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Implementing a spatial model of Urban Carrying Capacity Load Number (UCCLN) to monitor the environmental loads of urban ecosystems. Case study: Tehran metropolis

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ABSTRACT

The non-linear, unexpected and severe responses of ecosystems to the environmental changes crossing ecological thresholds or environmental limits, necessitate the regular monitoring of the human-induced pressures to the urban ecosystems. The present study aims to introduce a spatial decision support system for sustainable environmental planning and management of urban ecosystems by establishing an Urban Carrying Capacity Load Number model (UCCLN) based on carrying capacity concepts and sustainability principles .This model, by applying 30 temporal and spatial indicators continuously monitors the environmental loads on the urban ecosystems. Environmental load was represented by load number index. It was calculated in each zone of study area (urban districts). Geographical Information System (GIS) was used to establish UCCLN model and Spatial Decision Support System (SDSS). The study area was Tehran metropolis, the capital of Iran. The results showed that none of the 115 urban districts of Tehran had optimal Total Load Number (TLN) ranging from (10 to100); 7 districts (6%) had low-to-medium range of TLN (TLN = 100–200); 11 districts (9.5%) had medium-to-high range (TLN = 200–300); 57 districts (49.5%) had high-to-very high range (TLN = 300–400); 40 districts (34.7%) had the TLN range of very high-to-critical (TLN = 400–500); and none of them had the TLN of 500. Furthermore, the results revealed that Tehran has already overshot its ecological thresholds. Not only most of the 30 indicators of environmental pressure in most of the districts (85%) had high DCC and LN scores, but also most of the 115 districts obtained high DCC, and as a result LN scores. The need for developing more efficient urban planning and management strategies to cope with the increasing environmental loads in the study area is inevitable.

1. Introduction

Human activities, such as the conversion of land, depletion of natural resources and discharge of emissions, affect the function and structure of urban ecosystem. In fact, urban ecological problems have close linkage to the disorder of its metabolism in material or energy flow, (Li et al., 2010; Zhang et al., 2009). Ecological scholars (Alberti, 2005; Odum, 1963; Boyden et al., 1981; Collins et al., 2000) have described the city as a heterotrophic ecosystem highly dependent on large inputs of energy and materials and a vast capacity to absorb emissions and wastes. This trend results in the great environmental changes and the non-linear, unexpected and severe responses of ecosystem to this environmental changes crossing ecological threshold or environmental limits, necessitate the regular monitoring of human impacts on urban ecosystem, so that the human-induced pressures not to exceed from its carrying capacity.

Urban carrying capacity implicates the level of population or development that can be sustained in an area, without adversely affecting the area beyond an acceptable level. This concept can be applied in two ways for human communities: first, by determining thresholds that changes beyond them are not acceptable; and second, defining population or activities (so-called development) that are reaching these thresholds (Randolph, 2004). Catton (1986) argued that it would be more sensible to define human carrying capacity as a maximum load the environment can support safely, where this load is a function of the size of the population, per capita consumption and waste production. This concept is based upon the assumption (Kozlowski, 1990) that there are certain environmental thresholds which when were exceeded, can cause serious and irreversible damages to the natural environment.

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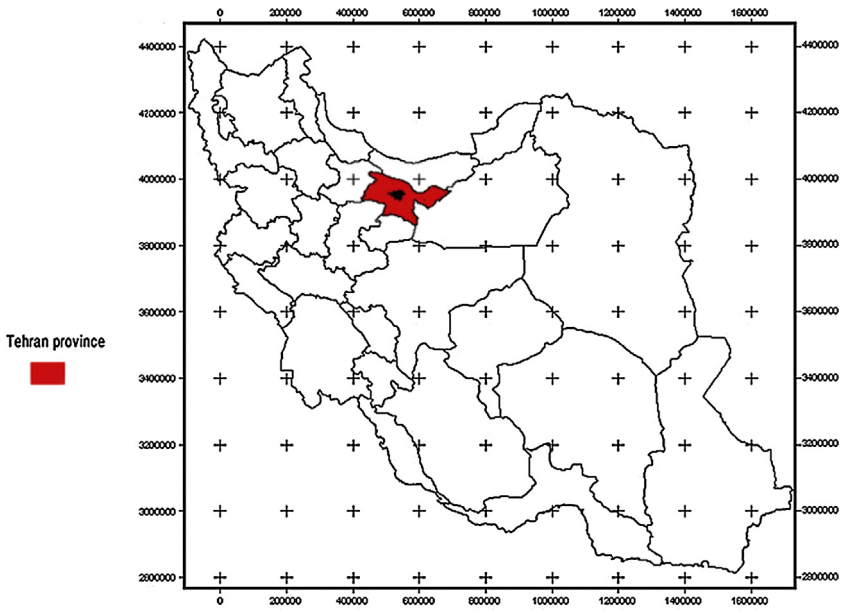

Fig. 1. Location of Tehran metropolis in Tehran province and the country of Iran.

Oh et al. (2002, 2005) defined the urban carrying capacity as the level of human activities, population growth, land use and physical development, which can be sustained by the urban environment without causing serious degradation and irreversible damage.

The present study aims to introduce a Spatial Decision Support System (SDSS) for sustainable environmental monitoring of the urban ecosystems by establishing an Urban Carrying Capacity Load Number model (UCCLN) based on carrying capacity concepts and sustainability principles. Here, urban carrying capacity refers to a range of "acceptable" values of indicators related to environmental loads, derived from different structural and functional components of urban ecosystem such as: natural state, population, resources consumption, waste/emission production and urban facilities. This model, by applying 30 spatial indicators, continuously monitors the environmental loads on the urban ecosystems to insure that they are not exceeded from the acceptable environmental limits.

2. Case study

The study area was Tehran, the capital of Iran and one of the largest cities of the world, with the area of 613 km^2 and nearly 9 million inhabitants (2010). Recently, many environmental problems have raised in Tehran due to its rapid sprawl and population growth. Fig. 1 shows the location of Tehran in the country of Iran. The city of Tehran is divided into 22 region and 115 districts. Tehran's Regions and districts are demonstrated in Fig. 2.

The population of Tehran has increased from 200,000 to over 9 million during the last 90 years (1921–2010). This high population growth rate led to many environmental and socio-economic problems.

3. Methodology

The approach introduced in the present study is based on continuously monitoring the ecosystem condition in terms of its distance from the desirable to critical limits of chosen indicators by means of developing Urban Carrying Capacity Load Number model as a spatial decision support system (SDSS). This model developed based on the integration of ecological and socio-economic dimensions of urban ecosystem. In the process of carrying capacity analysis, the minimum and maximum (environmental limits) of chosen indicators were considered. The comparative importance of each indicator- to put a limitation (load) on the environment-was determined by creating indicator's coefficient matrix .The matrix was developed from expert judgment through Analytic Hierarchy Process (AHP). In order to develop the model, the minimum (desirable) and maximum (critical) values of indicators were calculated. Fig. 3 shows the flow chart process of the study.

3.1. Goal definition and site selection

The aim of developing the UCCLN model is to create a system to regularly evaluate and monitor the status of urban ecosystem and its distance from the desirable carrying capacity of selected indicators. In the selected city, smallest managerial and administrative zones are urban districts which have official responsible, accessible data and appropriate scale for change detection. The city of Tehran consists of 115 districts which have to be separately studied from the aspect of induced environmental loads.

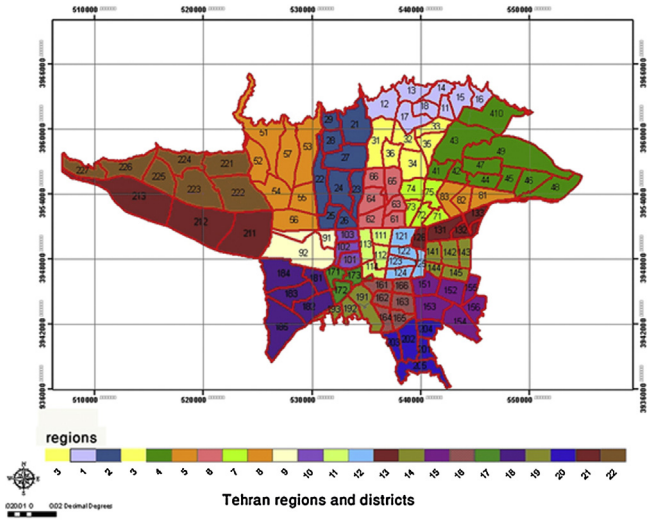

Fig. 2. 22 Regions and 115 districts of Tehran metropolis.