Approaches for the sustainable management of the Apulian coastal areas: the potential of a geoportal

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ABSTRACT

In order to identify the most suitable strategies and to support territorial decision-making processes, it is necessary to operate with an integrated vision of coastal systems, considering the complex phenomena of sediment production, erosion and subsequent transport from the supply systems to the coastal areas.

In this work we propose a new approach to the management of the Apulian coastal areas based on a sustainable and low impact management of sediments and integrated with a WebGIS-based system. The webgis platform was developed to allow interactive and intuitive navigation between the different layers. The platform allows to identify the municipal / provincial / regional territory of interest and to identify the areas characterized by greater or lesser sediment production.

The result is the creation of a webgis platform, which allows to identify, in the territorial planning process, the strategic areas for sediment production, and consequently to minimize the impact of the sediment deficit for the coastal system. This approach therefore represents a low-impact solution that will make it possible to mitigate the risk of coastal erosion and increase the resilience of coastal systems, also in consideration of the ongoing climate changes.

KEY-WORDS: coastal systems, sustainable management, geoportal.

INTRODUCTION

Coastline retreat is a worldwide phenomenon caused by an imbalance between the processes of feeding, deposition and erosion of sediments in the sedimentary budget.

Currently, around 24% of the world's sandy beaches are subject to erosion, with erosion rates exceeding 0.5 m/year, while 28% are accreting and 48% are stable. (Luijendijk et al., 2018; Giardino et al., 2019).

The causes of erosion are often linked to the space-time dynamism of the coastal environment, in its turn connected to the interaction of natural processes (e.g., landslides, sea level variations, natural gradients in the transport of longshore sediments, storms, presence of submarine canyons nearby to the coast, subsidence) (e.g., Ruberti et al., 2020; Bonasera et al., 2022) and of anthropogenic origin (e.g., construction of dams, ports, coastal protection works and sediment extraction processes) (e.g., Kondolf et al., 2014; Wang et al., 2015, Giardino et al., 2018, 2019; Scardino et al., 2022). These variables, sometimes interacting in a very complex way, can control and modify the entire sedimentary balance, thus causing the erosion of the stretch of the coast (e.g., Stronkhorst et al., 2018).

The sustainable management of coastal zones is a very complex problem. However, every approach should be based on identifying and evaluating sedimentary sources, or "strategic sedimentary reserves". Strategic sedimentary reserves represent volumes of sediments, with certain characteristics, available for the supply of coastal areas, both temporarily (the reserves compensate for losses due to serious events) and in the long term. Strategic sedimentary reserves can be identified throughout the hinterland through the use of sediment production estimation models.

The exclusive use of the coastal balance of these specific areas will make it possible to minimize the impacts of some anthropogenic actions (dams, soil consumption, etc.) with almost zero costs.

In literature (e.g., Mancino et al., 2016; Majhi et al., 2021; Amini et al., 2021; Santos Alves et al., 2022) there are several semiquantitative methods developed for assessing erosion and sediment yield at the catchment scale (e.g., USLE, RUSLE, PSIAC, FSM, FLORENCE…).

These models easily adapt to large contexts because they exploit readily available information: morpho-climatological, geological characteristics, vegetation cover and land use, slope dynamics and anthropogenic actions.

Among the different models, the Erosion Potential Model (EPM model) is the most used in the Mediterranean area (e.g., Bazzoffi et al., 1985; Emmanouloudis, et al., 2003; Tazioli, et al., 2009; Milanesi, et al., 2015; Lovric and Tosic, 2018) for estimating the average (annual) soil loss obtained through the integration of several factors: meteo-climatic factors (based on average temperature and precipitation), of erodibility (based on land use, lithology and basin morphology) and physical factors of the basin (surface, average slope, perimeter, average elevation and hydrographic network).

The model has been extensively applied in Geographic Information System (GIS) environment (Tangestani, et al., 2006; Tosic et al., 2012; Barmaki, et al., 2012; Noori et al., 2016; Aslam et al., 2021). Furthermore, the PyQGIS YES plug-in allowed the semiautomatized use of the EPM in GIS environment (Dominici et al., 2020).

The model was also implemented in the case study of the Ofanto basin (Tenuta et al., 2021) and further implemented to possibly identify the volumes and areas capable of impacting the grain size range that characterizes the stretch of coast and consequently affect the entire physiographic unit (Tenuta et al., 2023). A further implementation allows to estimate the areas of the feeding system with the highest impact on the production of sediment and consequently define the most suitable areas for the construction of a dam (Imbrogno et al., 2023).

However, although the PyQGIS YES plug-in automatically performs a series of GIS operations during data pre-processing, the estimation of sediment production at the river basin scale remains a complex operation requiring: (i) in-depth knowledge of the mechanisms of operation of GIS systems, (ii) information related to the various databases to which the various parameters necessary for estimating sediment production are linked, (iii) the application of specific models and different calibrations for estimating sediment production.

For this reason, the idea was born to develop a web gis that contains all the results deriving from the application of the EPM model and all its related implementations to the Ofanto basin, in addition to a collection of databases related to the topic of coastal erosion and dispersed in various sections of regional geoportals, databases, etc.

The web gis was born from the integration product of GIS and Internet technologies (Song et al., 1998). WebGIS differs from traditional GIS in that it masks the differences between diverse types of hardware, software, networks and databases, which results in interoperability among different applications and data sources (Jia et al., 2009).

In addition, WebGIS promotes the sharing and synthesis of multi-source data, and enables the widespread sharing of spatial data and geoscience models (Qu et al., 2002). Therefore, WebGIS offers a powerful and effective approach to geoscience studies (Qu et al., 2002).

There are several recent studies in the geoscience and eco-environmental fields using WebGIS systems. For example, Kourgialas et al. (2022) developed a WebGIS for parcel irrigation water management on a large spatial scale (Water District of Crete, in Greece); Mourato et al. (2021) developed an interactive Web-GIS fluvial flood forecast and alert system in operation in Portugal, while Aekakkararungroj et al. (2019) developed a WebGIS for reservoir inundation mapping in the lower Mekong region (Southeast Asia).

Although WebGIS are now widely spread, no WebGIS based on the several methods developed for assessing erosion and sediment yield at the catchment scale has yet been realized.

The purpose of the paper is therefore to develop a WebGIS that acts as a geoportal and in which it is possible to identify areas with higher or lower sediment production and then estimate the impact of an infrastructure on the sedimentary balance. In this way it will be possible to evaluate the impact that the construction of a dam or a town has on the coastal balance of a given area.

The study area is the Adriatic coast of Apulia comprised between Otranto and the Gulf of Manfredonia, where in the last 20 years about 95 km of beaches have been affected by erosion (14.1% of the total). The causes of erosion are different, but the main one concerns the drastic reduction of sediments transported by rivers to the sea, which in the Apulian context refer to the reduced volumes of sediment from the Ofanto river, which represents the main water course feeding the beaches (Dominici et al., 2016; Donato et al., 2019).

STUDY AREA

The Apulia region stretches for 350 kilometers in the southeastern part of Italy, between the Adriatic and Ionian Seas.

The coast of Apulia is characterized by the alternation of cliffs, rocky sloping coasts and beaches. The landscape is also characterized by marine terraces produced by the superimposition of regional uplift and glacio-eustatic sea level changes occurring since the Middle Pleistocene (Mastronuzzi et al., 2011).

Erosion affects several tracts of Apulia coastline, both on rocky coasts and beaches. However, while the former represent a severe problem only in some spots, the latter have raised very diffuse problems during last forty years (Mastronuzzi & Sansò, 2003).

The cause can be connected to all the numerous hydraulic works carried out on the drainage basins influent on the Apulian coast, on the construction of harbour structures and defence works and to the growing urbanization of the coastal area (Mastronuzzi et al., 2008; De Santis et al., 2018).

However, the main cause remains the drastic reduction of sediments transported by the Ofanto river to the sea (Mastronuzzi et al., 2008).

The Ofanto River is the main river in Apulia and is approximately 170 km long; its drainage basin has an area of approximately 2790 km^2 (AAVV, 2010). The rivers' source is located in Campania, where about 20 % of the catchment area is included, then the river flows through the Basilicata (about 45 % of catchment) and Apulia regions where the river debouches between the towns of Barletta and Margherita di Savoia into the Adriatic Sea (about 35 % of the catchment, Gentile et al., 2007; Campanale et al., 2019).

This river has greatly changed great changes over the last several centuries (Pennetta, 1988). In particular, its mouth has been changed by natural factors such as floods, winds, storms, nearshore currents, relative sea level rise and slope processes. In the last few decades, harbor buildings (both the Barletta and the Margherita di Savoia harbor piers) have enclosed the study area, thus exerting great effects on longshore transport (De Santis et al., 2018).

METHODS

EPM model and PyQGIS YES plug-in

The Erosion Potential Method (EPM) was developed originally by Gavrilovic, (1988). This method considers six factors: surface geology, soils, topographic features, climatic factors (including mean annual rainfall, and mean annual temperature), and land use. The EPM calculates the coefficient of erosion and sediment yield (Z factor) of a sub-basin by the following equation:

$$Z = YX\,(\gamma + \sqrt{Im}) \tag{1}$$

where Y is the coefficient of the rock and soil resistance (a function of geology and soil type), X is the land use coefficient, γ is the coefficient of type and extent of erosion and Im is the average slope steepness of the watershed (%).

According to this model, the average annual specific production of sediments (W) in $m^3\ a^{-1}$ can be determined using the following equation:

$$W = T \cdot h \cdot \pi \cdot F \cdot Z^{3/2} \tag{2}$$

where h is the mean annual precipitation (mm a^{-1}), F is the watershed area (km^2), and Z is the erosion coefficient. Finally, T is the temperature coefficient calculated from the mean annual air temperature, t (°C), using the following equation:

$$T = \sqrt{\frac{t}{10} + 0{,}1}$$

The PyQGIS YES plug-in developed in Dominici et al., 2020 has simplified and speeded up the EPM application. Thanks to the automated geoprocessing operations of the needed layers (e.g.,, geological and soil use maps), the plugin allows to reduce the calculation time of 90%, while the "squared cell" method makes it possible to obtain the spatial distribution of the solid volume (W - m^3 / year) produced annually by the basin.

The calibration of the EPM model

The average annual specific production of sediments (W) was calibrated with an innovative approach based on the integration of the EPM with the petrographic, mineralogical and geochemical analysis.

Using a probabilistic approach, the combinations of values of attribute Y were identified which would allow to obtain the same ratios between the volumes produced by the lithologies and the results of the modal analysis carried out on sand samples taken in the same drainage sub-basins.

The lithologies capable of producing two components (e.g., sedimentary and volcanic), were considered individually, while the fine sedimentary component (clays, marls, silt, ...) was, after calibration, multiplied by a factor of reduction, depending on the presence of clays, marls, silts, etc. in the analyzed beach samples.

Finally, by means of the weighted average between the different Y values obtained for the different sub-basins, the final Y value was obtained (Dominici et al., 2022).

The isotopic study (Donato et al., 2022), on the other hand, made it possible to discriminate a double volcanic source in the sands of the Ofanto river: a first of a Campanian nature and a second deriving by the erosion of Monte Vulture volcanic rocks.

The calibration process obtained from the comparison with the petrographic - mineralogical and geochemical composition of the sand transported by the Ofanto river made it possible to draw up a map of the areas with the highest production of sand and gravel in the basin.

A further implementation was carried out on the basis of the granulometric parameters of sediment sampled (i) along the main course of the Ofanto river and (ii) at the mouth of the river. In this way it was possible to calibrate the model and identify the areas of the feeding basin mainly contributing to the production of beach sediment at the river's mouth.

Architectural design of the system

The program interface design was made using the Lizmap plug-in. Lizmap is an open-source software designed by 3Liz.

The server configuration was instead made on a clean machine Ubuntu 20.04, created specifically for the installation of the geoserver. In order to ensure an efficient access to data , and to have a solid data structure based on consolidated and widespread technologies, it was decided to design a relational database, and manage it in Open Source DataBase Management System. The design choice fell on the PostgreSQL DBMS, which has the stored particularity of being able to manage the geometric component of the data, through its PostGIS extension, and to interface in this way with GIS-type platforms.

The overall structure of the system was abstracted into five layers: user layer, presentation layer, processing layer, domain layer, and data layer (Fig. 1).

User layer: Different types of users can access the system flexibly to the geoportal. The geoportal is in fact designed for researchers from public bodies and universities, for public administrations (local authorities, ministries, ...) who want to know the possible impact on the production of sediments following the construction of a work on their territory, by associations and bodies non-profit organizations that can use the geoportal to evaluate the impact of an anthropic work already carried out on the territory and more generally by anyone who is potentially interested in the topic.

Presentation layer: The different levels of presentation contain information relating to the characteristics of the territory, the

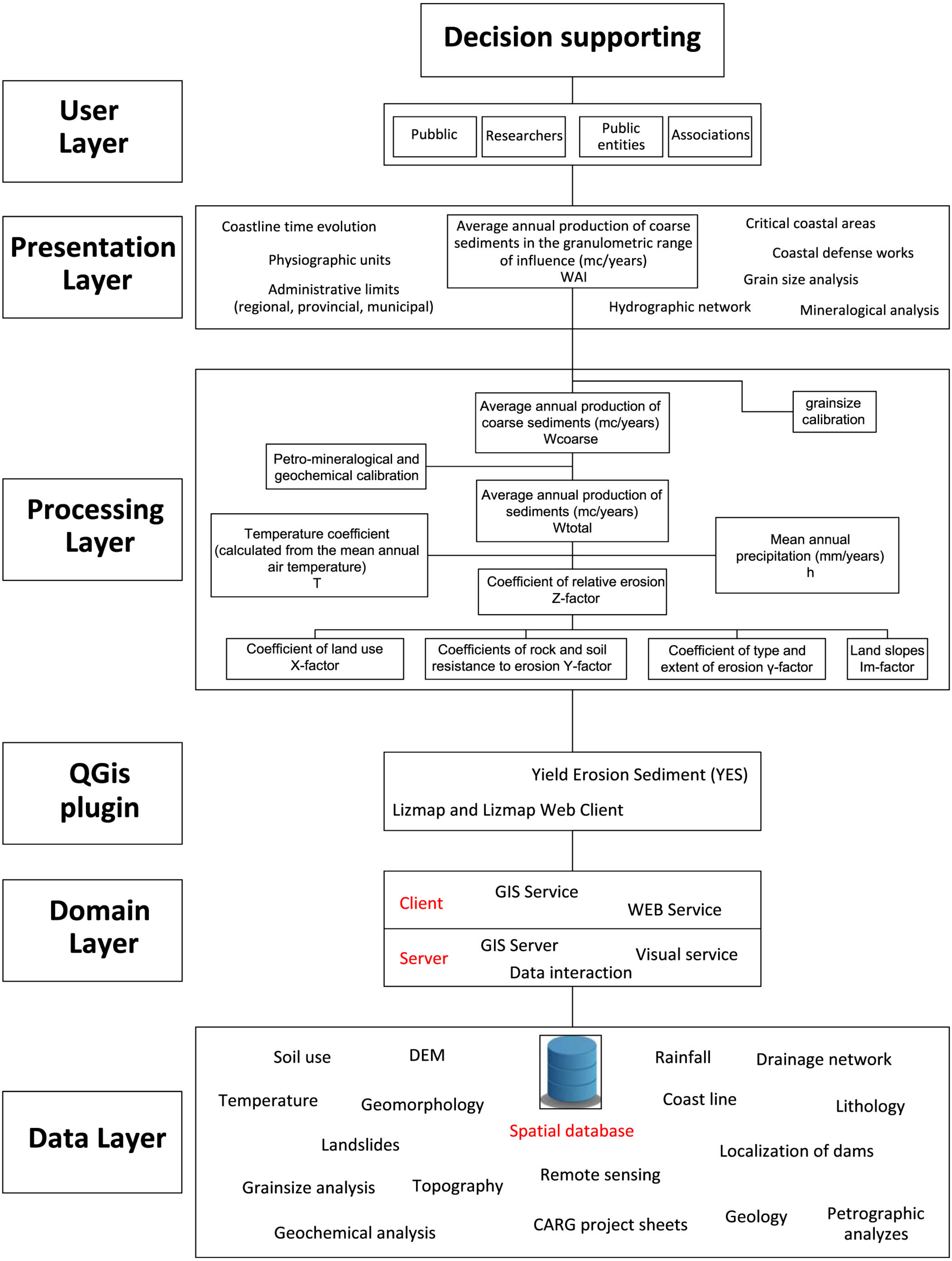

Fig. 1 - Diagram of the system structure.

characteristics of the coast and human impacts. There are also several points where it is possible to observe the petrographic, mineralogical, geochemical and granulometric characteristics of the sediment. Finally, it is possible to estimate the production of sediments (m^3 / year).

Processing layer: In this section there are a whole series of layers, which are hidden by the geoportal, but which have been used in the various phases of data processing and are necessary for the correct functioning of the Presentation layer section. For example, this section contains all the input coefficients used to implement of the EPM model to the catchment area.

Domain Layer: The main function of the domain layer is technical and service support for system function. The client includes GIS and Web services. The server mainly provides basic geographic services, model services, visualization services, data interactions, and other services.

Data layer: The data layer is the last layer of the entire system. The information regarding the repertoire of the various data is present in a specific section.

DATA

This study is based on 3 different datasets. The first contains information relating to the characteristics of the territory (administrative limits, hydrographic network, ...), to the characteristics of the coast (physiographic units, evolution of the shore line, ...) and human impacts (defence work, distribution of dams, critical coastal areas, ...). The second dataset contains a map with different points where it is possible to observe the petrographic, mineralogical, geochemical and granulometric characteristics of the sediment both along the Ofanto river and along the Adriatic coast of Apulia. Finally, the third contains a map of the estimate of the sediment production (m^3 / year) for the entire Ofanto basin made by applying the model EPM.

Data relating to the characteristics of the territory

The information relating to administrative limits, for the year 2022, comes from the dataset of the National Statistical Institute (https://www.istat.it/it/archivio/222527); the limits of the Ofanto river basin were recovered from the site of the Ministry of the Environment (http://www.pcn.minambiente.it/mattm/); while the hydrological characteristics and the digital elevation model (DEM), with a cell size of 20 × 20 m, were obtained from the national geoportal (http://wms.pcn.minambiente.it/wcs/dtm_20m) on a national scale and tailored for the Ofanto basin. Topographic information was obtained by digitizing the IGM MAP 100K sheet in WMS format (http://wms.pcn.minambiente.it/ogc?map=/ms_ogc/WMS_v1.3/raster/IGM_100000.map), while the information relating to the geomorphological characteristics was obtained from the PAI - Hydrogeological Asset Plan (http://www.pcn.minambiente.it/_mattm/servizio-di-scaricamento-wfs/). The data of temperatures and precipitation were provided by ISPRA (https://www.isprambiente.gov.it/pre_meteo/idro/BIGBANG_ISPRA.html); information on land use obtained from Corine land cover 2018 is available at the link (https://land.copernicus.eu/pan-european/corine-la nd-cover/clc2018?tab=download); the information relating to the geological characteristics of the basin was obtained (i) from the lithological map of Italy at the scale of 1: 100,000; (ii) from sheet N ° 450 S. Angelo dei Lombardi project CARG, ISPRA; (iii) from sheet 451 Melfi project CARG, ISPRA; (iv) from sheet 452 Rionero in Vulture project CARG, ISPRA.

The information relating to the distribution of the dams was obtained from the mapping using Google Earth, while the information relating to the coast lines and all the related historical reconstruction was carried out through the study and digitization of satellite images and in particular of:

i. Orthophoto in black and white years 1988-1989 of the Italian territory with the relative encumbrance polygons showing the information on the date of the aerial shot. Resolution 1: 10,000.
ii. Black and white digital orthophotos of the national territory acquired in the period between 1994 and 1998 with the relative encumbrance polygons showing information on the date of the aerial shot. Resolution 1: 10,000.
iii. Digital color orthophotos of the Italian territory acquired with the relative encumbrance polygons showing the information on the date of the aerial shot. Resolution 1:10,000. The digital color orthophotos were acquired for the years: 2000; 2006; 2010; 2011; 2013; 2015; 2016; 2019.

Finally, the following information relating to the peculiarities of the Apulian coasts were obtained from the geoportal of the Puglia region (http://www.sit.puglia.it/):

i. the identification of the main critical issues affecting the Apulian coastal area;
ii. the distribution of coastal defense works;
iii. the identification and subdivision of the different physiographic units;
iv. the state of the beaches (retreat, stability, advancement).

Data relating to the characteristics of the sediment of the Ofanto river and of the Apulian beaches

For 22 sites along the main course of the Ofanto river or of its tributaries (the granulometric characteristics of the sediment (from Tenuta et al., in press) and its petrography and mineralogy (from Tenuta et al., 2021) are available on the geoportal by selecting the single sampling point.

The same kind of data are available for 19 sites along the Apulian coast, from the beaches of the Gulf of Manfredonia to the beaches of San Foca (Fig. 2). The samples are related to dunes, backshore areas and heavy mineral placers (data from Parise, 2018).

Data required for the estimation of the sediment production

The coefficient of land use (Zemljic, 1971) is classified by EPM into seven categories, for each of which a coefficient X ranging from 0 (urban area) to 1.0 (a completely denuded area that cannot be cultivated) is assigned (Table 1).

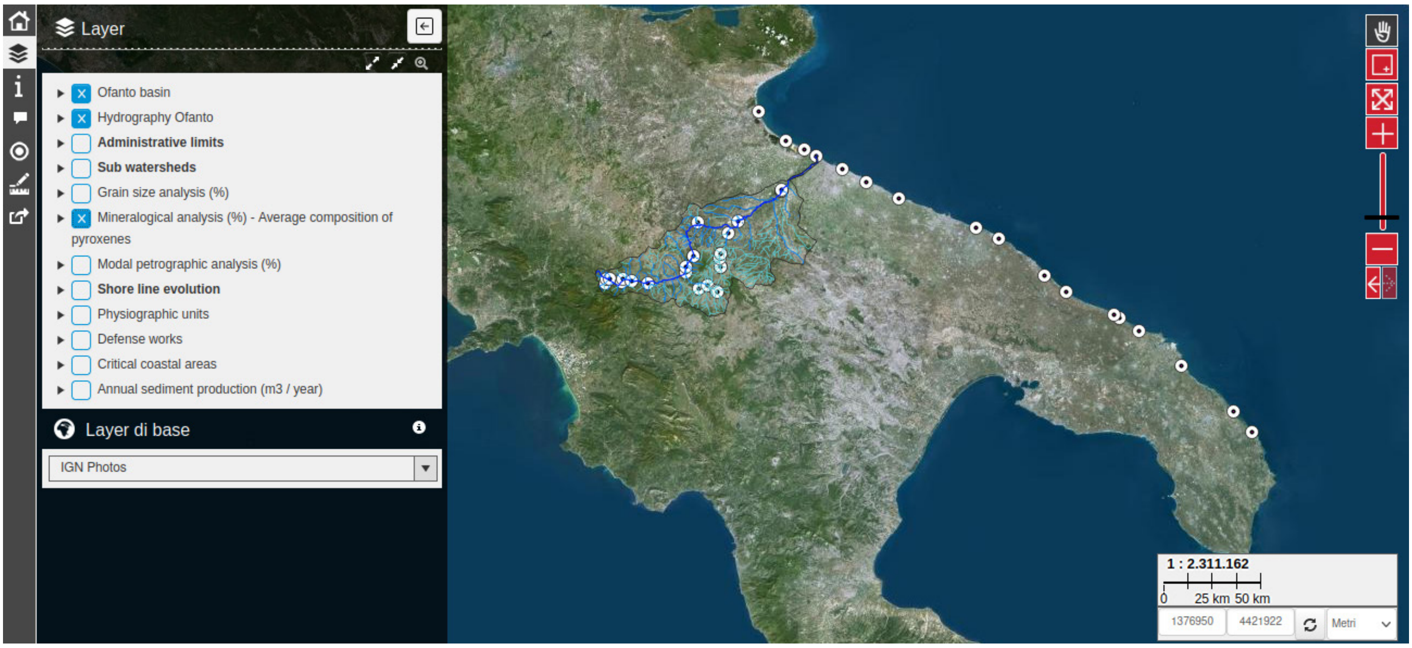

Fig. 2 - Map of the distribution of sites along the Ofanto river and Apulian coast for which granulometric and petrographic data are available.

Table 1 - Coefficient values for rock and soil resistance, land use and type and extent of erosion (geomorphology) used for the estimation of sediment production in the Ofanto basin.

Land use coefficient (X)	**Value**
Completely denuded land that cannot be cultivated	1
Fields worked according to the lines of maximum slope	0.9
Orchards and vineyards without ground vegetation	0.7
Pastures, degraded woods and scrubs with eroded soil	0.6
Meadows, clover fields and other similar crops	0.4
Dense and well-structured woods or scrubs	0.05
Urban area	-
Water	-
Rock and soil resistance coefficient (Y)	**Value**
Sediments, moraines, clay and other rock with little resistance - Volcanic rock	1.99
Fine sediments and soils without erosion resistance - Fine sedimentary rock	1.87
Sediments, moraines, clay and other rock - Fine sedimentary rock	1.47
Sediments, moraines, clay and other rock - Coarse sedimentary rock	1.40
Weak rock, schistose, stabilized - Coarse sedimentary rock	1.30
Weak rock, schistose, stabilized - Carbonate rock	1.17
Weak rock, schistose, stabilized - Fine sedimentary rock	1.07
Rock with moderate erosion resistance - Volcanic rock	0.87
Rock with moderate erosion resistance - Sedimentary rock	0.80
Rock with moderate erosion resistance - Carbonate rock	0.67
Lake	0
Coefficient of type and extent of erosion (y)	**Value**
Whole watershed affected by erosion	1
50-80% of catchment area affected	0.80
Erosion in rivers, gullies	0.60
Erosion in waterways	0.30
Little erosion on watershed	0.10

The coefficients of rock and soil resistance to erosion (the Y factor) were assigned using the methodology proposed by Zemljic (1971). The values were integrated into the EPM model with petrographic, mineralogical and geochemical analyzes (Table 1).

Data for estimating the coefficient of type and extent of erosion (the γ factor) were obtained using the methodology proposed by Zemljic (1971) (Table 1). Land slopes were calculated using a DEM of the basin area. The slopes were reclassified into five categories ranging from 0–5 to 30%. The mean value of each slope class was converted in a 0–1 scale to determine the 'Im factor' (Gavrilovic 1988). The values of Z obtained using equation (1) were grouped into five ordinal classes to generate the erosion potential, using the method described by Gavrilovic (1988).

RESULTS: SYSTEM INTERFACE

The webgis platform was developed to allow interactive and intuitive navigation between the different layers. The platform allows to identify the municipal / provincial / regional territory of interest and to identify the areas characterized by higher or lower sediment production (Fig. 3a, 3b).

Other layers allow to analyze information regarding: the hydrographic network of the Ofanto river basin (Fig. 4a), the distribution of the various physiographic units in which the Apulian coast is divided (Fig. 4b), the presence of coastal defense structures (Fig. 5a), the state of coastal areas (retreat, advancement, stable) (Fig. 5b) and the temporal variations of the coastline for the reference physiographic unit (Fig. 5c).

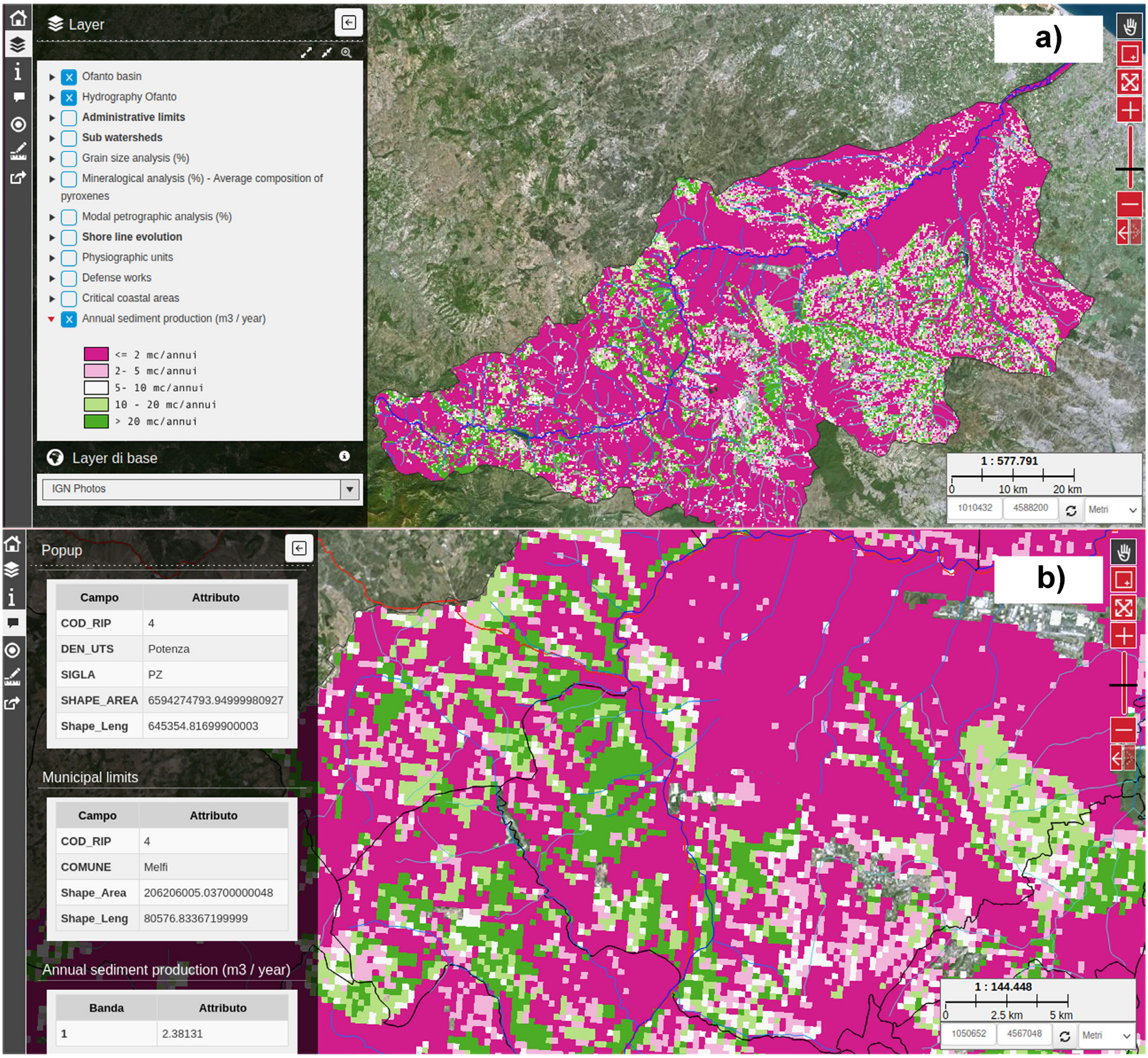

Fig. 3 - a) Map with areas of different sediment production; b) Description of the layer.

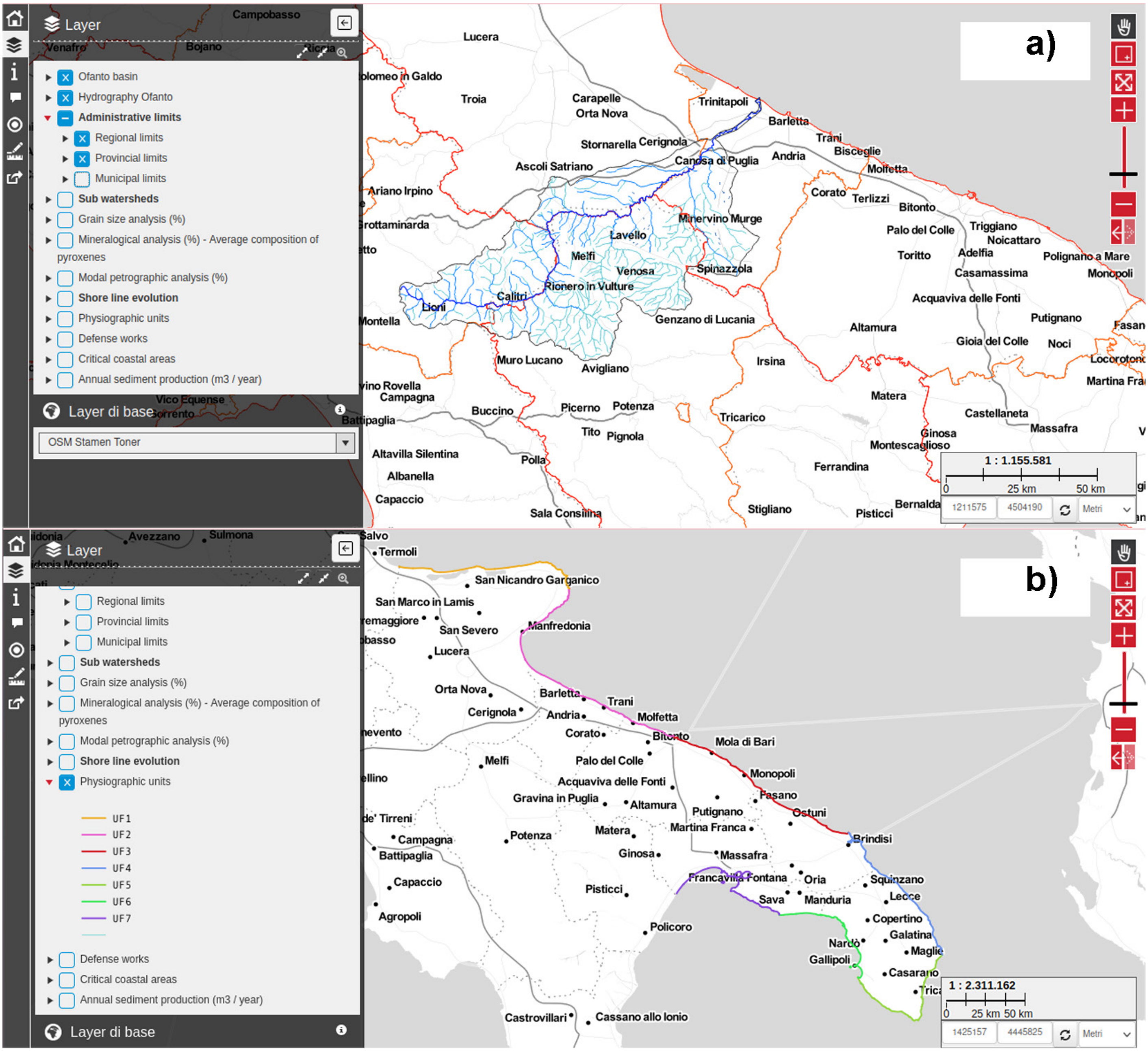

Fig. 4 - a) Hydrographic network of the Ofanto river basin; b) Distribution of the various physiographic unitspresent along the Apulia coast.

The basic operation of the system mainly included map enlargement, reduction, translation, overall situation, eagle's eye view, map transparency adjustment, coordinate point positioning, and map printing and output. For user management, the system sets permissions for different types of users to prevent the abuse and modification of data. Guest users could perform basic map operations. Administrator users could use all the functions in the system. By clicking on each individual layer, it is possible to obtain an in-depth description of the theme and precise information on the point that has been selected.

Finally, by selecting specific points, the user can observe the petrographic (Fig. 6a), mineralogical (Fig. 6b), geochemical and granulometric (Fig. 6c) characteristics of fluvial and coastal sediment samples arranged along the course of the Ofanto river and along the Apulian beaches.

DISCUSSIONS

Correct planning of the coastal territory implies an objective, reliable and timely risk assessment, based on an in-depth technical / scientific knowledge of physical processes and which, at the same time, manages to involve both the population and the authorities, avoiding a distorted perception of risk conditions.

The geoportal can be used quite effectively in the sustainable management of coastal areas thanks to the sharing of information on dual environmental aspects.

A first application concerns the ability to easily identify areas with higher or lower sediment production, which in a specific way affect the stretch of coast.

The presence of these areas and their easy identification make the geoportal a tool to support the decision-making process by local

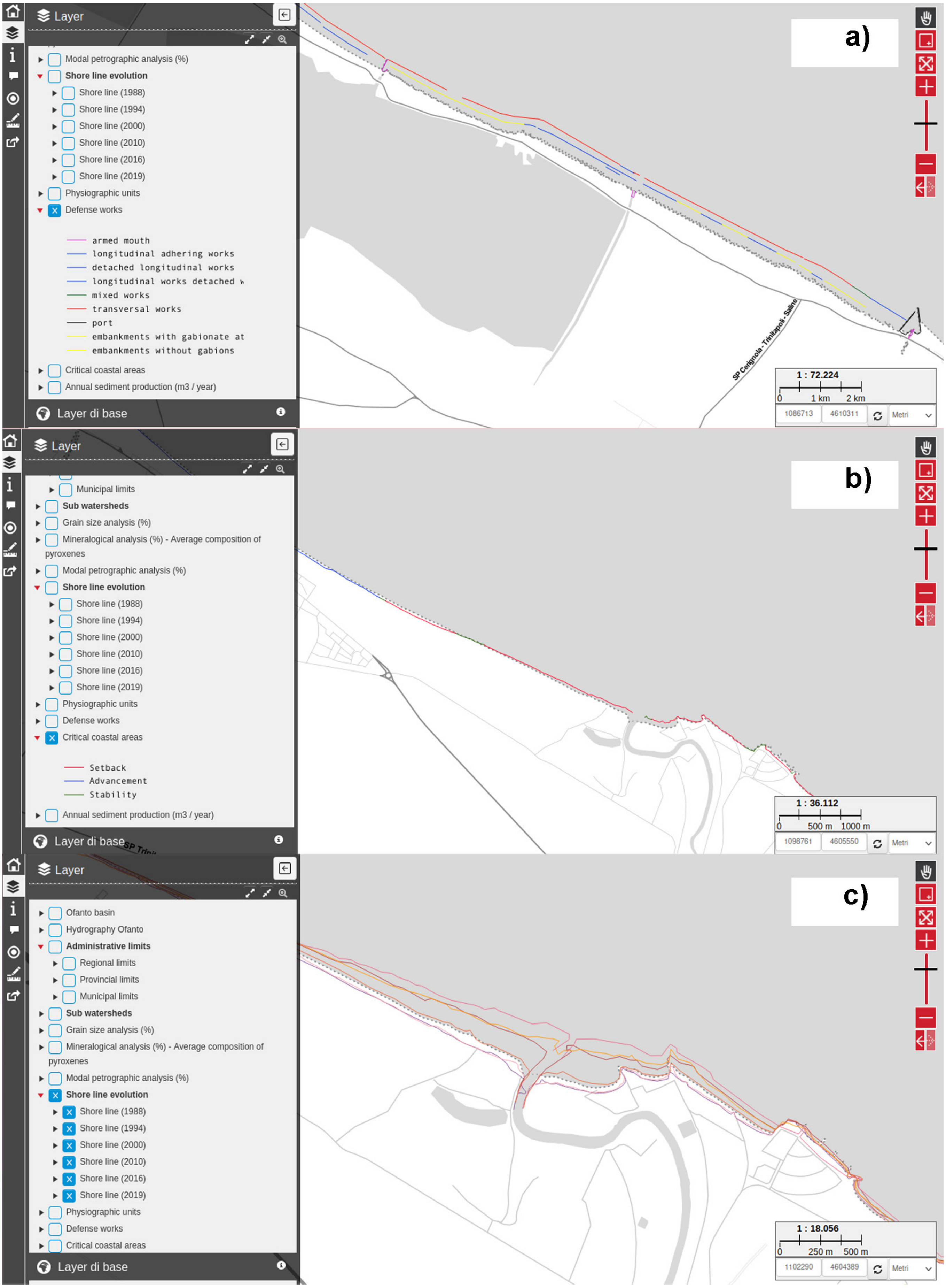

Fig. 5 - a) Map relating to the presence of coastal defense structures, b) Map relating to the state of coastal areas (retreat, advancement, stable) and c) Map relating to the temporal variations of the coastline for the reference physiographic unit (Fig. 5c).

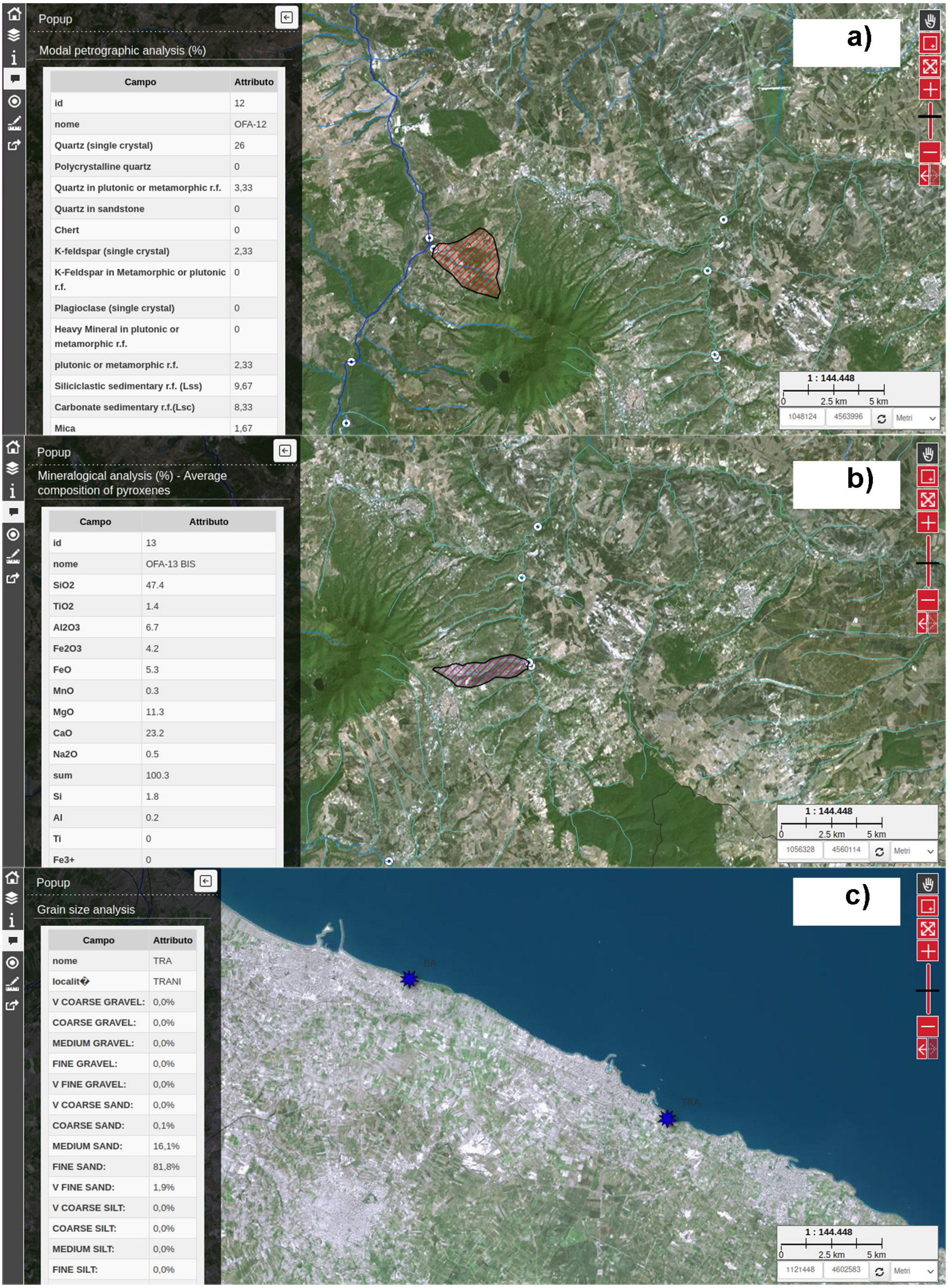

Fig. 6 - a) Modal petrographic analysis b) average composition of pyroxenesand c) granulometric analysis characteristics of fluvial and coastal sediment samples arranged along the course of the Ofanto and along the Apulian beaches.

authorities. Thanks to the use of the geoportal, local authorities can in fact define a priority scale within a municipal or provincial territory, of the most suitable areas for urbanization works and/or land consumption, limiting the possible impacts on the stretch of land to a minimum.

The impact that a correct management of the territory can have on the coasts and the potentialities of using the geoportal to support territorial planning are shown by hypothesizing the creation of two urban areas (area A and area B). Both areas have an area of 1 square km.

As evidenced by Fig. 7 developing an urban area in area A would produce a deficit in sediment production capable of influencing the physiographic unit of reference equal to 763.11 cubic meters / year. If the same urban center were built in area B, the deficit in sediment production would be just 3.1 cubic meters / year.

The potential of the geoportal can also be extended to identify changes in land use (e.g., agriculture, urbanization, ...) and by anthropogenic structures (dams, embankments, bridles) on the delivery of sediments to rivers (e.g., Boix-Fayos et al., 2008; Kondolf et al., 2014; Wang et al., 2015; Zhou et al., 2019; Imbrogno et al., 2023).

A second application of the geoportal concerns the fact that the environmental and management issues of the coast are little known, especially by the general population. Although the user may believe that the natural process of coastal erosion is important, he does not know the relationships between the phenomenon and the natural dynamics of the landscape and, consequently, of the management and intervention tools necessary to combat and defend the coast.

Although the residents of a coastal area may have a different perception (more responsive to reality) of the state of the coasts, as they 'experience' the constant changes of the coast, the problem remains the lack of knowledge of the processes that lead to the problem of coastal erosion.

In this case, the geoportal allows to easily identify the coastal municipalities subject to the highest risk, characterized by the presence of long sandy coasts in an evident state of erosion.

Through the geoportal, citizens can acquire, with direct access, a whole series of information on the state of the stretch of coast, on possible evolution trends of the coastline, on the presence of a possible retreat phase and on any defense structures. Citizens can also understand how the processes at source are causing the sediment deficit along the Ofanto river basin.

Finally, the geoportal has been enriched with a whole series of points on which it is possible to observe the petrographic, mineralogical, geochemical and granulometric characteristics

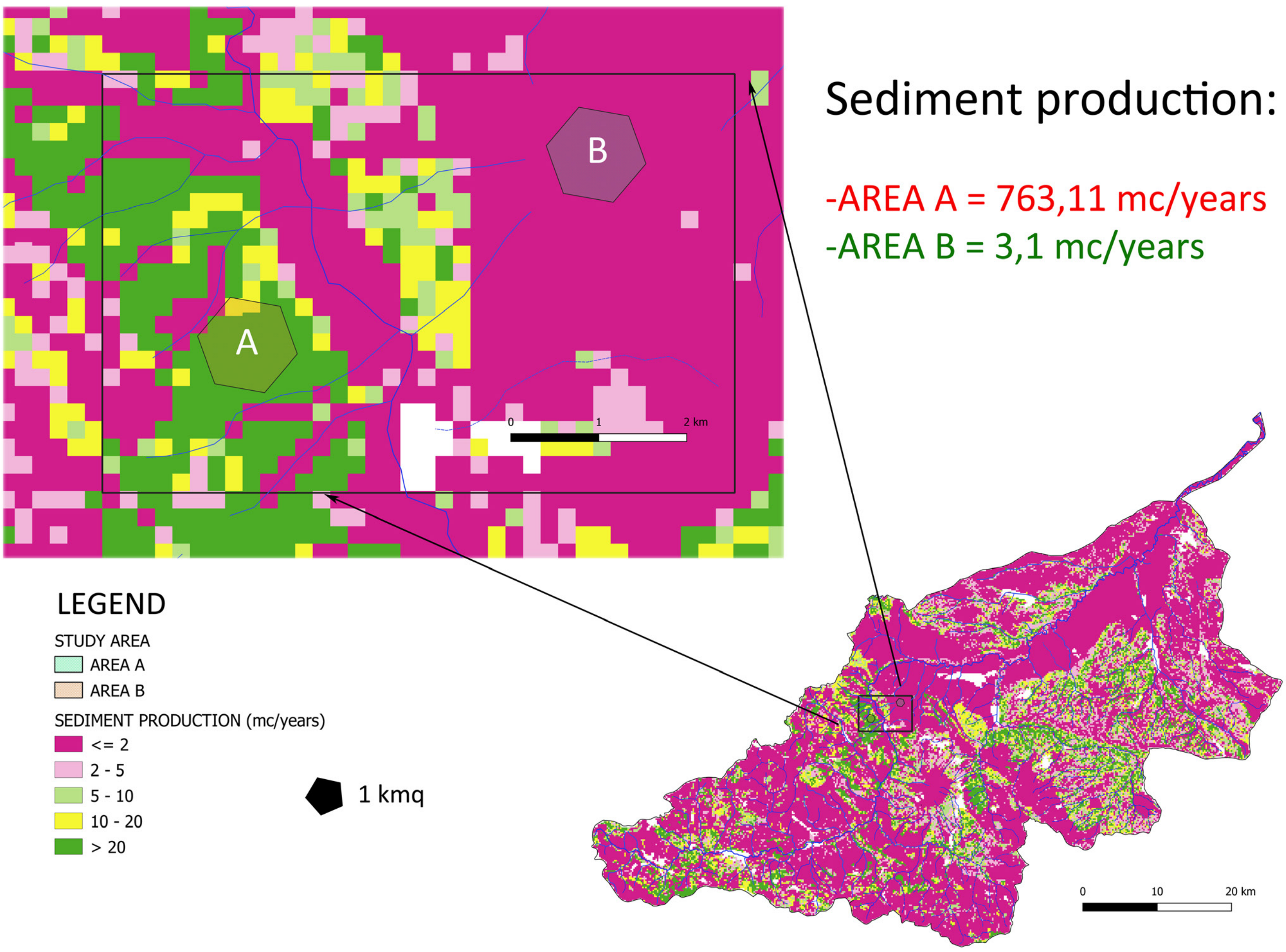

Fig. 7 - Estimation of sediment production in two potential urban areas (area A and area B).

of fluvial and coastal sediment samples. These data can be freely used both by freelancers interested in reconstructing the characteristics of the territory and by researchers from research institutions and universities who can easily and intuitively analyze the characteristics of the sediment in the exact position in which it was collected.

Among future developments, we find the possibility of adding additional layers to the information already present through the use of GIS. In this way it will be possible to add additional information such as the presence of urban planning and hydrogeological and landscape constraints within the territory.

CONCLUSIONS

The complexity of coastal erosion processes and the impact of the ongoing climate crisis is making coastal environments extremely vulnerable to natural disasters. It is therefore clear that the sustainability of coastal management, carried out according to different choices, must have an adequate system of knowledge on the processes of production. It is also essential to have a monitoring system that on the one hand constantly updates knowledge and on the other hand allows to evaluate the effectiveness of the choices made and the interventions carried out according to the objectives set.

As highlighted in the course of the paper, GIS, and in particular the use of a geoportal, can integrate the results of existing and new scientific methods on various aspects. Furthermore, they can provide results through easily understandable maps and interactive web tools, which can be combined under a common platform, now easily accessible from both a personal computer and a mobile device.

Therefore, they provide the necessary framework for successful land management and at the same time for the effective dissemination of the knowledge generated.

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