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Quantifying the impacts of roads on Isfahan landscape pattern using gradient analysis and landscape metrics methods

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Abstract

Quantifying urban landscape`s pattern is fundamental for monitoring and assessing socio-economical and ecological urban applications. Road expansion is considered as one of the most significant factors in changing urban landscape`s pattern. The aim of this study is to quantify the impacts of roads on Isfahan`s landscape pattern. To achieve this aim, Isfahan land use map was prepared in six classes of urban, green spaces, agriculture, arid land, road and water. In the next step, a 15×3 km2 east-west transect crossing Isfahan`s city center was designed and then they were quantified using gradient analysis and patch density , index of the largest patch and the percentage of coverage metrics in class and landscape level . The class of road was integrated with the class of urban lands in order to show the effects of roads, then comparing these two transects, the effects of roads were assessed. The results showed that roads severely increased the density of patches in the city landscape. Metric values of the largest patch increase after integrating two applications of road and urban lands .Also, there was a significant correlation between the percentage of road coverage and patch density values. Therefore, the most important effect of road networks on city landscape is increased fragmentation of the city landscape.

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Introduction

Assessment of urban landscape is one of the important research issues in geographic research, design and landscape architecture and urban ecology (Zhang *et al.*, 2006). Structure of city and its spatial pattern affects physical, ecological, economic and social processes of cities (Luck and Wu, 2002). To evaluate the urban landscape one can use quantitative methods which are Based on land indices and metrics and these indices and metrics are sensitive to land cover data including type and percent of applications, number, size and shape of the patches and the density and complexity of margins, etc (Luck and Wu, 2002). In recent years, various metrics and indicators have been developed to quantify landscape patterns. Density of patch, index of the patch shape, fractal index, Shannon diversity index, the largest patch size, etc are some of these factors (Turner, 1989). Roads as one of the urban applications have a large impact on cities (Forman and Alexander, 1998). From the viewpoint of landscape ecology, roads will lead to the fragmentation of cities (Forman and Alexander, 1998). Road networks have disrupted the pattern of ecological trends and have change the spatial pattern of landscape (Forman and Alexander, 1998). In addition to ecological impacts, roads lead to numerous social and economic impacts. A study in Wuhan City, China, showed that the probability of land use conversion (from other uses to urban uses) is closer to the roads (Yang and Lo2003; Cheng and Masser, 2003). On the other hand expanding the road network is related to social and economic factors, urban planning and preparation (Kalnay and Cai, 2003; Turner *et al*, 1995). Therefore roads should be considered in modeling and prediction of uncontrolled growth of the city (Cheng and Masser, 2003). The aim of this study was to evaluate the effects of roads on the structural model of Isfahan city using a combination of gradient analysis and Metrics of patch density (PD), the index of the largest patch size (LPI) and the percentage of coverage (PLAND) in two levels of class and landscape.

Materials and methods

A: studied area

Isfahan city is located at the center of Isfahan province and the east of the Zagros mountain range, its latitude is 32" 28' 30◦ and its longitude are 51" 39' 40◦. It covers an area of about 34,000 acres, and also is the third largest city after Tehran and Mashhad. The city is one of the largest dry cities in the world with very little rainfall and its altitude from sea level is about 1580 meters (Shafaqi 1381 and Isfahan City Atlas). Fig. 1 shows the Position of Isfahan in Iran.

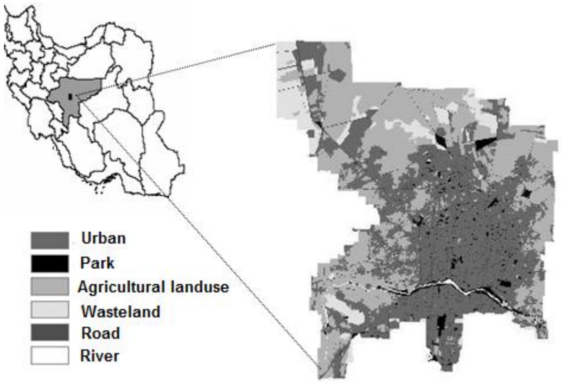

Fig. 1. Position of Isfahan in Iran.

B: Data preparation

In this study Isfahan maps which were provided by city hall`s computer service center using????? photographs were used to make Isfahan`s use map. First all available classes in 1/2000 maps were extracted and then according to table 1, they were re recategorized in 6 classes of urban, green land, agricultural lands, arid lands, roads and rivers. Then the produced map was updated using the IRS PAN images.

Table 1. Classification of urban land use map of Isfahan

Description	Acronyms	Classification types of patch
Residential areas Facilities Industries Areas under construction Service centers (hospitals, etc.) Cultural and historical sites	U	Constructed land
paces reeng rbanu types of	G	Green space
Agricultural lands Fallow land Gardens and vineyards	A	Agricultural areas
arid land Pastures Saline Soils lands without construction	B	area arid
roads	R	roads
Zayandeh_Rud River	W	river

C: Methods

Transect design for gradient analysis

To investigate the effect of roads on structure and landscape pattern, a transect with the length of 15 km and the width of 3 km was designed in east – west axis passing through the center of Isfahan city where urban and road use was studied in two es along with other uses.(transect 1 or T1).

To study the effect of roads on landscape, road and manmade use were integrated in transect 1(transect 2 or T2) and then patch density metrics (PD), largest patch index (LPD) and percentage of coverage (PLAND) were quantified.

Analysis of moving window in transects

Moving window analysis was performed to detect gradients along transect. For performing moving window analysis, east - west Transects was divided into 7 blocks with an overlap of 2 km according to table 2. In this transect, city center was located at block4.

Table 2. The distance from the northern margin of city comparing to each blocks of sampling transect

7	6	5	4	3	2	1	Block number
12-15	10-13	8-11	6-9	4-7	2-5	0-3	Distance from eastern edge(km)

Then maps converted to raster format with a pixel size of 5/7 m, were introduced into FRAGSTATS3.3 environment. According to Table 3 the most appropriate metric were chosen to study and investigate the effect of road on the city and it was estimated separately for each transect of PD and LPI in two levels of class and landscape. PLAND metric was only calculated in class level for two transects.

Results

These metrics were calculated and quantified along transects in two levels of class and landscape for Isfahan city as follow:

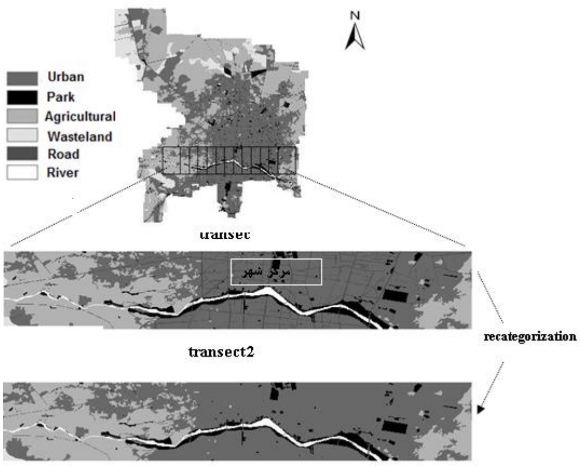

Fig. 2. the Location of east - west transects in Isfahan compared to transects 1 and 2

Table 3. Metrics used in this study to quantify the effects of roads on landscape structure

(McGarigal and Marks 1995 l)

fprmula	metric
$$PLAND = P_i = \frac{\sum_{j=1}^{a}}{A}(100)$$ P_i =Proportion of the landscape occupied by patch type i a_{ij} =the Area of patch(sq m) ij A=The total area of landscape	PLAND*the **percentage of land use**
$$PD = \frac{n_i}{A}(10000)(100)$$ n_i =*The number of patches of type(class) i* A=The total area of landscape	PD **(patch density)** In class level
$$PD = \frac{N}{A}(10000)(100)$$ N=Total number of patch in the landscape A=The total area of landscape	In the level of landscape
$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$$ a_{ij} =*the Area of patch(sq m) ij*	*LPI* ***largest patch index*** *In class level*
A=The total area of landscape $$LPI = \frac{\max(a_{ij})}{A}(100)$$ a_{ij} =*the Area of patch(sq m) ij* A=The total area of landscape	In the level of landscape

*these metrics only were calculated at class level

Percentage of coverage of landscape types in T1 and T2

Fig. (3) show that in both transects percentage of coverage is the same for all users except for urban use. The Percentage of urban patches in transect 1 is 2/54 and it reaches to 7/60 in transect 2 by integrating urban use with road. Road use accounts for 5/6 of the entire transect coverage. Urban and agricultural uses were two main uses along transect. Green space patches occupied 8 % of the whole transect. The percentage of this use is higher around the river than in other parts of the city. With a very low percentage (close to zero), arid lands are among rare coverings along transect that it could be due to allocating lands to other uses because of the high value of them. River use covers two percentage of the transect area. Although the area of this use is small but it has a great effect on the city landscape. Economically, socially, ecologically this impact is very important and also for the current composition of landscape.

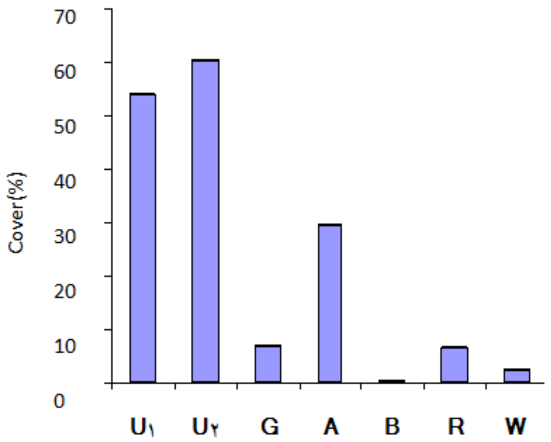

Fig. 1. Percentage of coverage of each land use in T1 and T2

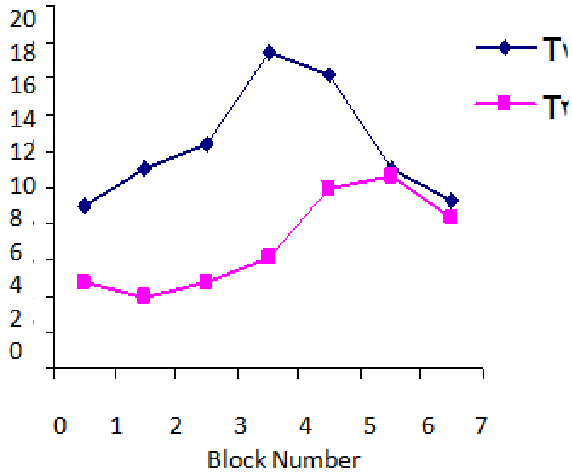

Fig. 2a. PD metric valuesacross the landscape at T1 and T2

Gradient analysis of landscape

Patches density and the largest patch index are metrics considered for gradient analysis of landscape. These metrics were calculated and quantified for each of the blocks in both transects. PD index in T1 in block 4(city center) accounted for the highest value. In this transect, road use has caused urban use to be fragmented and Because of this, the highest value of patch density metric was related to city center. The amount of these metrics decreases by getting away from city center toward the margins. As Fig. 1 – A shows, a symmetric pattern is seen as we get away from city center toward East and West. In T2 due to integration of road use with urban use, the PD decreased along transects. This reduction was more noticeable in city center than the other parts.

Largest patch size metric had higher values in T2 in contrary to PD metric (1 - b). At T1 the highest value of this metric was related to blocks 1 and 7 where urban development was less and agricultural lands were more and land fragmentation was less and consequently the patches were larger. In T2, due to the integration of road with urban patches, the value of this metric was higher in middle blocks.

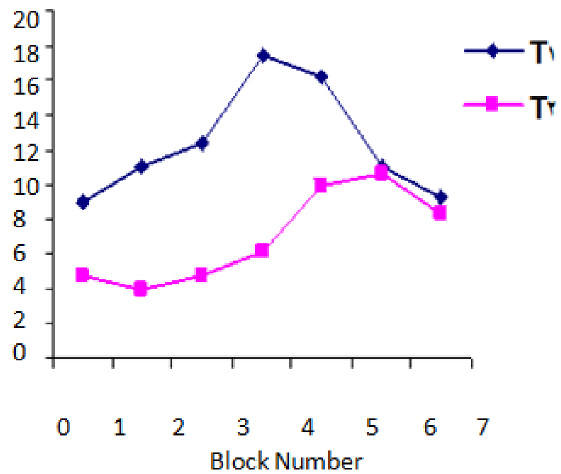

Fig. 2b. LPI metric values across the landscape in T1 and T2

Gradient analysis of class

PLAND and LPI and PD metrics for agricultural, arid land and river classes were similar on both transect (Fig. 2 - a).but the value of this metric was different in two transect for urban use. The percentage of coverage for the lands of urban class had the highest value in blocks 3 and 4. Green space percentage coverage had lower values in margins of transect than its center. By getting away from eastern margin toward city center, the coverage percentage of agricultural land decreased and increased again towards the West. The highest and lowest values of this metric in agricultural class were related to blocks

7 and 4 respectively. In Block 1, e.t eastern margin, about 25% of the block was related to agricultural lands. The coverage percentage of different uses was different along transect with the change of distance from eastern margin toward city center. In general, the dominance of different types of land use showed a symmetrical pattern along the east-west transects and this change was as agriculture-urban-agriculture. This means that a greater percentage of transects margins are occupied agricultural lands but the percentage of agricultural lands was bigger in transect`s western margin than its eastern margin. In the central part of the transect, the main use is related to urban lands and Isfahan`s city center is located at middle blocks of transect. The coverage percentage of arid lands is very low and close to zero in this transect. River patch has allocated a small percentage to itself but it has a great role in the formation of Isfahan`s current pattern. Road use had a similar trend to urban class along transect. Its maximum was at the center and its minimum was in margins. PD metric for each class was calculated over the entire transect (Fig. 2 - (b). in T1, the highest urban class was seen in the city center where the road density is higher. But in T2, the values of this metrics significantly decreased in all transect especially in city center. This decrease was due to the integration of road with urban use and consequently lowering of patches density. The highest value of this metric was for patches of green space in Block 4. The highest value of this metric in agricultural classes was observed in Block 6. LIP metric has significantly decreased due to the existence of the roads and consequently decreasing of urban patches in central blocks. The maximum value of this metric was seen in transect 1 in block 1 for urban class. However, due to lack of road, central blocks had the maximum value of LIP in transect 2. Maximum values for agricultural class were seen in eastern-western margins and they strongly decreased in central blocks (Fig. 2 C).

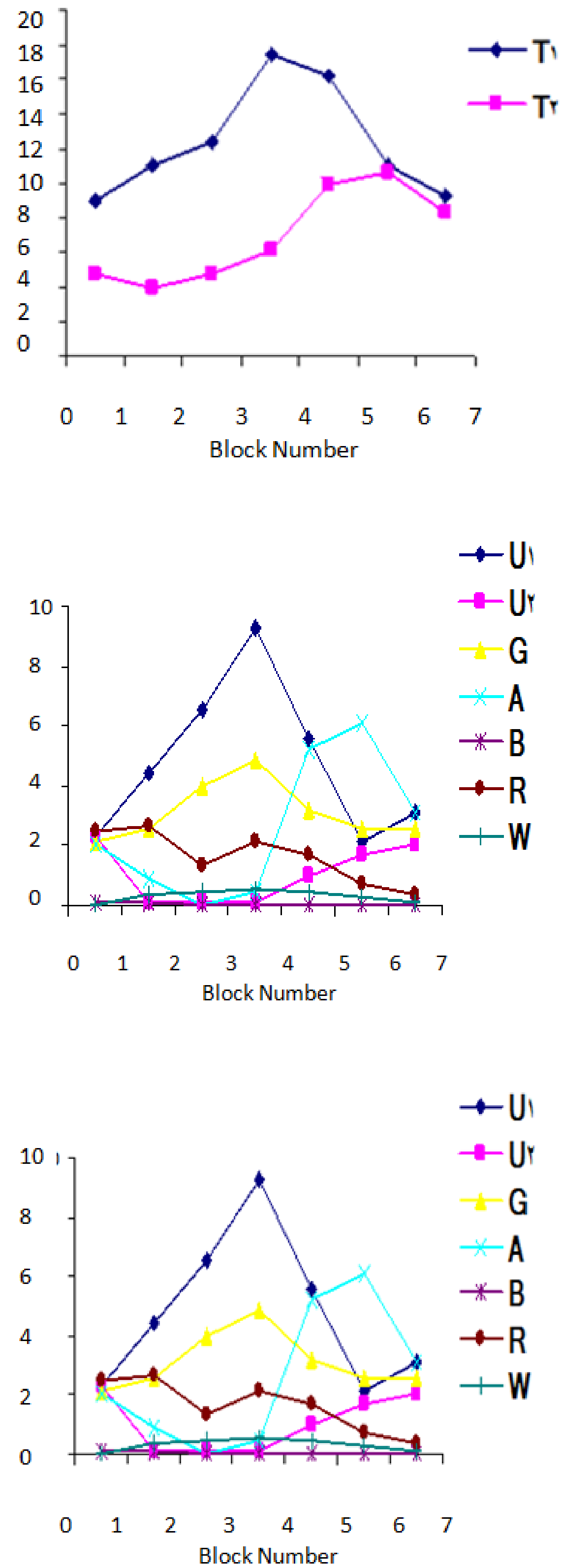

Fig. 3.

A - percentage of land coverage along transects

B - PD metric values along transects at class level

A - LPI metric values along transects at class level

Discussion and conclusion

This study showed that comparing landscape pattern in two transects 1 and 2, makes it possible to investigate the spatial effects of roads on the structure of landscape. Patch density was distinctly different in patch 1 and 2 and the difference in this metric shows the difference in landscape. Applying two transects made it possible to investigate the effects of roads of landscape (Zhu *et al.*, 2006). Transects were designed to bypass the city center.this method causes the existence of samples from city center, city margins and interpass regions in data provided for analysis. (Zhang *et al*, 2006). However, the possibility of gradient analysis is also provided. In this study, the effects of road on Isfahan`s landscape were studied in two levels of class and city. Results showed that metric values have considerable difference in two levels of class and landscape in transects. This plot making along the urban-rural gradient has clearly shown the changes of landscape pattern in response to urban growth (Weng, 2007). Choosing the right metrics is another important factor in landscape studies. The density of the patch was the appropriate metric for assessing the effects of roads on landscape in the study of Ming Zhou *et al* (2006). LPI metric was also studied in Isfahan research. LPI metric is widely used as an indicator of the degree of landscape fragmentation (Bowersox and Brown, 2001). Integration of road use wit urban use in transect 2, increased the size of the patches and thus increased the LPI metric. Along transects a symmetric pattern was observed in the percentage of road uses, thus in two margins i.e. Eastern and western parts, the road use includes a smaller percentage and gradually increases toward central blocks i.e. city center. This pattern can also be observed in urban and agricultural use. In both sides of transect, the percentage of agriculture is more and the percentage of urban use is less and moving toward center, the percentage of agriculture decreases (and eventually is eliminated) and the percentage of urban use increases. Along transect, there is a same trend between the percentage of roads and the value of patch density which follows a normal distribution (Fig. 4). In city center where the coverage percentage of roads is the highest, metric of patch density was at its highest. Linear regression analysis showed that two variables of road percentage of coverage and patch density are significantly correlated (r^2= 0.62 , p=0.033). Zhou *et al* (2006) in the city of Shanghai had a correlation of 0.84 between these two factors (Zhu *et al*.2006).

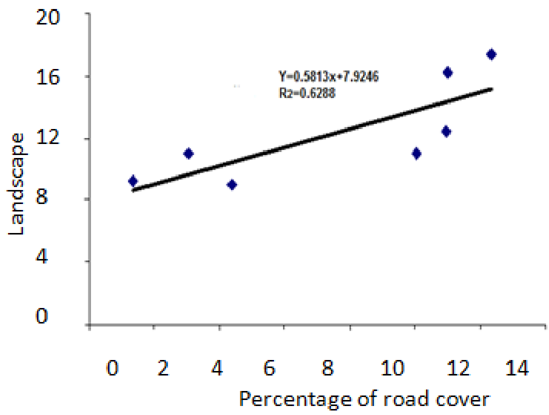

Fig. 4. the scatter plot of the correlation of patch density and the percentage coverage of road in transect 1

The percentage coverage of road in the studied transect in Shanghai city was about 2/7 and in the east-west transect of Isfahan was 5/6 % of the whole transect.

The results showed that there is a regular trend of agricultural coverage to manmade from transect margins toward its center. This result confirmed Forman and Gordon (1983) assumption stating the increase of patch density along gradients moving from normal to manmade and artificial (eg, normal gradient-managed-cultivated-suburb-city) .(Forman and Gordon, 1983; Luck and Wu, 2002).

Landscape ecology has a fresh look to the importance of spatial pattern on ecosystem processes. These concepts are applicable in land use to reduce the negative impacts of urban development (Botequilha leitato and ahern 2002). The increase of roads led into the increase in city fragmentation and consequently the increase of patch density in landscape and decrease in largest patch metric in landscape class. The study of landscape changes due to road development will help to investigate cities from ecological perspectives.

notes

1- Fragmentation
2-Patch
3-Gradient Analysis
4-landscape metrics
5- Moving Window
6- Percentage of landscape
7-Patch Density
8- Largest Patch Index

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