A Method for Selecting Sustainability State Environmental Indicators for Insular Areas

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Abstract. *The notion of sustainability has become a modern catchword. Although it is used widely at the policy level, only few cases deal with its measurement, especially at the local level. Here, we develop and apply a practical tool at island level with the use of indicators selected and adapted from international agencies and institutes. The identification of the environmental state significant factors and the selection of the indicators are based on island characteristics and the fact that it is in the Mediterranean. The values of these indicators were calculated for the island of Paros, Greece. The findings reveal that the method can be of great use for sustainability evaluation and planning islands' sustainable development.*

Keywords. Islands, Environmental indicators, State Indicators; Sustainability Measurement.

1. Introduction

Sustainability and sustainable development are notions that are widely used today in areas of research, policies, monitoring and planning. After their original adoption from the United Nations (UN) back in 1992, a number of different approaches have been developed, both at theoretical and practical levels. The outcome is that sustainability has become a modern 'catchword' that everyone uses, but its content and estimation methods vary. Most of these approaches however, even if they define it differently, aim at constructing measurement tools for evaluating policies. These methods can be classified into three categories: (a) sectoral methods of measurement; (b) methods based on the different dimensions of sustainability; and (c) integrated methods.

Most of the sectoral methods found in the literature are restricted to issues regarding enterprises and their performance [5], or sustainability and impact of specific sectors such as agriculture [20].

Measurements of the different sustainability dimensions include methods for:

(a) Economic dimension based on traditional economic methods and models, with the Index of Sustainable Economic Welfare (ISEW) a common one [6].

(b) Social dimension, based on the welfare of people and societies, including issues such as quality of life, social cohesion, human development etc. [9], mostly at the international level [19].

(c) Environmental dimension, such as the Environmental Sustainability Index (ESI) [28] and the Environmental Performance Index (EPI) [13] among others. A special category here is resource efficiency measures, such as the ecological footprint [26]. Also, here international organizations have developed conceptual frameworks for measuring sustainability such as the PSR (Pressure – State – Response), the DSR (Driving Forces – State – Response), and the DPSIR (Driving Forces - Pressure – State – Impact - Response) [16]; [24]; [11].

Integrated methods for measuring sustainability include methods that develop theoretical frameworks for the analysis and/ or assessment of sustainable development such as UNEP [25], among others [2]; [3]; [18]. Other methods assist the development and/ or selection of sustainability indicators, some with a single index [29]; [1] and others with many indicators

[12]. The EU has incorporated sustainability and sustainable development in all its policies, with a so-called ‘three pillars approach’, which simultaneously aims at the achievement of economic efficiency, social equity and cohesion and environmental conservation [5].

Here, we develop and apply a practical tool for sustainability measurement and improvement at the local level that of an island. The conceptual model behind the method is that of the DPSIR, adapted to include economic and social issues as well as environmental ones [22]. Overall, 9 indicators were selected for the state of the economy in the area, 11 for the state of society and 19 for the state of the environment [22]. In this paper, the approach of recording the environmental state with the use of selected indicators will be presented for a specific island, that of Paros in the South Aegean Region of Greece. In the next section the method is presented in some detail, along with the research conducted to apply it to the case study island. The presentation of the results follows with a discussion of the application of the method in the particular case study and its positive and negative points.

2. Methods and Data

2.1 The Method Developed

In the DPSIR framework, the state of the environment at the local level is presented with the use of selected indicators. By state of the environment, we refer to the quality and quantity of the environmental resources under change or pressure from human activities. This definition is adopted to highlight the problems and then offer solutions that eventually will improve the state of the environment. The indicators used are scale specific and site specific. Different scales (e.g. international, national, local) allow focusing on different aspects and issues that are more significant and relevent for the environment at each scale. Especially for environmental issues, scale is very important because as the level of detail grows, different spatial and temporal aspects of the environment have to be taken into account. At the same time, different localities also require different indicators, as the importance of most of the environmental issues differs in different localities.

In this particular approach, the method is developed for a small island, that of Paros (and the smaller island of Antiparos). The identification of the most significant factors for the environmental state in such a locality is performed with producing a general matrix of environmental issues and selecting the significant factors by their relevant importance for the study area. This matrix (Table 1) is divided in five unities (visually five columns): (a) the ecosystem type which is considered to be the basic environmental unit designating natural resources quality and quantity and human activity intensity; (b) biotic and abiotic resources in each of these types; (c) liquid, gas and solid waste for each ecosystem type; (d) natural dangers and catastrophes; and (e) ecosystemic functions that change or threats resulting from changes in the previous unities. In the horizontal dimension of the matrix, concepts mentioned once are not repeated (e.g. the flora and fauna of the biotic resources correspond to all ecosystem types but are only mentioned once). Three types of ecosystems were considered: natural, agricultural and built. Natural ones were further subdivided to terrestrial, inland waters, coastal and marine ones; the agricultural ones are divided to cultivated and grazing lands; and built areas were divided to settlements, tourism areas (is separate from settlements), infrastructure and industry – manufacture areas.

The selection of the significant factors and threats for the area studied from this general matrix is done according to environmental, social and economic criteria compiled with the use of previous research (especially [16]; [10]; [24]).

The study area, small Mediterranean islands (in contrast with bigger islands like Corse, Crete, etc.) are thus characterized by:

(a) Insularity, which involves small spatial scale, limited natural resources, accessibility problems and high population variability during the year [20].

(b) “Mediterraneanity”, which involves (i) a climate characterized by long, dry and hot summers and short and intense rainfalls in a short period of winter [8]; (ii) a relief of mountain areas of high gradients and variability of geology and soil types [8]; [4]; (iii) strong human presence and shaping of landscapes in most of the areas for long time periods, leading to semi-natural habitats and environments that fluctuate with economic and social changes. Moreover, human presence is connected with cultural heritage, which is regarded as an asset and a resource for the area and at the same time imposes restrictions on economy and land use.

(c) An economy based on tourism and services mostly, but also on small scale, family agriculture. In the approach employed here, we are interested in the more “dynamic” sectors of the economy. By “dynamic”, or “competitive” activities we refer to activities that can be characterized as ‘exporting’, namely products or services that bring incomes to the area and not those that are mostly for the local civil sector that recycle existing incomes (e.g. commerce, public administration, education services). Such activities for the areas in question are considered agriculture (in the extent that it may produce products that are exported from the islands) and tourism services.

From the analysis of the functions, threats and particularities that are studied (Table 1), five environmental factors were considered as most important for the local level: (a) biodiversity; (b) land use; (c) water quantity and quality; (d) soil quantity and quality and; (e) urban environment. The indicators that are selected for each of these factors are taken from existing approaches from international agencies and institutes [10]; [24]; [12]; [17]. Some were adapted to the particularities of the Mediterranean islands’ conditions and additional some new indicators were created according to this study’s requirements. Overall, 19 indicators were selected for the state of the environment [22] (Table 2).The selected significant environmental factors are:

(i). Biodiversity or biological diversity measures ecosystem and species richness in an area. Three different ‘levels’ are used: genetic, species and habitat diversity. Higher levels of biodiversity are generally linked with environmental stability and better state of the environment. Protection and protected areas are essential in preserving biodiversity [24] and the percentage of such areas can serve as an indicator of the existence of ecosystems that are rare or endangered or are habitats for rare or endangered species. Here, it is covered by two indicators (I1, I2), measuring the percentage of protected areas as a whole and per type of ecosystem. These indicators are considered as Response in the DPSIR framework, but are used here as it is assumed that they can assess biodiversity at the local level.

(ii).Land uses are indicators of the environmental state and their changes assess pressures on the environment due to human actions. The type of land use defines or affects species and soil and water resources [16] and the type of change can alter the state of an area permanently, especially when it involves building or infrastructures. Land uses also shape landscapes and their changes alter the functions and forms of these landscapes. Land use change is covered by five indicators. The first of these is actually a series of indicators, with values as many as the land uses that are measured in the area (I3). The rest indicators cover important aspects of land use change like fire (I4), sparse built-up area in general (I5) and in particular for coastal areas (I6) where the pressures are greater in tourism islands and land use diversity with the use of Shannon’s index (I7) [27].

(iii). Water quantity and quality is an environmental issue of great importance and refers to marine, coastal, surface and underground waters. For each of these ecosystems, different issues are more important, according to the type of pressures applied on them. Especially for, surface and underground water quality is very important. On islands, surface waters are rare and most of the water used for drinking and irrigation comes from the underground aquifers via pumping. At the same time, coastal waters are a vital tourism resource and their quality is of great importance. Here, it is covered with five indicators, measuring underground water quantity (I8) and drinking water quality (I9) (measured by the concentrations of a number of chemical compounds and elements according to EU directives 75/440 and 98/83/EE and relative national legislation). Available water in storage reservoirs (I10) is also measured, along with desalinated or imported water (I11) that indicates local scarcity of drinking water. Finally, bathing water quality (I12) is measured according to EU Directive 76/160/EEC.

(iv). Soil quantity and quality is also an environmental issue of great importance and is mostly related to cultivated soils that are under more pressures than the rest. Apart from the type of land use, farming practices and management techniques are very important for determining the intensity of pressures on soils [11]. In the Mediterranean, the threats on soils come mostly from erosion and quality degradation that can cause desertification [23]. Degraded soils are less productive and support less diverse ecosystems and this degradation is usually permanent [24]. There are also soils that are affected from actions such as landfills and waste treatment in general. These soils may be severely degraded but on a small scale compared to agricultural lands. Here, Soil quality and quantity is measured with four indicators, a complex index [14] of Environmental Sensitive Areas to desertification (I13), a series of indicators for the different types of cultivated land per category of practices intensity (low, medium, great)(I14), the percentage of the organic farming area (I15) and the solid waste landfill area (I16).

(v). Urban environment includes settlements, tourist areas, infrastructures and industry – manufacture areas. Each of these types generates different pressures on the environment. Besides waste generation and land use change, the quality of the built environment is also related to the quality of life in it (landscape, commonly used areas, traffic, noise, microclimates, etc.). On islands with high tourism intensity, air pollution is not very important, although traffic and noise issues can be severe seasonally. Here, urban environment is covered with three indicators measuring non built-up urban areas in the total urban area of the main settlement (I17), the number of cars per km of road (I18) and the percentage of renewable energy produced per total conventional energy produced (I19).

2.2 Data for the Application of the Method

Data for calculating the values of the selected indicators were derived through primary research and from official sources (published or unpublished). Research was required due to unavailability of monitoring data even for relatively simple issues, such as the land uses or the water reserves of the island in question. As land uses and their changes are central to the approach developed here, an exact calculation was essential. This was accomplished via photograph interpretation of aerial photos of 1996, the most recent available. These photographs were digitally corrected and 16 different categories of land uses were calculated (Table 3). Field observations were conducted in winter 2006 for disputed areas. Overall, the data sources and the calculation method (where applicable) are presented in detail in Table 2.

3. Application of the Method and Findings

Paros is a medium size island of the Aegean Sea Greek islands (approximately 230 km^2), with a population of 12,853 inhabitants (2001). It is a tourism dependent island and a popular summer destination for Greeks and foreigners. It can be reached via ferry-boat from Pireas port and airplane from Athens airport. It can be regarded as one of the most accessible Aegean islands [23]. In the past, agriculture was also developed, due to the extended plain areas and fertile soils comparatively to most small neighboring islands, but nowadays it is abandoned. Today, 11% of the active population is still employed in agriculture, most aged.

Table 3. Area per ecosystem type and areas under protection on Paros

Type of ecosystem under protection (NATURA 2000)	Land use class (aerial photo interpretation)	Land use type	Total area in km^2 (%)	Area for protection in km^2 (%)
Cultivated land	Arable land	High intensity agricultural land	70.11 30.5)	0.2 (0.3)
	Tree crops	Low intensity agricultural land	14.35 (6.2)	
	Vines	Medium intensity agricultural land	6.80 (3.0)	
Mediterranean bushes (maquis)	Shrub (<10%)	graze land	77.0 (33.6)	9.37 (7.7)
	Shrub (10-40%)	graze land	17.14 (7.5)	
	Shrub (>40%)	Natural shrubland	27.4 (11.9)	
Forests	Forest	Forest	0.33 (0.1)	0.1 (21)
	Forest (10-40%)	Forest	0.15 (0.1)	
Built areas	Coastal urban	settlements	2.03 (0.9)	0.04 (0.4)
	Sparse urban area	settlements	4.06 (1.8)	
	Settlements, infr.	settlements	3.09 (1.3)	
Coastal rocky	Bare rock	other	5.75 (2.5)	0.44 (7.7)
	Quarry	other	0.49 (0.2)	
Coastal sandy	Sandy beaches	other	0.54 (0.2)	0.44 (81.3)
Freshwater	Rivers	surface water	0.24 (0.1)	0.24 (100)
Wetlands	Lakes – wetlands	surface water	0.07 (0.0)	0.04 (55.6)
Total			**229.6 (100)**	**10.87 (4.7)**

For considering the biodiversity factor, two areas of Paros are placed among the sites to be protected in the NATURA 2000 network: the area *Petaloudes* on Paros island (GR4220016) and small islets *Despotiko* and *Stroggilo* (GR4220017) of total land area 10.87 km^2 (4.7% of the total). These areas include cultivated land, Mediterranean maquis vegetation, forests, settlements, coastal rocky ecosystems, coastal sandy ecosystems, freshwater and wetlands (Table 3). Some of the most important and fragile types (such as wetlands, sandy beaches and rivers) are under protection in a great extent, along with forests.

For land uses, 16 different types were identified (Table 3): 3 types of cultivated land (arable; trees; vines), 2 types of grazing land distinguished by the density of shrubs (<10%; 10-40%), 1 type of natural shrubland, 2 types of forest also distinguished by tree density (dense forest; 10-40%), 3 types of built areas (coastal urban; sparse urban; settlements, airport, infrastructure), 2 types of surface waters (rivers;

lakes – wetlands) and 3 other (bare rock; quarry; sandy beaches). Most of the area is shrub (53% of the total area), which is grazed at different degrees of intensity and an important part (30.5%) is arable land. Urban areas are less in size than sparse built up areas, revealing urban sprawl, especially in coastal areas. Burnt areas are few on the island and in 2003 only 7 incidents occurred burning a small percentage of cultivated and grazing land (Table 2). Overall, the different patches are small and diversity values are high, a positive result, although local differences can be important, especially between hilly and plain areas and coastal and non coastal, with higher diversity in plain and coastal areas.

Drinking water quality is in general satisfactory, as all measurements of 2005 are always below the official limits, with the exception of one measurement for which further monitoring is required. Nevertheless, microbial measurements are not conducted (as the water is chlorined), neither analysis for pesticides or organic substances in general. Moreover, monitoring is inconsistent and the possibility of seasonal or accidental high or low values can not be estimated. Coastal water quality is also satisfactory for all 17 points of sampling, with the exception of 2 sites in 2002 and 6 sites in 2003 (high values but lower than the limits). These measurements indicate point local sources of organic waste that require further monitoring to identify them. But, older measurements indicate that the state of coastal water quality is improved, as the values of tar, organic waste and oils is significantly reduced since 1994 when annual monitoring begun.

Water quantity indicators show that the drinking water is not enough as 450,000m^3 are desalinized each year with maximum daily rate at 1,200 m^3. Underground water is theoretically enough (8,960,000 m^3 together with the island of Antiparos), but not all of it can be used. Supplementary fresh water is stored in small dams approximately at 220,000 m^3 per year (3% of the underground reserve) and it is used for irrigation, as it is available only in winter months, where demand is lower than summer, where tourists increase the population demand for fresh water.

Soil quality is at risk on Paros. The ESAI method results (Figure 1) reveal that a significant part of the island is under desertification threat (79% of Paros and 81% of Antiparos are classified as critical), especially hilly grazed areas. Brave decisions both at EU, national and local policy levels are required to reduce this risk, as management practices are held responsible for this situation to a great extent. Such decisions should include reducing grazing pressure and maintaining terraces among others. These findings are verified by the intensity of agricultural land uses (cultivated and grazing lands). Although exact and comparable data are not available for all types of land use, the grazing pressure (number of grazing animals per ha of grazing land) is overall high (in total 1,533 cows, 4,091 sheep and 6,446 goats graze the 94,190 ha of grazing lands, resulting to densities of 3.1 Animal units/ha), but locally it is even higher, leading to increased risks of soil degradation. Arable land on Paros is mostly irrigated vegetables, irrigated animal feed and non irrigated cereals. The first two types can be considered of high intensity for the islands resources. The rest land use types (olives and vines) are considered of lower intensity, but hold together 18% of the total area (Tables 2 and 3). Moreover, organic farming is very limited and only on less intensive uses (olives and vines). Finally, the area where untreated solid waste is laid is small (0.105 km^2 or 0.05 % of the area), but it is a source of point pollution, especially since waste is untreated.

The state of the urban environment appears to be overall satisfactory, but averages can be misleading. The percentage of open spaces stands at 20% of the total urban areas in the main settlement of the island, but a closer look reveals that the way this settlement is built leaves no open spaces in its old and preserved centre and the wider spaces are located in the more recently built edges. As the centre is traditional and part of the islands' identity, this situation will not change. Therefore, traffic problems are severe in the tourism peak season. Finally, the local branch of the Public Energy Enterprise provided no data for renewable energy sources on the island. Our experience and local informants converge that there are no such sources besides domestic solar water heating. All the indicators' values and an initial assessment are summarized in Table 2.

4. Discussion

The method developed here for the estimation of environmental sustainability state at a local scale and its application on the island of Paros has revealed a number of issues for such methods:

(i) Although there is no standard monitoring method for the environmental state in Greece, data for many of the indices used here (with the exception of land use allocation) are available from different public services (National, Regional or local). An agency that could collect the data from all these sources could monitor the environmental state at all levels.

(ii) Local scale environmental sustainability state estimation is a difficult target, more difficult than higher spatial level approaches (regional, national, international. As the level of detail grows, averages prove less and less suitable and explicit spatial specialization is required. Some examples of how averages shade local issues are grazing pressure that available data do not allow its spatial allocation and water quantity and quality, where acceptable average values may hide local problems. This is an inherent problem of environmental issues at all spatial levels, but the local level appears more troublesome, as more seasonal concerns may be applicable as well. In the case study used here, the overall environmental state of Paros appears as less than acceptable, but more severe problems may shade themselves underneath this overall assertion.

(iii) Constant monitoring is required if the method presented here is to produce useful results. The values of the indicators provide a baseline for an initial assessment and for further reference. Different indicators require different monitoring time scales to cover seasonal issues as well. The unavailability of an existing monitoring system implies that such a system should be build. If so, then these findings could be used for identifying the causes that the state is not satisfactory and respond to these causes to improve the sustainability state eventually.

(iii) The fact that the case study is an island is very helpful in determining people, material and energy flows. Indeed, islands are exemplary cases for these types of estimations at local level, revealing both their strength as concrete spatial entities, but also their weakness, in the sense that separate estimations are necessary for each island, while in continental areas 'summing up' can be easier.

The method presented here has provided an initial but necessary step for environmental sustainability state evaluation and eventually planning for sustainable development at the local scale. It has produced a set of indicators and applied them to an island to underline the strong and weak points. Further research is required for its connection with planning procedures and monitoring systems for its application.

Acknowledgments

The method and its application were financed by the ISTOS program (Innovation for Sustainable Tourism and Services in the South Aegean, Action 1.1 of Activity 7.1), a co-financed regional innovation program (by EC and the Greek Ministry of Economics and Finance).

References

[1]. Anderson J, Nicol S, Ng M, Veale A, Imberger I. The sustainability index for Western Australia: a methodological framework for the contribution of a new measure of progress. Proceedings of the International Conference Nature, Science and Social Movements; 2004 June 25-28; Mytilene, Greece; 2004.

[2]. Bell S, Morse S. Sustainability indicators: measuring the immeasurable. London: Earthscan; 1999.

[3]. Bell S. Morse S. Experiences with sustainability indicators and stakeholder participation: a case study relating to a 'Blue Plan' project in Malta. Sustainable Development 2004; 12: 1-14.

[4]. Brant C J, Thornes J. B. Mediterranean desertification and land use. London: John Wiley and Sons; 1996.

[5]. CEC. Draft declaration on guiding principles for sustainable development. COM(2005) 218 final. Brussels: CEC; 2005.

[6]. Dalal-Clayton B, Sadler B. Sustainability appraisal: a review of international experience and practice. IIED; 2005.

[7]. Daly E H, Cobb B J. For the common good: redirecting the economy toward community, the environment and a sustainable. London: Greenprint 1990.

[8]. Di Castri F. Mediterranean-type shrublands of the world. In: Di Castri F, Goodall, Specht editors. Ecosystems of the World-Mediterranean–type shrublands. The Netherlands: Elsevier; 1981.Duhaime G, Searles E, Usher J P, Myers H, Fréchette P. Social cohesion and living conditions in the Canadian Arctic: from theory to measurement. Social Indicators Research; 2004; 66: 295–317.

[10]. European Commission. Towards environmental pressure indicators for the EU. Luxembourg: European Commission, http://www.e-m-a-i-l.nu/tepi/document.htm; 1999.

[11]. EEA. Indicator Factsheet, Signals 2001. www.eea.eu.int/indicators; 2001.GHK, PSI, IEEP, CE & National Evaluators. The Thematic Evaluation on the Contribution of the Structural Funds to Sustainable Development. Final Report to the European Commission, DG REGIO, ECOTEC Research and Consulting Ltd, Birmingham, Brussels, London, Madrid; 2002.

[13]. Hoti S, Pauwels L L, McAleer M. Measuring environmental risk. Proceedings of the iEMS Conference; 2004; June 7-9; Copenhagen Denmark; 2004.

[14]. Kosmas C, Kirkby M, Geeson N, editors. Manual on key indicators of desertification and mapping environmentally sensitive areas to desertification. The MEDALUS project: Mediterranean Desertification and Land Use. EC; Luxemburg; 1999.

[15]. OECD. OECD core set of indicators for environmental performance reviews. OECD Environment Monographs No. 83. Paris: OECD ; 1993.

[16]. OECD. Environmental Data, Compendium 2002. Paris: OECD; 2002.

[17]. OECD. OECD environmental indicators: development, measurement and use. Reference Paper. Paris: OECD; www.oecd.org/env; 2003.

[18]. Ravetz J. City region 2020. Integrated planning for a sustainable environment. London: Earthscan Publications; 2000.

[19]. Sirgy M J, Lee D J, Miller C, Littlefield E J. The impact of globalization on a country's quality of life: towards an integrated model. Social Indicators Research; 2004; 68: 251-298.

[20]. Smith C S, McDonald G T. Assessing the sustainability of agriculture at the planning stage. Journal of Environmental Management; 1998; 52: 15-37.

[21]. Spilanis I. Qualité versus quantité: une stratégie durable pour les îles'. In Meistersheim A. Editor. L'île laboratoire, Ajaccio: Alain Piazzola; 1998.

[22]. Spilanis I, Kizos T, Kondili J, Koulouri M, Vakoufaris H. Sustainability Measurement In Islands: The Case Of South Aegean Islands, Greece. Proceedings of the Conference Biodiversity conservation and sustainable development in mountain areas of Europe; 2005; Sep 20-24; Ioannina, Greece; 2005.

[23]. Spilanis I, Kizos T, Kondili I, Misailidis N. Accessibility and attractiveness of Aegean Islands. Aeihoros; in press (in Greek).

[24]. UNCSD. Indicators of sustainable development: guidelines and methodologies. New York: UN; 2001.UNEP. Integrated assessment and planning for sustainable development. Guidelines for pilot projects. UN; 2004.

[26]. Wackernagel M, Rees W E. Our ecological footprint: Reducing human impact on the earth. New Society Publishers; 1996.Wacsher D M. Agri-Environmental Indicators for Sustainable Agriculture in Europe. The Netherlands: ECNC; 1999.

[28]. Yale Center for Environmental Law and Policy and Center for International Earth Science Information Network. 2005 Environmental Sustainability Index. Benchmarking National Environmental Stewardship. USA: Center for Environmental Law and Policy www.yale.edu/esi; 2005.

[29]. Zoeteman K. Sustainability of nations. International Journal of Sustainable Development and World Ecology; 2001; 8: 93-109.

Table 1. Specification of a general environmental problems matrix for the area studied

Ecosystem	Resources			Waste			Dangers / natural catastrophes	Functions/threats	Environmental issues
	Biotic	*Abiotic*	*Cultural*	*Liquid*	*Solid*	*Gaseous*			
Natural*:* *Terrestrial* Water *Coastal* *Marine*	Flora Fauna Micro-organisms	- Soil - Underground aquifers - Rocks - Minerals - Climate - Water - Coastal formations - Marine soil formations	Landscape Recreation		Soil material from erosion		Fires Earthquakes Floods /storms Landslides Drought Major ship accidents	Reduction of flora and fauna diversity	
								Underground water quality and quantity: Exhaustion, overexploitation; Salinization	Underground water quality and quantity
								Land use changes: Land clearing; Abandonment; **Building**	Sparse and unplanned building
								Fires	Fires
								Floods	
								Erosion	
								Desertification	Desertification
								Landscape change	
								Protected habitats and species	Protected habitats and species
								Coastal water quality: Eutrophication; Deposition; **Illuviation**	Coastal water quality; Landfill
								Surface water quality	Surface water quality
								Sea water quality	
Agricultural *Cultivations* *Graze lands*	Cultivated species – Animals raised Flora Fauna	Soil Underground aquifers Rocks	Landscape Recreation	Agricultural land runoff	Erosion sediments		Biotechnology Diseases of large scale Fires Earthquakes Floods /storms Landslides Drought	**Farming practices: conventional or sustainable**	Organic / sustainable agriculture
								Soil salinization	
								Soil crusting	
								Fertility degradation	
								Productivity degradation	
								Chemical substances use	Chemical substances use
								Monoculture	Cultivated species – Animals raised
								Cultivation terraces maintenance	
								Natural vegetation clusters maintenance	
								Local / adapted species and varieties	
								Overgrazing	Overgrazing
								Fires	
								Flora and fauna diversity reduction	
								Underground water quality and quantity: Exhaustion, overexploitation; Salinization	
								Land use changes: Land clearing; **Abandonment***;* **Building**	Abandonment
								Erosion	
								Desertification	
								Landscape change	
								Protected habitats and species	
Built *Settlements, Tourist areas, Industry - Manufacture*		Atmosphere	Culture	Untreated urban waste Untreated industrial waste	Untreated urban waste Untreated industrial waste	Vehicle emissions Industry waste	Fires Earthquakes Floods /storms Landslides Drought	**Untreated liquid waste**	Untreated liquid waste
								Untreated solid waste	Untreated solid waste
								Gas emissions	Gas emissions
								Transport / traffic	
								Unplanned building	
								Impermeable areas increase	
								Urban environment quality	Urban environment quality
								Energy production	Energy production

Bold: threats of high significance for the area studied; *Italics: threats of medium significance for the area studied;* Grey colored: threats of low sfor the area studied

Table 2. Sectors of the state of the environment of the area studied, indicators used per sector, data sources and calculation method

Environmental Issue	Indicators (measurement units)	Data sources (year); Calculation method	Results	Assessment
Bio-diversity	I1 .Protected area / total area (%)	Ministry of Environment, Spatial Planning and Public Works database on NATURA 2000 sites and Ministry of Agriculture, Interpretation of aerial photos (1996)	4.7 %	++
	I2. Protected area per type of ecosystem/ total area (%)	Ministry of Environment, Spatial Planning and Public Works database on NATURA 2000 sites and Ministry of Agriculture, Interpretation of aerial photos (1996)	Table 3	++
Land use types	I3. Land use area per land use/ total area (%)	Ministry of Agriculture, Interpretation of aerial photos (1996)	Table 3	+
	I4. Burnt area per land use/ total area (%)	Fire Department of Paros (2003) and Ministry of Agriculture, Interpretation of aerial photos (1996)	Cultivated land 0.04% Grazing land 0.2%	++
	I5. Sparse built-up area / total area (%)	Ministry of Agriculture, Interpretation of aerial photos (1996)	2.7%	-
	I6. Built-up coastal area/ total area (%)	Ministry of Agriculture, Interpretation of aerial photos (1996)	0.8%	-
	I7. Diversity of land use (Shannon's index, number)	Ministry of Agriculture, Interpretation of aerial photos (1996); Calculation with Shannon equation [27] $H(b) = -\sum p_{i/j} \times \ln p_{i/j}$; *H(b)* stands for limit diversity between different land use patches, *Pi/j* stands for the percentage of the limit between neighbouring patches *i* and *j* for the total number *N* of limits in the area		++
Water quality and quantity	I8. Freshwater resources quantity (m^3)	Water reserves management program for Greece (2002) and meteorological data (1998-2002); Calculations with use of "Theoretical existing ground water potential" ($m^3 * 10^{-6}$) that represents the maximum quantity of water that can be stored in the aquifers of the area (in most cases 30-40% can actually be used)	$8.96\ m^3 * 10^{-6}$	++
	I9. Quality of drinking and irrigation water (concentration of chemicals, ppm, ppb)	Public Enterprise for Drinking Water and Sewages of Paros (2005); Calculations according EU Directives 75/440/EE, 98/83/EE and 2000/60/EE	Acceptable	+
	I10. Available water in storage reservoirs (m^3)	Public Enterprise for Drinking Water and Sewages of Paros (2004)	7.600.000 m^3	++
	I11. Desalinated or imported water (m^3)	Public Enterprise for Drinking Water and Sewages of Paros (2004)	450.000m^3	-
	I12. Bathing water quality (bacteria concentration, ppm, ppb)	Ministry of Environment, Spatial Planning and Public Works measurements (2002-2004); Calculations according to EU Directive 76/160/EEC	Acceptable	+
Soil quality and quantity	I13. Desertified area / total area (%)	Ministry of Agriculture, Interpretation of aerial photos (1996); Calculation with the use of the index for Environmentally Sensitive Areas to desertification (ESAI) [14] with quality indicators for soil (SQI), climate (CQI), vegetation (VQI) and management (MQI). ESAI calculated with formula: ESAI = $(SQI*CQI*VQI*MQI)^{1/4}$. According to the values of ESAI, the areas are characterized into 8 classes: 3 critical; 3 sensitive; 1 possible and 1 neutral	Figure 1	-
	I14. Cultivated area per category of intensity / total area (%)	Ministry of Agriculture, Interpretation of aerial photos (1996)	Arable (high intensity): 70.11 km^2 (37.8%) Grazing lands (high intensity): 94.19 km^2 (50.8%) Tree crops (low intensity): 14.35 km^2 (7.8%) Vines (low-medium intensity): 6.8 km^2 (3.7%)	-
	I15. Organic farming area / total cultivated area (%)	Department of Agriculture and Rural Development on Siros island (2003) and Ministry of Agriculture, Interpretation of aerial photos (1996)	Olives: 1.28% Vines: 1.18%	-
	I16. Solid waste landfill area (ha)	Municipality of Paros (2005)	0.105 km^2 (0.05 % of total)	+
Urban environment	I17. Non built-up urban areas / total urban area (%)	Municipality of Paros (2005) and Ministry of Agriculture, Interpretation of aerial photos (1996)	0.057 km^2 (20% of urban)	++
	I18. Number of cars per km (cars / Km)	National Statistics Service of Greece (2003) / Municipality of Paros (2005)		-
	I19. Renewable energy produced / conventional energy produced (%)	Local branch of Public Electricity Enterprise (no data)	No data	*

(++): Good state; (+) Acceptable state; (-): Not acceptable; (*): Unknown (no data)

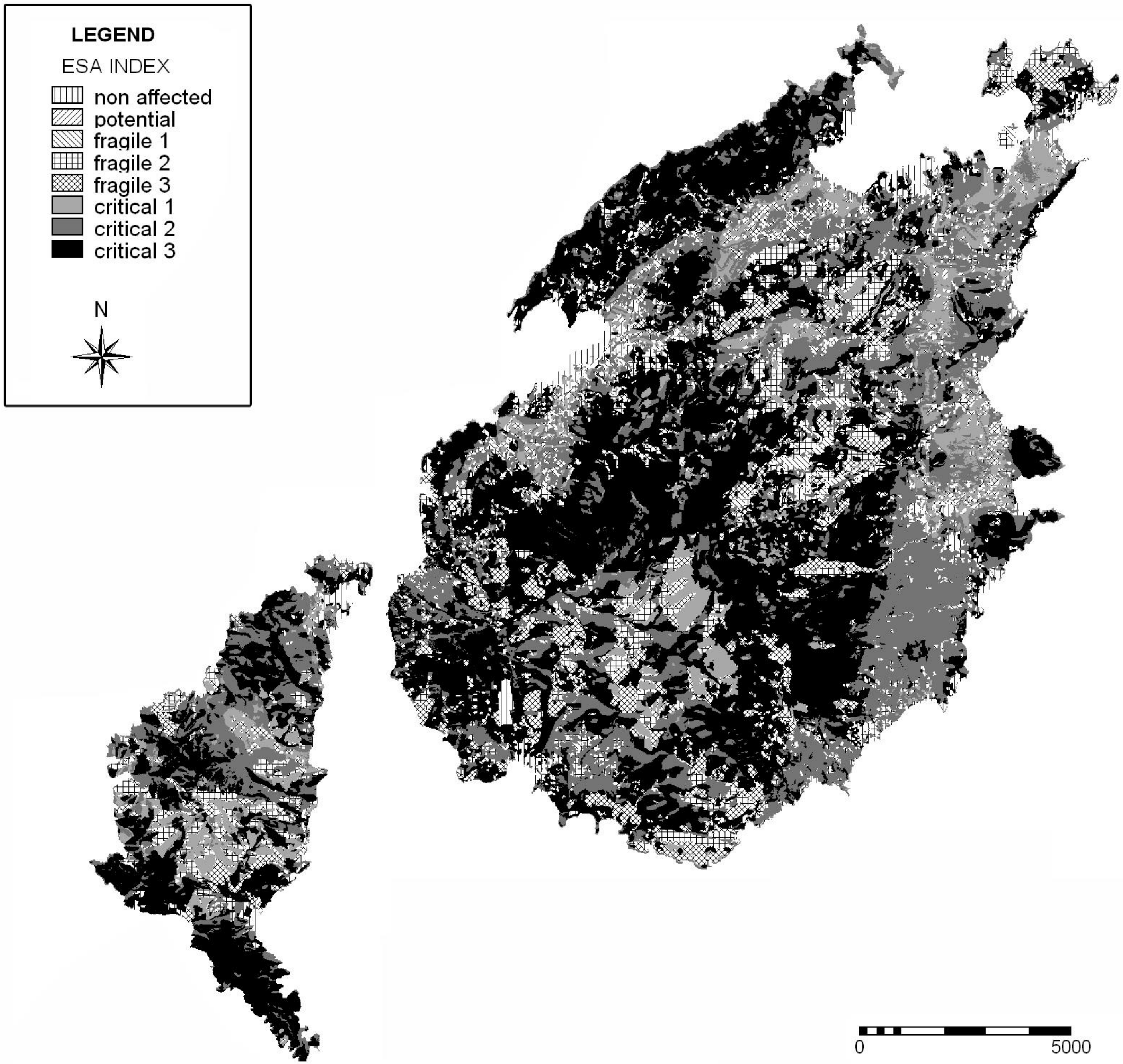

Fig. 1 : Map of the environmentally sensitive areas (ESA INDEX) to desertification for the islands of Paros and Antiparos