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Predict the Physical Development of the Shiraz City and Its Impact on the Vegetation Dynamics Using Cellular Automata, Fuzzy Techniques and Satellite Imagery

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ABSTRACT

Remote sensing is the main technology for assessing expansion and rate of change of land cover. Knowing the different kinds of land cover changes and human activities in different parts, as a basis for a variety of planning has special importance. Accordingly this study aimed to evaluate the physical growth of the Shiraz city during the years 2009 to 2016 and forecasts until 2021 and also calculate the amount and intensity of the destruction of vegetation in the study area using satellite images. To achieve this, the data of remote sensing and geographic information system is used. Calculation of trends in physical growth, stating that the area of the city from 13160.07 hectares in 2009 reached to 17350.29 hectares in 2016, over a period of 7 years. If these conditions persist, area of the city in 2021 with 19.21 percent growth will be 20683.58 hectares. Assessment NDVI index show that the density of vegetation in the Shiraz city had a significant decreasing trend. So that the sum of very good and good vegetation cover results NDVI index, in 2009 was equal to 6128.37 hectares, while this amount has decreased to 4282.47 hectares in 2016, that this means a 43.10 percent reduction in vegetation cover in this period. The results showed that between 2009 to 2016 more than 1891 hectares of vegetation and gardens has become built lands.

KEYWORDS
Land cover map, Comparison of classification, Detection of changes, Remote Sensing, Cellular Automata, Fuzzy method.

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Introduction

Cities after the Industrial Revolution are being expanded with accelerated growth and development, so that now the process of urbanization is one of the most important issues facing researchers in urban issues. In addition the rate of urban growth, land use changes on the macro level, causing problems such as: traffic congestion, environmental pollution, loss of open space and unplanned

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land development (Soyoung et al., 2011). This trend in recent decades, especially in developing and underdeveloped countries, resulting in the marginalization of the rural population growth rate, migration of much of the rural population to urban centers and destruction of urban green areas, and have suffered issues on the these countries (Shiea, 1998).On the other hand due to population growth and urban sprawl in the world, It is expected that about 60 percent of the world's population live in urban areas by 2030, which 90 percent of this are in developing countries (Kristine & Margrete, 2016). The growth of cities is inevitable in the next few years. According to the Europe Environment Agency, urban expansion is a threat to the immediate rural environment, urban green space and green belt around towns (Reid et al., 2016).

Former researches

Due to its importance, many studies have been done in this regard; (Park et al., 2011) in an article examine the role of centralization, population growth and uneven distribution of urban, on land use change in Norway. They found that most farmland in recent years have become construction zones. (Ebrahimzadeh & Rafiei, 2008) studied the role of uneven urban distribution in class displacement in the United States. They pointed out that, contrary to popular myth, the caste system in in the United States is stronger than in other Europe rich countries. Also uneven distribution of the city for any reason can has a positive influence either directly or indirectly in the formation and stability of caste system. (Ahadnejhad et al., 2011) using GIS and remote sensing assessed the appropriateness of urban development and regional rankings based on environmental conditions, geology, and geotectonics of the coast of Egypt. (Pourahmad et al., 2014) in a paper began predict and compare urban growth using GIS and remote sensing. To this end, they were used logistic regression, neural networks and analytic hierarchy process. (Fang et al., 2005) in an article titled "optimal site aspects of urban development by taking advantage of GIS" with regard to natural and human factors such as slope, land capability, land flood-prone, fault, industries, etc., and using GIS functions were identified appropriate directions for the city of Marvdasht. Seifeddini et.al. in 2011 explained the distribution and density of urban form in Amol focused on sustainable urban form approach and has concluded that despite the fact that Amol during the past 40 years has been sporadic form but in recent decades, the distribution rate was reduced and the process of centralizing is taken. (Pourahmad et al., 2011) examined Ardabil city expansion using multi-temporal imagery and geographic information systems. They also used the CA-MARCOV model to predict the changes until 2021. (Mir Katouli et al., 2014) in an article assessed physical development in Urmia city in order to preserve vegetation and agricultural land. For this purpose, land use changes in Urmia between 1986 to 2012 was calculated using satellite imagery.

Problems that had been created by the growth of large cities, was felt to develop and apply the rules and regulations for monitoring, controlling and directing urban growth all over the world. Garden City Movement, which was founded in 1898 in England, to be considered the underlying spatial planning with an emphasis on natural and rural areas with an weight on preservation of green space (Peng et al., 2010). One of the ways that can reduce the problems above, and could play a role in growth and urban development in developed countries, is applying the analysis of the process of urban development and use of management strategies tailored to fit the urban environment (Pham et al., 2011).

Iran, like many other developing countries, has been witnessed such a trend. Changes in the socio-economic and political system of Iran, especially since 1340 onwards and expansion of rapid urbanization and consequently increasing urban population due to migration trends from rural to urban is main cause and origin of changes in land use and destruction of vegetation in many cities and villages in country (El-Kawy et al., 2011). This is the least affected in two ways: 1) Expansion of the existing city spaces by immigrants 2) Swelling population of rural areas surrounding large cities due to extensive migrants and their conversion to urban areas and changes in rural- special land use system to urban land use system, non-standard and without a pre-conceived plan (Bhatta et al., 2010). Thus, the issue of occupation of space around towns and urban growth towards surrounding lands is important in Iran. Farmers land and garden preservation law (Approved 21/Jun/1994) governing the protection of agricultural land and urban green areas and prevent their use changes outside the city limits, ranging from territory and or outside territory. On this basis, and considering the above-mentioned problems, urban management have to think about urban development space to provide public interest and the interests of present and future generations living in and around cities (Gandaseca et al., 2009). In this regard, the necessary tools to control urban space must be provided. Using traditional methods and land surveyors, due to high costs and time consuming nature, is not suitable and effective so use of new techniques and tools are needed in this case (Zaeri Amirani & Sofianian, 2012). Recent advances in the field of remote sensing, GIS, geospatial techniques and advances in fields such as landscape ecology in quantity, monitoring, modeling and forecasting of urban development, had a big impact on the management of city expansion on the one hand and has caused environmental conservation on the other hand (Václavík & Rogan, 2009). So remote sensing data can be used to understand how changes in urban patterns goes on, modeling urban development and change processes and maping of the city's physical development, and associated with it analyzing land cover map (McConnel et al., 2004). And its combination with GIS and techniques such as fuzzy collections provides good tool for wise-space development monitoring that in addition of identify the current trend of development, to estimate the expansion of the city in the future and thought about necessary measures.

By the same token in this paper, the physical expansion of the Shiraz city and its impact on vegetation around the city using satellite images examined, and by realize the intensity of land use changes, significant step towards optimum management of the city are taken. The aim of this study is considered include:

I) Evaluation of the physical growth of the Shiraz city.
II) Evaluation of vegetation index in the study area.

III) The impact of physical development on the fringes of the city and its role in the destruction of vegetation.

Research Methodology

The main purpose of this study was to evaluate the physical growth of the city during the years 2009 to 2016, forecast To 2021 as well as estimated the amount and intensity of the destruction of vegetation in the study area. To achieve this, the data of remote sensing (RS) from geographic information system (GIS) is used. The main source of remote sensing data, is Landsat satellite images (in 2009, 2014 and 2016), which was used after radiometric and geometric corrections applied. For the purposes of this study, the land-use plan in the period under study, was prepared by FUZZY ARTMAP model and to evaluate the accuracy of the classification Google Earth images with quality as-a-half meters was used. Then the land use changes during the study period were calculated using the LCM1 model And by use changes in this period, the process of change to the year 2021 was determined using the model CA-MARCOV. The next step the density of vegetation were determined by calculate normalized difference vegetation index (NDVI).

According to the figure that shows the structure of the proposed model Physical growth of the Shiraz city from 2009 to 2021, as well as the growth and destruction of vegetation in the study area examined.

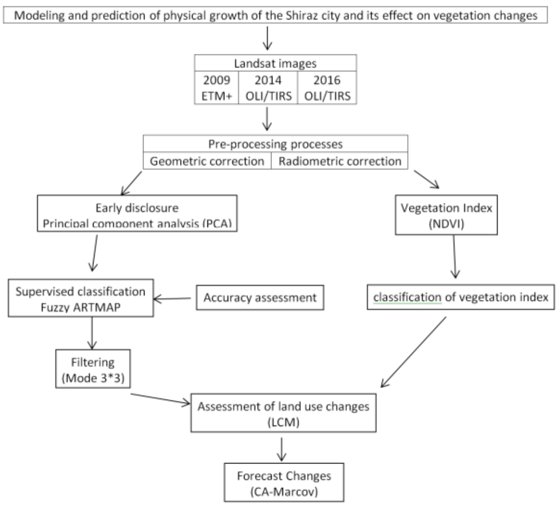

Figure 1. The conceptual model of research.

Research theory

FUZZY ARTMAP Method

Fuzzy ARTMAP and its associated neural network architecture were presented by carpenter and grossberg. This model can be implemented in two distinct phases: training phase and performance phase. In the training phase set of

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[1] Land Change Modeler

inputs and outputs ((I1;label(I1));:::;(Ir;label(Ir));:::;(IPT;label(IPT))) repeated regularly to provide the final map. Closest level to the input pattern of Ir is determined by finding the pattern with a maximum for function:

$$T_j(I^r, w_j, \alpha) = \frac{|I^r \Lambda w_j|}{\alpha + |w_j|}$$

If the function is called ratio caution, is determined as follows:

$$\rho(I^r, w_j) = \frac{|I^r \Lambda w_j|}{|I^r|}$$

That will change as follows:

$$\rho(I^r, w_j) \geq \rho$$

If the label input pattern Ir have intensified such as category labels, so wj category template is provided as follows:

$$w_j = w_j \Lambda I^r$$

If the category j elected as intensity and win, but wj category labels is different from the input pattern label Ir, therefore, this category retrieved and caution parameter ρ transferred to a higher level:

$$\frac{|I^r \Lambda w_j|}{|I^r|} + \epsilon$$

In the above formula and ρ, α and ε values are fuzzy network parameters, α usually takes low positive quantities, ρ chooses quantities between 1 and 0, ε is a very low positive factor.

In conventional supervised classification of remote sensing, Sample points and ranking results based on the method, are pixels of a class or a mix class and category cannot be considered as training points and the membership pixels not clear.

In fact, in the classical methods of classification, the boundary of education districts varies so sudden and not gradual. These obvious limitations, reduced levels of value and data mining may cross poorly and may destroy valuable information. Theory of fuzzy sets is used to eliminate ambiguity in the data and is a new concept upon which, partial membership allows information on complex situations such as mixed coatings or circumstances mediocrity, shown and used better. Although remote sensing image analysis using fuzzy sets is difficult but given that the boundary between two different categories often is not easy to determine in remote sensing data, the of the theory of fuzzy sets can be used as well. In this theory out date can has a value between 0 and 1. While in the usual membership of set theory, ranking member of only one or zero is considered. Unlike the conventional method of ranking that each of the Sample points, contain substances that are pure in their own and there is no gradual changes in them, in this way, the training points does not have to be completely uniform (Azizi Ghalati et al., 2014). FUZZY ARTMAP is a method of classification of remote sensing based on neural network analysis that rests to use of adaptive resonance theory (Norouzi et al., 2008).

LCM method

LCM or Land Change Modeler (available in IDRISI software and as extension on the ArcGIS) provides tools to assess and design land cover change and analysis land use or land cover (Soltani, 1992). This model is able to generate scenarios of land change with integrate biological, physical and social – economic agents that affect land use (Asghari Zamani et al., 2016). After selecting the sub-models and according to selected independent variables, each land use change potential is modeling using logistic regression. This means that every pixel of the image has how much potential to change from one use to another (Talkhabi et al., 2016).

Markov model

Markov chain, is a sequence of random variables that all of them have the same sample space, but they can vary at the distribution possibilities and also a random variable in a Markov chain is only dependent into the variable before itself. Markov chain model during a discrete period of time is formed by use distribution that was Mt at the beginning and Mt+1 at the end, as well as a use changes transfer matrix MLC, that occurred during this period. Assuming that the sample was representative of the area, these changes intended to fit as possible use changes in the whole sample area and make the transition matrix. The three matrix, forming a Markov chain based on the following equation (Alavi Panah, 2003):

$$M_{LC} * M_t = M_{t+1}$$

NDVI Index

In this method, algebraic operations between bands can be used to extract specific information. One of the most important operations carried out in this way, is using different Indexes to extract plant coatings from the image. One of the most famous indexes is the normalized difference vegetation index (NDVI), which can undergoes following operation to reveal vegetation to other complications (Seif-Al-Dinni, 2011).

$$\text{NDVI}=\frac{\text{NIR}-\text{R}}{\text{NIR}+\text{R}}$$

The images used to create the normalized difference vegetation index (NDVI) are related to TM sensor data. That in this case data relating to infrared and red bands with a spatial resolution of 30m was used. Pictures belong to year 2011 in date. In TM images NIR or near-infrared is related to band four of this sensor and R band is related to red band that is second in this sensor. And knowing that the numbers obtained from the index is ranged between -1 to +1, in this case after achieving index, by re-classifying image, vegetation from non-vegetation cover separated and so the final vegetation map for the area was created. Given that the TM sensor images compared to other sensors of the Landsat has good spatial and spectral resolutions so results can be used properly in detecting vegetation, and even for spaces and areas that are at least 900 square meters this type of images can be used in to accurately identify them.

Research Implementation

Introduction and data preparation

The main source of remote sensing data, was Landsat satellite images (in 2009, 2014 and 2016 years) That after applying radiometric and geometric corrections were used, For visual clarity and prepare a false colored image, at TM and ETM+ images 7-4-1 band recombination and for OLI sensor of Landsat8 8-5-2 band recombination were used (fig.2).

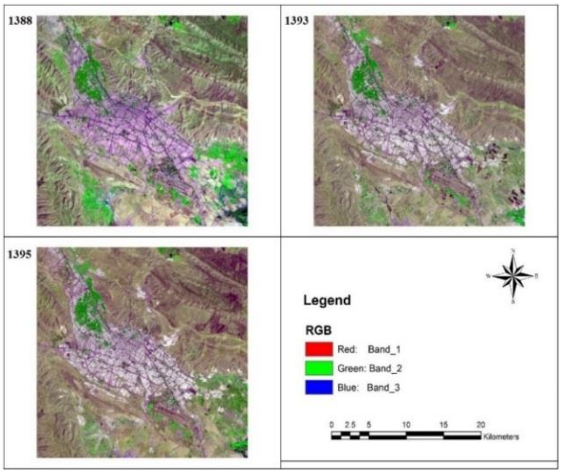

Figure 2: false colored image of the Shiraz city in the years of study.

Table 1: Characteristics of satellite images used

Satellite	Sensor	Pixel size	No. of bands	Date
LANDSAT 4-5	TM	30	7	2009
LANDSAT 7	ETM+	30	8	2014
LANDSAT 8	OLI/TIRS	30	11	2016

Prior to classification of images, to try to reveal and detection bands data in the study, analysis of the main components (PCA index) was used in the IDRISI software. Principal component analysis or PCA transform is one of information detection processes in which existence correlations between different bands removed and new set of imaging components placed. This analysis collecting and aggregating of presence phenomena information in different bands in fewer band number or components will have significant role in increasing the accuracy and ease of working on the next steps.

4-2- Assessment and accreditation results

Most cities of Iran in the early stages of formation, were located in the agricultural lands with the aim of good soils for agriculture and over time with the development of the countryside and development into the cities and towns, high quality land buried below body of cities and agricultural activities inevitably retreated to the poor lands; As a result, many problems arise in these areas by expanding metropolis. Shiraz was not an exception, so the physical growth of the city over a period of 7 years from 2009 to 2016 was analyzed in satellite images.

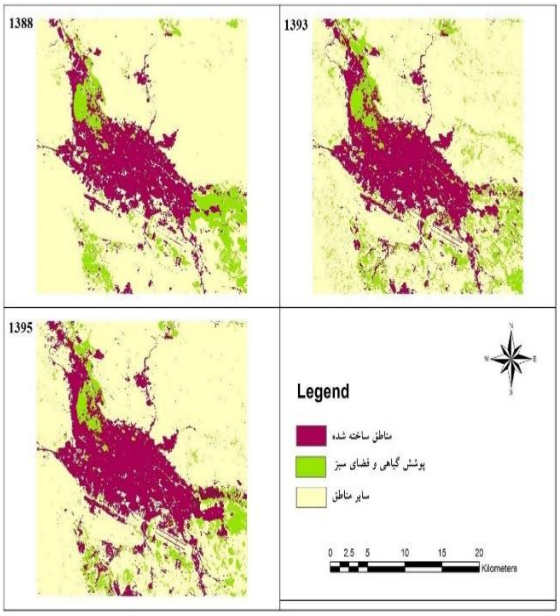

Figure 3: The trend of land between the years 2009 to 2016.

Table 2: Changes in land use of the Shiraz city (in hectares) from 2009 to 2016

Year	Built Area	Growth (in hectares)	Growth (in %)	period
2009	13160.07	-	-	-
2014	15765.66	2605.59	19.799	5
2016	17350.29	1584.63	10.05	2

Calculate trends in physical growth that took place by FUZZY ARTMAP method stating that the area of the city in 2009 from 13160.07 hectares over a period of 5 years has been increased to 15765.66 hectares. This increase is equivalent to 19.8%. In the second period (between the years 2014 to 2016 the physical growth of the city continued so that the area of the city has reached to 17350.29 hectares in 2016. Thus, during the two-year period we see the physical growth of 10.5 percent. If we accordance calculations to trends of land uses in past, by assuming this rate constant we can forecast process of physical growth of city. Accordingly, using Markov model the probability of changes until 2021 calculated then with the help of CA-Markov function in the IDRISI software, process changes anticipated (fig.3).

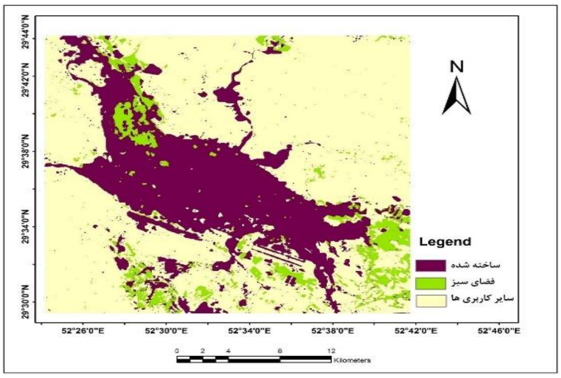

Figure 4: Predict the physical development of the Shiraz city until 2021

Table 3: The results of the predicted changes to the year 2021

Year	Built Area	Growth (in hectares)	Growth (in %)	period
2021	20683/58	3333/29	19/21	5

The forecast results of the changes by the year 1400 (Table 3) showed that if all the conditions retains constant, built area with 19.21 percent growth will rich to area of 20683.58 hectares.

Take a look at the map shows that trend of physical growth of the Shiraz city is in the North West-South East direction, on the main roads of the city, which this is favorable with the most desirable agricultural lands and lands with the highest density of vegetation. In fact, the findings of analysis of images are well-lit that urban creep in this area has tangible effect on the vegetation dynamics. So it should be expected that in a future not far away, Shiraz city will face severe problems with environmental and agricultural.

Therefore, to understand the changes in vegetation and their relationship with the built land, NDVI index were calculated for the region. One of the most practical vegetation indexes is NDVI vegetation cover index that showed uo good performance in many studies reported by various researchers. This index value is fluctuating between +1 and -1 and proven that whatever the number is close to +1 the amount of vegetation is increased. Figure 4 shows a map of the classified vegetation. By analyzing the NDVI index amount in Software and according to Figure 5 the red regions illustrations larger positive values than other parts, which represents the vegetation is denser. Then percentage of area allocated to each class for each year is calculated and the results were compared.

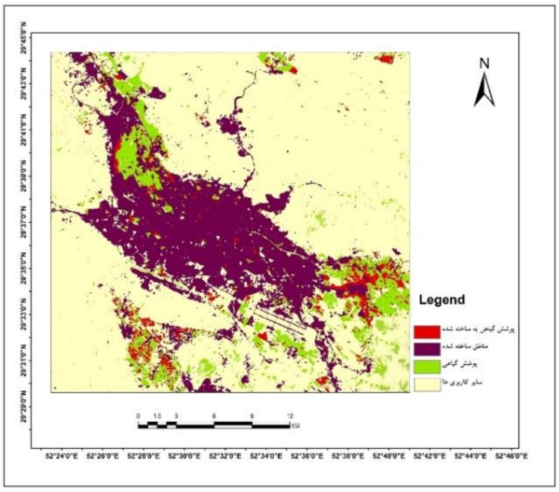

Figure 5: Change from vegetation to build areas from 2009 to 2016

Table 4: Change from vegetation to build areas from 2009 to 2016

period	Sum of good and excellent coverage at the beginning of the period	The destruction in hectares at the end of period	The destruction in % at the end of period
2009-2014	6128.37	1650.26	27%
2014-2016	4777.65	241.42	5%

To assess the qualitative changes in vegetation during the 7-year study NDVI map output in five vegetation class (very good, good, fair, poor or no coverage) were classified. Five categories based on the mean and standard deviation was divided. First class: areas without vegetation, Second class: values smaller than the mean minus the standard deviation, Third class: The mean minus the standard deviation to the mean, Fourth class: The mean to the mean plus standard deviation, Fifth class: larger quantities than the mean plus standard deviation.

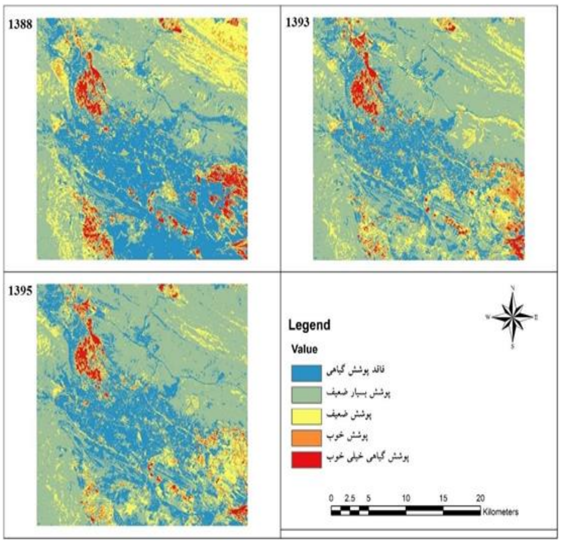

Figure 6: NDVI index between the years 2009 to 2016

Table 5: Trends of NDVI index between the years 2009 to 2016

Year	no coverage	Poor coverage	fair coverage	good coverage	very good coverage
2009	25329.87	32787.9	13060.98	3345.03	2783.34
2014	16060.68	44853.57	11971.08	3020.94	1756.71
2016	20034.81	44551.35	8082.63	2665.08	1617.39

Vegetation density in the city has a significant decreasing trend so that the sum of good vegetation cover and very well vegetation (class one and class two) resulting from NDVI index was 6128.37 hectares in 2009, whereas in 2016 this amount has been reduced to 4282.47 hectares, which means reduced vegetation cover in this period is 43.10%. Finally, using LCM models in IDRISI software all areas where vegetation and during the study period has been converted to urban and residential areas were calculated (Figure 4).

The assessment vegetation areas made by the LCM showed that since 2009 to 2016, more than 1891 hectares of vegetation and gardens has become built lands.

Evaluating the accuracy

One of the issues deserve attention after the processing of land use classification from satellite images to assess the accuracy of classification. To this at first with use of high-resolution data from Google earth, mapping of study area are discussed. Finally, for accuracy assessment, the results transferred to IDRISI software and the accuracy of land-uses obtained for the analyzes was equal to 97.3%.

Conclusion

Land cover and its changes are important variables that have significant effects on the environment and its processes. Earth's surface is significantly affected due population growth and the development of human activities in recent decades. Owing to the growing population and tend to live in urban most variations in land cover occur in urban areas. The use of remote sensing technology and new technology due to the advantage of high spectral and temporal images, is known as an efficient tool to record and detect changes. Irregular physical development, urban sprawl, along with changes in vegetation and replacing it with manmade environment are among the issues that the Shiraz city faces since the late 60's. Based on this physical growth of the Shiraz city in the period 2009, 2014 and 2016 were examined using satellite imagery. FUZZY ARTMAP method to calculate trends in physical growth took place, indicate that the area of the city in 2009 from 13160.07 hectares over a period of 5 years has been increased to 15765.66 hectares. This increase is equivalent to 19.8%. In the second period (between the years 2014 to 2016) the physical growth of the city continued so that the area of the city has reached to 17350.29 hectares in 2016. Based on this, assuming the constancy of the past trend, Built lands with 19.21 percent growth will reach to area of 20683.58 hectare. On the other hand NDVI index for the region showed that the density of vegetation in the city also has a perceptible downward trend. Vegetation density in the city has a significant decreasing trend so that the sum of good vegetation cover and very good vegetation cover calculated by NDVI index in 2009 was equal to 6128.37 hectares, While in 2016 this amount has been reduced to 4282.47 hectares, which means reduced vegetation cover in this period is 43.10%. What is impressive is significant role of physical growth of the city in the destruction of green space area so as assessment of change vegetation to the made areas by the LCM showed that since 2009 to 2016 more than 1891 hectares of vegetation and gardens has become built lands.

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