

# MODELLING URBAN CHANGES USING GEOMOD MODEL IN ARAK, IRAN

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## *Abstract*

*Up-to-date information about urban expansion is needed for managers and planners for urban planning. Arak is one of cities which has experienced fast urban expansion during recent decades due to industrialization and population growth. The objectives of present study are to analyze urban changes of Arak and to predict urban changes in future. Aerial photographs and Landsat TM and IRS-P6 LISS-III images were used to detect and simulate urban changes. Visual interpretation of aerial photos and neural network classification of satellite images were employed for generating land cover maps with 2 main classes: Urban and non-urban. Geomod model, land cover map of 2006 and suitability map were used to predict urban changes for 2025. Land cover map for 2006 was also predicted and capability of the model in projecting this map was validated using real map of 2006. Results showed that the model had good predictive power in Arak.*

**Keywords:** Geomod, Urban changes, Arak, Neural network

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## I. INTRODUCTION

Urban studies are becoming important tools for planners knowing that in 2015 more than half world's population will be living in cities [1]. Urbanization is a major trend in recent years all around the world. Rapid urbanization is often the cause of enormous pressure on rural and natural environments [2] and cause changes in other land cover or land use types of an area. As a developing country, Iran is now witnessing an almost continual large-scale urbanization. The number of towns and cities has also increased significantly, such that a total of 199 towns in 1956 reached 825 in 2001 [3]. Arak is one of cities in Iran which has undergone fast urban expansion during recent decades due to industrialization and population growth. Land-cover and land-use change analyses and projection provide a tool to assess ecosystem change and its environmental implications at various temporal and spatial scales [4]. Satellite remote sensing in conjunction with GIS has been widely applied and been recognized as a powerful and effective tool in detecting land use and land cover change [5]. Satellite remote sensing provides multi-spectral and

multi-temporal data that can be used to quantify the type and location of land use and land cover change. GIS provides a flexible environment for displaying, storing and analyzing digital data necessary for change detection. One of the most widely used change detection methods is post-classification comparison method [5, 6]. Post-classification comparison method use separate classifications of images acquired at different times to produce difference maps. Although the accuracy of the change maps is dependent on the accuracy of the individual classifications and is subject to error propagation, the classification of each date of imagery builds a historical series that can be more easily updated and used for applications other than change detection [7]. This method minimizes impacts of atmospheric, sensor and environmental differences between multi-temporal images and provides a complete matrix of change information [8, 9]. There are some models for predicting land cover and land use changes such as CA-markov, Geomod, etc. Geomod is a model which uses exactly two categories of land use or land cover and can simulate only the transition from the first category to the second category. Geomod is a land use change model that was originally designed to simulate the loss of tropical forests and to estimate the resulting carbon dioxide emissions. This model has a method to create empirically and automatically a suitability map based on several driver maps [10]. The aims of this study are to detect changes in urban area during 1956-2006 and to predict urban growth for 2025 using Geomod model.

## II. MATERIAL AND METHODS

### 2-1- Study Area

The study area is located between latitudes 34° 03'–34 °08' N and longitudes 49° 37'–49 °47' E in the center of Iran and has an area of about 8780 hectares. It contains Arak which is capital city of Markazi Province. Arak has experienced rapid expansion due to population growth and industrialization during recent decades. The population of Arak increased from nearly 59000 in 1956 to 446760 in 2006 [11]. Average annual temperature of Arak is 13.8° C and average annual rainfall is 316 mm.

### 2-2- Data

A time series of remote sensing data including aerial photos and satellite images spanning 5 decades were used to generate land cover maps. Landsat TM and IRS-P6 LISS III images for the years 1990 and 2006 were used in this study. Also aerial photos of 1956 at the scale of 1:50000 were employed for producing land cover map. IRS-1C PAN image was used to enhance the spatial resolution of IRS-P6 LISS-III image.

### 2-3- Data preprocessing

To prepare data for generating land cover maps and detecting its changes, following procedure were applied.

**Geometric correction:** All images and aerial photographs were rectified to UTM zone 39 N with at least 25 well distributed ground control points. At first geometric correction was carried out using topographic maps with the scale of 1:25000 to geocode aerial photos. Also for geometric correction of the 2006 IRS-1C PAN image, topographic maps with the scale of 1:25000 were used and then this rectified image was employed to register the 2006 LISS-III image. Geometric correction of Landsat TM image of 1990 was carried out by the use of IRS-P6 LISS-III image. Finally, a first-order polynomial model was applied and all data were resampled to a 30 m pixel size using the nearest neighbor method. After geometric correction of aerial photos, all photos for each year were mosaicked to prepare one image for land cover mapping.

**Image enhancement:** The goal of image enhancement is to improve the visual interpretability of an image by increasing the distinction between features [12]. In this study, two false color composites (FCC) were produced for selecting training samples. Also image fusion was done to increase spatial resolution of the LISS-III image. LISS-III image was fused with IRS-1C PAN image to generate an image with high spatial resolution.

### 2-4- Generating Land cover maps

For generating land cover maps from aerial photos and satellite images, 2 main land cover classes were selected, namely urban and non-urban. For this study, urban areas involve residential, commercial, industrial, educational, recreational establishments and transportation systems.

**Aerial photos interpretation:** Land cover pattern was interpreted visually on black and white aerial photographs and simultaneously digitized with the Arcmap software. Identifying features in aerial photos was performed based on tone, texture, pattern, size and shape.

**Image classification and accuracy assessment:** All land cover maps were generated through artificial neural networks classifier. In order to get precise classification results, the training samples were selected from false color composite (FCC) images and topographic maps. To map land cover information, a three-layer-perceptron neural networks were employed which contained one input layer, one hidden layer and one output layer. Input layer included spectral bands and training samples and output layer had two nodes. Experiments were conducted for selecting the best number of nodes in the hidden layer to improve the classification accuracy. The number of nodes in the hidden layer was selected equivalent to the number of nodes in the input layer. The parameters of momentum and learning rate were set at 0.5 and 0.2 based on experimental results. The Overall accuracy of land cover maps was calculated by error matrices. The Ground truth data were derived from GPS, topographic maps and false color composite images and error matrix was generated for each land cover map.

## 2-5- Post-classification change detection

Post-classification comparison change detection algorithm was used to determine changes in urban areas in 5 decades from 1956 to 2006.

## 2-6- Change prediction

Geomod predicts a one-way conversion from one category to one other category and has the advantage that it does not require large amounts of data for calibration and validation compared to other complex dynamic models [13]. This model examines a suitability map to find the pixels with the largest suitability value and then predicts conversion of new urban at the non-urban pixels that have the largest suitability for urban [10]. Land cover map of 1990 was used to calibrate Geomod model and after that the model predicts urban changes from 1990 to 2006. Projecting urban area changes for 2025 carried out using the suitability map and land cover of 2006. The suitability maps determine which pixels will change according to the largest suitability [1]. The suitability map in the present research is a map that Geomod generated automatically from three driver maps: slope, distance to urban areas and distance to main roads.

## 2-7- Model validation

To evaluate the predictive power of the model two methods below were used:

**Examine the goodness-of-fit of validation and kappa indexes:** We used VALIDATE module of Idrisi software which examines the components of agreement and disagreement between the comparison and reference maps of the same time. Real land cover map derived from neural network classification was regarded as the reference map and the comparison map was the result of simulation. Validity of the predicted map was assessed using reference map. VALIDATE module also computes the Kappa index of agreement and its variants. The kappa index of agreement has several variations, each of which measures different characteristics of agreement. Klocation indicates the level of agreement of location, given a specified quantity. Kquantity indicates the level of agreement of quantity, given the model's ability to specify location. These variations complement the standard Kappa. Kappa equals 1 when agreement is perfect and equals 0 when agreement is as expected by chance [14].

**Error matrices:** Assessment of the model's predictive power also was performed by calculating the overall accuracy of predicted map. For this purpose, Ground truth data obtained for classification accuracy assessment were used and the overall accuracy of simulated land cover map were calculated.

## III. RESULTS AND DISCUSSION

Accurate per-pixel registration of multi-temporal remote sensing data is essential for change detection because registration errors may lead to an overestimation of actual change [15]. The root mean square errors for all aerial photographs were between 0.2 and 0.7 pixels. RMSE for PAN, LISS III and TM images were determined to be 0.42, 0.48 and 0.58 pixels, respectively. The RMSE for urban areas was lower than other areas because finding more control points in urban areas was easier than other areas. Image fusion was carried out and resulted in producing an

image with high spatial resolution equal to 5.8 meter. The fused image enhanced the capability of identifying features and selecting training samples.

Land cover mapping was carried out using visual interpretation of aerial photos and neural network classification of satellite images and both methods generated land cover maps with high accuracy. A standard overall accuracy for land-cover and land-use maps is set between 85 and 90 percent [13]. In this study, the overall accuracy of the land cover maps for 1956, 1990 and 2006 were 95.03%, 95.53% and 90.6%, respectively. The Kappa index for the 1956, 1990 and 2006 land cover maps were found to be 0.93, 0.92 and 0.81.

### Change detection

At first, area and percentage area of urban and non-urban classes were calculated which is shown in table 1. Non-urban to urban transformation from 1956 to 2006 occurred at a rate of 71.6 ha per year. Transformation of nearly 3581 ha from Non-urban to urban areas was due to industrialization and population growth. The population of Arak city increased from nearly 59000 in 1956 to approximately 446760 in 2006 [11]. During this time period, a lot of companies and factories were constructed in Arak and this factor attracts people from other cities of Iran and also some villages of Markazi province to migrate to this city.

Table 1. Area and area percentages of land cover classes for 1956 and 2006 (area in hectare)

Categories	Area (1956)	Percentage area(1956)	Area (2006)	Percentage area (2006)
urban	461	5.2	4011	45.7
Non-urban	8322.2	94.8	4772.2	8783.3
total	8783.2	100	8783.2	100

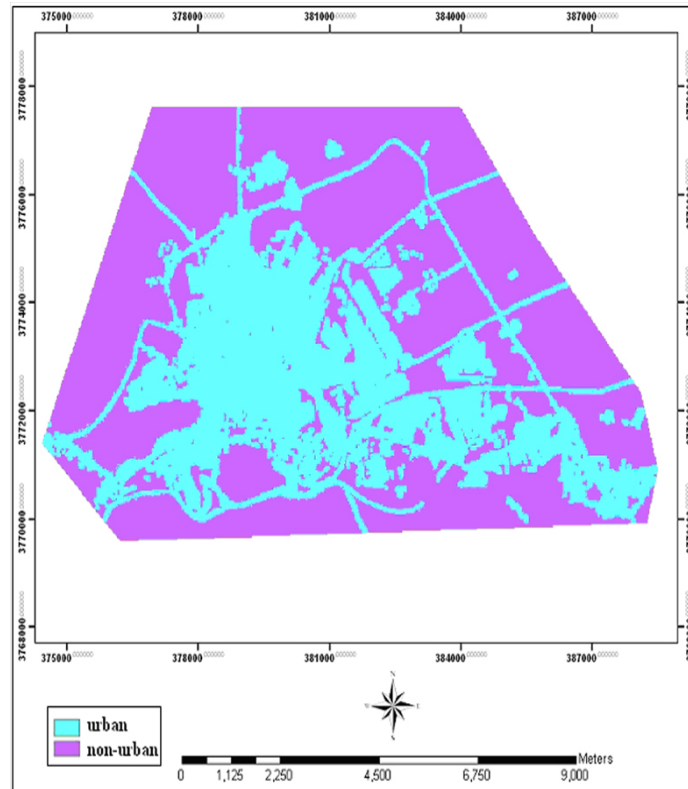
Table 2 shows that approximately 31 ha of urban area were converted to non-urban areas from 1956 to 2006. Observation indicated that these changes are due to classification errors. Main parts of these areas were urban areas such as highways and streets that were classified as green spaces mistakenly. Highways and streets are generally classified as urban, but when trees along the streets grow, they may be classified as green spaces. Yuan et al. (2005) addressed this problem in their study on land cover classification and change analysis of Twin cities metropolitan area. They mentioned transformation of about 6200 ha of urban area to forest from 1986 to 2002 [7].

Table 2. Matrix of urban and non-urban area changes from 1956 to 2006.

		1956		
		Urban	Non-urban	Total
2006	Urban	430.4	3580.6	4011
	Non-urban	30.6	4741.6	4772.2
	Total	461	8322.2	8783.2

### Change prediction and Model validation

Geomod and suitability map derived from driver maps were used to predict changes in urban area for 2006 and 2025 (Fig. 1 & 2). Real land cover map for 2006 has been generated through neural network classifier and because of validation, it was predicted. According to the results of the model, urban area tend to increase in future, as Geomod predict built-up area to be 5973 ha in 2025.



*Figure 1. Simulated land cover map of 2006*

Table 3 and Fig. 3 show agreement and disagreement components between real and simulated land cover maps. The value of overall agreement is 90 % and it indicates that Geomod had high potential in predicting changes during 1990-2006. Disagreement due to location is 7 % and disagreement due to quantity is 3 %. It means that the model had better performance in simulating the quantity of pixels rather than the location of pixels. The results of kappa indexes confirm the fact mentioned above as  $k_{location}$  which reveals the level of agreement of location is 0.89 and  $k_{quantity}$  which shows the level of agreement of quantity is determined to be 0.95. The overall accuracy of simulated land cover map for 2006 which was assessed using ground truth data is found to be 81.9 %. This value for accuracy is acceptable; however the overall accuracy of real map is 90.6 %. In general, the result indicates that Geomod model has high potential in predicting urban area changes in the city of Arak (table 4 & 5).

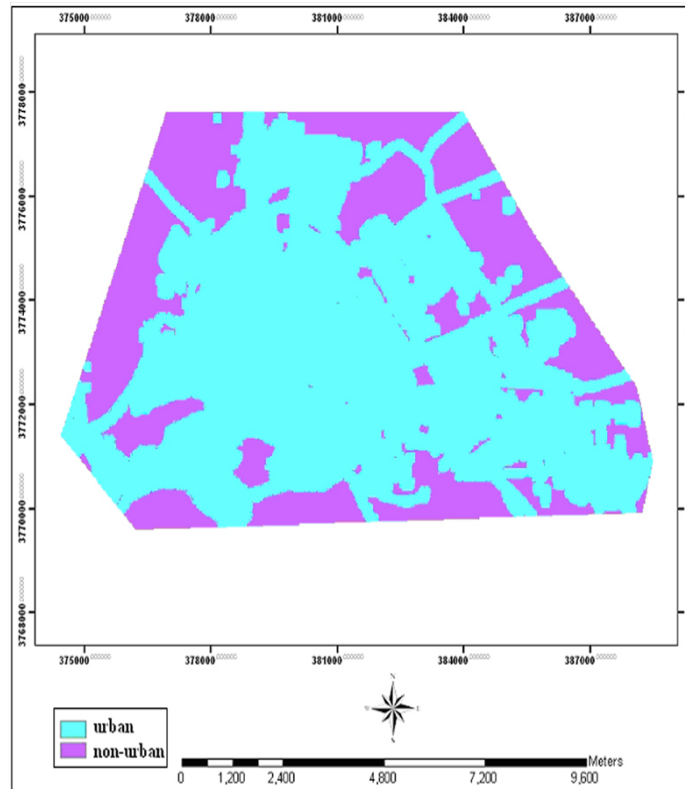


Figure 2. Predicted land cover map of 2025

Table 3. Components of agreement and disagreement between real and simulated map of 2006

Agreement and Disagreement	Percentage
Agreement due to chance	33
Agreement due to Quantity	2
Agreement due to location	55
Disagreement due to location	7
Disagreement due to quantity	3
Overall disagreement	10
Overall agreement	90
Kstandard	0.85
Klocation	0.89
Kquantity	0.95

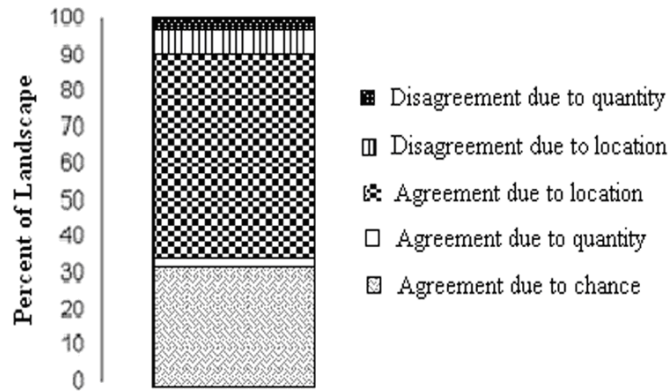


Figure 3. Agreement and disagreement components (2006)

#### IV. CONCLUSION

The outcomes of present study demonstrate the capability of multitemporal data which were used in this study for mapping urban land cover, detecting its changes and also predicting changes in future. Outputs of this research can be useful for land management and land use planning. The results indicates that Landsat TM and IRS-P6 LISS-III images can be effectively used for generating accurate land cover maps and monitoring urban area changes.

This study showed that the urban area of the study area has expanded significantly during 5 decades between 1956 and 2006 due to industrialization and population growth. A lot of people immigrated to Arak because of job opportunities during recent years. In the present study, post-classification comparison was successfully employed for detecting and monitoring urban expansion and changes occurred in urban areas. Urban expansion and subsequent degradation of farmlands and natural vegetation has been occurred and is occurring in different places in Iran and also in all over the world such as Bangkok in Thailand and Shijiazhuang in China [16, 17]. Modelling methods provide useful information about probable changes in future and can be used to prevent some adverse effects on environment. According to the results of model validation, Geomod had appropriate performance and predicted urban area changes effectively.

Table 4. Error matrix of predicted land cover map for 2006

Classes	Urban	Non-urban	Total	Commission error
urban	262	10	272	0.036
Non-urban	102	246	348	0.293
Total	364	256	620	
Omission error	0.280	0.039		0.180

Overall accuracy: 81.93 %      Overall kappa: 64.63 %

Table 5. Error matrix for real land cover map for 2006

Classes	Urban	Non-urban	Total	Commission error
urban	281	26	307	0.084
Non-urban	27	230	257	0.105
Total	308	256	564	
Omission error	0.087	0.101		0.094

Overall accuracy: 90.60 %      Overall kappa: 81.05 %

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