Journal of Coastal Research	12	1	171–178	Fort Lauderdale, Florida	Winter 1996

Multicriteria Evaluation in Coastal Management

Amalia Moriki†, Harry Coccossis‡ and Michael Karydis‡

†Institute of Biology
National Center for Scientific Research "Demokritos"
153 10 Aghia Paraskevi
Athens, Greece

‡Department of Environmental Studies
University of the Aegean
Karadoni 17
81 100 Mytilini, Greece

ABSTRACT

MORIKI, A.; COCCOSSIS, H., and KARYDIS, M., 1996. Multicriteria evaluation in coastal management. *Journal of Coastal Research*, 12(1), 171–178. Fort Lauderdale (Florida), ISSN 0749-0208.

The driving forces of the development of the coastal area of the island of Rhodes (Greece) are examined in relation to the quality of the marine environment. The integrated variables of the system were analysed by four multidimensional techniques: Multicriteria Analysis, Cluster Analysis, Multidimensional Scaling and Principal Component Analysis. The analysis was performed in five zones of the island with different socio-economic structure and marine environmental quality. All these methods revealed the same trend in each zone suggesting the robustness of the multidimensional approach. The conflict between the quality of natural resources and the intensity of land use was expressed through the dissimilarity measures of these techniques, and therefore a quantification of the conflicts was obtained. In addition, a graphical illustration of the interrelated variables contributed to a better understanding of the system structure. The use of these algorithms is well established from applications in the fields of ecology and physical planning. They are therefore proposed as an effective analytical tool in problems where coastal development and marine quality are encountered. The combination of the multiple criteria, analytical techniques can contribute to the work of planners and decision-makers to identify the major trends of the system and quantify the interrelated socio-economic and environmental aspects.

ADDITIONAL INDEX WORDS: *Integrated analysis, multivariate methods, environmental management.*

INTRODUCTION

Coastal development in our century is accompanied by growing environmental problems and the need for evaluation and reorientation of the management strategies, taking into account environmental concerns.

Awareness of the conflict between coastal development and coastal environmental quality emerged as a priority issue in the 1970's (WCED, 1987) and led scientific research towards the study of environmental problems, the assessment of quality criteria and prediction of future trends. In planning and policy-making, the need for holistic approaches to coastal management is seriously considered. There still seems to be a gap between experimental work and decision-making, mainly because of the incompatibility of methods for the policy interpretation of scientific analysis. In this way, environmental-ecological aspects appear only theoretically in the actual decision-making process; huge data bases, originated from physical and chemical monitoring of the marine environment, remain unexplored, restricted to academic purposes only.

Environmental protection and sustainability require integration of environmental and socio-economic variables and the application of effective methodologies. However, complex problems involve multiple aspects and require analytical and systematic work to measure the degree of conflict and quantify the interrelations between them. Modelling has offered a tool for integrated management especially with scenario-predictive models and economic-ecological simulation. However, models require sophisticated techniques and need to be tested under real conditions. At the same time, coastal management requires effective decisions in a reasonable time-scale; therefore, holistic approaches should be based on realistic methods rather than complicated and time-consuming techniques. So far, multivariate statistical methods have been used extensively in the assessment of ecological impacts in natural sciences (WARWICK, 1986; CLARKE and GREEN, 1988), but without integrating socio-economic variables. Applications of multiple criteria methods, based on the assignment of scores in the multiple objectives

93124 received 20 November 1993; accepted in revision 20 January 1995.

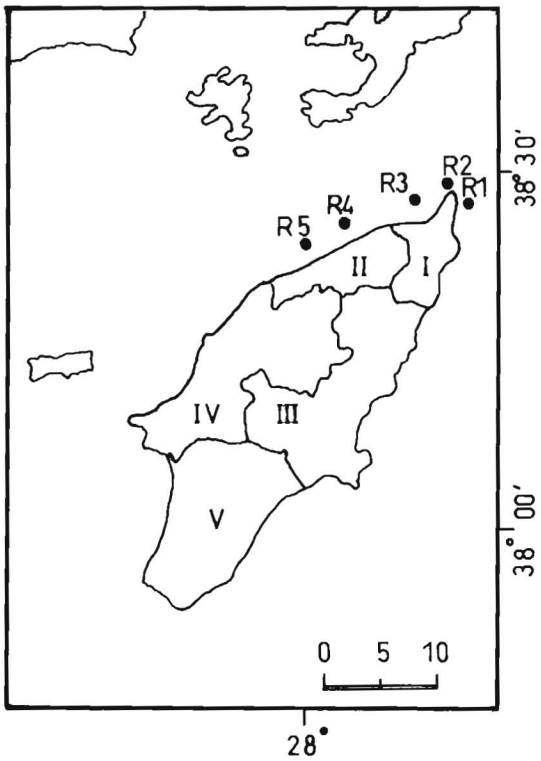

Figure 1. Map of the island of Rhodes, divided in five zones, and the sampling locations along the northwest coast.

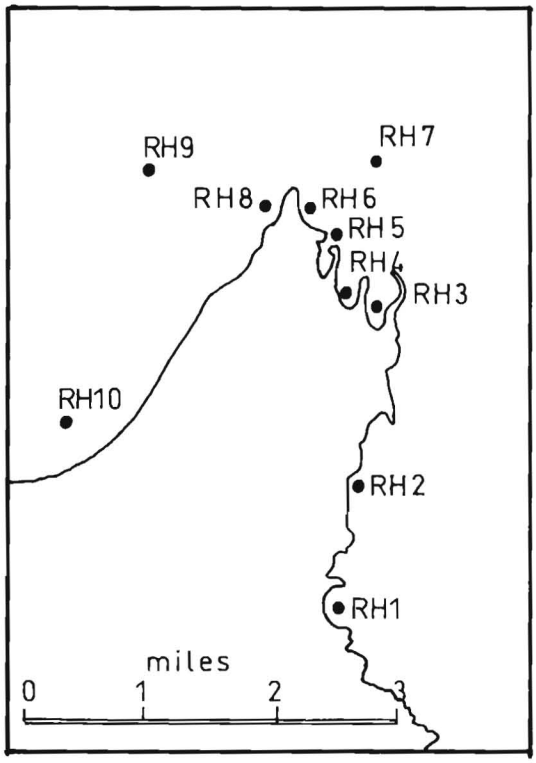

Figure 2. Map of the sampling locations along the coastal area of the city of Rhodes (KARYDIS and COCCOSSIS, 1990).

of a complex problem and the classification of the objectives in a ranking list, have been limited in the field of physical planning and policy-making (HARTOG *et al.*, 1989; NIJKAMP *et al.*, 1990).

In the present work, a case study of the island of Rhodes, Greece is presented, analysing simultaneously economic, social and ecological data of the coastal system. Four different multi-variable techniques were used: Multicriteria methods, the non-parametric method multidimensional scaling and two multivariate statistical methods: cluster analysis and principal component analysis. The aim of the study was to explore the potential of the island for development, maintaining the quality of the marine environment and to examine the effectiveness of the above methodologies in their application to holistic approaches in system analysis. The qualities and disadvantages of each technique are discussed as well as their use as a multi-method system for the support of environmental management.

METHODOLOGY

Description of the Study Area

The island of Rhodes (Greece) lies in the Eastern Mediterranean Sea and covers an area of 1,400 km^2 (Figure 1). The population of the island is approximately 110,000 persons (COCCOSSIS *et al.*, 1993), 50,000 of them inhabiting the city of Rhodes which is a major tourist resort. During the summer, Rhodes city and its surroundings receive more than a million visitors. Tourism is the main economic activity on the island; commerce, services and other tourist related activities are also growing.

The island is divided into five geographical zones by the Ministry of Planning and the Environment (COCCOSSIS *et al.*, 1993) named Zones 1–5 (Figure 1). Zone 1 is the northeastern area and includes the capital of the island, the city of Rhodes. This is the area where most of the tourist facilities (33,000 hotel beds of the 36,000 for the whole

island), services and industrial-manufacture units are concentrated. Zone 2 is the northwest area. The airport is located in this zone, while many hotels and other tourist facilities are located along the beaches. Zone 3 is a rapidly growing tourist area which also has the largest concentration of manufacturing. The area represents a high percentage of agricultural land and shares with Zone 1 the largest part of cultural resources in the island. Zone 4 is the western mountainous part of the island, while Zone 5 presents the southern, relatively underdeveloped part of Rhodes. The last two areas represent a high priority of agricultural employment.

Collection of Data

Data on the socio-economic system have been obtained through the National Statistical Service of Greece (1986, 1991) and the Development Scenarios for Rhodes, Phase I, Appendix (COCCOSSIS *et al.*, 1991). Data on the quality of the marine environment concern nutrient values (nitrate and ammonia) as well as a biological parameter Chlα (VOUNATSOU and KARYDIS, 1991; KARYDIS and COCCOSSIS, 1990). Ten nearshore stations RH1–RH10 were spaced along the coastal area of the city of Rhodes (Figure 2) and five more stations in the north west coast of the island (Figure 1).

Manipulation of Data

There are two types of data: most of the variables are cardinal, but some of them such as the relief structure, the suprastructure and the cultural value, are measured in an ordinal scale, taking values from 3 to 0 (3 being the most favorable).

The values of nutrient and Chlα are numerical but have been given an opposite sign in order to conform to the idea "the greater the value, the more favored the criterion. In Zone 1 for example, the value for Chlα is 0.28 and appears in the table as -0.28.

All values have been standardised according to SNEATH and SOKAL (1973) prior to the analysis. Standardisation is a necessary procedure for both multicriteria analysis and multivariate procedures, so as to permit the comparison of variables with different dimensions.

Multicriteria Analysis: The Regime Method

The Regime Method is used for the classification of alternative sites; the five zones of Rhodes Island are classified according to the values of various criteria, which form the "Impact Matrix". The criteria are the stated variables of the coastal system of Rhodes and are presented in the Impact Matrix of Table 1. After the pairwise comparison of the values of two alternatives for each criterion, a new matrix is formed by the signs of the output of the comparison. This output might take a positive value for some of the criteria and a negative for others. The relative sizes of the subsets of the criteria with negative and positive values are interpreted as the probabilities that Zone 1 dominates over Zone 2. The final ranking of the Zones is based on the calculation of the mean value of all probabilities for each Zone (HINLOOPEN and NIJKAMP, 1990). One of the advantages of the Regime Method is that it allows for different priorities among the criteria. This is very useful since some criteria are more important than others.

Classification

Numerical Classification (cluster analysis) was performed based on the euclidean distances among sampling locations:

$$ED_{jk} = \sum_{i=1} (X_{ij} - X_{ik})^2$$

The hierarchical sorting strategy for the development of dendrograms was the group average sorting. This method joins two groups of samples together at the average level of similarity between all members of one group and all members of the other (SNEATH and SOKAL, 1973). The dendrogram was obtained using Primer Programs (CLARKE, 1993).

Ordination

The non-metric multidimensional scaling (MDS) was applied on the similarity matrix developed for cluster analysis. MDS was originally developed in psychometrics but has found many applications in the social sciences as well as in ecological studies (FIELD *et al.*, 1982; WARWICK, 1986; KARYDIS, 1992). MDS uses proximities among samples to indicate how similar (or dissimilar) two samples are. The output is a graphical representation, consisting of a geometric configuration of points, making the comprehension of the structure of the data easier. Additional details and the software used have been given by CLARKE (1993).

Principal Component Analysis

Principal Component Analysis (PCA) is a well-known and popular statistical method (ANDERSON,

Table 1. *The values of the sixteen variables of the coastal system of Rhodes island, in the five zones.*

Variables	Zones				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Social subsystem					
Population (thousands)	82	17	8	5	12
Services (thousands of employees)	10	0.80	1	0.40	1.10
Industry (thousands of employees)	1.90	0.19	0.31	0.04	0.30
Agriculture (thousands of employees)	0.38	0.13	0.27	0.72	0.79
Industrial annoyance	0	3	0	3	3
Tourism					
Hotels (thousand beds)	33	1.20	1.30	0.01	0.05
Distance	3	3	2	2	1
Marinas	3	0	0	0	0
Suprastructure	3	3	2	1	1
Cultural resources	3	1	3	1	0
Morphology					
Relief	3	3	2	0	2
Agricultural land (thousand stremmas)	49.80	43.50	66.90	45.60	67.60
Beaches (thousand stremmas)	0.90	6.40	1.80	0	2.70
Marine subsystem					
Chlorophyll a (μg-at/l)	−0.28	−0.10	−0.08	−0.08	−0.08
Nitrate (μg-at/l)	−2.25	−0.20	−0.15	−0.15	−0.15
Ammonia (μg-at/l)	−0.69	−0.54	−0.44	−0.44	−0.44

1984). It is applied in cases of large numbers of variables reducing their number by linear transformations. The Principal Components are the characteristic eigenvalues of the Covariance Matrix, of the original variables. PCA was performed with the statistical software STATGRAPHICS (1989).

RESULTS

Table 1 presents 16 criteria-variables of the five zones of the island of Rhodes (Figure 1). These variables concern the social subsystem, tourism-related activities, the geomorphology and the marine subsystem. The variables were selected to represent the major social, economic and ecological characteristics of the system of Rhodes island (Greece). Wherever possible, the values of each variable at each zone are quantitative. However, certain variables necessary for the analysis could not be expressed in quantitative terms and ordinal scaling has been used from 0 to 3, situation 0 representing the least favorable condition. The majority of population inhabit Zone 1; therefore, the population variable shows a great difference between Zone 1 and the remaining Zones. The percentage of employees in the tertiary sector and the number of hotels are about the same in each zone.

Table 2 presents the standardised values of Table 1 and forms the impact matrix for multicriteria analysis as well as the similarity matrix for cluster analysis and multidimensional scaling. Correlation Factors for the Principal Component Analysis were also calculated from the Matrix of Table 2.

Table 3 presents the results of the Regime Method. In Table 3(a), all criteria have been given equal priorities. Zone 1 is classified first in the ranking list, followed by Zone 5, Zone 3, Zone 2 and the mountainous Zone 4, in descending order. This analysis means that Zone 1, the most de-

Table 2. *The values of the variables of the coastal system of Rhodes after standardization.*

Number	Variable	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
(1)	Population	1.98	−0.27	−0.56	−0.69	−0.44
(2)	Services	1.99	−0.51	−0.45	−0.61	−0.42
(3)	Industry	1.99	−0.53	−0.35	−0.75	−0.37
(4)	Agriculture	−0.31	−1.27	−0.73	1.00	1.27
(5)	Industrial annoyance	−1.22	0.82	−1.22	0.82	0.82
(6)	Hotels	1.99	−0.46	−0.45	−0.55	−0.54
(7)	Distance	1.07	1.07	−0.26	−0.26	−1.60
(8)	Marinas	2.00	−0.50	−0.50	−0.50	−0.50
(9)	Suprastructure	1.18	1.18	0.00	−1.11	−1.11
(10)	Cultural resources	1.17	−0.50	1.17	−0.50	−1.33
(11)	Relief	0.39	0.39	−0.10	−0.59	−0.10
(12)	Agricultural land	−0.47	−1.07	1.17	−0.87	1.24
(13)	Beaches	−0.67	1.83	−0.25	−1.07	0.15
(14)	Chlorophyll	−1.99	0.31	0.56	0.56	0.56
(15)	Nitrate	−1.99	0.45	0.51	0.51	0.51
(16)	Ammonia	−1.83	−0.30	0.71	0.71	0.71

veloped at the present time, is the most favorable area from a development point of view, in cases where all variables of the socio-economic and ecological subsystems are of equal importance. In Table 3(b), the criteria that concern the primary sector have been given priority to reveal the potential of each zone for agricultural development. Zones 3 and 5 are the most favorable for primary sector, followed by Zone 2. Zones 4 and 1 are the least important for agricultural development. In Table 3(c), priority has been given in the quality of the marine environment. In this case, Zone 5

Table 3. *Multicriteria analysis results, Regime Method (Hinloopen and Nijkamp, 1990).*

Zones	Scores																Result
(a) Equal priorities																	
	Criteria number																
	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Z1	2	2	2	−0	−1	2	1	2	1	1	0	−0	−0	−2	−2	−0	0.926
Z5	−0	−0	−0	1	1	−1	−2	−1	−1	−1	−0	1	1	1	1	0	0.674
Z3	−1	−0	−0	−1	−1	−0	−0	−1	0	1	−0	1	0	1	1	0	0.583
Z2	−0	−1	−1	−1	1	−0	1	−1	1	−1	0	−1	0	0	0	−0	0.297
Z4	−1	−1	−1	1	1	−1	−0	−1	−1	−1	−1	−1	−2	1	1	0	0.020
(b) Priority to primer sector																	
	Criteria number																
	11	4	12	1	7	9	2	3	5	6	8	10	13	14	15	16	
Z3	−0	−1	1	−1	−0	0	−0	−0	−1	−0	−1	1	0	1	1	0	0.836
Z5	−0	1	1	−0	−2	−1	−0	−0	1	−1	−1	−1	1	1	1	0	0.836
Z2	0	−1	−1	−0	1	1	−1	−1	1	−0	−1	−1	0	0	0	0	0.506
Z4	−1	1	−1	−1	−0	−1	−1	−1	1	−1	−1	−1	−2	1	1	0	0.249
Z1	2	−0	−0	2	1	1	2	2	−1	2	2	1	−0	−2	−2	0	0.073
(c) Priority to the quality of the marine environment																	
	Criteria number																
	16	15	14	5	1	2	3	4	6	7	8	9	10	11	12	13	
Z5	0	1	1	1	−0	−0	−0	1	−1	−2	−1	−1	−1	−0	1	1	0.771
Z3	0	1	1	−1	−1	−0	−0	−1	−0	−0	−1	0	1	−0	1	0	0.747
Z2	−0	0	0	1	−0	−1	−1	−1	−0	1	−1	1	−1	0	−1	0	0.498
Z4	0	1	1	1	−1	−1	−1	1	−1	−0	−1	−1	−1	−1	−1	−2	0.484
Z1	−0	−2	−2	−1	2	2	2	−0	2	1	2	1	1	0	−0	−0	0.000

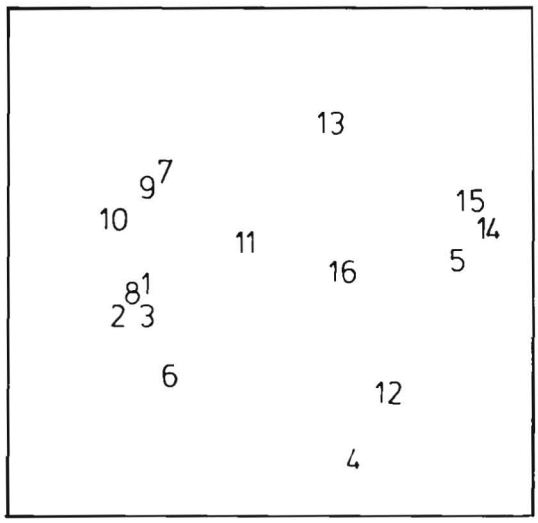

Figure 3. MDS plot for the 16 variables in the five zones of the island of Rhodes. The names of the variables are given in Table 2.

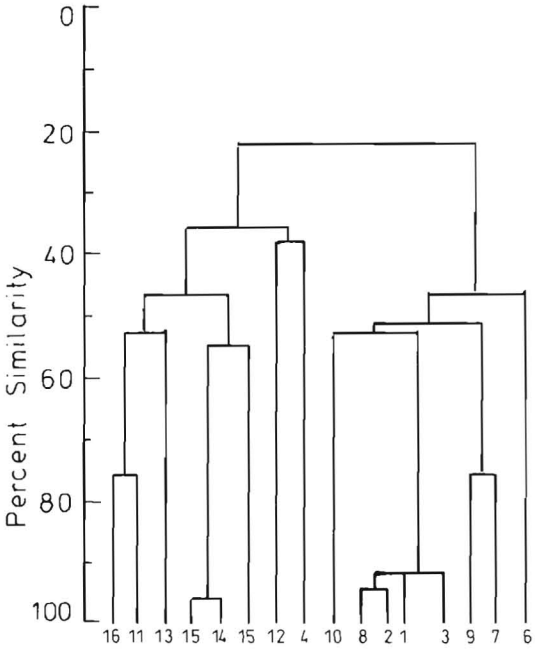

Figure 4. The classification pattern based on the euclidean distances among the 16 variables in the five zones of the island of Rhodes. The names of the variables are given in Table 2.

is the first in the ranking list, followed by Zone 3; Zone 2 is again of medium quality and Zone 1 takes the last position. An overview of Table 3 reveals that the most favourable Zone for a balanced development of primary sector and tourist activities with the protection of the marine environment is Zone 5, in the southern part of the island. Zone 3 can be classified as the second best; Zone 1 gains in order when criteria are equal because most of services and tourist activities take place in this area, but loses in primer sector and in ecological value. Zone 2 presents a medium profile, while Zone 4 is almost unfavored in all three cases.

Figure 3 presents the MDS plot for the 16 criteria in the five zones. Two aggregates can be observed, one to the right with criteria 15, 14 and 5 and one to the left with criteria 1, 2, 3, 8, 10, 9 and 7. The aggregate to the right concerns environmental quality while the aggregate to the left represents the intensity in the land use and the coexistence of services (2), population (1), industry (3) infrastructure and tourist activities (7, 8), suprastructure (9) and cultural resources (10). Criteria 4 (employees in primary sector) and 12 (agricultural land) seem to separate from the others in a third group.

Figure 4 presents the classification pattern based on the euklidean distances among the 16 variables in the five zones of Rhodes island. Two clusters can be observed in 50% similarity in the dendrogram. As in the ordination pattern, one of them, the cluster to the left, concerns environmental quality, while services, population, suprastructure and touristic activities form the cluster to the right. A third cluster can be observed in the medium of the dendrogram consisting of criteria 12 and 4, thus the primary sector.

Figure 5 presents the Principal Components, where the variables appear in four aggregates. At the top and the right of the diagram, variables that concern population, hotels, marinas, services and industry are aggregated together. The variables that characterise the quality of the marine environment are found in the left quarter to the bottom, while the variables concerning suprastructure (9) and distance (7) are found in the right quarter to the bottom. The variables that refer to the primary agriculture sector (4), agricultural land (12) and beaches (13) are aggregated to the top and left of the diagram. The two axes can be interpreted as the environmental quality (the ver-

tical axis) and the intensity of land use (the horizontal axis).

DISCUSSION

Coastal areas face increasing pressures for development which threaten coastal environmental resources. Planners and policy-makers have become aware of the need to integrate environmental issues in policy making. Recently, ecologically sustainable economic development has become a key issue in coastal management. The complexity of coastal systems requires the adoption of integrated coastal managing strategies focusing on the resolution of conflicts among the various uses of the coastal environment.

The island of Rhodes in Greece is a typical example of excessive concentration of multiple and conflicting activities in a small area. Monitoring studies in the area have shown eutrophication trends in the coastal waters of the city of Rhodes (KARYDIS, 1992; IGNATIADES *et al.*, 1992). Hence, an integrated approach to the application of ecologically sustainable policies in the island requires consideration of all the different aspects of the socio-economic and the marine environment.

The present work had four main purposes: a) to analyze the conflicts in coastal uses; b) to explore the potential for development of the different parts of the island; c) to examine the effectiveness of multivariate procedures and multiple criteria analysis as integrated tools in coastal management; and d) to assist the development of guidelines for future planning and decision-making in the area.

The island has been divided in five zones and analysis concerns the major socio-economic characteristics in these five areas as well as chemical and biological parameters of the marine environment that indicate coastal water quality. Multiple Criteria analysis by the Regime Method (HINLOOPEN and NIJKAMP, 1990) promoted the most developed area (Zone 1) in the highest position, when there was no particular concern for protection of the marine environment or for change in the present economic activities in the island. However, the analysis when priority is given to environmental protection reduces the final score of Zone 1 placing it in the worse position. The development of the primer sector could be a future challenge for the island, making it self-sufficient in agricultural production and keeping a balance in employment and economic activities.

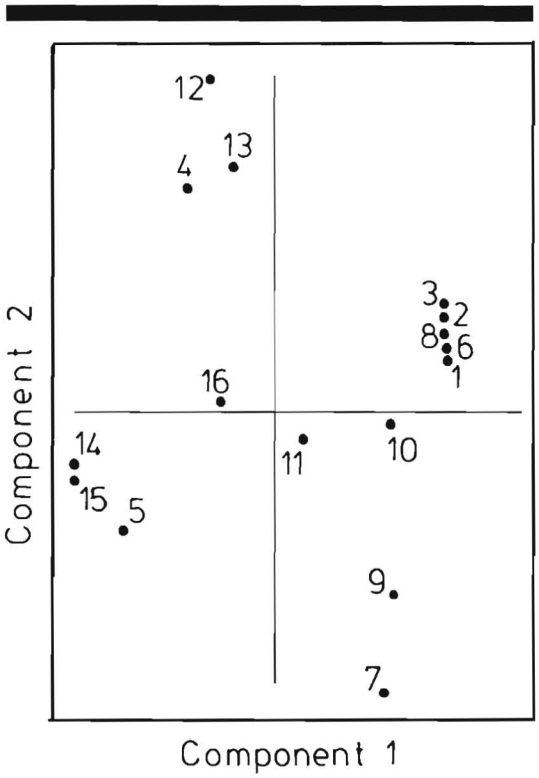

Figure 5. Representation of the variables of the system of Rhodes in two dimensions by Principal Component Analysis. The names of the variables are given in Table 2.

The first Zone is without doubt the least probable for agricultural development; tourism occupies the largest part of employment and agriculture is not important in this urban area. The results of the multicriteria analysis indicate that the fifth Zone, the southern area of the island, holds a high score in all three multicriteria trials with different priorities. Therefore, this area presents a land for future exploration in regard to tourist activities and agricultural development and allows for the application of an integrated policy. The third zone rates about the same; the fourth zone, the western and mountainous part of the island, does not present a development potential, *i.e.*, suprastructure, population and employment. The second Zone in the northwest, presents a moderate profile in the three multicriteria runs, and this can be interpreted as an indication that this area is going to develop the same way as the first Zone unless a different policy is applied.

Ordination and Classification techniques as well

as Principal Component Analysis have been used with the same data set as multicriteria analysis. The results of the three different methods show a clear distinction between intensity of land use and environmental quality on the island, probably as a result of the weak implementation or absence of land use controls. This evidence is supported by the findings of multicriteria analysis. In fact, the MDS plot, the dendrogram and the PCA plot resulted in two main aggregates, on the one hand the variables characterising the quality of natural resources and on the other the variables characterising the intensity of land use. Future policy for the development of the island should acknowledge the necessity to link these above two components in a coherent strategy of integrated management of coastal resources.

Multiple Criteria Analysis has proved to be a powerful tool for a systematic analysis of complex systems where quantitative and qualitative variables are involved. Multivariate techniques can assist in the illustration of existing patterns of interactions of the various components of an economic/environmental system and the identification of key factors in the development/environment interface. Therefore, both tools are valuable in policy-planning for multidimensional systems, for instance in coastal areas.

LITERATURE CITED

ANDERSON, J.W., 1984. *An Introduction to Multivariate Statistical Analysis.* New York: Wiley, 675p.

CLARKE, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology,* 18, 117–143.

CLARKE, K.R. and GREEN, R.H., 1988. Statistical design and analysis for biological effects study. *Marine Ecology Progress Series,* 46, 213–226.

COCCOSIS, H., KARYDIS, M., MARGARIS, N., PAPAGEORGIOU, G., PYRGIOTIS, Y., VERNICOS, N., and CHIOTIS, G., 1991. *Development Scenarios for Rhodes, Phase I Report.* Athens: University of the Aegean, Department of Environmental Studies. UNEP/MAP/BLUE PLAN.

COCCOSIS, H., KARYDIS, M., MARGARIS, N., PAPAGEORGIOU, G., PYRGIOTIS, Y., VERNICOS, N., and CHIOTIS, G., 1993. *Development Scenarios for Rhodes, Phase III Report.* Athens: University of the Aegean, Department of Environmental Studies. UNEP/MAP/BLUE PLAN.

FIELD, J.G., CLARKE, K.R., and WARWICK, R.M., 1982. A practical strategy for analysing multispecies distribution patterns. *Marine Ecology Progress Series,* 8, 37–52.

HARTOG, G., HINLOOPEN, E., and NIJKAMP, P., 1989. A sensitivity analysis of multicriteria choice-methods. *Energy Economics,* October, 293–300.

HINLOOPEN, E. and NIJKAMP, P., 1990. Qualitative multiple criteria choice analysis, the dominant regime method. *Quality and Quantity,* 24, 37–56.

IGNATIADES, L., KARYDIS, M., and VOUNATSOU, P., 1992. A possible method for evaluating oligotrophy and eutrophication based on nutrient concentration scales. *Marine Pollution Bulletin,* 24(5), 238–243.

KARYDIS, M. and COCCOSSIS, H., 1990. Use of multiple criteria for eutrophication assessment of coastal waters. *Environmental Monitoring and Assessment,* 14, 89–100.

KARYDIS, M., 1992. Scaling methods in assessing environmental quality: A methodological approach to eutrophication. *Environmental Monitoring and Assessment,* 22, 123–136.

NATIONAL STATISTICAL SERVICE OF GREECE, 1986. *Distribution of the Country's Area by Basic Categories of Land Use.* Hellenic Republic, Athens.

NIJKAMP, P., RIETVELD, P., and VOOGD, H., 1990. *Multicriteria Evaluation in Physical Planning.* Amsterdam: North-Holland, 219p.

OFFICE NATIONALE DE STATISTIQUE DE GRECE, 1991. *Resultats du Recensement de la population et des Habitations, effectue le 5 Avril, 1981.* Republique Hellenique, Athens.

SNEATH, P.H.A. and SOKAL, R.R., 1973. *Numerical Taxonomy.* San Francisco: Freeman, 573p.

STATGRAPHICS (STATISTICAL GRAPHICS SYSTEM), 1989. *User's Manual.* Rockville, Maryland Statistical Graphics Corporation, 546p.

VOUNATSOU, P. and KARYDIS, M., 1991. Environmental characteristics in oligotrophic waters: Data evaluation and statistical limitations in water quality studies. *Environmental Monitoring and Assessment,* 18, 211–220.

WARWICK, R.M., 1986. A new method for detecting pollution effects on marine macrobenthic communities. *Marine Biology,* 92, 557–562.

WCED (WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT), 1987. *Our Common Future.* Oxford: Oxford University Press.