THE ENVIRONMENTAL FUNCTION ANALYSIS: A PROMISING TOOL TO EVALUATE THE COASTAL ZONE CONSERVATION POTENTIAL

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Abstract – In recent years, we have become aware of the concept that the complex dynamics that characterize coastal zone systems impose a close balance with the anthropogenic environment. Particularly, human activities and environmental resource exploitation are often responsible of changing the vocation of a coastal area. Moreover, recent studies demonstrated that coastal zones have a capacity to provide ecosystem goods and services; this capacity can be heavily modified by uncontrolled human activities. In the framework of Integrated Coastal Zone Management (ICZM), a multidisciplinary and issue-oriented system analysis can be helpful to understand the ecological and socio-economic system functioning, while a complete assessment of the environmental quality of the coastal area can be performed by means of Environmental Function Analysis (EFA) employing physical and biogeochemical indicators coupled with socioeconomic indicators.
This study reports and compares the application and usefulness of the EFA tool to discover the potential for conservation of two very different coastal areas located along the Campania Region (Southern Italy).
The first EFA site is located in the Volturno River Coastal Zone while the second EFA study site is located at the western end of the Sorrento Peninsula in the Bay of Naples.
Results demonstrated that EFA permits to effectively synthetize the information on coastal system functioning and on their potential for conservation or development.

Introduction

The Environmental Function Analysis (EFA) tool has been widely used to enhance coastal management plans [1, 6, 7, 9, 17, 19, 20, 21] and to assess land use conflicts in planning [11]. The EFA methodology is based on robust indicators to synthesize information on the environmental quality in coastal areas [8]. In this framework, a system of indicators and indices can be used to determine the quality of a coastal system and its potential for development by using a specific scoring system as described in [9]. In essence, the procedure describes the mixed and complex CZ system by following a Cartesian principle and dividing the coastal region into ecological and anthropic components identified by some specific features described by selected indicators [9].

This operational framework is developed on a matrix based on the principles of Ecosystem-Based Management (EBM) to describe the relationship between environmental

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functions and environmental characteristics [11]. Subsequently, EFA suitability was also demonstrated to assess the quality of coastal areas of Malta [20].

This study aims to assess the benefits of EFA methodology application comparing the potential for conservation and the potential for use of the Volturno River Coastal zone (central Tyrrhenian Sea – Italy) and of the Sorrento Peninsula Coastal Zone in the Bay of Naples.

These study areas were chosen because they represent two challenging decision-making contexts both characterized by protected areas coexisting with environmental disturbance and possible land-use conflicts [2, 3, 12, 14, 16]. The EFA application aimed to investigate the conservation potential and/or the potential for use detecting the possible anthropic influence and conflicts for use comparing environmental features and human features indicators.

Materials and Methods

The EFA's theoretical framework can be summarized into four main steps [2] as follows:

1) Definition of study area boundaries and selection of homogeneous land-use units within these boundaries. This is the first EFA fundamental step that allows depicting the study area merging geological, environmental and human features. This first step can be carried out by desktop study and literature data analysis.
2) Identification of characteristic parameters (indicators) for the study area, to describe and distinguish between the environmental and socio-economic components of that environment. In this study, based on the method of [9] later modified by [20], the application of the EFA methodology was tested by defining appropriate environmental and socio-economic components and selecting a set of relevant indicators.
3) Allocation of values to the parameters established in the previous step. Indicators are evaluated by means of the scoring process with a tripartite system. Single values are expressed qualitatively using a scale ranging from 1 (worst) to 3 (best), and are subsequently normalized and combined into synthetic indexes that help to obtain an integrated environmental and social value assessment [19,20].
4) Comparison of environmental (conservation) value with human (use/development potential) value to determine the potential management conflict. This is the last step of the EFA methodology, therefore the normalized values for each group of indicators are plotted into a conservation/use development matrix using a simple Cartesian space ranging between 0 and 1; the x coordinate expresses the development potential of the area, while the y axis returns the conservation value.

Results

1) Definition of study areas boundaries:

The Volturno River Coastal Zone (VRCZ) area extends onshore and offshore for 50 km^2 comprising the Volturno River mouth (Fig. 1-A). The boundaries of this unit were

traced mainly considering the geological setting, coastal dynamic and human settlements. This coastal system is geographically confined landward by the Volturno plain, formed during the Quaternary, characterized by a flat topography (0-25 m a.s.l.) and constituted by alluvial deposits and anthropogenic filling deposits [2].

The Punta Campanella Coastal Zone (PCCZ) study area extends onshore and offshore for 7,5 km^2 including the Crapolla fjord (Fig. 1-B). The boundaries of this unit were traced following the geological features settings. Since, the Sorrento Peninsula is located along the west coast of southern Italy, it consists of a WNW trending calcareous ridge elongated between the Naples Bay and Salerno Bay [4,5,8,12].

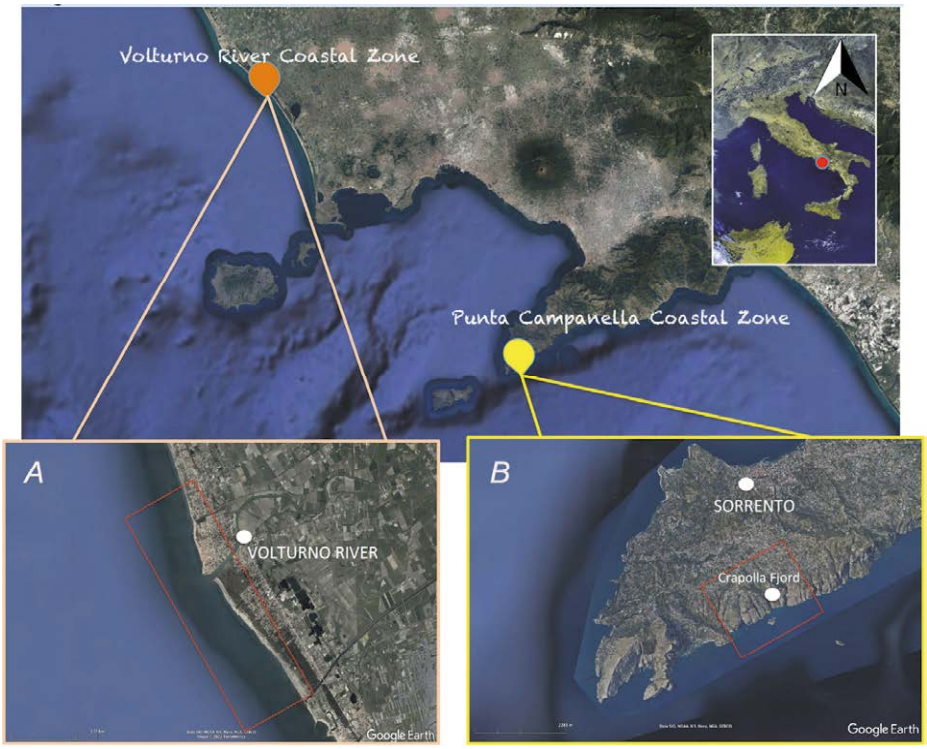

Figure 1 – Location and boundaries of the two EFA Study areas: A) "Volturno River Coastal Zone" (VRCZ) and B) "Punta Campanella Coastal Zone" PCCZ.

2) Identification of characteristic parameters (indicators):

The list of indicators used in this study area reported in Tables 1-2. Environmental features and human features have been explored using National Geodatabases and literature studies. The thematic maps have been visualized from the ISPRA data Portal (*Sistema Informativo di Carta della Natura*) and from the Regional Geoportal of the Campania Region (https://sit2.regione.campania.it/node last connection 01/06/2022).

Table 1 – List of indicators describing environmental features more details on indicators range values can be found in [1,19].

Environmental Features	Characteristic	Indicators
Coastal waters	Quality	Aesthetic Condition Microbiological Pollution
Fresh waters	Quantity	Supply (runoff)
	Quality	Ecological and Chemical pollution
Marine biota	Diversity	Biological diversity (Benthic foraminifera)
		Species of special interest
Terrestrial biota	Quality	Ecological Value
	Diversity	Species of special interest
Geological and topographic features	Quality	Size of bathing area
	Diversity	Lithological properties
Hazards	Coastal damage	Coastal erosion
		Coastline instability
		Subsidence
Resources	Landscape (Renewable)	Uniqueness

Table 2 – List of indicators describing human features.

Human Features	Characteristic	Indicators
Social values	Potential for use	Land use
		Population density (human pressure)
		Land consumption
		Cultural historic interest
		Accessibility
	Human well-being	Perception of the environmental quality
		Public recreation facilities

3) Allocation of values to indicators:

The allocation of values to indicators was based on thematic maps (showed in Figures 2, 3) and on literature data analysis for both the study areas the same indicators were evaluated. The indicators list for environmental features and human features is reported in Table 1-2, while the value ranges definition can be found in [1,20]. For the VRCZ the dataset is comprised between the years 2010-2013 (for more details see [16]), while for the PCCZ the full dataset is comprised between 2006-2012 references are reported in this study.

For the VRCZ (Fig. 2-A) a detailed classification of the environments through a geological-geomorphologic map is reported by [2,3]. Within the left bank of the Volturno delta there are several Natural Reserves such as the Site of Community Importance "Riserva Variconi", a good example of a morphological pristine site (EU Directive, Important Bird Area, Regional Nature Reserve - Ramsar site no. 1664 - SIC-IT8010028) (Fig. 2 B-C). The overall environmental status of the VRCZ as reported in [24] is intensively affected by human activities (Fig. 2-D), with a critical influence of intensive agricultural practices. Furthermore, due to the absence of a wastewater treatment plan, the bathing waters are frequently contaminated by organic pollution, and generally the marine coastal ecosystem can be classified between trophic and hypertrophic level, being strongly influenced by the river plume [14, 24].

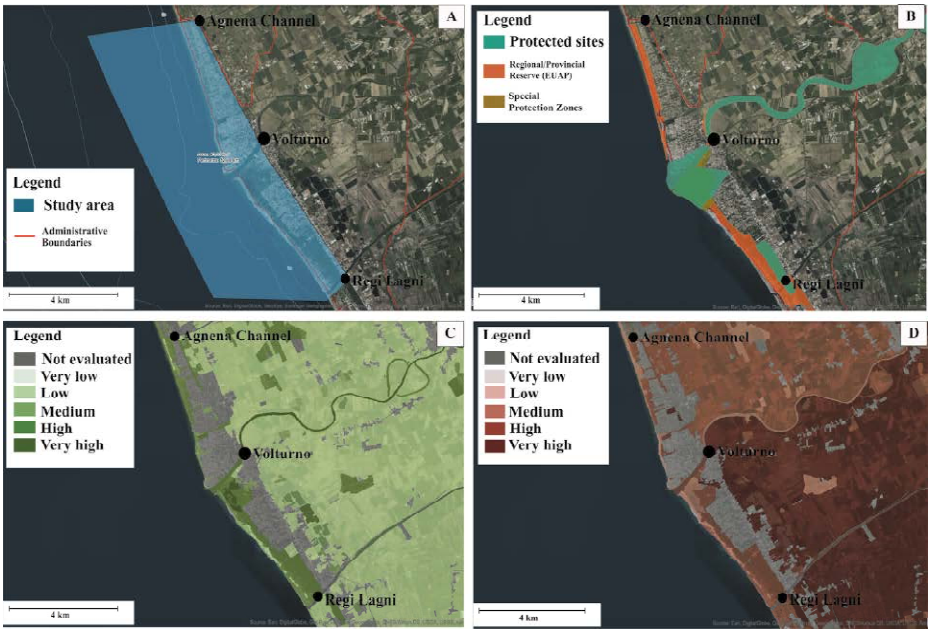

Figure 2 – Thematic maps for Volturno River Coastal Zone study site: A) Study area boundaries and bathymetry, B) Protected areas, C) Ecological value and D) Human Pressure (thematic data source Carta della Natura – ISPRA, modified from [16]).

In the PCCZ (Fig. 3-A) the coast is characterized by a steep fault scarp eroded and cut by gullies and ravines, moreover it is classified with hydrogeological constraints and high costal sensitivity [13]. Offshore the sea floor is characterized by coarse grained deposits close to the coast, passing to sandy clay and bioclastic sand moving offshore [4,5]. The continental shelf is narrow, steep and it is practically absent near Punta Campanella and Capo Sottile [4,12]. Since the coastal strip includes the Marine Protected Area of Punta Campanella (Fig. 3 B-C) the natural value of the area is classified as high [15, 22, 23]. Moreover, there is an ancient multi-level overlap of crops such as horticultural products and herbaceous crops, legumes, vineyards, fruit trees (Fig. 3-C). The Fjord of Crapolla, a narrow and deep crack in the rock, is characterized by archaeological findings [18]. It is categorized as cultural heritage site in the Sorrento Coast implying that this area is classified as high cultural value (Fig. 3-D). The vulnerability of shallow aquifer is high [10], while coastal water quality has been affected in the past by the presence of the Torca water treatment plan no longer operational.

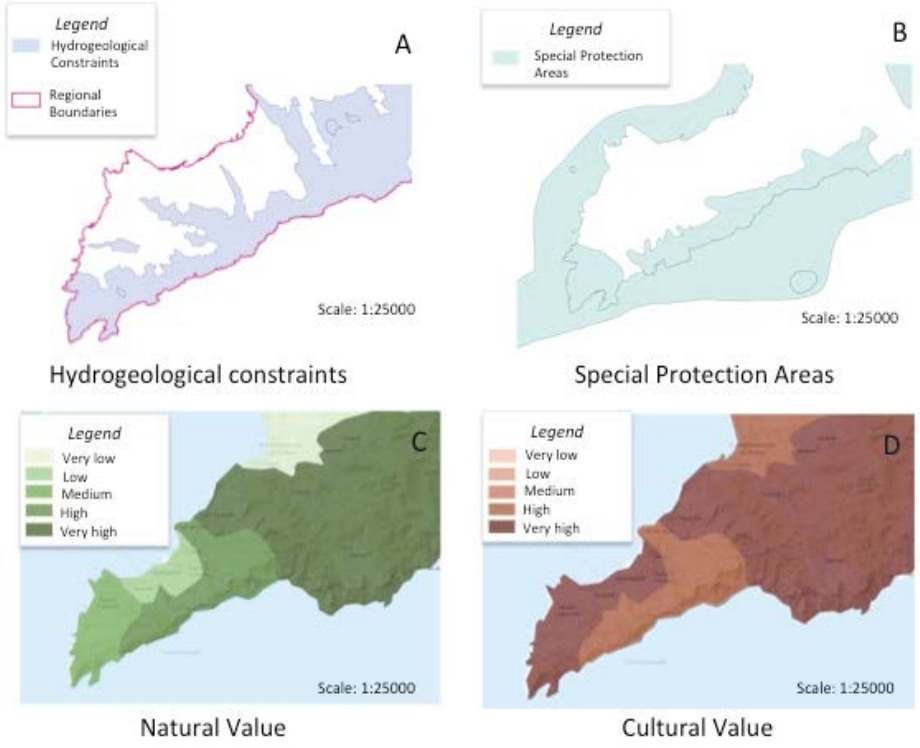

Figure 3 – Thematic maps for Punta Campanella study area: A) Hydrogeological constraints, B) Special Protection Areas, C) Natural Value, D) Cultural Value (thematic data sources: Geoportale Regione Campania and Carta della Natura ISPRA scale 1:25000).

4) Comparison of environmental (conservation) value with human (use/development potential)

Normalized values obtained for each group of EFA indicators are reported in figure 4. The histogram chart shows a comparison of values obtained for the VRCZ and for the PCCZ.

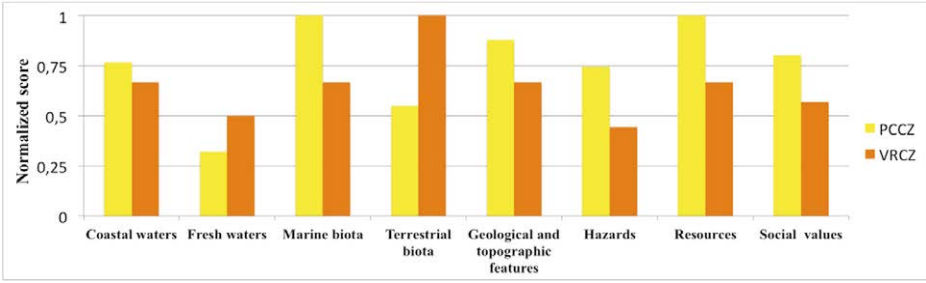

Figure 4 – Normalized values for Environmental and Human features (indicators are reported in Table 1) for Punta Campanella Coastal Zone (PCCZ) and Volturno River Coastal Zone (VRCZ).

The classification of potential for conservation versus the potential for use for the two study areas is reported in the EFA matrix showed in figure 5.

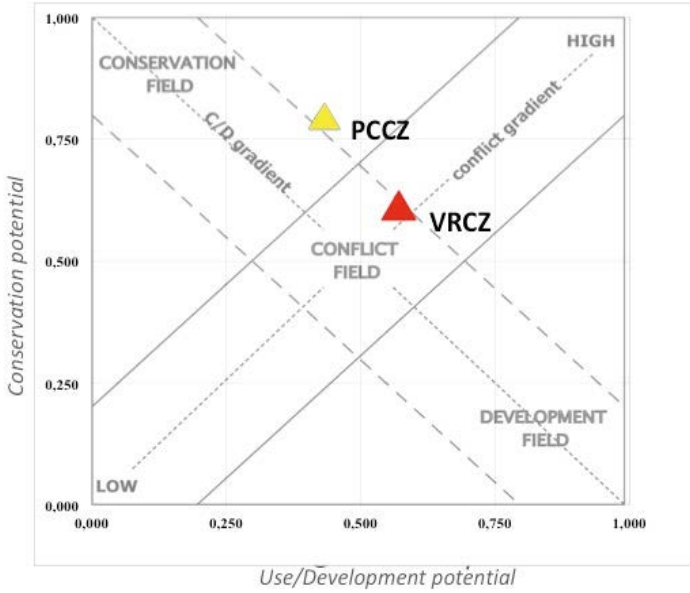

Figure 5 – Example of EFA matrix including the classification of the two study areas.

Discussion

The two EFA areas presented in this study are quite different for extension and for their geomorphological features. The first one is a river delta costal zone human impacted, while the second is a rocky coast characterized by cliffs and inaccessible areas where human settlements are scarce. Their similarity can be found in the presence of special protection areas on-land and also at sea in the case of the PCCZ. Comparing the normalized values of EFA indicators (Fig. 4), the marine biota is higher in the PCCZ than in the VRCZ, while for the terrestrial biota the situation is reversed. Coastal waters quality is comparable while resources and social values are higher for the PCCZ. The EFA matrix results (Fig. 5) showed that the EFA is a suitable methodology in order to detect conflicts for use recognizing the conservation potential versus the development potential. As a matter of fact, VRCZ resulted in a full conflict field despite the presence of a protected area testifying that dedicated management strategies should be improved. Conversely, the PCCZ was classified on the boundary of the conservation field testifying the prevalence of the conservation potential of the area respect to the development potential.

Conclusion

The two EFA results comparison presented in this study demonstrated the feasibility of EFA methodology in order to depict the potential for conservation and/or for development of two morphologically different coastal zones. This evaluation can be carried on easily including both inland and offshore areas leading to understand the complex relationships that characterize the coast zone functioning. The EFA can be easily applied in a wide range of case studies, a limit remains due to the availability of territorial data and open literature datasets.

Comprehensively, the EFA methodology permitted to detect if the management strategies implemented for conservation are effective or some corrective effort should be applied to shift towards the conservation field or to prevent conflicts.

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