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Evaluating the strategy of integrated urban-rural planning system and analyzing its effects on land surface temperature in a rapidly developing region

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ABSTRACT

This study highlights the importance of integrated urban-rural land-use planning system in a rapidly developing region, Falavarjan Township, Iran. It also analyses the effect of various urban growth policies on land surface temperature (LST). In doing so, this paper combines several modeling methods including LST map generation algorithm, urbanization suitability mapping, and scenario-based analysis of future circumstances through cellular automata (CA)-Markov modeling and regression analyses. The potential impact of various urban growth policies including historical growth, extensive growth and rural development on LST values of interior urban environments are quantified and compared. These scenarios are introduced to the CA-Markov model by generating several urbanization suitability layers insisting on various urban-rural planning perspectives. In addition, linear, quadratic and logarithmic regression models were also developed to measure the relationship between LST values and urban patches areas. The results demonstrated that logarithmic regression model yields stronger relationships ($R^2 = 0.35$, $p < 0.01$) such that the model is capable of predicting LST values over temporal scales. By coupling the results derived from CA-Markov model and temporal estimation of LST values, an integrated urban-rural land-use planning system is developed. The findings of this study can effectively assist land managers in central Iran to adopt a sustainable planning strategy in a highly developing region.

1. Introduction

The world has witnessed an unprecedented urbanization growth rate during the last century and this urbanization demonstrates no sign of slowing down (Alhowaish, 2015; Jusuf, Wong, Hagen, Anggoro, & Hong, 2007). Urbanized lands are responsible for approximately 80% of carbon emissions, 60% of residential water consumption and almost 80% of wood utilized in industry (Schneider, Friedl, & Potere, 2010; Wu, 2010). The astonishing rate of growth in both human population and human-made constructions alarms on future environmental consequences originated from this rapid and sharp expansion (Douglas, Goode, Houck, & Wang, 2011; Niemelä et al., 2011).

One of the well-documented effects of urbanization is possibly the urban heat island (UHI) effect. Drastic changes on climatic conditions brought about by human activities affected urban sustainability by aggravating the conflict between water supply and demand, increasing energy use and rising flood risk (Hansen, 2010). Conversely, there is a loop feedback by which urban growth can similarly affect some meteorological parameters that can significantly alter regional climatic regimes (Gu, Hu, Zhang, Wang, & Guo, 2011; Wu, 2014). In this regard, several studies have reported that future land-use changes are inevitably correlated with modification of climatic conditions and urban landscape would undergo different situations in terms of various spatial policies and meteorological circumstances (He, Zhao, Huang, Zhang, & Zhang, 2015; Solomon, 2007). Therefore, evaluating the interrelated relationships between land-use pattern changes and climatic regimes can provide valuable insights on urban sustainability (Sánchez-Rodríguez, 2005; Wu & Wu, 2013). In this case, Land surface temperature (LST) has been an active topic of research during the last decade.

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Majority of researches in this field adopted a static approach. These studies have basically been undertaken to examine the linkage between LST and land surface characteristics such as impervious surface (Bokaei, Zarkesh, Arasteh, Hosseini, 2016) and vegetative covers (Huang, Chen, Li, Shen, & Li, 2016), the size and spatial patterns of different land-use/covers (Zhou, Huang, & Cadenasso, 2011), neighbor cover types (Asgarian, Amiri, & Sakieh, 2014; Feng & Myint, 2016) and fraction variables (Amiri, Weng, Alimohammadi, & Alavipanah, 2009; Lu and Weng, 2005). Moreover, there is also a high number of studies dealing with the spatiotemporal variability of LST in relation to urban growth patterns and trajectories (Chaudhuri & Mishra, 2016; Du, Xiong, Wang, & Guo, 2016; Feng, Zhao, Chen, & Wu, 2014) and natural/open space land cover changes (Vlassova & Pérez-Cabello, 2016). In this regard, there are few studies focusing on temporal predictive ability of LST in dynamic landscapes. To our knowledge, only a limited number of researches such as He et al. (2015), Verburg, van Berkel, van Doorn, van Eupen, and van den Heiligenberg (2010) and Bryan, Crossman, King, and Meyer (2011) adopted an integrative approach by coupling system dynamics and land-use/cover change models to link climate change (not LST) to future land-use change trajectories.

The dynamic approach permits the modeler to examine the cumulative effects of urban growth policies on LST and also it allows comparing the effectiveness of various planning strategies over time (Feng et al. 2014). Generally, dynamic studies are inevitably multidisciplinary which necessitate integration of various databases from different sources. Moreover, dynamic studies rarely follow a holistic manner to compare and analyse the effect of multiple scenarios ranging from urban development plans to rural land management. The results of such study can provide an informed set of decisions and offers an interactive planning tool that systematically analyses a developing landscape. Therefore, rural and urban land enforcements can be wisely regulated that finally improve comprehensive urban sustainable development plants.

The present study adopts an integrative modeling approach and implements several modeling tools. In other words, the current paper couples scenario-based CA-Markov modeling, LST map generation algorithm, and statistical analyses to quantitatively explore the relationships between urban growth policies and LST values distribution across a developing landscape in Falavarjan Township, Iran. These modeling tools are mainly incorporated to answer the following questions:

(1) What is the actual relationship (linear, quadratic or logarithmic) between area of built-up structures of various physical sizes in Falavarjan Township area and LST values distribution in interior urban environments?
(2) In case of any relationship, do LST values can be predicted over temporal scales using built-up land area as an explanatory variable?
(3) How both temporal LST prediction and predictive urban growth modeling can be coupled in an integrative geospatial study?
(4) What is the appropriate growth policy for designing an urban landscape with lower levels of LST values?
(5) How integrated urban-rural development plans can be adopted to design an urban landscape with lower LST values and appropriate connectivity and compactness of human-made elements?

2. Materials and methods

2.1. Study area

Falavarjan Township as a typical and representative case of urbanized landscape in central Iran was selected as the study area for this research (Fig. 1). Nearly 70 towns and villages in the south-west of Isfahan City border the Falavarjan Township, with a complete

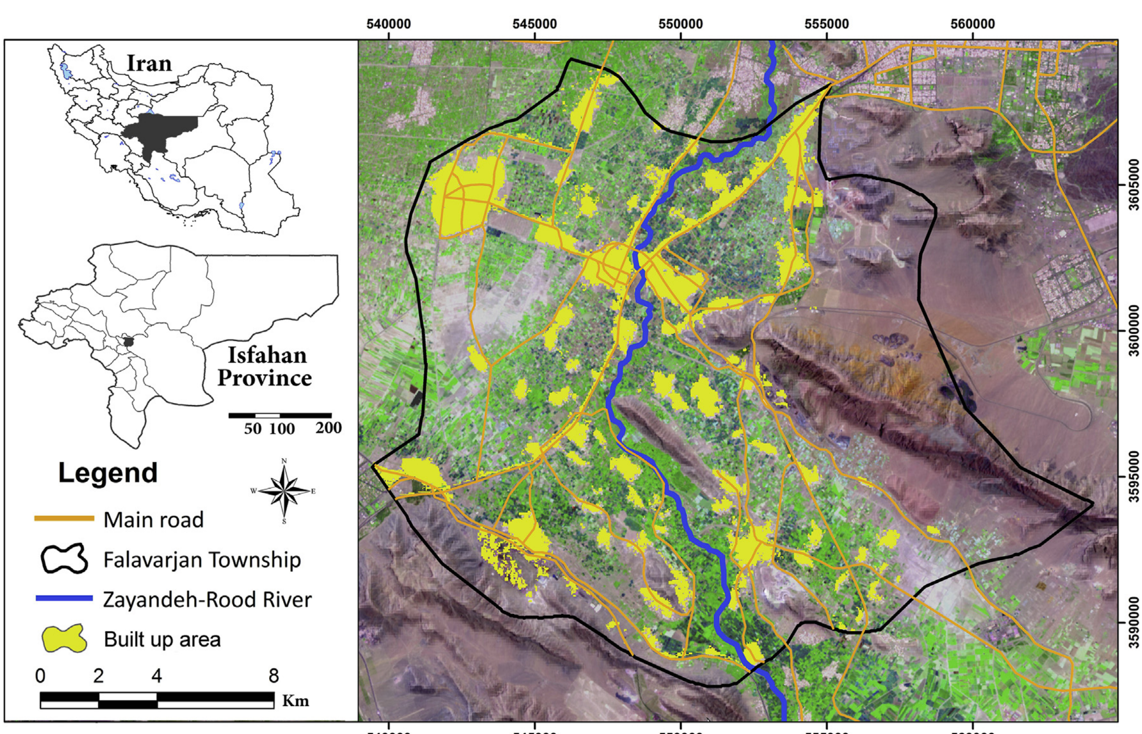

Fig. 1. Geographic location of the study area.