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RESEARCH ARTICLE

A contribution to Cumulative Effects Assessment for regional sustainable development – the case of Panagiouda-Pamfilla bay, Lesvos Island, Greece

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Abstract

1 - Environmental management is based on the environmental response to cumulative stress. We identified and evaluated cumulative impacts arising from 11 small-size commercial/processing/industrial units at the 92.9 km^2 catchment of Panagiouda-Pamfilla bay, Lesvos Island, North East Aegean, Greece, by devising a methodology suitable in the case of lack of data on actual impacts.

2 - Our methodology consisted of the following steps: definition of spatial boundaries; development of an environmental baseline; scoping of key industrial units, environmental receptors and valued environmental components for cumulative impacts; construction of a conceptual framework of cumulative environmental change that links causes, pathways and results of change on environmental receptors and valued environmental components; assessment of the likelihood and significance of impacts on valued environmental components; and recommendations on management practices.

3 - Significant impacts are likely to have accumulated at the studied region on the environmental receptors of ground, air, water, fauna, common utility, aesthetics, recreation, and cultural heritage. Disposal of wastes, water consumption and air pollution are of immediate priority for the environmental management of the studied region.

4 - The proposed methodology for the analysis, evaluation and management of cumulative impacts at the watershed level is generic, systematic, straightforward, flexible, holistic, and synthetic. It's rather qualitative nature may make it particularly useful within the context of regional development planning when there is no data on actual impacts. However, it requires Geographic Information System expertise and is based on expert/professional judgment.

Keywords: assessment tool of interactions of human activities; significance and certainty of impacts; system diagrams; environmental receptors; valued environmental components; expert judgment.

Introduction

An individual environmental effect from a single human activity may not have a great significance when considered in isolation but when combined with other impacts from the same activity and/or other human activities may acquire great importance. This is because seemingly insignificant individual effects of human activities may accumulate over time and across space, in an additive, synergistic, interactive, or antagonistic manner. Cumulative effects have been defined as net changes to the environment caused from incremental, accumulating and interacting effects of a single or multiple human actions in combination with other past, present, and reasonably foreseeable ones (refined definition based on US Council on Environmental Quality, 1978; but see also Sadler, 1996; CEQ, 1997; Ross, 1998; Hegmann *et al.*, 1999; Parr, 1999a; MacDonald, 2001). Examples of cumulative environmental effects are the effects of car emissions on the climate, the depletion of water resources due to over-abstraction, cumulative loss of open space due to policies that encourage development, cumulative noise effects from construction activities, and farming (in Cooper, 2004). Central properties of cumulative effects involve that they: (i) may arise on any type of environmental receptor at any scale; (ii) are triggered by multiple causes or affecting factors; and (iii) are generated by multiple effect pathways, generally involving multiple root causes and lower and higher order effects, interlinked by cause-effect relationships (Brismar, 2004).

Relevant policies and legislation mandating the identification or/and assessment of the cumulative effects of human activities have been adopted by several countries, such as the United States (Thatcher, 1990; Herson and Bogdan, 1991), Canada (Sonntage *et al.*, 1987; CEARC and USNRC 1998), New Zealand (Dixon and Montz, 1995), and the European Union (Commission of the European Communities 1985 (Environmental Impact Assessment Directive 1985/337/EE); 1992 (Habitats Directive 1992/43/EE on the conservation of natural habitats and of wild fauna and flora); 2001 (Strategic Environmental Assessment Directive 2001/42/EE)). Cumulative Effects Assessment (CEA) is a systematic procedure for identifying and evaluating the significance of interacting environmental effects from a single or multiple human activities (Canter, 1999; Piper, 2002). CEA addresses the complex interactions that may be observed as a result of human activities: interactions among human activities; interactions among effect types (e.g. noise, lighting); interactions between sites and resources; or interactions among pathways of effects (Perdikoúlis and Piper, 2007).

There are also two distinct but complementary approaches to CEA. An analytic approach regards CEA primarily as an information-generating activity to identify and assess changes in environmental systems brought about by cumulative processes. A planning approach, on the other hand, focuses on the use of such information, utilizing social norms and decision rules to compare and rank alternative choices, to trade-off environmental, economic, and social objectives, and to initiate management actions (Spaling and Smit, 1993).

CEA is a valuable tool that has been incorporated into specific project-oriented Environmental Impact Assessments (EIAs, Parr, 1999b) facilitating the determination of the acceptability of individual development projects. In this view, CEA is an extension of the EIA process for project developments and has resulted in development of Stressor-Based CEA methods (Dubé, 2003). It has also been undertaken as part of regional Strategic Environmental Assessments (SEAs; Cooper, 2004; Diaz *et al.*, 2001; Oñate *et al.*, 2003) aiming at evaluating sustainability (socio-economic and environmental) of development plans, policies or programs at an ecologically meaningful area (e.g. watersheds, ecoregions). In this view, CEA is a broader, regional assessment tool where Effects-Based methods specialize in quantification of existing aquatic effects (Dubé, 2003). If EIA assesses the effects of a project to identify and mitigate its key impacts and SEA is the same thing for strategic actions, then CEA cuts in the opposite direction. Instead of focusing on the effects of a given action – a project, plan – it focuses on the receiving environment and considers all of the effects on a given receptor, e.g. air, climate, water, community (Fig. 1 in Therivel and Ross, 2007).

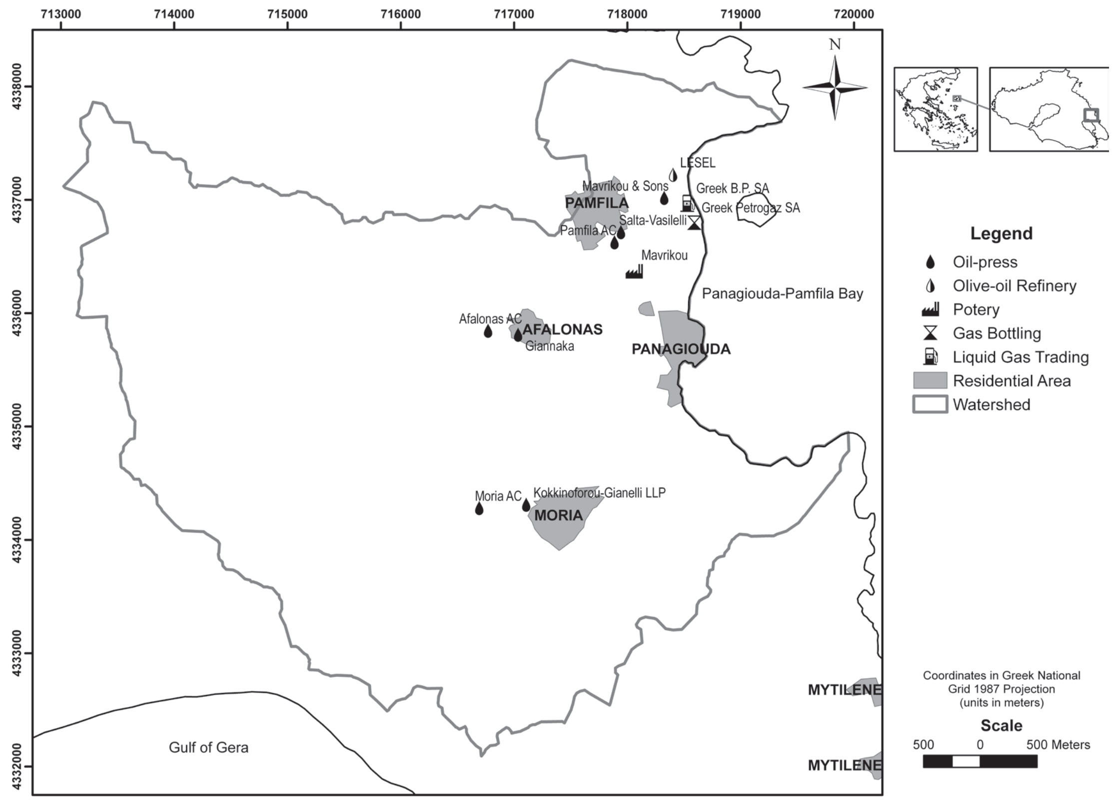

Figure 1. Location of studied catchment and selected industries.

The advantages of regional over project-CEA have been repeatedly advocated (Cocklin *et al.*, 1992; Court *et al.*, 1994; Parr, 1999b; Kennett, 1999; 2002; Antoniuk, 2002; Fischer, 2002; Dubé, 2003; Therivel, 2004; Duinker and Greig, 2006). Recently, Dubé (2003) proposed a conceptual framework for integrating project-CEA with regional-CEA methods for aquatic systems that could improve CEA and its ability to better monitor and assess sustainable development of aquatic resources.

Methods for CEA have been developed over the years: three manuals with practical guidance were published in the late 1990s: CEQ (1997) for the USA, Hegmann *et al.* (1999) for Canada, and Parr (1999b) for the EU. Yet, Mulvihill and Ali (2007) concluded that conventional approaches to environmental assessment and planning are characteristically deficient in addressing the full range of impacts and risks, particularly those originating from pathogens and dispersed and insidious sources. Piper (2000) examined the extent to which the principles and tools of sustainable development have been incorporated into a set of four UK cases of CEA and concluded that the potential of CEA had not been fully realized in these cases and there was a need for more awareness of what issues must be prioritized before CEA makes a broader contribution to meeting sustainable development objectives. Furthermore, findings from reviews of UK (Cooper and Sheate 2002), Canadian (Baxter *et al.*, 1999; Mendoza Duran *et al.*, 2000) and US (McCold and Holman, 1995; Burris and Canter, 1997) EIAs revealed that the standard of CEAs undertaken was unsatisfactory. Efforts to evaluate and manage cumulative effects are hampered by the lack of a focused and directed process of defining key issues, impacts and resources (scoping); specifying the appropriate spatial and temporal scales; lack of data; determining the numerous interactions and indirect effects (complexity); threshold criteria for biophysical VECs must be ecologically meaningful and much better understood; interpretation of cumulative effects assumes a rather reactive instead of a proactive approach to planning; application of a variety of tools ranging from qualitative, simple checklists to quantitative, complex, physically-based models; and uncertainty of future events (McDonald, 2001; Brismar, 2004; Duinker and Greig, 2006).

With a view to benchmarking lessons learned, we propose a framework for the detection and evaluation of contemporary cumulative effects of human activities to facilitate environmental planning and management at the watershed level when no data on actual effects is available. We demonstrate our framework at the catchment of Panagiouda-Pamfilla bay, Lesvos Island, North East Aegean, Greece, to identify, evaluate, and manage probable cumulative impacts arising from the accumulation of a number of small-size industrial units. Environmental management is based on the environmental response to cumulative stress. Regional approaches are not constrained by any approval/permit process and also offer a realistic mechanism to assess sustainable development of the environment. In this case, CEA is conducted as an independent, integrated, environmental assessment operation and is used as a decision making tool for adaptive management.

Methods

In order to identify and assess cumulative effects arising from the accumulation of a large number of small-size industrial units at the catchment level, we followed recommendations in Parr's (1999b) review on best practices in identifying and assessing cumulative impacts of development and devised a methodology that combines Damman's *et al.* (1995) seven steps framework, Clark's (1994) seven steps analysis and Therivel and Ross's (2007) four steps analysis for CEA. Our methodology consists of the following steps: 1) definition of spatial boundaries; 2) development of an environmental baseline; 3) scoping of key industrial units, environmental receptors, Valued Ecosystem Components (VECs; Beanlands and Duinker, 1983; 1984) or terminal system elements (Perdicoúlis and Piper, 2007) for cumulative impacts; 4) construction of a conceptual network that links causes, pathways and effects of change on environmental receptors and their corresponding VECs; 5) assessment of the likelihood and significance of impacts on VECs; and 6) recommendations on management practices. For each one of the aforementioned steps, different tools were employed depending on objectives, access to and quality of data, and available resources.

We employed spatial (landscape) analysis using Geographic Information Systems (GIS) to delineate the drainage basins and the hydrographic network that discharges into the Panagiouda-Pamfilla bay and also depict the exact location of the industrial units of interest. An environmental baseline comprising of hydrological, geological, morphological, and land use/cover information was constructed based on available maps, EIA documents, and GIS. A conceptual network of cumulative environmental change that links causes, pathways and results of change induced by key industrial units on key environmental receptors and, in turn, on VECs was constructed based on available EIAs and depicted with the use of system diagrams (Perdikoúlis and

Piper, 2007). It was based on the commonly employed cause-effect relationship implied in standard EIA questionnaires although, in theory, determining that an impact is humanly induced requires that a comparison be made between the type, rate and variance of system responses before and after the suspected human intervention (Dickert and Tuttle, 1985). VECs were defined as those environmental attributes or components that if their utility or availability are to be adversely impacted, they will become the focus of administrative actions. They were readily available in EIA standard checklists of probable effects of development activities as VECs of environmental receptors (Official Journal of Greek Government, 1990). The significance of a cumulative effect on a VEC was defined as the product of its magnitude, geographic extent, duration and irreversibility and was evaluated by expert/ professional judgment. Recommendations for regional planning were based on the results of the CEA.

RESULTS

Spatial boundaries

The studied area (92.2 km^2) is situated at the eastern side of Lesvos Island, Greece and is comprised of two drainage basins (Fig. 1). Currently, 439 commercial/ processing/industrial units operate in the studied catchment area (Members Inventory Commercial Chamber Lesvos, pers. com.). Accumulation rate of new units remained positive throughout the period 1925-2005 exhibiting the highest peak during the decade 1985-1994 (242.3%) (Fig. 2).

Establishment of an environmental baseline

The hydrographic network of the studied area is 62 km long (Fig. 3). The studied catchments are generally flat with 1-5% slopes (Fig. 3). The coastal zone is rocky in front of Panagiouda's settlement and sandy in front of Pamfilla's settlement. Pamfilla and the northern studied area comprise of quaternary eluviations, such as ash, red argil, sand, and shingles. Argil soils are characterized by low values of water penetration, compared to sand and shingles. At Moria and eastern wards there are interchanges of marbles, limestones, and schist. Afalonas consists of marls and limestone ("white soil"). Basalts with middle lava are encountered south of Panagiouda-Pamfilla bay (Vouleli and

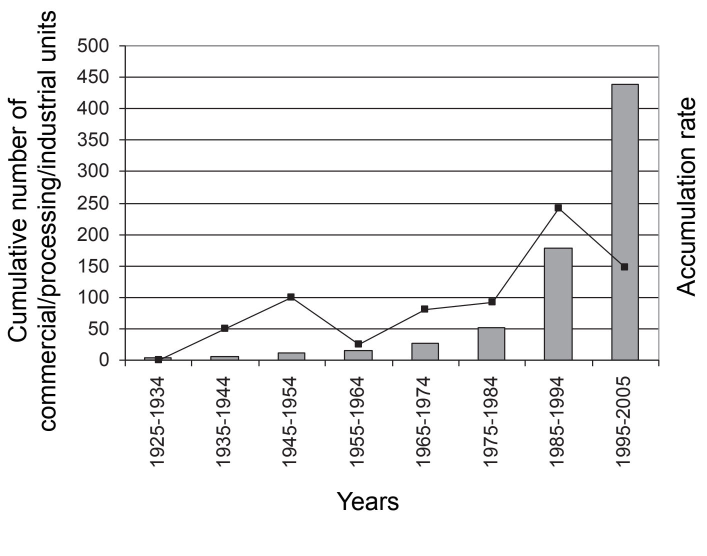

Figure 2. Accumulation rate of commercial/processing/industrial units at the studied catchment area during 1925-2005 (Members Inventory Commercial Chamber Lesvos, pers.com.).

Figure 3. Three-dimensional map of the studied catchment area indicating relief and hydrography.

Kampourelis, 2002). Drillings that took place at different times showed that the water horizon is medium to high at the south of the studied area (Vouleli and Kampourelis, 2002) (Fig. 4).

The climate is of the Mediterranean type with a mild winter and a dry, hot summer. Median annual temperature is 17.6 °C (Moutzouris, 2000); average humidity is 64.3 % (Moutzouris, 2000); rainfalls are of limited duration with a height ranging between 400-500 mm per year (Moustakounis, 1993). Winds are generally mild (<3 Beaufort) with a northerly prevailing direction (25.25%) and regular sea breezes (meltemia, 10%) (Moutzouris, 2000).

Land cover includes cultivations (mainly olive groves) (78.68 %), grasslands (1.86%), settlements (3.68 %), low-lying vegetation (acorns, palms, cypresses as well as annual bushes and turfs; 2.33 %), industrial units, and firewoods (12.32 %) (Fig. 5). Approximately 4.000 people reside within the studied area (General Secretariat of National Statistical Service of Greece, 2001), 70% of whom are economically non-active. Moreover, 90% of the economically active residents work for the tertiary sector (transport, communications, trade, and banking; Spilanis, 1996). One out of three of the 2.213 residences present are not employed. There is a declared marine archaeological site close to Moria (Municipality of Mutilene, 2007) (Fig. 6). The coastal zone of interest, along with the city of Mytilene belong to an extended area of special protection and planning, which aims to protect the natural and historic environment (Municipality of Mytilene, 2007) (Fig. 6).

Scoping of key industries, environmental receptors and VECs for cumulative impacts

On the basis of availability of compulsory EIA documentation after 1981, 11 industrial units out of the total of 439 commercial/processing/industrial units were selected in order to evaluate their cumulative effects on environmental receptors and VECs.

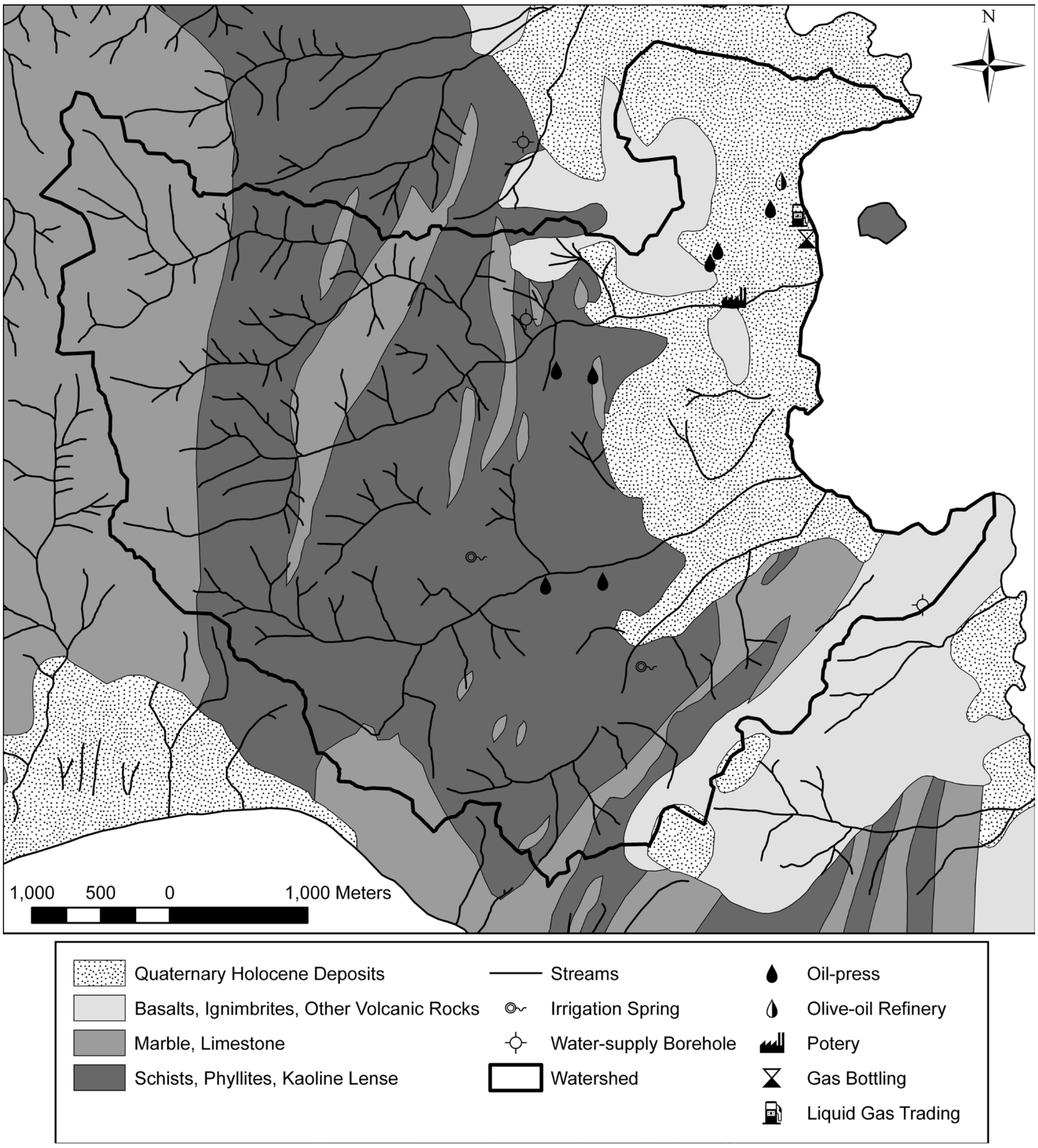

Figure 4. Geological map of the studied catchment area.

The 11 industrial units were: eight oil-presses, one pottery, one industry of gas bottling and one industry of liquid gas trading. Environmental receptors and VECs are provided in standard EIA questionnaires. Appendix A presents evaluations based on expert judgment for probable impact on each VEC by each of the 11 industrial units selected using the standard EIA questionnaire.

To consider that a cumulative impact may take place, more than one industries should be suspect ("M") or certain ("Y") of impacting the same VEC. In that case, a probable cumulative impact on the specific VEC is denoted with a "Y". When combined, the selected industries are expected to affect almost every environmental receptor examined and a total of 16 VECs (Appendix A).

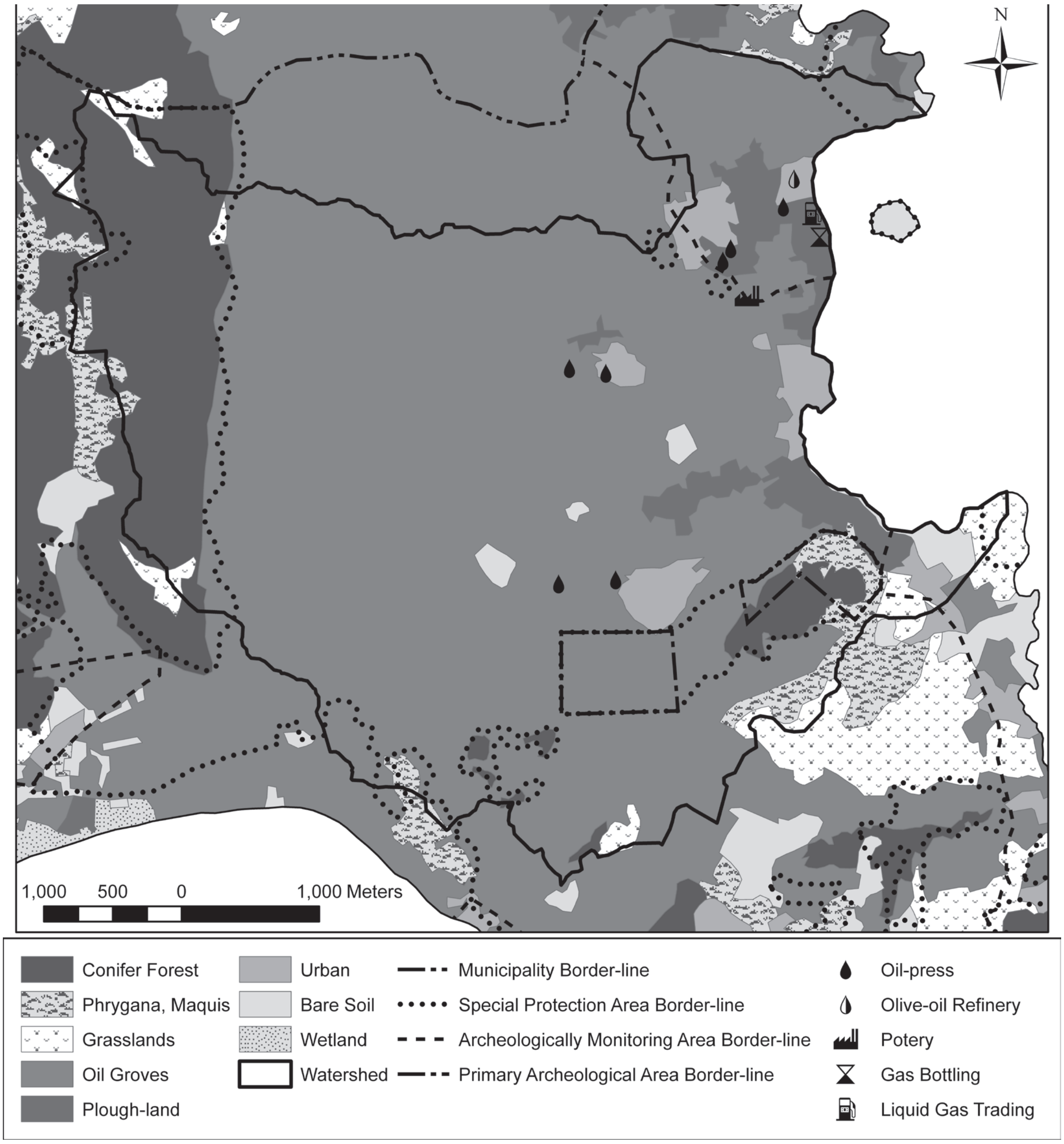

Figure 5. Land use map of the studied catchment area.

Causes, pathways and consequences of change on environmental receptors and VECs

Ground

The examined industries can affect both physical and chemical characteristics of the ground. Excavations, such as those carried out at the oil-press of Giannaka for the installation of the phase segregation of wastes, and the cesspool, may cause splits, shifts, compactions, overlaps of the surface layer of the ground as well as changes in their rate of absorption. At the same time, these excavations may create minor alterations in the topographic or the relief characteristics of the surface layer of the ground (Komilis, 2003). Furthermore, the residual/settling sludge of oil presses contains olive-mill wastewater,

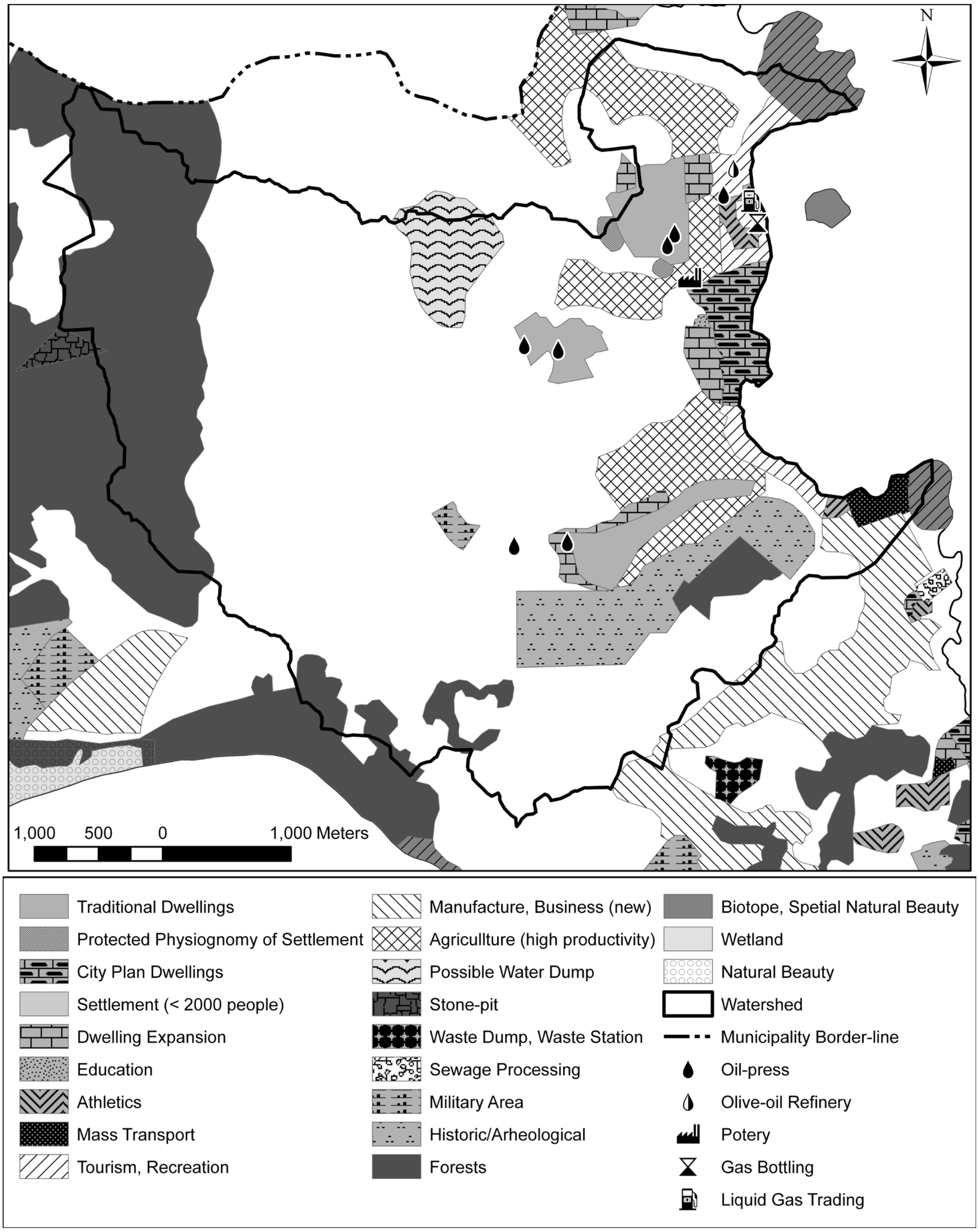

Figure 6. Urban planning of Mytilene Prefecture to be implemented (Municipality of Mytilene 2007).

which may lead to increase in hydrophobia of soil and decrease in preservation and rate of filtering of water. In addition, when disposed at surface (aerobic) or underground (anaerobic) dumb sites, it may cause alterations in the electric conductivity and the content of phenolic substances (Niaounakis and Halvadakis, 2004). Also, flooded olivecake stored in the outdoors to use as fuel, may contain remnants of the solvent hexane. Degradation and alteration of certain characteristics of ground may also be caused by the wastewater of the soap-making industry. The Directorate of Urban Planning and Environment reported that the biological wastewater treatment did not function properly. In addition, there was not available an analyses book stamped by the Prefecture, where monthly chemical analyses of wastes are recorded. Moreover, in one of the inspection reports of the soap-making industry, it was noted that the system of irrigation was disconnected and, as a result, the wastes were deposited only at a certain locality.

Air

All examined industries, but the soap-making, may affect air quality. Emission of pollutants from the chimney-stacks of oil-presses and of LESEL, emission of dust during the construction phase of the underground disposal system of the wastewaters in Giannaka's oil-press, leakage of petrol from the two petrol tanks of Greek B.P. (Moustakounis, 1993), and stenches from the dust of the argil ground and the chimney of the furnace for bricks of Mayrikio's pottery may lead to alterations in air quality.

The unpleasant smells produced via the aforementioned processes may cause air pollution in the nearby Pamfilla. Unpleasant smells was a major problem caused by crowding of industries (A.P. pers.obs.). Moreover, in a report of the Pamfilla's Community against the oil press of Salta-Vasilelli, it has been recorded that neighbours complained about the stench reaching their settlement. The location of LESEL and the atmospheric conditions, mainly during spring when there is light wind, create an unpleasant condition not only for Pamfilla but also for Mytilene.

Water

Serious degradation of water quality may be caused directly by the operation of the industries. Wastewater of the olive-presses containing high organic load ends up at the coastal zone of Panagiouda-Pamfilla, where it may impede the renewal of waters, cause discoloration of waters due to oxidation and polymerization of tannins, and impairment of the balance of the entire ecosystem through the process of eutrophication (Chatzimanolakis, 2002). According to the EIAs, the majority of the oil-presses allocate their untreated wastes in aquatic recipients with final destination the coastal zone of Panagiouda-Pamfilla. Further, lack of compliance aggravates the problem. For example, the local government of Lesvos Island realised that installation of a wastewater treatment plant for the Mayrikio's oil-press had never taken place even though it was required within approved environmental terms and directives of the Address of Health, Ministry of Planning, Environment and Public Works. The operation of the Greek B.P may also cause indirectly alterations in the water quality of the coastal zone of Panagiouda-Pamfilla. Wastewater of the oil-separator may pollute the underground water table.

Furthermore, the examined industries share the same water resources with households, namely the underground water table. Water needs of oil-presses, Mayrikio's pottery, and the LESEL are met with private drillings, which may cause lowering of the underground water table.

Fauna

The release of wastewater or/and oil from oil-presses at sea may lead to eutrophication and toxicity effects (Chatzimanolakis, 2002), which in turn, may affect marine communities, including fish and avian fauna.

Noise

Increase in noise level may be caused by

LESEL (Konstas, 1994) and by Giannaka's oil-press, mainly during the construction phase of a wastewater management system (Komilis, 2003).

Natural resources

Increase in the rate of use of underground water resources may be caused through private drillings by the LESEL and the pottery. In addition, the G.P. causes increase in demand for water resources to meet hygiene and fire-fighting needs.

Transport/Circulation

The operation of Maurikio's pottery induces increase in traffic of large vehicles (trucks), which transfer the argil ground to the pottery as do large vehicles of the B.P. and the G.P.

Energy

According to the EIA of the G.P., the total installed power reaches 72 HP, which exceeds by 18 HP the quoted authorisation for operation.

Common utility

The operation of the majority of the examined industrial units may affect sectors of common utility, such as water supply, sewerage system, and disposal of solid wastes. The pottery and the G.P. can exert pressure on water supply because they consume water to meet hygiene needs. The overflowing liquid from some of the oil-presses drains in the Community sewer leading to pipes' erosion. Moreover, suspended solids concentration of the wastewater of olive presses is too high, resulting in the obstruction of circulation in draining sewages (Niaounakis and Halvadakis, 2004). Sediments of wastes lead to unpleasant smells and increase in acidity of wastewater. Sewage from olive presses and wastewater from the oil-separator of the B.P. end up in septic cesspools, which may result in groundwater pollution. The problem of urban sewage disposal is accentuated considering the fact that the domestic sewage of Pamfilla is also disposed at the same cesspools (Chatzimanolakis, 2002). The mud that accumulates on the seabed of the biological wastewater treatment plant is removed at regular intervals and is placed in barrels (Gavriilidis *et al.*, 2000). However, it is not reported where these barrels are disposed. The same also applies for the Greek B.P. (Moustakounis, 1993), the G.P. (Moutzouris, 2000), and the Maurikio's pottery (Tsamouras, 1995).

Human health

Explosion of oil reservoirs of the Greek B.P. can jeopardize the health of residents of Pamfilla since the settlement is only 500 m away from the installation. Also, if the two reservoirs of liquid gas of the G.P. explode, the whole region will be set on fire, many residential houses will be destroyed, and there will be fatalities.

Aesthetics

Installation and operation of industries, which are 100 m away from residential areas, contribute to an aesthetically non-acceptable landscape. For example, the tallest chimney of LESEL caused aesthetic pollution because of the optical contact from larger distances (Makarigakis and Gargoulas, 2001).

Recreation

Concentration of industries at the coastal zone degrades its potential use for recreational purposes due to vexations from wastes, emissions of unpleasant smells, and the probability of explosions.

Cultural heritage

A site of archaeological importance has been designated at the proximity of Pamfilla's coast. It is worth noting, that during an inspection in 1997, there were spotted antiquities at wastewater disposal sites. Thus, industries, such as the oil-presses, the olive-kernel-oil processing plants, and the B.P., may degrade seawater quality of this archaeological site through the disposal of wastewater.

A conceptual framework of cumulative environmental change links the causes (aspects of the operation of the industrial units), pathways (environmental processes) and results of change on environmental receptors and VECs (Fig. 7).

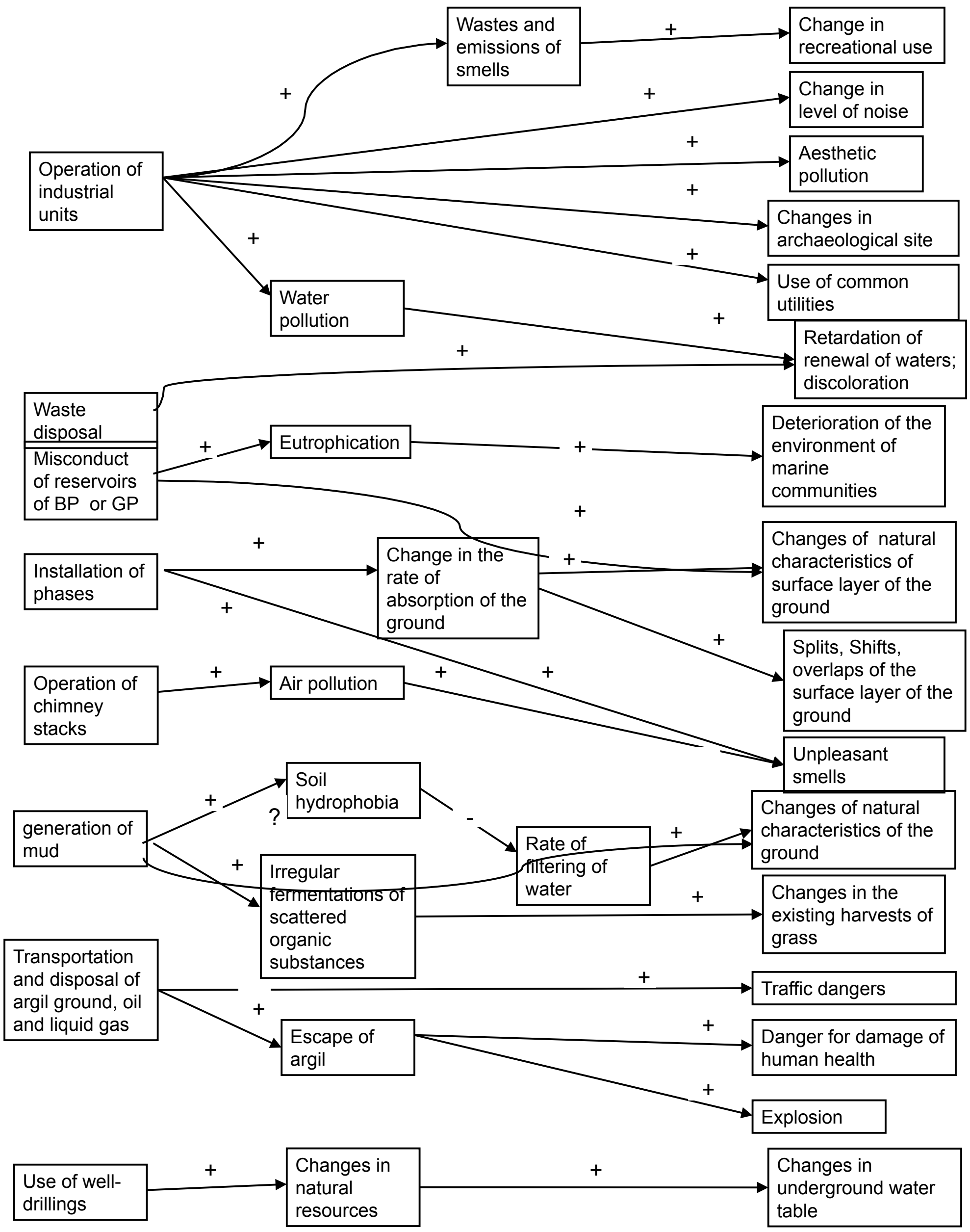

Figure 7. System diagram with relationship types (+: increase; -: decrease; ?: unknown) for the Panagiouda-Pamfilla bay.

Evaluation of the likelihood and significance of cumulative impacts on VECs

Probable cumulative impacts were consistently evaluated applying the same criteria across VECs. Significance of a cumulative impact is regarded as the product of the magnitude, scale, duration and irreversibility of that impact. The magnitude of a cumulative impact may be large, medium or small. The scale of a cumulative impact may pertain to the whole catchment, a drainage basin, a neighbor or specific localities. The duration of a cumulative impact may be continuous, intermittent or snap shot. A cumulative impact may be irreversible or not after removing the causing agent. If a cumulative impact is large, or/and affects the whole catchment, or/and is continuous, or/and is irreversible, then it is considered of high significance. If a cumulative impact is small, affects only specific location/s, is snap shot, and reversible, then is regarded as of low significance. All other combinations of cumulative impacts characteristics are regarded as of medium significance.

The level of certainty assigned to the significance of a cumulative impact ranges from low through medium to high. Low uncertainty denotes the availability of data verifying the actual cumulative impact. High uncertainty, on the other hand, denotes lack of any data on the cumulative impact. Medium uncertainty denotes that a cumulative impact is experienced/apparent but no data is available. Table 1 presents the results of the evaluation of cumulative impacts on VECs according to the aforementioned criteria using expert judgment. Cumulative impacts on five VECs were found of high significance with medium uncertainty. Cumulative impacts on eight VECs were found of high significance with high uncertainty. Cumulative impacts on

Table 1 - Evaluation of significance and associated uncertainty of cumulative impacts on Valued Ecosystem Components (VECs) at the studied region.

VEC	Magnitude	Scale	Duration	Irreversibility	Significance	Uncertainty
G4. destruction, overlap or change of any unique geological or natural characteristic	large	local	continuous	Yes	High	High
A1. important emissions in atmosphere or degradation of atmospheric quality	large	neighbor	continuous	No	High	Medium
A2. unpleasant smells	large	neighbor	continuous	No	High	Medium
W1. change in currents or change in the course or direction of movement of all nature of surface waters	large	drainage basin	intermittent	No	High	High
W5. disposal of wastewater in surface or underground waters with subsequent change in their quality	large	drainage basin	intermittent	Yes	High	Medium
W7. change in the quantity of underground waters via direct addition or withdrawal or via hindrance of underground feeding from cross sections or excavations	large	drainage basin	continuous	No	High	High
FA4. deterioration of the natural environment of existing fish or wildlife	large	drainage basin	continuous	No	High	High
N1. increase in the existing level of noise	small	local	snap shot	No	Medium	Medium
NR1. increase in the rate of the use/exploitation of any natural resource	large	drainage basin	continuous	No	High	High
T6. increase in transportation dangers	small	neighbor	continuous	No	Medium	High
CU4. use of sewers or septic cesspools	large	drainage basin	continuous	No	High	High
CU6. solid wastes production and their disposal	large	local	continuous	No	High	High
HH1. creation of any danger or probability of danger for damage of human health (excluding psychological health)	large	neighbor	snap shot	No	High	High
AT1. obstruction of any view of the horizon or any common view or creation of an aesthetically non-acceptable landscape to common view	large	region	continuous	No	High	Medium
RC1. affect on the quality or quantity of the existing potential for recreation	large	region	continuous	No	High	Medium
CH1. change or destruction of archaeological site	medium	local	continuous	No	Medium	Medium

one VEC were found of medium significance with high uncertainty. Cumulative impacts on two VECs were found of medium significance with medium uncertainty.

Recommendations on Management Practices

Probable significant cumulative impacts from the 11 industries examined at the 92.9 km^2 catchment area of interest affect environmental receptors of ground, air, water, fauna, common utility, aesthetics, recreation, and cultural heritage (Table 1) through wastewater and solid waste production and disposal, alterations in structural and chemical characteristics of the soil, emission of atmospheric pollutants and unpleasant smells, increase in consumption of municipal water, and increased load of the municipal sewerage system. In particular, it is mainly waters receiving wastes and waters available for human use that are expected to suffer greatest impacts from the examined industries (Table 1). Thus, disposal of wastes and water consumption are of immediate priority for environmental management of the studied region.

Furthermore, the studied area has not been characterized as yet an industrial region or a region where the industrial element prevails or a region that the industrial-urban element prevails according to Presidential Decree 1180/81. Thus, there are no threshold limits to pollutants and this, in turn, facilitates the unregulated disposal of wastes and/or pollutants on ground, at sea and in the air. Finally, industries are situated within human settlements.

Among the four alternative strategies for managing cumulative effects proposed by Therivel and Ross (2007), i.e. avoidance and mitigation, compensation, follow-up or monitoring studies, and setting rules for siting, phasing and managing projects, the Municipality of Mytilene has recently chosen avoidance. It has decided to remove all impacting industries from the coastal zone of Panagiouda-Pamfilla bay so as to develop tourism and establish a marine reserve (Municipality of Mytilene, 2007) (Fig. 6).

DISCUSSION

The proposed methodology for the analysis, evaluation and management of cumulative impacts at the watershed level is generic (any number and type of development projects may be considered), systematic (based on successive steps), straightforward (based on qualitative evaluation of set decision criteria), flexible (evaluation criteria may be added or deleted according to context), holistic (integrates causes, processes and affects), synthetic (allows recognition of the "whole" as being more than the sum of the "parts") and suitable for local government regional planning. It uses a familiar to EIA tool (checklist of Table 1) for scoping contemporary cumulative impacts, GIS for depiction of spatial relationships, flow diagrams of causes-processes-impacts, and expert judgment to evaluate and interpret probable cumulative effects in order to facilitate regional planning. In our framework, CEA merges EIA fully with the regional planning process when currently the EIA constitutes the institutional context for CEA in Greece. The methodology provides the opportunity to consider simultaneously a number of relevant aspects of the environmental system, realise their interactions, and set priorities for action.

Cumulative effects assessment from various industries on various VECs simultaneously is too complex and data demanding. Thus, the literature contains CEAs of similar type of industries or/and on specific VECs. For example, CEAs addressed the same cluster of projects (e.g. Sanger *et al.*, 2004 for dock structures; King and Pushchak, 2008 for mariculture plants) or a specific VEC (e.g. avian fauna, Diaz *et al.*, 2001). Dickert and Tuttle (1985) used the land disturbance target approach to assess cumulative impacts (erosion and sediment deposition) in the context of planning for the land use related impacts of Elkhorn Slough watershed development on coastal wetlands, Monterey County, California. The method incorporated information on hydrologic processes of stream flow and sediment movement into a planning approach and employed a modified threshold approach in which the threshold is based on an assumed acceptable amount of land use change over time, as measured by historic rates of land use change, rather than an intrinsic ecosystem tolerance. Later on, Abbruzzese and Leibowitz (1997) proposed a synoptic approach that provided a framework for making comparisons between landscape subunits, such as counties, watersheds, and ecoregions, so that cumulative impacts to wetlands can be considered in management decisions. These comparisons were made by evaluating one or more landscape variables or "synoptic indices" for each subunit. Dubé *et al.* (2006) developed a quantitative approach for aquatic cumulative effect assessment in Canada under the Northern Rivers Ecosystem Initiative based on a review of existing national monitoring practices and the presence of existing thresholds for aquatic health assessments. Xiongzhi *et al.* (2004) assessed cumulative environmental impacts at Xiamen harbour, China, based on the use of VECs and key indicators in order to develop an institutional framework for integrated management of coastal resources.

Here we have been able to document spatial contemporary accumulation of particular impacts on particular VECs. We give only a qualitative account of what kinds of effects may or can occur in association with the 11 chosen developments and a range of VECs in the catchment area and the likelihood and significance with which they are expected to occur based on expert judgement. We give no clues as to whether most of these impacts are actually occurring in the area. Although this approach of basing on impact hypotheses that posit that effects may or can occur, in no way can substitute the actual assessment of impacts, it may be a useful approach for decision-making when no data on probable cumulative impacts is available, which is the usual case. The next step in a CEA framework is to obtain data through monitoring of VECs suspected of having been affected by cumulative impacts and then assess this data against established benchmarks to evaluate changes over time or space and ascribe causality. Environmental quality as well as socio-economic information from monitoring programs could be integrated into a spatially explicit, geographic information system where it could be displayed, graphed, summarized and be accessible to different users in order to facilitate sustainable regional development of the studied area.

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Appendix A - Review of standard EIA questionnaire pertaining to expected effects of development actions for selected industrial units of the studied region. Environmental receptors in capitals. 1) Oil–presses of Eustratios Maurikios & Co. 1, 2) Oil-presses of Salta-Vasilleli 2, 3) Oil-presses of the Agricultural Cooperative of Afalona 3, 4) Oil-presses of Agricultural Cooperative of Pamfila 4, 5) Oil-presses of Agricultural Cooperative of Moria 5, 6) Oil-presses of V.Kokkinoforou and I.Gianelli 6, 7) Oil-presses of T.Giannaka 7, 8) Oil-presses of Agricultural Cooperative of Lesvos (LESEL) and Soap-trade 8, 9) Greek B.P.9, 10) Greek Petrogaz 10, 11) Pottery of Maurikios & Co 11. Y: Yes; N: No; M: Maybe.

The proposed work will cause:	INDUSTRIAL UNITS											Cumulative Impact
	1	2	3	4	5	6	7	8	9	10	11	
GROUND												
G1. instability of soil or change in the geological configuration of rocks	N	N	N	N	N	N	N	N	N	N	N	N
G2. splits, shifts, compactions or overlaps of the surface layer of ground	N	N	N	N	N	N	Y	N	N	N	N	N
G3. change in the topography or the relief of the surface of ground	N	N	N	N	N	N	Y	N	N	N	N	N
G4. destruction, overlap or change of any unique geological or natural characteristic	M	M	M	M	M	M	M	M	M	N	N	Y
G5. local or distant increase in soil erosion caused by wind or water	N	N	N	N	N	N	N	N	N	N	N	N
G6. change in the deposition or erosion of coastal sediments or in the production, deposition and erosion of sediments that can change the watercourse of rivers or streams or the seabed of any gulf or lake	N	N	N	N	N	N	N	N	N	N	N	N
G7. danger of exposure of humans or properties to geological catastrophes such as earthquakes, landslides and subsidences	N	N	N	N	N	N	N	N	N	N	N	N
AIR												
A1. important emissions in atmosphere or degradation of atmospheric quality	M	M	M	M	M	M	M	M	M	N	M	Y
A2. unpleasant smells	Y	Y	Y	Y	Y	Y	Y	Y	M	M	N	Y
A3. change in patterns of air circulation, humidity or temperature or any change in climate either locally or at larger scales	N	N	N	N	N	N	N	N	N	N	N	N
WATERS												
W1. change in currents or change in the course or direction of movement of all nature of surface waters	M	M	M	M	M	M	M	N	N	N	N	Y
W2. change in absorption rates, drainage courses or in the rate and quantity of washout of ground	N	N	N	N	N	N	Y	N	N	N	N	N
W3. change in the course of flooded waters	N	N	N	N	N	N	N	N	N	N	N	N
W4. change in the quantity of water of any aquatic system	N	N	N	N	N	N	N	N	N	N	N	N
W5. disposal of wastewater in surface or underground waters with subsequent change in their quality	Y	Y	Y	Y	Y	Y	M	N	M	N	N	Y
W6. change in the direction or flow out of underground waters	N	N	N	N	N	N	N	N	N	N	N	N
W7. change in the quantity of underground waters via direct addition or withdrawal or via hindrance of underground feeding from cross sections or excavations	Y	Y	Y	Y	Y	Y	Y	Y	N	M	Y	Y
W8. important reduction of water quantity that would be available for the public	N	N	N	N	N	N	N	N	N	M	N	N
W9. danger of exposure of humans or properties in catastrophes caused by water, such as floods or tidal waves	N	N	N	N	N	N	N	N	N	N	N	N
FLORA												
FL1. change in species diversity and density of flora (including trees, bushes etc)	N	N	N	N	N	N	N	N	N	N	N	N
FL2. reduction in the density of any unique, rare or threatened with extinction species of flora	N	N	N	N	N	N	N	N	N	N	N	N
FL3. import of new species of flora or hindrance of the physiologic renewal of existing species	N	N	N	N	N	N	N	N	N	N	N	N
FL4. reduction in the extend of any rural culture	N	N	N	N	N	N	N	N	N	N	N	N
FAUNA												
FA1. change in species diversity and density (including birds, reptiles, fish, marine, benthic organisms, and insects)	N	N	N	N	N	N	N	N	N	N	N	N
FA2. reduction in the density of any unique, rare or threatened with extinction species of fauna	N	N	N	N	N	N	N	N	N	N	N	N

Appendix A - Continued.

The proposed work will cause:	**INDUSTRIAL UNITS**											**Cumulative impact**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
FAUNA												
FA3. import of new species of fauna or hindrance of the physiologic renewal of existing species	N	N	N	N	N	N	N	N	N	N	N	N
FA4. deterioration of the natural environment of existing fish or wildlife	M	M	M	M	M	M	M	N	M	N	N	Y
NOISE												
N1. increase in the existing level of noise	N	N	N	N	N	N	M	M	N	N	N	Y
N2. exposure of humans to high levels of noise	N	N	N	N	N	N	N	N	N	N	N	N
LAND USES												
LU1. important change in the present or programmed land uses	N	N	N	N	N	N	N	N	N	N	N	N
NATURAL RESOURCES												
NR1. increase in the rate of the use/exploitation of any natural resource	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
NR2. depletion of any non-renewable natural resource	N	N	N	N	N	N	N	N	N	N	N	N
POPULATION												
P1. change in the settlement, distribution, density or growth rate of human population at the project's region	N	N	N	N	N	N	N	N	N	N	N	N
RESIDENCE												
RS1. affect of the existing residences or need for additional residences at the project's region	N	N	N	N	N	N	N	N	N	N	N	N
TRANSPORTATION/CIRCULATION												
T1. creation of additional traffic of vehicles	N	N	N	N	N	N	N	N	N	N	M	N
T2. affects on the existing parking places or need of new parking places	N	N	N	N	N	N	N	N	N	N	N	N
T3. important affects on the existing systems of transportation	N	N	N	N	N	N	N	N	N	N	N	N
T4. change in the existing means of transportation of humans and/or goods	N	N	N	N	N	N	N	N	N	N	N	N
T5. change in transportation by sea, railways and air	N	N	N	N	N	N	N	N	N	N	N	N
T6. increase in transportation dangers	N	N	N	N	N	N	N	N	M	M	M	Y
ENERGY												
E1. use of important quantities of fuel or energy	N	N	N	N	N	N	N	N	N	M	N	N
E2. important increase in demand of existing sources of energy or need for new sources of energy	N	N	N	N	N	N	N	N	N	N	N	N
COMMON UTILITY												
CU1. use of electricity	N	N	N	N	N	N	N	N	N	N	N	N
CU2. use of systems of communication	N	N	N	N	N	N	N	N	N	N	N	N
CU3. use of water supply	N	N	N	N	N	N	N	N	N	M	N	N
CU4. use of sewers or septic cesspools	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y
CU5. use of rainwater drainage	N	N	N	N	N	N	N	N	N	N	N	N
CU6. solid wastes production and their disposal	N	N	N	N	N	N	N	N	Y	Y	Y	Y
HUMAN HEALTH												
HH1. creation of any danger or probability of danger for damage of human health (excluding psychological health)	N	N	N	N	N	N	N	N	M	Y	N	Y
HH2. exposure of people in probable dangers that could damage their health	N	N	N	N	N	N	N	N	N	N	N	N
AESTHETICS												
AT1. obstruction of any view of the horizon or any common view or creation of an aesthetically non-acceptable landscape to common view	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RECREATION												
RC1. affect on the quality or quantity of the existing potential for recreation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
CULTURAL HERITAGE												
CH1. change or destruction of archaeological site	Y	Y	Y	N	N	N	N	Y	N	N	N	Y
PROTECTED AREAS												
PA1. the proposed work is located within a protected area according to article 21 of Law 1650/86	N	N	N	N	N	N	N	N	N	N	N	N

Sources: [1]Karnas 1994, [2]Saltas 1996, [3]Vavaliaros 1997, [4]Kiriakis 1998, [5]Kiriakis 2002, [6]Skarlatos 1996, [7]Komilis 2003, [8]Gavriilidis et al. 2000, [9]Moustakounis 1993, [10]Mountzouris 2000, [11]Tsamouras 1995.