



Recent developments

Fuzzy analytic network process approach to evaluate land and sea criteria for land use planning in coastal areas

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ABSTRACT

Coastal areas are marginal regions between the land and sea. These areas have environmental value, but over-development imposes pressures on their ecosystems and brings about a multitude of challenges. Negative environmental impacts such as land-based source pollution are not only limited to land but also have adverse effects on the marine environment. Sustainable land-use planning has been applied to balance economic production, social needs, and environmental conservation in coastal areas. While previous studies have focused on land oriented criteria, they did not consider the interactions with adjacent marine environments. The purpose of this paper is to select criteria and outline the importance of integrating sea and land criteria in the context of land-use planning in coastal areas of Iran. This is the first time that the Decision Making Trial and Laboratory Model (DEMATEL) and Analytical Network Process (ANP) method with fuzzy logic have been used to select land-and sea-oriented criteria for land-use planning. The results illustrate that “biodiversity of fauna and flora at sea,” “area of spawning,” “biodiversity of fauna and flora in land,” “breeding grounds,” and “distribution of fauna and flora at sea” are the five most important criteria for coastal land-use planning. The integrated framework presented in this paper provides a holistic approach for coastal land-use planning.

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1. Introduction

The coastal area is a marginal region that includes areas of land and sea (Tausnik, 2007), but during land-use planning, only the state of the land environment is typically considered. Meanwhile, the marine environment faces numerous challenges, such as synergistic impacts of pollution from land-based sources or decreases in the ocean's food capacity (Siddiqui, 2011). Coastal areas may also be exposed to natural forces such as cyclones or storms (Saxena et al., 2013) that result in widespread loss of lives and assets. Integration within coastal planning schemes of both land and sea criteria is a considerable challenge for planners, because fundamental differences exist between land and sea. Moreover, merging and synthesizing available data concerning these two spatially

heterogeneous environments is a particularly difficult task (Caldow et al., 2015). Poor integration of land and sea criteria may within planning schemes may result in conflicts between land and sea resource users, impair essential ecosystem services, and increase marine pollution from land-based sources. The impacts of marine-based activities are also experienced on land and vice versa (Kerr et al., 2014). Integration of land and sea criteria into a unified land-use planning system can help planners to select suitable sites for various economic activities. Integrated land-use planning schemes can also provide protection against coastal disasters, ensure compatible uses and minimize damage to the marine ecosystem. Many countries have efficiently established land-use planning schemes, but considerable gaps (e.g. pollution of marine ecosystems from land-based discharges and depletion of resources) remain because sea criteria were not considered within planning. Small progress exists in setting up marine protected areas (MPA), integrated coastal zone management (ICZM), or marine spatial planning (MSP), because such schemes frequently neglected key land or sea criteria.

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1.1. Case study Bushehr- Iran

In the present study, we selected the coastal province of Bushehr, Iran, to assess the importance of integrating land and sea criteria in land-use planning on a local scale. Bushehr Province, with 639 km of Persian Gulf shoreline, has a high-value ecosystem and large oil and gas reservoirs (Fig. 1). Rapid industrial development, particularly in the oil and gas sector, has resulted in ecosystem damage and depletion of natural resources. ICZM has not been implemented in coastal provinces of Iran and, as such, there has been no need for a monitoring model. However, pragmatism of management systems will likely necessitate implementing ICZM as well as the formation of a model to monitor the effectiveness of ICZM implementation. The Iranian Ports and Maritime Organization (PMO) developed a model to monitor ICZM implementation (PMO, 2008). The model was based on the Driver, Pressure, State, Impact- Response (DPSIR) framework, and included ecological, social, and economic criteria. However, there is currently no coordination among responsible authorities for coastal management. The different authorities that are responsible for enforcing laws related to environmental management are not required to coordinate their activities (e.g. local provincial authorities, ministry of agriculture, ministry of labour and social affairs) with the central competent authority, Iran's Department of Environment (DOE). Therefore, the existing coastal management framework is sectorial and as such, lacks the transparency provided by properly defining responsibilities among relevant authorities regarding environmental protection (both with regard to scope and geographic coverage). In practice, coastal areas are managed by two or more responsible authorities (usually the DOE and the Port and Maritime Organization). However, for some issues of coastal management such as conservation of endangered species, their responsibilities are similar in nature. In contrast, there are several issues related to coastal management that currently lack responsible authorities, such as the "control of marine pollution from land-based sources". This situation results in increased conflicts among stakeholders and threatens the high-

value ecosystems of Bushehr, especially when the oil and gas industry is involved, being an important stakeholder at a national level. The DOE is the main agency responsible for identifying the competent authorities involved in environmental protection. In practice, different authorities have taken actions to enforce laws and regulations on various aspects of environmental management without the involvement of the DOE. Moreover, the legislative framework of environmental protection is completely separate between the land and sea environments, and lacks integration of environmental management in coastal areas. This means that environmental protection of coastal areas will necessarily need to merge the legislative frameworks concerning both land and sea. It is possible that a complete integration of land and sea environmental protection into one unified framework may be unattainable. For example, protection of sea from land-based pollution has been ignored by both of the responsible authorities. PMO has excluded land-based source pollution due to the fact that the source of pollution is based on the land, while the DOE has not taken action because pollution occurs at sea. In addition, there are various gaps in management practices along the coastal areas. Specifically, without a land-use plan, developers are required to find a location for their economic activities according to environmental impact assessment (EIA) guidelines, which do not include sea-oriented criteria. Thus far, compliance with legislative framework for protection of marine environments (for instance, limitations in coastal development dictate the removal of land-based installations at a distance/radius of 60 m from the shoreline) has not been successful.

Past studies (Pourebrahim et al., 2010; Ioppolo et al., 2012) mainly focused on land criteria for sustainable land-use planning in coastal areas. However, the integration of land- and sea- oriented criteria have received limited coverage by past research. Planning in coastal areas requires considering all three environmental dimensions, namely the atmosphere, the land, and the sea environments, as opposed to current approaches that only consider the atmosphere and the land (Smith et al., 2011). The purpose of the present study is to select and integrate criteria pertaining to both land and sea for developing sustainable land-use plans in coastal areas, thus encompassing environmental, economic and social considerations.

As such, the over-arching questions of the present study are: "What are the most important criteria for land-use planning in coastal areas?" and "Should land and sea issues be prioritized similarly during land-use planning?"

Selecting criteria for land-use planning in coastal areas is a type of a multiple criteria decision making process. To that end and for the purpose of the study, the Analytical Network Processes (ANP) method is used to identify the most important criteria to overcome the problem of interdependence and feedback among criteria (Saaty and Ozdemir, 2005) (see Section 3. Methodological framework).

By using the ANP in a fuzzy environment, we are able to effectively handle the relationships between criteria (Saaty, 1996) and vagueness of human judgment within the context of land-use planning. Moreover, it is also difficult to evaluate a single effect from a single criterion while avoiding interference from the rest of the system. All criteria may be either directly or indirectly related (Liou et al., 2007). To avoid such limitations, we adopted the decision making trial and laboratory (DEMATEL) method (Gabus and Fontela, 1972) to determine mutual relationships of interdependencies within criteria as well as the strength of interdependencies (Tzeng and Huang, 2012). To our knowledge, previous studies have not integrated land and sea criteria for land-use planning or combined these two methods in a fuzzy environment for land-use planning in coastal areas.

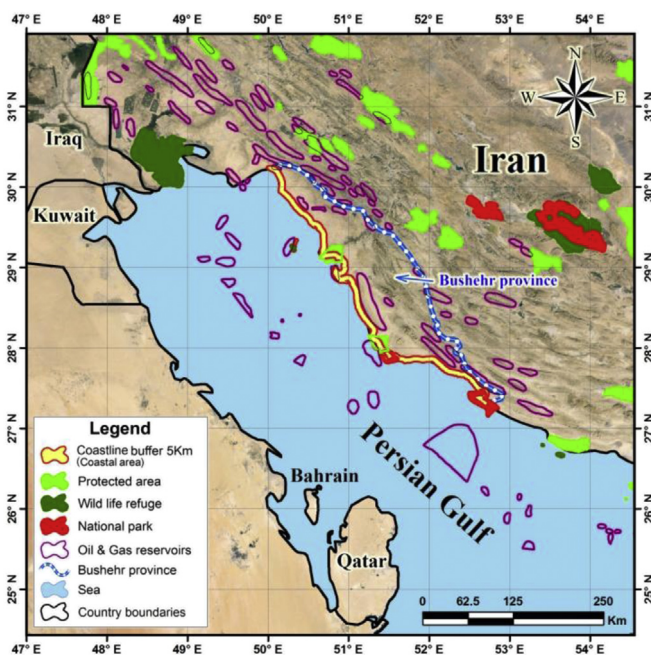


Fig. 1. The location of the study area.

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