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Simulation and Prediction of Urban Growth Pattern Until 2050 Using SLEUTH-3R Model (Case Study: Coastal Area of Parsian City)

Sorour Esfandeh[1], Afshin Danehkar[1*], Abdolrassoul Salmanmahini[2]

1 Department of Environmental Engineering, Natural Resources Faculty, University of Tehran, Karaj, Iran
2 Department of Environmental Sciences, Fisheries and Environmental Sciences Faculty, Gorgan University of Agricultural Sciences & Natural Resources, Gogan, Iran

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Abstract
The purpose of this study is to identify historical patterns and predict future urban growth and land-use changes in coastal areas. Despite the importance of coastal areas, no studies have been conducted in this field in the country. Therefore this study was performed in the coastal area of Parsian city using SLEUTH-3R model as a new version of automated cell models. According to the results, urban growth in this region is most affected by slopes and urban development has a linear relationship with the transportation network. Also, the growth of cities is more formed than the inner urban lands and the growth caused by the margins of the city will play a less role in the formation of the cities. The area of urban will increase from 1,200 hectares to 3,481 hectares from 2019 to 2050, which is equivalent to a growth rate of 73.58. Also, 47% of barren lands area changing to urbans. These results can provide a suitable perspective for decision making to planning land and natural resource and playing an important role in guiding sustainable urban development in this region.

Keywords: Modelling, Urban Development, Cellular Automata, SLEUTH-3R, Parsian

* Corresponding Author: Email: danehkar@ut.ac.ir

Introduction

The urbanization Phenomenon is expanding rapidly in most parts of the world due to population growth. The migration from rural to urban areas and, consequently, urban development has become a significant challenge worldwide. Urban development and changes in land-use patterns cause social and environmental impacts, Such as reducing natural and agricultural land with high production capacity, water quality, and local climate change. All of these are somehow related to changes in land-use patterns due to human activities. Because of extensive effects on the environment, water cycles, and natural habitats, understanding the quantity and spatial patterns of land-use/land-cover changes is vital. On the other hand, studying these effects in coastal areas with ecotone and more sensitive habitats is more important than in other areas. In this regard, models are a suitable tool to express the complexity of development processes in simple terms.Cellular Automata Models (CA) are dynamic tools in modeling natural and physical features of the land surface and have been widely used in predicting land-use change and urban development. In all of the CA models, the SLEUTH model is probably the most appropriate. It is a hybrid of two CA models that can model urban development and land-use change simultaneously. The SLEUTH model was developed to simulate urban growth based on automated networks. The abbreviation of the SLEUTH included its six input layers: slope, land-cover, the excluded area from development, urban areas, transportation network, and hillshade layer. There are two general steps in implementing SLEUTH: the model calibration to extracting patterns and trends in the past and the forecasting step in which past trends are used for the future. The original version of the SLEUTH model has some constraints such as the number of historical data required, memory limitation, the problem of the road search algorithm with spending time and more memory. This model also tends to the edge or organic growth, so it cannot produce a good level of dispersed growth. These constraints in the latest version of the model (SLEUTH-3r) have been fixed or improved. Reviewing the studies conducted in Iran shows that the new
version of this model has been used in none of these studies. Also, modeling and forecasting urban growth in the coastal areas of Iran has not been done so far. Overseas studies have not been conducted in coastal areas too. Therefore, this study aims to identify historical patterns and predict future urban growth and land-use change in a part of the Persian Gulf coastline.

Materials and Methods

Case Study

Parsian city is located in the southwest of Hormozgan province. The population of the city is 50,596 people. Parsian, with about 1619.5 square kilometers of area, two districts, two cities, four villages, and 42 towns, constitutes about 2.7% of the total population and 2.2% total area of Hormozgan province. Parsian coastal area includes large parts of Kushkenar, Behdasht, Buchir, and Mehregan. With an area of 1021 square kilometers, this sub-area involves about 63% of the Parsian city.

Research Method:

The steps for setting up the SLEUTH-3r model are as follows:

- Preparation of model database and its validation
- Model testing
- Model calibration
- Prediction validation
- Model Prediction
- Preparation of SLEUTH-3r model database:

In order to model the development of cities in the study area by the SLEUTH-3r model, the following maps should be prepared:

- Historical urban maps and their validation
- Historical land-use maps
- Historical maps of the transportation network
- Slope map
- Map of excluded areas from development
- Hillshade Map

- Model testing:

The test scenario file was defined, and then this test was performed to check the model installation and ensure the layers setting in the model.

- Model Calibration:

In the SLEUTH-3r model, the coefficients of diffusion, breed, spread, slope, and roads gravity affect how the growth rules are applied. These coefficients are calculated in the calibration step and on historical maps. The initial coarse calibration step was performed with 10 Monte Carlo. The SLEUTH-3r version uses two measures: Cluster Fraction Difference (CFD) and Area Fraction Difference (AFD). Then, by obtaining suitable coefficients, another execution was performed by setting 100 Monte Carlo to average these coefficients. The coefficients obtained in this step were used in the forecasting process.

- Prediction validation:

In this step, the model was implemented with a historical city map in 2013 to obtain a future city map in 2019.

- Model Predicting:

Ensuring the accuracy of the model prediction, the model with the historical city map in 2019 as the start year of the forecasting was implemented to obtain the city map in 2050.

Discussion of Results

Validation of historical urban maps shows that all of them have high accuracy. The accuracy of these maps in 1984, 1993, 2002, and 2019 is 99% and in 2013 is 98%. The calibration section lasted about 60 hours. Also, the value of AFD and CFD were about 0.1 means that the fraction difference between the modeled clusters and the modeled urban areas than observes one is the lowest. The distribution coefficient of 25 indicates the low probability of city distribution outside the main urban centers. According to the breed coefficient (50), about half of the city's growth will from the vacant land within the city; this means the possibility of the city's growth through its edges is low. Also, the relationship between urban growth and transportation networks is linear, and the effect of slopes on the city's development in this region is high. Also, the kappa statistic (0.99) shows that predicting urban growth has been done with great accuracy. Urban growth in the Parsian coastal area will occur with a very high rate (73.58) from 2019 to 2050. The urban area will increase to 2281.2 hectares and reach about 3481.4 hectares during these 31 years, indicating the rapid and extensive development of residential places in this area. The trend of changes in residential places over 66 years shows that the rate of urban growth from 1984 to 2019 had a slight slope, while from 2019 to 2050, increasing sharply, Which indicates the significant population changes followed by the rapid development of human settlements. Over 31 years, 47.14% of the barren lands will become urban; this confirms a breed coefficient and a road gravity coefficient of 50. Also, 4.96% of the vegetation area will be converted into urban, which indicates the conversion of urban vegetation into residential areas.

Conclusions

This study was performed using the SLEUTH-3r model, which is an improved version of the SLEUTH model. The pattern of urban growth in this region is most affected by the slopes, and the growth of residential places has a linear relationship with the transportation network. Urban areas will increase from 1,200 hectares to 3,481 hectares from 2019 to 2050, equivalent to a growth rate of 73.58 and 2281 hectares. Furthermore, about 47% of the barren lands area will be turned into urban. This rapid growth trend will lead to other environmental changes, and it will be accompanied by an increase in the needs of future residents. Therefore, policymakers and land planners must be fully aware of these issues and their consequences. These results can provide a practical perspective for planning land and be an essential role in guiding sustainable urban development in this region.