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Use of SLEUTH Model in Land Cover/Land Use Change Simulation, Corum City Example

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Abstract:*In this study, it is aimed to forecast for the future with respect to land cover/land use (year 2040) Turkey, Corum, one of the medium-sized city to understand much better the urban structure. SLEUTH model which is one of simulation technics in Cellular automata-based urban growth and land cover/land use change models was used. 2040 land cover/land use forecast for Corum city was carried out by means of SLEUTH model carried out by using development scenario of Current trends was estimated. Main materials of the study comprise Ikonos-2 for 2002 and 2006, QuickBird-2 for 2008, SPOT-5 for 2010 and SPOT-6 satellite images for the year 2014. According to carried out SELUTH simulation results to determine estimation of year 2040 change, the most changes have occurred in urban areas. According to data gained by current trends of development scenarios, it is estimated that urban structure will increase by 49.3% (1001 ha).*

Key Words:*Land cover/Land use, SLEUTH Model, Remote Sensing (RS), Geographic Information System (GIS)*

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I. Introduction

There are rapid population growth, migration, technological developments, soil erosion and so onfactors among the most important factors threatening the natural terrain feature. Lands using out of purpose has increased as a result of growth and development process in urban areas. Especially tourism, urbanization and industrialization have accelerated the destruction of natural resources. It is inevitable to ensure use/protection balance of existing intact natural resources in order to retain people's quality of life (Sanver 2008). Industrialization started in Corum city in 1970's is one of the most important factors determining economic structure of the city. The fact that Corum was included in the "Priority Province in Development" in 1972 was also effective in this situation. In the next period of time, investments in many different industries have become (Simsir and Unal 2013). Corum city land cover/land use patterns have changed significantly because of that issue.

Remote Sensing (RS) and Geographic Information Systems (GIS) play an active role determining, analyzing, questioning and observing changes in land cover/land use (Turner et al., 2001; Atak 2013). Many models and simulation tool have developed by researchers in order to determine changes in land use and land cover. When the researches carried out on this subject are examined, solutions based on cellular self-processing (CA-Cellular Automata) catch the attention. SLEUTH (**S**lope, **L**and use, **E**xclusion, **U**rban, **T**ransportation, **H**illshade) model is one of the notable model among land cover/land use change models which are accepted, in literature and have application samples. SLEUTH model by developed Dr. Dr. Keith C. Clarke at the University of California to simulate change in urban areas have used intensely in the spatial simulation of future planning scenarios (Clarke et al., 1997; Clarke and Gaydos, 1998; Clarke 2008; Chaudhuri and Clarke 2013). An application in Corum city of SLEUTH model which has wide area of utilization in land cover/land use change studies was carried out in this study and this study is contained in the following sections.

II. Study Area

Approximately 165 km^2 of the adjacent area of Corum Municipality with an area of 350 km^2, which is in the process of development was determined as area of the study. Geographical coordinates of this area were determined as the upper left (34^0 50'46.87" East, 40^0 35' 46.71" North), the lower right (35^0 01'14.42" East, 40^0 29' 42.14" North) and was shown in Figure 1.

Corum located in the south of the Middle Black Sea region is the 20th city of Turkey in the ranking with an area of approximately 12820 km^2. According to TSI, Corum comprises 14 districts, 16 municipalities, 124 neighborhood and 760 villages respectively.

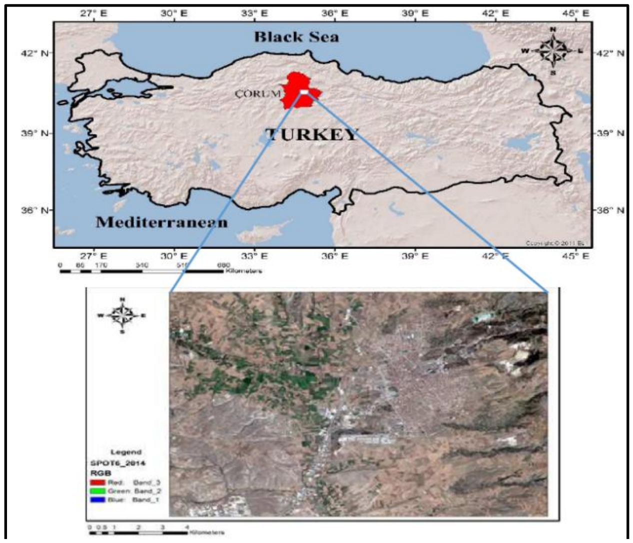


Figure 1: Study area - Corum city center 2014 (SPOT-6) RGB image

III. Material And Methods

Data sources and methods used in map production studies affect accuracy and reliability to be performed study. Thus, the quality and variety of data to be used in studies has great importance. 1/25000 scale topographic maps (G33-c-3, G34-d-4) created by General Command of Mapping in 1992 year were used in order to determine the topographic position of the study area and to perform the controls after geometric correction in the satellite images in this study. Numerical preliminary maps, digital construction plans with the update of 2014 and digital master building plans with the update of 2017 from Corum Municipality were provided to be used the study. Satellite image set of the study consist of Ikonos-2 for 2002 and 2006, QuickBird-2 for 2008, SPOT-5 for 2010 and SPOT-6 satellite images for the year 2014. Ikonos-2 images of 2002 and 2006 have 3-band (RGB), pan-sharpened and 1 m resolution. 2008 QuickBird-2 image has 3-band (RGB), pan-sharpened and 0.5 m resolution. The 2010 SPOT-5 satellite image has a 2.5 m panchromatic, 10 m multiband (MS), 2014 SPOT-6 satellite image has a 1.5 m panchromatic, 6 m multiband (MS) resolution.Data gained by means of Remote sensing methods have systematic and non-systematic faults due to environmental impacts. Thus, it is necessary to apply, some (radiometric, atmospheric and geometric) corrections before using applications to satellite images. Pre-processing applications have been performed on the SPOT satellite images used in the study. Ikonos-2 and QuickBird-2 images are not to be included due to gained pan-sharpened feature.

The gain values in the metadata files of the 2010 SPOT-5 and 2014 SPOT-6 satellite image bands were used in the radiometric correction process. Radiometric correction process was carried out with the help of band arithmetic in the Envi 5.2 software.

After radiometric correction, it should also apply atmospheric correction to minimize the effects of regular and irregular errors in the perception of satellite images. There are different methods (QUAC, ATCOR, FLAASH etc.) which are developed for this purpose and included in the remote sensing software. QUAC (Quick Atmospheric Correction) is an atmospheric correction method developed for multispectral and hyperspectral bands in visible and VNIR-SWIR wavelength ranges. QUAC is preferred for research because of its ease of use and little information. In this study, since the band characteristics of the SPOT-5/6 satellite images are within the specified range and there is no meteorological and atmospheric information related to these images, QUAC in the Envi 5.2 software modules for the atmospheric correction method is preferred.

With the help of pre-determined ground control points, the process of transformation into a desired coordinate system is called geometric correction (rectification). Geometric correction are after the ground control point selection, the determination of the conversion and resampling methods to be used; two-step correction application. The transformation equations that provide the link between the image coordinate system and the ground coordinate system were as 3rd degree polynomial. The total Root Mean Square Error (RMSE) does not exceed ± 0.5 pixel value for transformation and resampling process was determined with Nearest Neighborhood Method. All data used in the study was used by transforming into"WGS_1984_UTM_Zone_36N" reference system which is defined UTM projection 6^0, 36 in Zone and WGS84 datum plane.

After pre-processing phase in satellite images, pan sharpening was carried out in Satellite images of SPOT-5/6 (2010 and 2014). (Hyper spherical Color Space HCS) method was preferred for pan sharpening method. Classification of SPOT-5/6 satellite images was carried out with 8 land use classes that comprise built-up areas, transportation (Road), mineral extraction sites, agricultural areas, forest areas, bare rock areas, open spaces with little or no vegetation areas, and water bodies (dams, lakes). Classification was carried out using the pixel-based trained classification technique and the Support Vector Machines (SVM) method. Envi 5.2 was used to classificate SPOT-5/6 (2010 and 2014) satellite images and Erdas Imagine 2014 software was used to implement accuracy analysis. Accuracy analysis was carried out with reference data that selected 30 piece in each land cover/land use class, random and as homogeneous distribution as possible. Kappa statistical values for 2010 SPOT-5 and 2014 SPOT-6 satellite images as a result of accuracy analysis which carried out with 240 reference data was obtained as 0.94 and 0.90 respectively. Information on accuracy analysis is shown Table 1 and Table 2.

Table 1:2010 SPOT-5 Satellite image classification error matrix information

Classification Type: Pixel Based	Satellite image: ***2010 SPOT-5***					
Method: Support Vector Machine (SVM)	Error Matrix					
Land Cover/Land Use Class Name	Number of Reference Pixels	Classified Number of Pixels	Correctly Classified Pixels	Producers Accuracy %	User Accuracy %	Kappa Statistics
Built-up Area	30	33	30	100.00	90.91	0.8961
Transportation (Road)	30	30	28	93.33	93.33	0.9238
Mineral Extraction Sites	30	30	29	96.67	96.67	0.9619
Agricultural Area	30	28	25	83.33	89.29	0.8776
Forest Area	30	31	30	100.00	96.77	0.9631
Bare Rock Area	30	31	28	93.33	90.32	0.8894
Open Spaces With Little or No Vegetation Area	30	28	26	86.67	92.86	0.8961
Water Courses (Dam, Lake etc.)	30	29	29	96.67	100.00	0.9184
Total	240	240	225			1.0000
Total Accuracy %	93.75					
Total Kappa	**0.94**					

Table 2: 2014 SPOT-6 Satellite image classification error matrix information

Classification Type: Pixel Based	Satellite image: ***2014 SPOT-6***					
Method: Support Vector Machine (SVM)	Error Matrix					
Land Cover/Land Use Class Name	Number of Reference Pixels	Classified Number of Pixels	Correctly Classified Pixels	Producers Accuracy %	User Accuracy %	Kappa Statistics
Built-up Area	30	30	30	100.00	100.00	1.0000
Transportation (Road)	30	43	28	93.33	65.12	0.6013
Mineral Extraction Sites	30	26	25	83.33	96.15	0.9560
Agricultural Area	30	31	29	96.67	93.55	0.9263
Forest Area	30	31	30	100.00	96.77	0.9631
Bare Rock Area	30	23	22	73.33	95.65	0.9503
Open Spaces With Little or No Vegetation Area	30	27	26	86.67	96.30	0.9577
Water Courses (Dam, Lake etc.)	30	29	29	96.67	100.00	1.0000
Total	240	240	219			
Total Accuracy %	91.25					
Total Kappa	**0.90**					

SLEUTH Model

SLEUTH which based on Cellular Automat that was written in C programming language is a model which developed to simulate cities under the influence of urban change Dynamics. SLEUTH model that has developed as Unix-based, open source is run with Unix emulator Cygwin program in Windows environment. Data set to be need to prepared to run SLEUTH model need to have certain main standards. These basic standards are:

1. The entire data set to be used as input must be in 8-bit depth and in ".gif" format (graphics interchange format)
2. The entire data set to be used as input must have the same coordinate system and the same projection
3. All data set groups to be used as input must have an equal number of pixels (resolution) (row x column)
4. The entire data set to be used as input must have the naming standards in the model user guide

5. In the data set groups to be used in the calibration phase, the pixel size should have a ratio of 1/4 to 1/2 - 1 determined for the standards.

6 different data sets which is required to be able to start Urban growth and land cover / land use simulation process in SLEUTH model was produced. Data produced are below:

1.Urban data of at least 4 different cities (2002, 2006, 2008 and 2010)
2.At least two different transportation network-transportation data (2002 and 2008),
3.At least 1 slope (%) data (DEM),
4.At least 1 hillshadedata (DEM-Digital Elevation Model)
5.At least 1 exclusion data,
6.At least two different land cover / land use data (2010 and 2014).

SLEUTH model contains four predefined growth rules Spontaneous Growth, New Spreading Center Growth, Edge Growth and Road-influenced Growth. Growth rules are applied separately to each pixel and it is taken into consideration that whether the relevant pixel would be transformed into the urban area or not that. Implementation of growth rules and the system behavior are carried out with five-growth control factor (Dispersion/ Diffusion coefficient, Breed Coefficient, Spread Coefficient, Slope resistance coefficient and Road-gravity Coefficient). The growth control coefficients take full values in the range 0-100 (Gigalopolis 2018). Calibration stage constitutes the first step of SLEUTH model applications. Calibration is the step in which the growth coefficient values to be used in the forward simulation are determined according to the input data of the model. SLEUTH model calibration is performed in three steps: coarse, fine and final, in three different resolutions.

Satellite imagery data of 4 different dates used in the built-up area layer belongs to 2002, 2006, 2008 and 2014. Rule-based classification was applied by using Ecognition Developer 9 software in order to determine 2002 built-up texture in Ikonos-2 (1 m), 2006 Ikonos-2 (1 m) and 2008 QuickBird-2 (0.5 m) satellite images. The built-up area of the year 2014 also was obtained with pixel-based supervised classification of the 2014 SPOT-6 satellite image. Data on the urban fabric are shown in Figure 2.

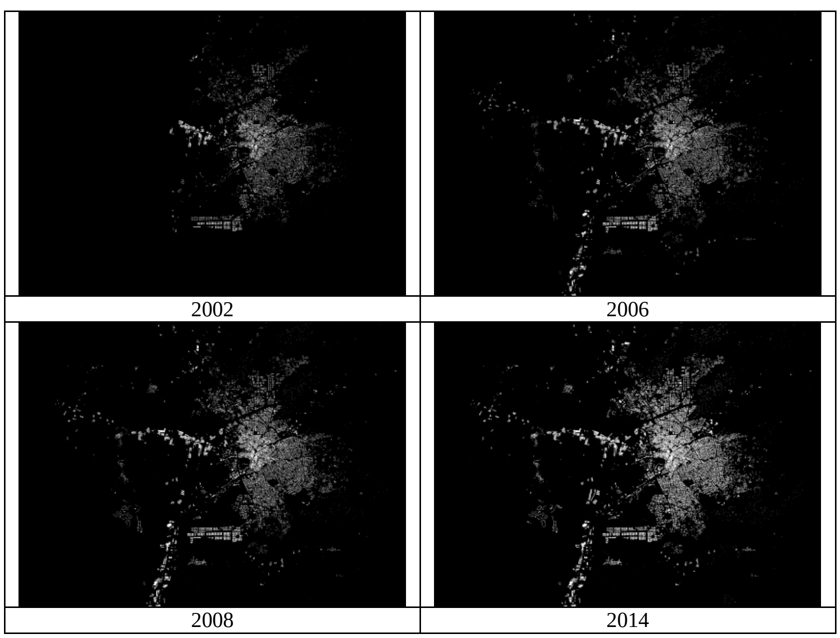
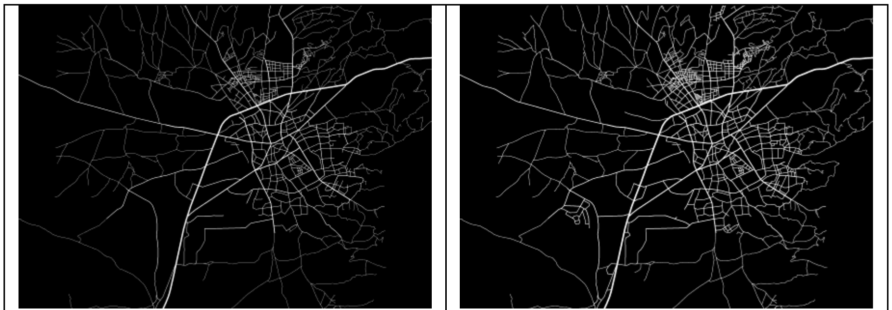


Figure2: Urban area data for 2002, 2006, 2008 and 2014

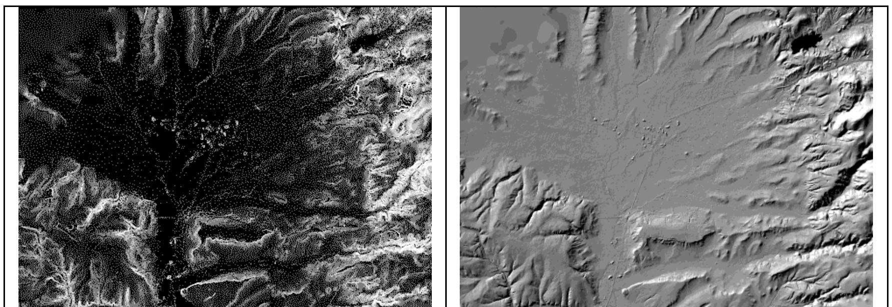
When considering the role of urban areas on accessibility of urbanization, this data layer is also very important in terms of urban simulation. Two transport network-path layer data were gained by integrating Ikonos-2 of 2002 and QuickBird-2 satellite images of 2008 with the road width information included in Corum province digital construction plan. Data on transportation network is shown in Figure 3.



2002 | 2008

Figure 3: Transportation data for 2002 and 2008

Slope data and hillshade data layers were prepared as in Figure 4 using numerical preliminary map data in ArcGIS 10 software, using DEM data.



Slope (%) | Hillshade

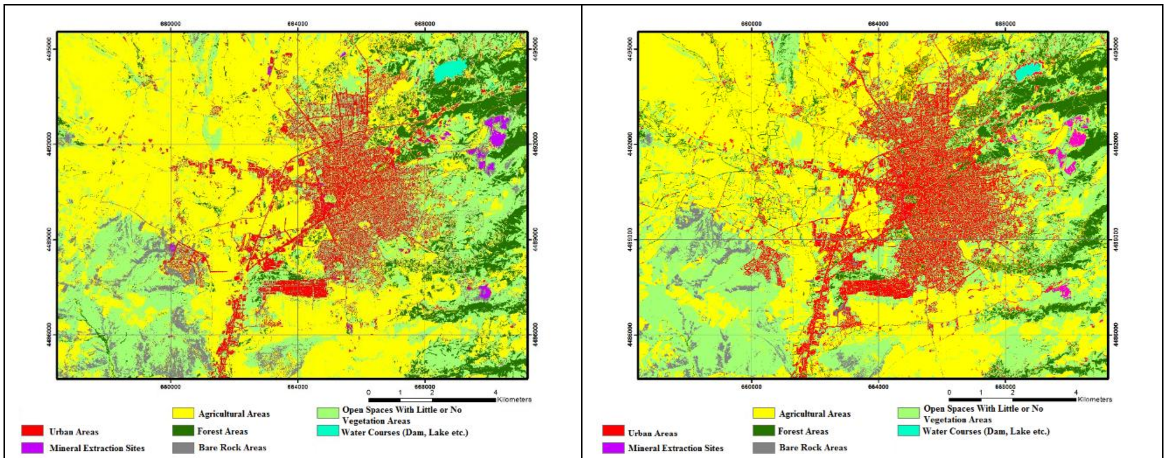
Figure 4: Slope and hillshade layer data

External region layer contains data on the SLEUTH model, which are appropriate and inappropriate for urban growth and development. Weights of regions that would be excluded entirely from growth or would be allowed to partially growth are determined pixel brightness values in which it will be 0-100 range, considering the level of protection contained in the created scenario file. The development scenario with the assumption that current trends will continue the current trend was prepared. In this scenario, water surface and mineral extraction areas and strict protection areas surrounding these areas were not be excluded from urbanization and exclusion layer data gained was created as in Figure 5.

Exclusionlayer

Figure 5: Exclusion region layer data

After eight classification performed by land use class, class of transportation and build-up areas were integrated because of determining along with transport network-road structure with build-up areas structure. The combined classes are grouped under the urban area class. Figure 6 shows TIF format views before converting to GIF format of data on seven land cover/land use classes for each two years.



2010	2014

Figure 6: 2010 and 2014 land cover/land use data layers

Data for SLEUTH model calibration were carried out in three different spatial resolutions (20 m for coarse calibration, 10 m for fine calibration and 5 m for final calibration stage). During the calibration process, calibration result of the growth coefficient values are determined with the help of metric and calibration phase is completed by using it in the next calibration stage. Although Lee-Sallee metric is the most preferred metric in previous results on many Sleuth calibration application evaluation, (Dietzel and Clarke 2007) were used Optimal SLEUTH Metric (OSM) which is the product of seven of the thirteen metrics. And also they were notice that OSM result usage would provide the most reliable results in calibration evaluation. Therefore, the calibration phase of the study was carried out considering OSM metric.

IV. ResultsAndDiscussion

During coarse calibration stage with 20 m spatial resolution, 0, 25, 50, 75, 100 values were used with 25 increase in value in growth control coefficients (Table 3).

Table 3: Coarse calibration result values

	Run	Diffusion	Breed	Spread	Slope resistance	Road-gravity	OSM	
1	1168	25	100	25	75	75	**0.311344**	20 m (750x550) pixel Monte Carlo Number of Iterations: 4 Total Processes: 3125
2	1165	25	100	25	75	1	**0.283956**	
3	1041	25	75	25	75	25	**0.282895**	
4	1171	25	100	25	100	25	**0.279464**	
5	1043	25	75	25	75	75	**0.273327**	

The most suitable fine calibration coefficient range values were determined, using the growth control coefficient value in the first five orders which ranked from the highest value to the smallest, according to the OSM metric in the result file (control_stats.log) obtained from the rough calibration process. Table 4 shows (fine) obtained after calibration values.

Table 4: Fine calibration result values

	Run	Diffusion	Breed	Spread	Slope resistance	Road-gravity	OSM	
1	2964	28	93	21	86	76	**0.212701**	10 m (1500x1100) pixel Monte Carlo Number of Iterations: 7 Total Processes: 3125
2	3081	28	100	21	79	19	**0.211224**	
3	3091	28	100	21	93	19	**0.205608**	
4	3076	28	100	21	72	19	**0.202089**	
5	2968	28	93	21	93	57	**0.196565**	

OSM metric values obtained with good calibration stage were ranked from the highest value to the smallest and final calibration coefficient range value were determined. Table 5 shows values gained after final calibration.

Table 5: Final calibration result values

	Run	Diffusion	Breed	Spread	Sloperesistance	Road-gravity	OSM	
1	2853	**28**	**96**	**24**	**72**	**63**	**0.193643**	5 m (3000x2200) pixel Monte Carlo Number of Iterations: 8 Total Processes: 3125
2	2979	28	98	24	72	78	0.193172	
3	2725	28	94	24	72	18	0.192538	
4	2980	28	98	24	78	18	0.191508	
5	3101	28	100	24	72	33	0.191310	

After the last calibration that constitutes the final of the calibration process, growth control coefficient values (28, 96, 24, 72, 63) having the highest value OSM are used to skip forecasting stage. After last calibration, last coefficient values that it will use in forecasting stage are obtained with estimation Coefficient Determination mode (Derive Forecasting Coefficients) where take places 150 Monte Carlo Iteration.After Estimation Coefficient Determination stage, Table 6 shows optimal growth control coefficients (best-fit value) to be used forecasting stage values in "avi.log" file created final file rolling to full number.

Table 6: The optimal growth control coefficients to be used for forecast

	Year	Diffusion	Breed	Spread	Slope resistance	Road-gravity
Derive Forecasting Coefficients	2014	31.24	100	26.78	62.58	63.94
Selected Coefficients for Forecast		**31**	**100**	**27**	**63**	**64**

SLEUTH Model Application and Scenario Results

The results of the urban growth scenario have been obtained according to the current trends of 2040 in the SLEUTH model simulation applications field. 2040 land cover/land use status that has taken place with current trends development scenario is given Figure 7.

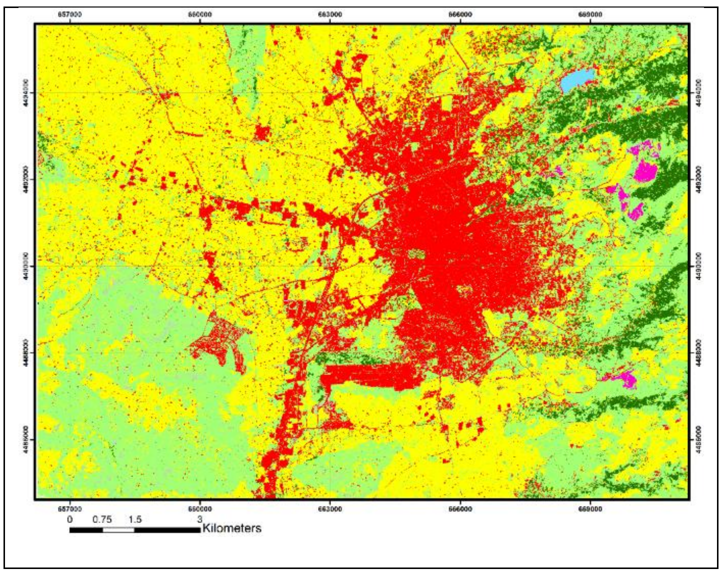


Figure 7: Forecast map for 2040 years

When 2040 land use changes due to current trends growth scenario with Land use data for the year 2014, which is the most recent data of the land use data used in the model estimation process is examined, class that can be called as build-up areas or city structure will increase by approximately 49.3%. On the other hand, forests and wooded areas after classification will decrease by approximately 37.2%, bare and rocky areas 74.8%, sparse plant areas 2.5%. Although there was no significant change in agricultural land, an increase of 0.8% was predicted according to the estimation results.

In the scenario files prepared in the SLEUTH model structure, as the mining areas and the water masses are not excluded from the simulation, there is not change as spatial in all forecasting results. Information on the changes taking place between 2014-2040 in the land cover / land use classes in line with the current trends development scenario are given in Table 7 and Figure 8.

Table 7: Change in land cover/land use between 2014-2040

	2014		2040		Change	
Land Cover/Land Use Class Name	Area (ha)	%	Area (ha)	%	Area (ha)	%
Urban area	2031	12.31	3032	18.38	1001	+49.30
Mineral Extraction Sites	77	0.46	77	0.46	0	0.00
Agricultural Area	6973	42.26	7026	42.58	53	+0.77
Forest Area	1394	8.45	876	5.31	-518	-37.17
Bare Rock Area	532	3.22	134	0.81	-398	-74.82
Open Spaces With Little or No Vegetation Area	5467	33.13	5328	32.29	-138	-2.53
Water Courses (Dam, Lake etc.)	27	0.16	27	0.16	0	0.00
Total	16500	100.00	16500	100.00		

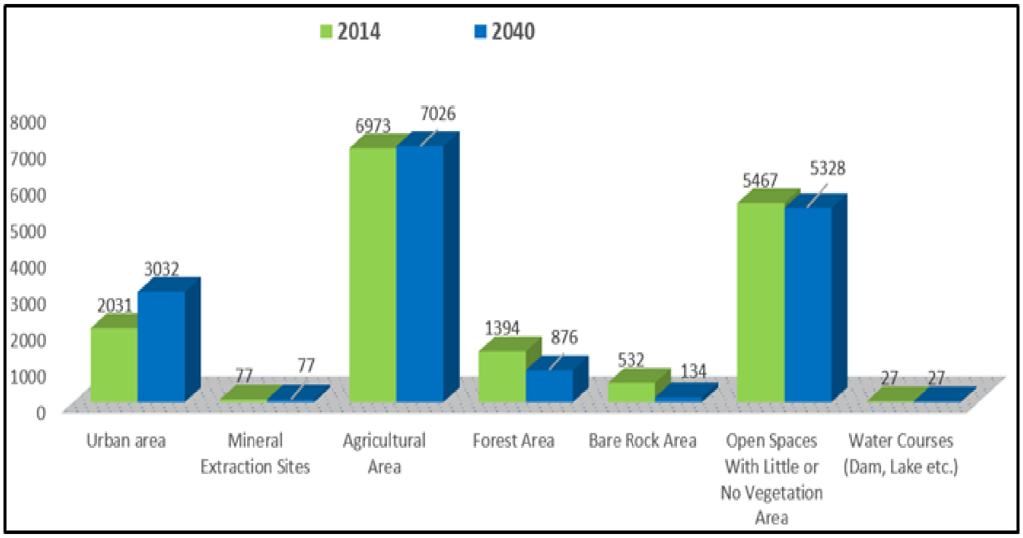


Figure 8: Change graph of land cover/land use classes between 2014 and 2040

V. Conclusion

GIS and remote sensing methods has brought to the fore as a result of developments in information technologies in the last quarter of 20 century. The use of these methods is increasing day by day in determining the change in the cities that constitute the living areas of people.

In this study, although there are many models that need different data on land use/land cover and product different results, it is concluded that decision-makers would provide to planning and investment decisions and changes in study areas would be determined with use of the SLEUTH simulation model because of having open source code structure. The results obtained with the SLEUTH urban growth model will provide data base that would be created with respect to Corum city land use.

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