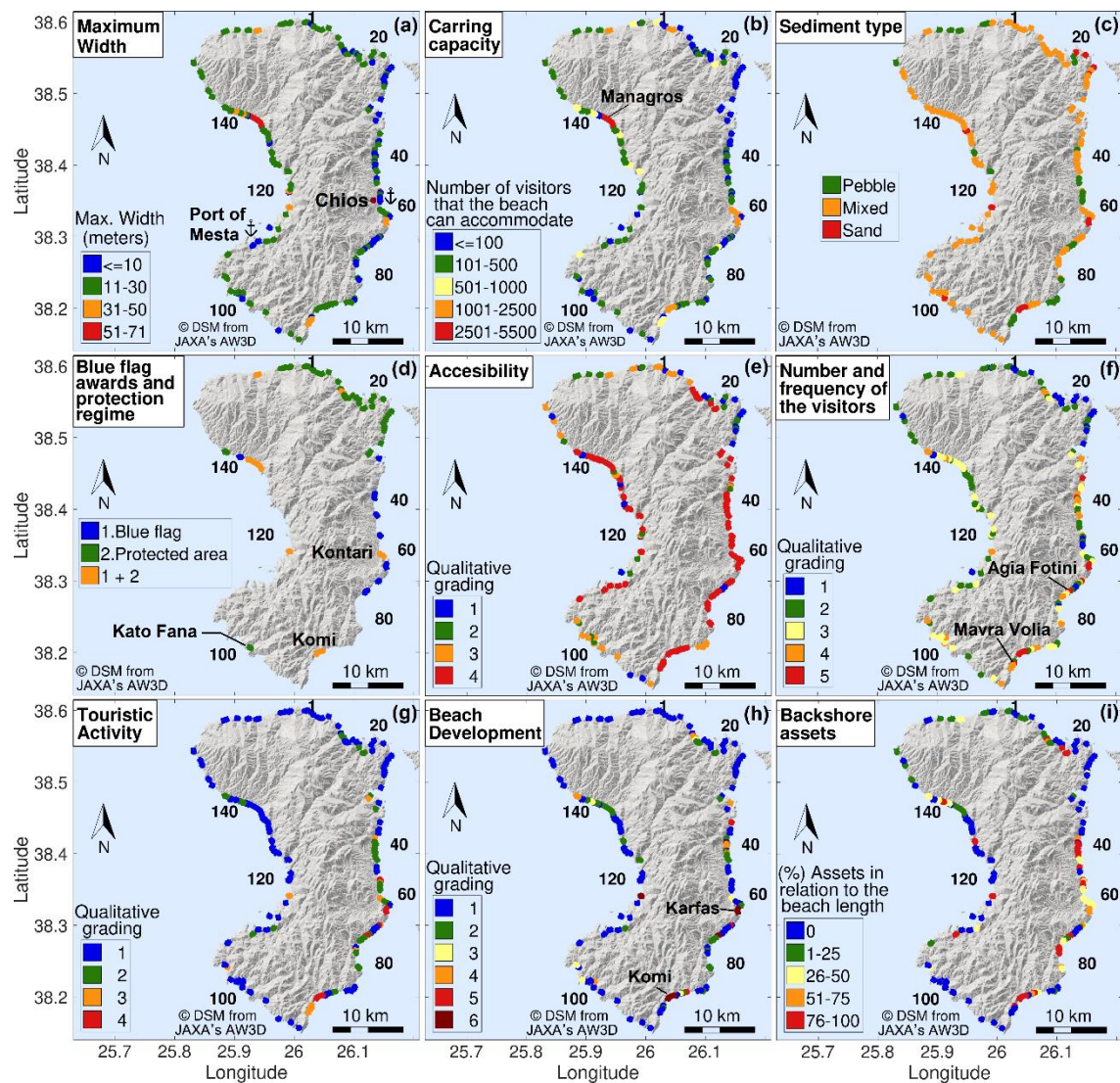


Figure 2. Geographical distribution of geo-spatial and environmental attributes: (a) Maximum width, (b) Carrying capacity, (c) Sediment type, (d) Blue flag awards and protection regime. Geographical distribution of socio-economic attributes: (e) Accessibility (grading from 1: only access by sea to 4: easy access to the main road network), (f) Number and frequency of visitors (grading is ranging from 1: none to 5: intense traffic), (g) Touristic activity (grading from 1: no activity to 4: intense activity (a lot of restaurants/hotels at the vicinity)), (h) Beach development (grading from 1: none to 5: intense (e.g. many umbrellas, watersports, lifeguard)), (i) Backshore assets

Chios is characterized by intense and steep relief, making access to the northern beaches of the island and some beaches on the southwestern coast difficult (Figure 2e). Some of these beaches are only accessible by sea, while

others have long and challenging unpaved roads connecting them to the main road network. The main road network appears to serve well mainly the eastern

(including SE) and western beaches of the island (Figure 2e).

Chios Island has low levels of tourism, reflected in its low tourist activity (Figure 2g) and development (Figure 2h) along the coastline. This may be due to the fact that the island's economy relies on other sectors such as shipping and mastic cultivation, and there is not much interest in boosting tourism or investing in tourist infrastructure and facilities. Most of Chios' beaches (90%) can be classified as "natural," meaning they have minimal (or no) human development (urbanization, coastal works, and tourist facilities/services). This is also evident from the distributions of the tourist activity (4) and coastal development (Figure 2g, 2h). Only a few beaches are characterized by intense development and also attract significant tourist activity (e.g., Komi (ID: 90), Karfas (ID: 63)).

Regarding the traffic (Figure 2f), i.e., the number and frequency of visitors, there is no particular distribution observed. However, there is low traffic to the difficult-to-access beaches in the northern part, and it also appears that many of the beaches with high traffic (level 4 and 5) are located on the eastern and southeastern coasts of the island. It is noteworthy that many undeveloped beaches are characterized by high or relatively high traffic, and this is due to the fact that the island has many vacation homes that are occupied during the summer months and significantly increase the population of the island. In other words, they are mainly used by local or seasonal domestic tourism. Examples include Mavra Volia (ID: 93) beach with a traffic level of 5, which has only basic facilities (showers, changing rooms). Of course, the most visited beaches are the highly developed ones on the eastern coast, which are simultaneously characterized by high tourist activity, such as Karfas (ID: 63), Agia Fotini (ID: 72), and Komi (ID: 90).

The sediment type distribution indicates that the few sandy beaches that exist are very popular and developed and with a fairly high degree of urbanization in the backshore (Figure 2).

The beaches of Chios generally have small dimensions and belong to the category of "pocket beaches". Their carrying capacity (Figure 2b), which is proportional to their area, ranges from moderate to small, except for Managros beach (ID: 133), which is located northwest of the island and seems to have low levels of development and tourist activity despite its capacity to accommodate many visitors. It is observed that several of the eastern beaches of Chios, which exhibit high tourist activity and development, are also characterized by small widths and a high degree of urbanization, making them particularly vulnerable to sea-level rise (Figure 2a).

4. Conclusions

The beaches of Chios, although most of them are not organized, have a significant number of visitors, which indicates their aesthetic value and high potential for sustainable tourism development. The organized beaches

of the island, although few, attract many visitors and have high economic value, since they are surrounded by significant business activity. This fact increases their vulnerability to erosion and emphasizes the need for their protection. The beaches of Chios are also characterized by excellent bathing water quality and 15 of them have been awarded with 'Blue Flag' certifications. The reason for not having more beaches awarded, despite their good water quality, is the lack of specific facilities/services. Overall, 43 beaches of Chios are under environmental protection regime (NATURA 2000, presidential decree 229/AAP/2012) which indicates their environmental importance.

The database developed in the present contribution (which can be further updated) can serve as a vital management tool, since its comprehensive and detailed information can support effective decision-making and aid in the sustainable management of the island's beaches. Also, it can facilitate the fulfilment of relevant legal obligations of Greece regarding coastal management (e.g. Directive 2008/56/EC (Marine Strategy Directive)).

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