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Urban Environmental Quality and Landscape Structure in Arid Mountain Environment

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ABSTRACT: Urban landscape structural analysis; focused on the remnant patch mosaic network as the component with closest interdependency with air and water related processes was undertaken to find and propose environmental planning suggestions.Assessments demonstrate that remnant patch mosaic network structure of Tehran is still restorable. With appropriate corrective measures based on the natural lay out of river valley corridor network it could function as a refuge network to improve urban environmental quality through compensation of the insufficient natural matrix connectivity. In terms of cost effectiveness landscape structural restoration in the north of Tehran has priority due to the presence of river valleys in a heterogeneous mosaic of large grain green patches and the added value of down stream positive impacts. Extension of urban forestry in the south with an added value of increased sink capacity for assimilation of accumulated polluted waste water and air pollution may be the next priority regarding remnant open and green patch mosaic restoration. Restoration is harder to achieve in the central parts of Tehran with small grain homogeneous mosaic. The “Refuge network” based on natural layout of river valleys along with core open patches of hills may be the conceptual framework to integrate various corrective measures. The “Aggregate with outlier” model can provide the spatial design framework necessary for the implementation of such an integrated comprehensive remnant patch network restoration plan aimed at improving urban environmental quality.

Key words: Urban landscape, Patch mosaic, River valleys, Metrics, Arid environment

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INTRODUCTION

The present condition of air and water related issues in major cities of developing countries are greatly affected by landscape structural alterations at urban region level (Nilson and Randrup, 1997) which have ultimately contributed to environmental and human impoverishment (Forman and Godron, 1986; Turner, 1989) for an increasing portion of global population.

The Iranian Department Of Environment-DOE declared air and water related problems as the two most alarming environmental concerns threatening public health in the capital ten years ago (DOE, 2001). Longer stagnations of emission prevail despite this recognition and ineffective mitigation efforts. Highways have been constructed over or as strip corridors parallel to river valleys (converted into sewage canals) to accommodate access of more than 50% of the population greatly increasing the number of cars (the source for about 75% of air pollution) in Tehran (by 1:500 per day; Zavoshtiaq, 1999). The same holds for environmental issues related to water resources. Fresh water remains insufficient despite diverting water from other basins resulting in the constant pumping of toxic wastewater in the southern part of the city to protect urban infrastructure against the destructive rising water table. The prevalent environmental problems in Tehran are due to the general neglect of ecological aspects in regional land use and urban development planning.

Recent improved understanding of urban landscape structural alteration (Forman and Godron, 1986; Wiens, 1995; Nilson and Randrup, 1997; Gustafson, 1998; Botequilha & Ahrea, 2002; Burel, 2003; Kong and Nakagoshi, 2005) responds to the spatial dimension of urban environmental issues or landscape function on the basis of "function-structure" linkages or feedbacks (Turner, *et al.*, 2001; Botequilha and Ahrea, 2002). Yet this newly emerging process-oriented (as opposed to object-oriented) discourse in ecological studies (Tjallingii, 2000) attains practical value only when considered in relation to specific processes with their respective specific paths or corridor networks (Zonneveld, 1995). Consequently; we have focused on air and water related ecological processes to propose planning suggestions , by means of remnant patch mosaic network restorations (Forman, 1995a & b; Zonneveld, 1995; Tjallingii, 2000; Botequilha and Ahren, 2002).

MATERIALS & METHODS

Two main types of aridity have been distinguished (Tricart, 1991). One is due to global climatic regimes while the other; "non-regional" aridity; is caused by local geographic barriers. Humidity is blocked and partially captured by high peripheral mountains of Iranian Plateau in wintertime. Snow comprising more than 65% of annual precipitation melts by spring rains that provide another 15% of total annual precipitation. About 80 % of potentially available water flows down stream during a short period of early spring. Eroded materials transported and deposited at various altitudes, have gradually shaped distinct sequences of land forms (Yavari, 2003) with intensive vertical connectivity (Messereli, 1983 & Gerrard, 1999).Tehran, located at 1000 to 2000 meters from sea level over the southern slopes of the Central Alborz mountain that is situated in mid-altitude of the largest drainage less water basin (depression) ending to the salt lake desert of Iranian Plateau (Fig. 1).

The history of urban development in Iran remains marred with uncertainty. Settlements are described as isolated islands amid the rising tide of Turkic; as well as Mongol and Arab nomad dynasties (Cambridge History of Iran, 1968). The settlements seem to have been arranged as a line of oasis penetrating the arid central plateau around its foothills; and alluvial cones of mountain piedmont where water was available (Darvishzadeh, 1999).

The contemporary urban development pattern of Tehran dates back to only after the Second World War; when a significant rural exodus transformed the cultural landscapes of provincial centers and was particularly noticeable in the capital city; Tehran. Until the 1980s; urban growth patterns were directed by the main north to south transportation corridors. Due to continued migrations; the urban growth pattern around major vertical (north-south) axes was first replaced by

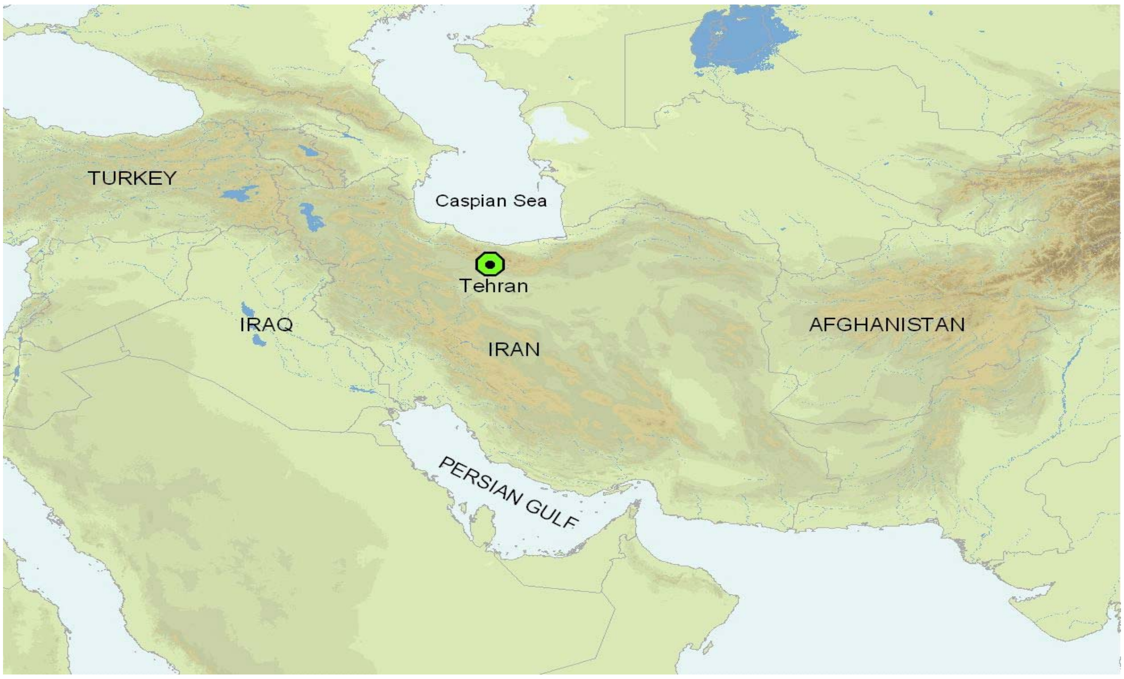

Fig. 1. Tehran in the context of high arid plateau of Iran

a temporary east to west axis of growth, but supplanted later by a sporadic, patchy growth pattern in the suburban zones.

Real estate speculations further reinforced this sporadic; patchy development and encouraged the inhabitants to leave the city center for less expensive residences in the suburbs. This particular mode of rapid and unattended growth of Tehran since the 1970s; generated a differential urban structure; rupturing the city center from its surrounding suburbs. The variegated consequences of this unattended urban growth include complex and gradual landscape transformations (Igegnoli, 2002); veering towards a complete loss of natural capital accompanied with incremental deterioration of public health conditions and an accelerated growth of urban sprawl (Cutway, 2005).

Recent developments in theoretical urban studies which emphasize on the relationship between land use pattern and ecological processes have important consequences for understanding spatial processes (Wiens,1995) involved in resource management and land use planning. Spatial solutions for addressing urban development planning have been provided through improved understandings of chorological interdependencies between heterogeneous environments (Forman, 1995). Now we realize that what we see today is produced by flows and processes of yesterday (Burel, 2003; Forman and Godron, 1986). The underlying premise of urban ecology is that the explicit composition and spatial form of an urban landscape mosaic consisting of interdependent ecosystems affects ecological processes in ways that would be different if the mosaic composition or arrangement were different (Wiens, 1995; Igegnoli 2002, Burel, 2003).

In order to enhance appreciation of spatial variations of remnant patch mosaic networks a regional landscape zoning and classification regarding natural and urban environmental characteristics was undertaken prior to the diagnosis. All finding were then integrated by the final analysis phase in order to evaluate alternative corrective measures with different effectiveness at different scales.

Part of spatial data on land use types and information concerning landscape structure were provided by 30 meters (with 7 bands) resolution Landsat images taken at 1998 and 2002. Land use maps of 1:12000 and 1:5000 scales and base topographic maps of 1:25000; officially released by the Central Iranian Bureau of Statistic (2000 to 2004) and the Geographical Institute of the Army (2004) were also employed. These spatial land use data and disaggregated statistics were used once completed and verified by random field inventories. For overlays and final integration statistics and field survey results were transferred, compiled and organized on geo-referenced maps and data bases as rectified covers in GIS.

Fig. 2. Tehran in the uplands of a closed water basin of Central Alborz ending to the salt lake of central desert

Metrics used in evaluation and diagnosis were computed and measured using large scale (1:2000 to 1:5000) land use maps of Tehran (2002 to 2004). Tehran has no consistently respected urban limits or borders due to its exceptional growth rate and its different decoupages of territory by different institutions or service providers. The present administrative borders of Tehran for example includes natural and rural landscapes and comprises more than what Tehran is for those living and working there. What we have selected for evaluation and analysis covers about 40 square kilometers (about two third of surface area called Tehran) comprising what has been consistently Tehran during the last two decades. The study area called "Tehran" in this paper excludes recent urban districts (5, 9, 18 and 21). If it was other wise decided results would have been greatly miss-leading; 40% of the city would be considered as open and green remnant patch cover type while for most of them construction permits have been already issued.

All spatially relevant issues are scale dependent in the sense that their explicit partial perception require specific scales of observation. There are no normative scales of analysis because landscapes are essentially unique living entities (Baschak & Brown, 1998); and it is not yet clear how the appropriate scale for understanding particular patterns and processes is to be determined. Different levels of analysis at different scales are required for a general understanding of relations between urban landscape structure and urban environmental function or for a specific comprehension of relations between remnant patch mosaic networks and air and water related environmental issues.

For example investigation of urban sprawl encounters changes in its definition; interpretation; and consequences at different scale and to detect and manage changes in the spatial dimensions or scale of both urban and non-urban environments must be monitored at several spatial scales to understand its causes and consequences (Cutway, 2005). A planning strategy conducive to sustainable urban development not only considers environmental capability or ecosystem carrying capacity (as Ian Mc Harg's approach to ecological landscape planning); but also spatial features of urban environment with chorological interactions between ecosystems and landscapes within it (Naveh and Lieberman, 1984; Zonneveld, 1995; Wiens, 1995; Forman, 1995 a and b; Iggegnoli, 2002).

RESULTS & DISCUSSION

Aggregated data with average values on interior landscape structure have no evident relation to specific locations and may consequently lead to incorrect interpretations regarding spatial aspects of cause and effect dynamics (Kong & Nakagoshi, 2005). Gradient analysis along with configuration metrics; have been used to integrate the effects of urbanization on the distribution of different ecosystem properties (Kong and Nakagoshi, 2000 referring to Sukopp, 1998; Kowarik, 1996; Douyat and Mc Donnell, 1991).

In order to enhance appreciation of spatial variations of remnant patch mosaic networks a regional landscape zoning and classification regarding natural and urban environmental characteristics was undertaken prior to the diagnosis. Classification of landscapes according to natural environmental resources and urban environmental features encounters the impacts of vertical connectivity and space time dimension of (ephemeral) resources as important variables shaping landscape associations in arid mountain environments. Boundaries of homogeneous landscapes; having relatively similar environmental condition in respect to climate; topography; landforms; soil and mosaic grain size were identified by overlaying maps illustrating spatial distribution of following parameters:

- Climate; as the first dominant factor creating heterogeneity particularly in arid and semiarid regions
- Topography; all environmental attributes affecting the interior structure of landscapes are correlated to local variations in altitude and slope.
- Landform; distinct from topography; it reflects an integrated entity of environmental or land attributes in action.
- Surface sediment (soil); as a separate variable distinguished from land cover type; it strongly alters; inter alia; micro-climates.
- Patch grain size that shapes the context of landscapes.

These parameters were used to assess and sort landscapes prior to evaluations regarding the remnant patch mosaic network.Large green remnant patches have been recognized as irreplaceable elements of a quality urban environment since a decade ago (Forman 1995; Forman and College, 1995). Their centrality to the provision of air and water quality; flow and other related ecological processes which may be otherwise unattainable is also well-known (Forman, 1995). In deference to the irreplaceable position of remnant patches in juxtaposition to urban growth (Kong and Nakagoshi, 2005; Nilson and Randrup, 1997); and the rehabilitation of degraded urban environment (Forman and Godron, 1986; Naveh, 2005); the "function-structure" relations matrix (Table 1) insisted on the remnant patch network mosaic as the structural component having the highest interdependency with air and water related ecological processes and urban environmental issues (Botequilha and Ahrea, 2002).

It was decided that for spatially explicit planning proposals diagnosis would be better if it took into account variations of spatial distribution of remnant patch mosaic network due to relative location of each landscape within the urban region along with the variations of impacts of landscape alterations due to urban growth patterns.

Defining the landscape patch mosaic composition and configuration by metrics has emerged during the last decade as a useful method for landscape structural evaluation and diagnosis (Turner, 1998; Botequilha and Ahrea, 2002; Kong and Nakagoshi, 2005). Conventionally; metrics are used to measure; describe or define the relative composition and spatial configuration of patch class types in different landscape mosaic networks (Gustafson, 1998) and to assist planners in evaluating urban landscape with regard to the expansion of urban green spaces or remnant patch mosaic connectedness (Botequilha and Ahren, 2002).

The many landscape metrics frequently used are strongly correlated to each other and can be confounded either through theoretical considerations or more objective criteria such as statistical analysis (Botequilha and Ahren, 2002). Analysis of authors' recommendations as cited by Botequilha & Ahren, 2003; Riitters *et al.*, 1995; Reynolds, 1995; in Gustafson, 1998; Mc Gangal and Mc Comb, 1995; Hargis *et al.*, 1998; and Tinker *et al.*, 1998; revealed reasonable agreement on a core set of metrics. The following four metrics were selected for diagnosis focused specifically on the existing remnant patch mosaic composition and configuration within the interior structural context of each of the landscapes identified through the classification phase of assessments as well as with in the context of the urban region as a whole:

A- Number and density of remnant patches;

Table 1. Structure-Function inter-dependencies of air and water related ecological processes in Tehran urban region

Environmental features	Relevance to air resource and related process#	Relevance to water resource and related process#
Micro/Meso-Climate	Air quality; ventilation; pollution; temperature and evaporation	Supply; consumption; and evapo-transpiration rate flow;
Geomorphology Landform *	Air sheds; ventilation and corridors of air flow;	Infiltration run off or erosion; flow and quality
Soil/Sediment	Air quality	Infiltration; erosion; movements and flow
Topography Altitude and Slope	Ventilation; temperature; humidity; evapo-transpiration	Runoff or infiltration; water table; flow and
Land use and cover types	Air quality; temperature humidity flow and pollution (emissions)	Water use; balance; infiltration; quality flow ;
Landscape mosaic type; size and relative heterogeneity	Air quality; ventilation; temperature; heat islands pollutions and flow	Water supply; provision; use; flow; circulation; quality;
Remnant patch and natural matrix	Air quality; temperature; humidity; flow; and ventilation	Water quality; balance; flow; circulation; infiltration quality;

1-"The Number of Patches" - NP metric was used to measure the total number of remnant patches existing in each landscape and the region as a whole.
B- Area and proportion of remnant patch cover type;
2-"The Class Area Patch" - CAP metric or the "proportion or percentage of the total area occupied by a particular patch type"
C- Relative size of remnant patches and distances between them;
3-"The Mean Patch Size" - MPS metric was used to measure the average size of remnant patches in different parts of both the entire landscape and the whole region. MPS was calculated by dividing the remnant patch surface area with NP at each scale that was required.
4-"Mean Nearest Neighborhood Distance" - As a surrogate for connectivity; MNND was measured directly between remnant patches with surface areas larger than the average patch size on samples selected in each landscape according to their interior spatial structure; mosaic grain size; and relative heterogeneity.

Metrics for the remnant open and green patches were computed at both patch class type and landscape levels. In order to relate spatial patterns of urban growth to the natural regional context; metrics were computed for each of the individual landscapes identified through aforementioned classification as well as for the whole landscape association within the urban region. Considering the space-time dimension of resources with intensive vertical connectivity between heterogeneous landscapes in closed water basins of non-regional arid zones; the restoration of remnant patch mosaic network of Tehran involves taking into account the location of where the remnant patch mosaic network is embedded and functions. Significance of location in relation to landscape function and particularly those related to air and water requires addressing it at different scales (Forman, 1999).

At one level; the arrangement of natural ecosystems and urban patches are the major determinants of functional flows and movements of air and water through the landscape. At the higher level of regional analysis; air and water flow; and related ecological processes are greatly affected by structural disturbances and alterations or transformations at landscape and urban region levels. Interaction among landscapes with different resistance to flow due to their interior mosaic spatial pattern is more significant in this respect when impacts of non-regional aridity and mountain specificities on landscape structure and function are considered. Further more air and water related ecological processes and environmental functions at any one level of analysis might have significant effects or may be significantly affected by other levels of analysis. During the final phase of analysis findings obtained at various scales are integrated. Findings regarding structural aspects of remnant patch mosaic networks in different landscapes and all findings related to correlations between the remnant patch network to natural environmental contexts and urban growth patterns were reconsidered to suggest restorative proposals. Further more interpretations aimed at proposing planning suggestions were based on the integration of both environmental capability evaluation and landscape structural analysis results at this final stage of analysis.

An ordinal rating system was adopted for an integrated evaluation of alternative corrective measures. Potentials and constraints facing each choice at various scales were rated from one to twenty as follows:

- One to five scores are given regarding the remnant patch network mosaic composition (CAP) and configuration (MNND); low CAP and high MNND will have only one score out of five; while high CAP and low MNND earns all five scores.
- Landscape interior spatial structure context not only affects supply and demand of air and water but also their various qualitative and quantitative aspects and movement (Forman 1999). Accordingly; large grain and heterogeneous mosaics were given a higher score of five as the most suitable; while small grain homogeneous mosaic; the least appropriate; earns a score of zero.
- The presence of advantageous land forms for the restoration of remnant patch mosaic networks is another attribute included in the rating. Hills (core open & green patch) earn one point; while river valleys have three. Additional functional values attributed to landscapes; such as serving as a source or sink scores one point; and being situated in an upland position earns another three.

• Other attributes endemic to the outlined restoration priorities are awarded an extra point. Finally; a constant may be multiplied by all the scores attributed to each landscape in order to offset the ramifications of their varied surface areas; multiplied by one if equal or above average and by a half in those cases that fall below the average landscape surface area.

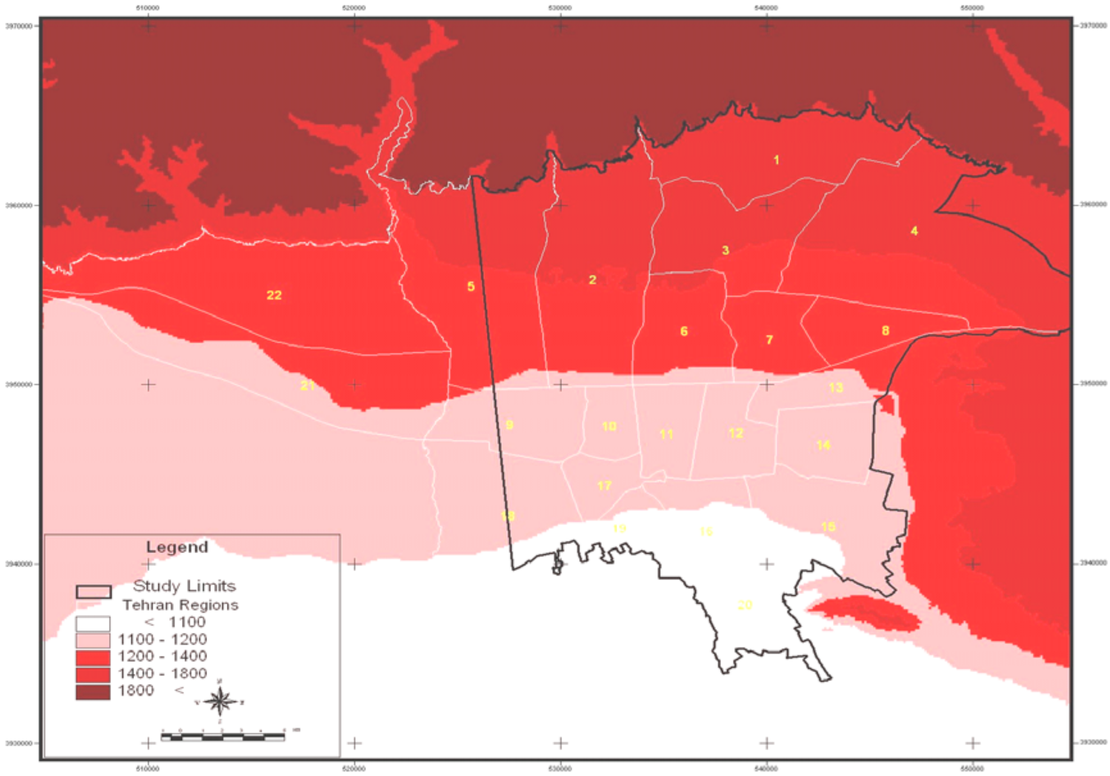

Fig. 3. Different altitudinal belts in Tehran urban region

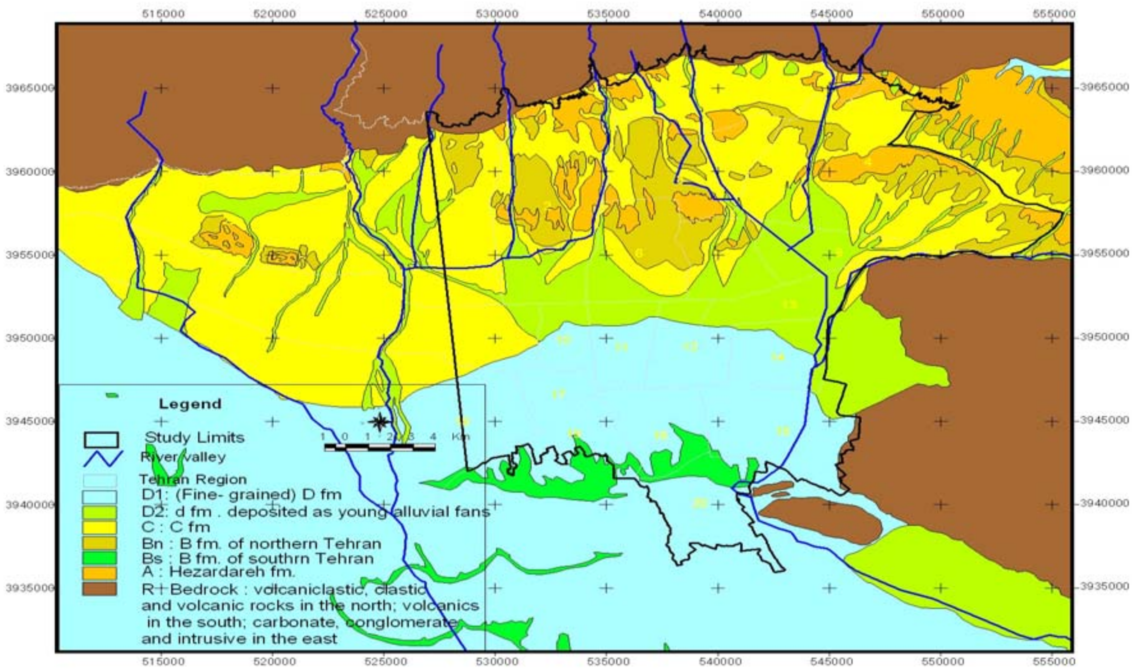

Fig. 4. Geology; geomorphology of Tehran urban region

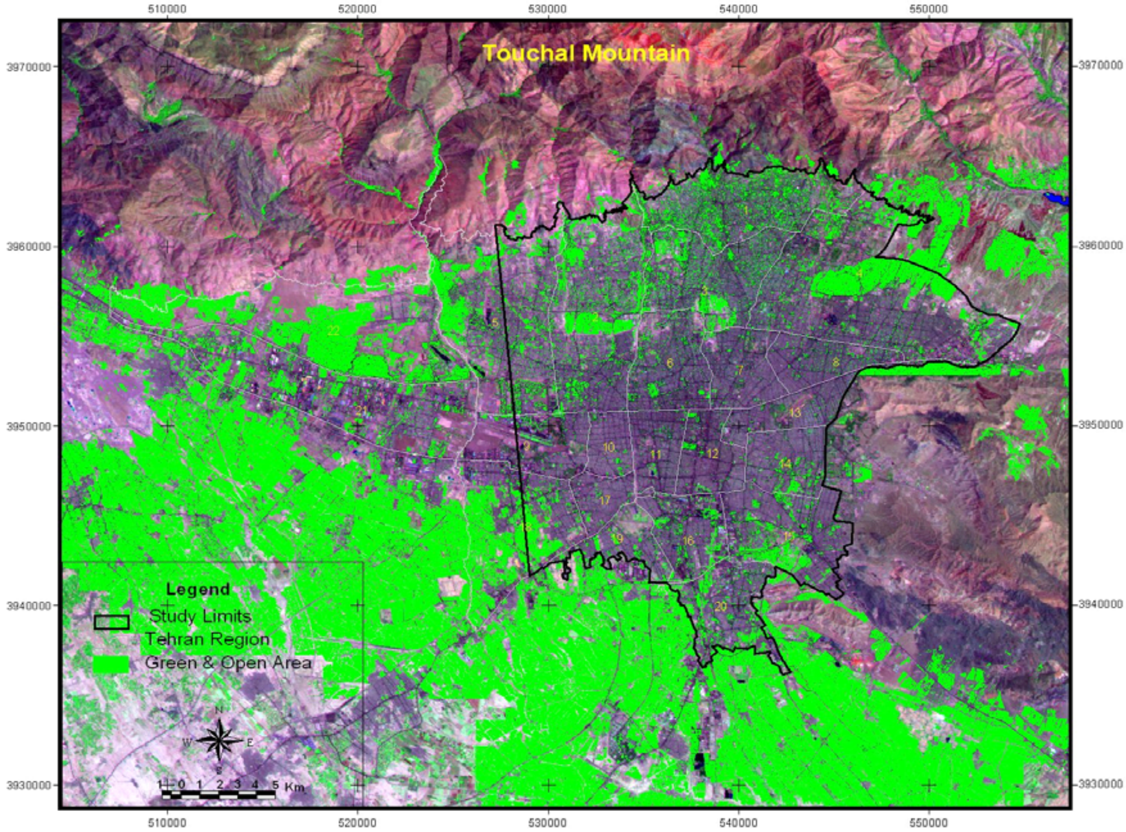

Fig. 5. Remnant green/open patch mosaic in Tehran urban region

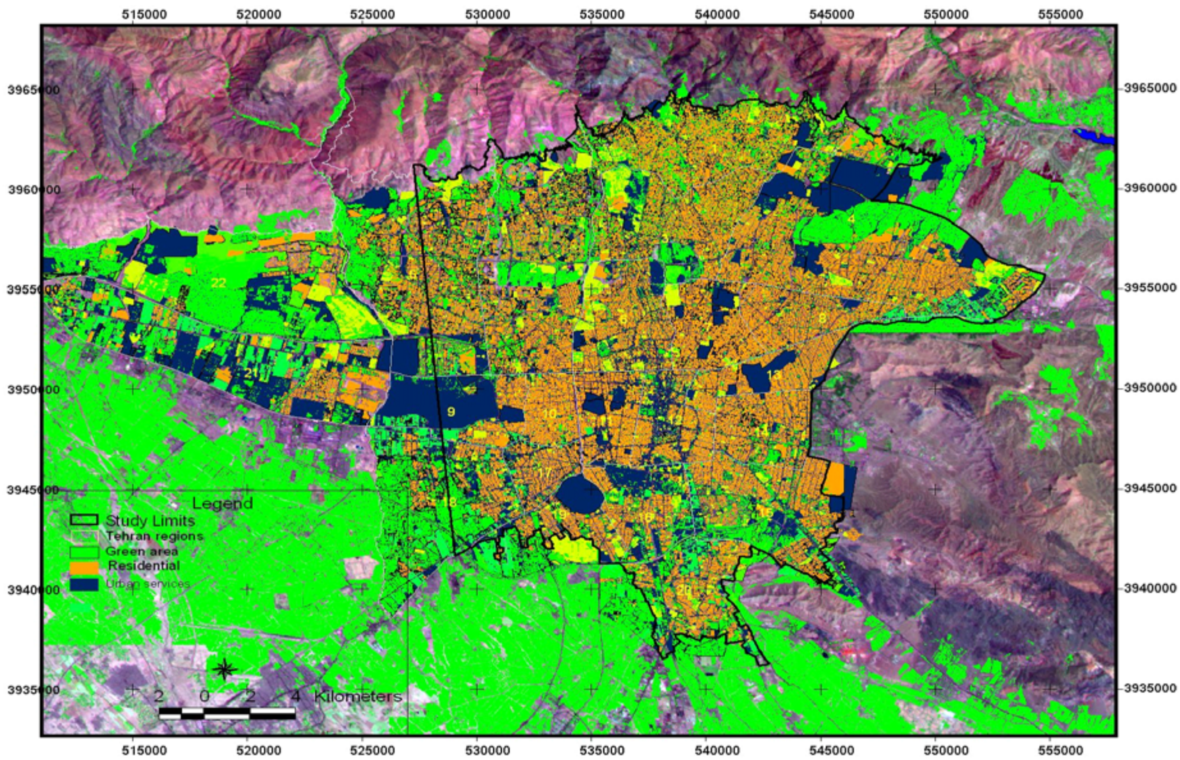

Fig. 6. Urban landscape mosaic patch types in Tehran urban region

Variations in environmental conditions seem to be closely correlated to altitude (Tables 2, 3a & 3b). Consequently; at finer level of analysis; spatial configuration and composition of ecosystems with different capabilities as well as patches with different interior values seem to be correlated to altitude. Four distinct natural landscapes with different environmental conditions and ecosystem capabilities for urban development are distinguished within the urban region considered (Fig. 7) arranged in correlation to altitude with close association to each other through path flows and corridors that maintain the regional vertical connectivity within Tehran's urban area.

The present urban landscape structural difference is a result of transformations caused by the multivalent impacts of urban growth patterns on distinct natural landscapes within the Tehran urban region during the past few decades. The integration of natural environmental diversity (Fig. 8 and Tables 3a and 3b) existing with in the landscape association from plain to mountain; with the impacts of contemporary urban growth pattern on mosaic structure has further increased structural heterogeneity within each of the natural landscapes and the urban region.

Findings regarding remnant patch mosaic network demonstrate insufficient class area proportions (CAP) and/or low connectedness (high MNND) of remnant patch mosaic network in various parts of the urban landscapes. Changes and heterogeneity of remnant patch network conditions; as well as their contextual landscape mosaic structure where these are embedded; are correlated to natural environmental heterogeneity and to the urban growth patterns of Tehran.

Three major gradients of change in metric values; Mean patch size; area proportion and relative connectedness of remnant patch mosaic network are from south to north, from east to west and from the center towards suburban regions. While during earlier (1940 to 1970) periods a gradual change in mosaic structure has been dominant in a north-south axis; during later periods (during 1970 to 1990) landscape heterogeneity is more abrupt and in contrast to the natural landscape gradient of change is most tangible on an east to west axis due to a different urban growth pattern. At present urban growth pattern (or change) is in form of scattered patches and relatively more in the suburbs.

Table 2. Landscape heterogeneity in respect to air and water related environmental features in Tehran urban region

Characteristics	Landscape A	Landscape B	Landscape C	Landscape D
Meso/Micro-climate Affects air / water flow quantity and quality	Cold semi-arid 6 C° and high RH 400-600 mm. 0.5-2 ppm 20-40 ug/m3	Temp. and semi-arid 12 C° and Med. RH 300 - 400 mm. 4-8 ppm 60-90 ug/m3	Temp. and arid 16 C° and low RH 200-300 mm. 2-4 ppm 40-70 ug/m3	Hot and arid 18 C°and low RH 200 mm 4-6 ppm 30-50 ug/m3
Topography and Landform; altitude; slope etc. as affect air / water flow quality / quantity	Terrace and depression 2/3 of hills 95 km. river Extrinsic slope 5 % Alt. 2000-1600 m.	Alluvial cones 1/3 of hills 80 km. river 3 % slope and 1600-1300 m. altitude	Sediment plain with out relief 20 km. river 2 % extrinsic slope and 1300-1100 m. alt.	Sediment plain with out relief Drain tributary Slope less than 1% Alt. 1100-900 m.
Soil/Sediment as affect air and water quality flow infiltration erosion	Highly permeability and good porosity soil with very good vegetative growth	Medium permeability with good density vegetative growth	Low permeability and porosity soil with low potential vegetation density	Very low permeability (lodged) with low vegetative growth
Land use and landscape mosaic structure affect air / water flow; use; quality 'and related biotic and abiotic processes;	Heterogeneous* large grain of mix residential; public and commercial land use very high open/green to built ratio	Homogeneous medium grain of residential and public land use with medium open/green to built ratio	Homogeneous small grain of public commercial and residential land use with very low open to built ratio	Heterogeneous large and small grain of farm military; industry and residence land use with very high open to built ratio
Remnant patch act as source; sink and corridor for air and water	Large cores with 3700 H. Remnant patch area and 11.03 m per capita green space	Medium size cores with 2200 H. Remnant area and 6.80m per capita	Small green patches limited cores with 1300 H. and 1.47 meters per capita	Small or very large cores 'with 2900 H. Remnant area and 6.43 m. per capita
Surface Area	10000 Hectares	11000 Hectares	9500 Hectares	8500 Hectares

Table 3a. Metrics computed for remnant green & open patches in different homogeneous parts of urban landscapes in Tehran urban region

Landscape	A	A1	A2	A3	B	B1	B2	B3
Surface area	10000	4250	2500	3250	11000	4000	2500	3500
Remnant S. area	4600	2200	400	2000	2850	650	400	1800
Core Rem. S. area	3950	2000	250	1700	2133	445	298	1390
CAP Rem. Tot.	46	52	16	61	26	16	16	51
CAP Rem. Core	395	47	1	52	19	11	12	38
NP Rem Core	310	102	57	151	190	59	38	93
MPS Rem. Core	13	19	4	12	11	5	6	17
MNND Rem. Core	447	350	650	340	350	370	370	310
Mosaic	Hetero.	Hetero.	Homo.	Hetero.	Hetero.	Hetero.	Homo.	Hetero.

Table 3b. Metrics computed for remnant green & open patches in different homogeneous parts of urban landscapes in Tehran urban region

Landscape	C	C1	C2	C3	D	D1	D2	D3	Tot/Ave
Surface Area	9500	3750	2250	3500	8500	2000	5000	1500	39000
Remnant S. area	1320	1000	150	170	1800	700	430	670	10570
Core Rem. S. area	994	738	100	156	1166	589	247	330	8243
CAP Rem. Tot.	13	26	6	4	21	35	8	44	27
CAP Rem. Core	10	19	4	4	14	29	4	22	21
NP Rem Core	133	82	25	26	80	31	19	30	713
MPS Rem. Core	7.5	9	4	6	14.5	19	13	11	11
MNND Rem. Core	516	430	560	560	300	300	300	300	403
Mosaic	Homo.	Hetero.	Homo.	Hetero.	Hetero.	Hetero.	Homo.	Hetero.	Hetero.

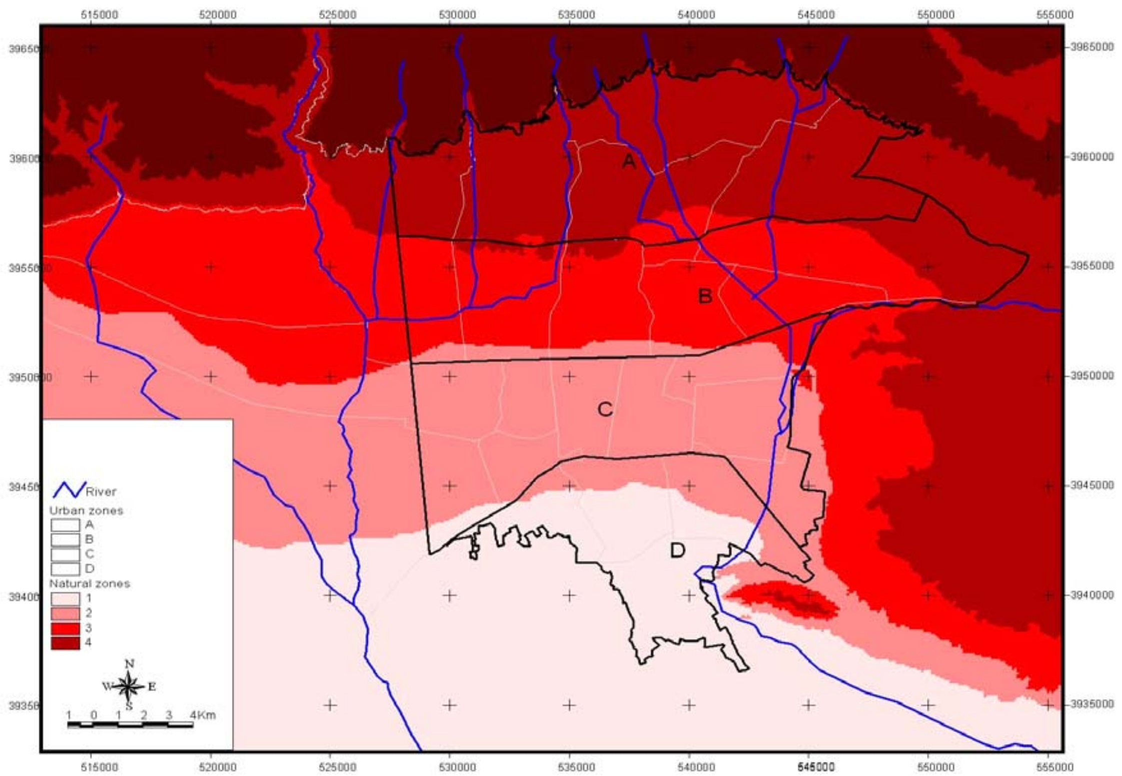

Fig. 7. Natural regional landscape association with in Tehran urban region

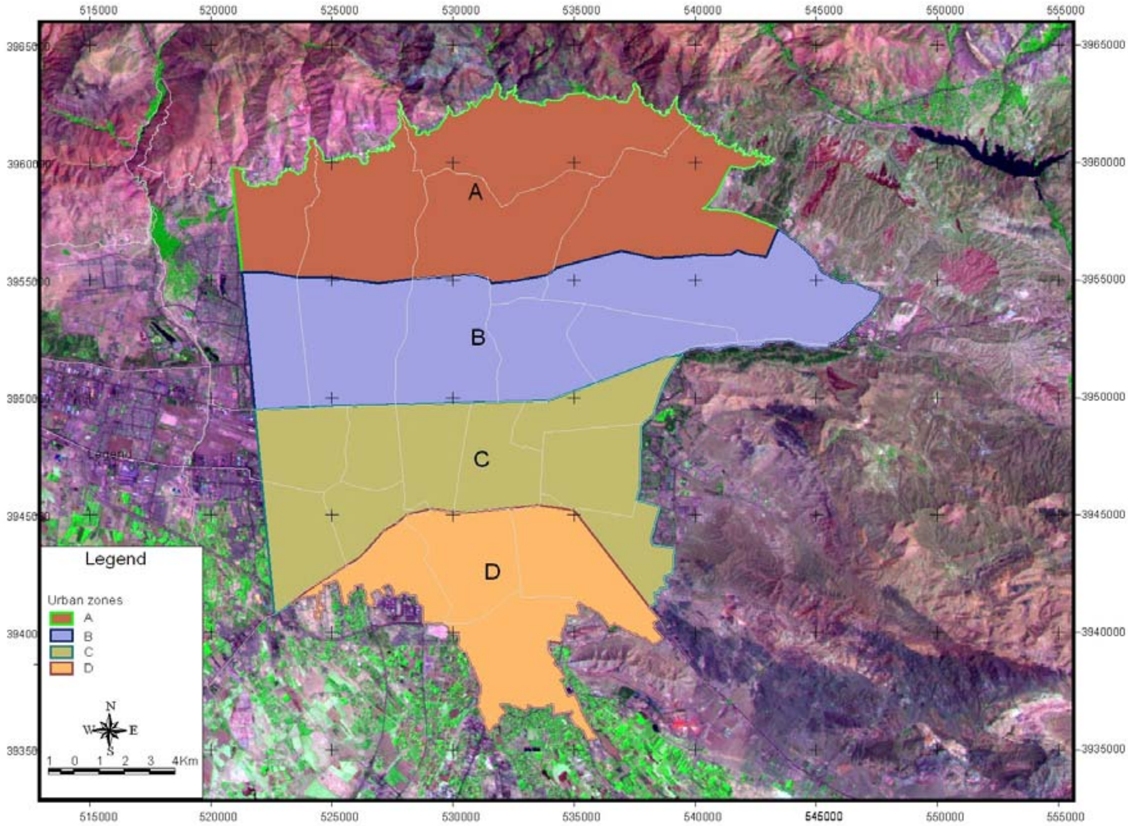

Fig. 8. Homogeneous urban landscapes in Tehran urban region

Despite the general increase in the Mean Patch Size values (MPS) from the center towards the suburbs; there is an incremental and more palpable trend of remnant patches in the north-south direction. Mean values for Class Area Proportion (CAP %) metrics for different landscapes also increases from the center to the north and particularly to the northeast and northwest of the urban fringe. The number of remnant open and green patches (NP) and their total surface area also increase from the center to the suburban margins. Average values for the Mean Nearest Neighborhood Distances (MNND) in different urban landscapes decrease to the north and the south of the Tehran urban region. This is due to patch grain size of landscape mosaics with a generally increasing trend from the center to the urban fringe. Finally; in contrast to MPS values; CAP metric value is higher in southern Tehran. The suburban landscapes in contrast have heterogeneous large grain interior mosaic structures. In the southern and eastern urban fringes; remnant patch mosaic networks have better CAP values with large grain (MPS) remnant patches despite insufficient connectedness between the patches.

In the center; urban landscape has homogeneous interior structure with small grain remnant patch mosaic; resulting to insufficient remnant patch class area proportion with low MPS values. Pollution sources are widely distributed throughout this central part of Tehran and the quality of air and water tend to be low. Such landscapes (B and C types) have higher resistances to flow of air and water. Landscape structural restorations are nevertheless necessary to mitigate their negative impacts on broader scale connectedness of the remnant patch network at the entire urban region level.

The remnant patch mosaic network with the highest MPS value and most appropriate connectedness is found in landscape A; in the northern part of city; with valuable additional downstream ecological and environmental services that are owed to its upland location. Improving the remnant patch mosaic network will have the most cost effective results in landscape type A because of its proximity to mountain; source of valuable services that may be transferred into the city by means of several river valleys still remaining little altered Table 4). The two urban landscapes; A3 and A2; which are associated with in this natural landscape offer the most interesting restoration opportunities in terms of remnant patch network mosaic connectedness and natural matrix connectivity. This is mainly due to the presence of river valleys that improve the efficiency of remnant patch networks' function as natural source patches and its connectedness as natural corridors (see spatial design frame work in conclusion).

Landscape type D; at the extreme southern part of the urban region; has high CAP and MPS values; and once again offers interesting opportunities for the improvement of their remnant patch mosaic network structure. A greater portion of the remnant patch mosaic cover type is of open (agricultural fields) patch type; while quantities of waste water is also available. In such a situation urban forestry would be very advantageous for improving the remnant green network's structure and function; in respect to air and water resource allocation and the alleviation of pollution. Excess wastewater; creating costly impacts at present may be easily utilized for the extension of urban forestry in these abandoned core patches. They may also be manipulated to function as natural sinks for emissions and for wastewaters; in addition to providing restoration of the remnant patch mosaic network.

Integration of results; landscape classification and diagnosis findings in the final analysis phase of landscape assessment (Fig. 9) takes into account all potentials or constraints affecting cost effectiveness of corrective measures. Results indicate that urban landscapes A3; B3; D1 and C1; have relative priority for restorations. Ranked by the evaluation matrix it follows that:

- (A) A3 has the first priority and needs improved connectedness rather than expansion of surface area. Presence of river valleys and terraces; permeable soil and appropriate micro-climate as well as a heterogeneous large grain mosaic and availability of water are also important elements that facilitate restoration measures. Finally impacts of restoration will be significant at its down stream.
- (B) B3; Remnant patch mosaic has a low class area proportion as well as insufficient connectedness. Never the less presence of hills and river valleys and alluvial cones remaining as open cores within an intermediate part of urban region with conducive environment have been such to select it as an urban landscape where cost effective restorations are potentially achievable.
- (D) D1; Despite low class area proportion of urban green space it has a high class area proportion of open (agricultural land) patch type with good connectedness.

Table 4. Evaluation of relative cost effectiveness regarding remnant patch mosaic network restoration in different landscapes of Tehran urban region

Land-Scape	Remnant Patch	Mosaic Context	Land Form	Location Factor	Extra value	Total Value	Relative Extent	Final Score	Priority
A scores = 29.5									
A1	VI	V	III	III	0	XVII	0.5	8.5	V
A2	IV	I	IV	III	0	XII	0.5	6	VII
A3	**VI**	**III**	**III**	**III**	**0**	**XV**	**1**	**15**	**I**
B scores = 24									
B1	VI	II	IV	I	0	XIII	0.5	6.5	VI
B2	IV	II	IV	0	0	X	0.5	5	IX
B3	**VI**	**III**	**III**	**I**	**0**	**XIII**	**1**	**13**	**II**
C scores = 15.5									
C1	**V**	**IV**	**I**	**0**	**0**	**X**	**1**	**10**	**IV**
C2	II	I	0	0	0	III	1	3	X
C3	V	I	III	I	0	X	0.5	2.5	XI
D score = 21.5									
D1	**IV**	**II**	**0**	**I**	**I**	**XIII**	**1**	**13**	**III**
D2	III	II	0	I	I	V	0.5	2.5	XII
D3	IV	II	0	I	I	VI	1	6	VIII

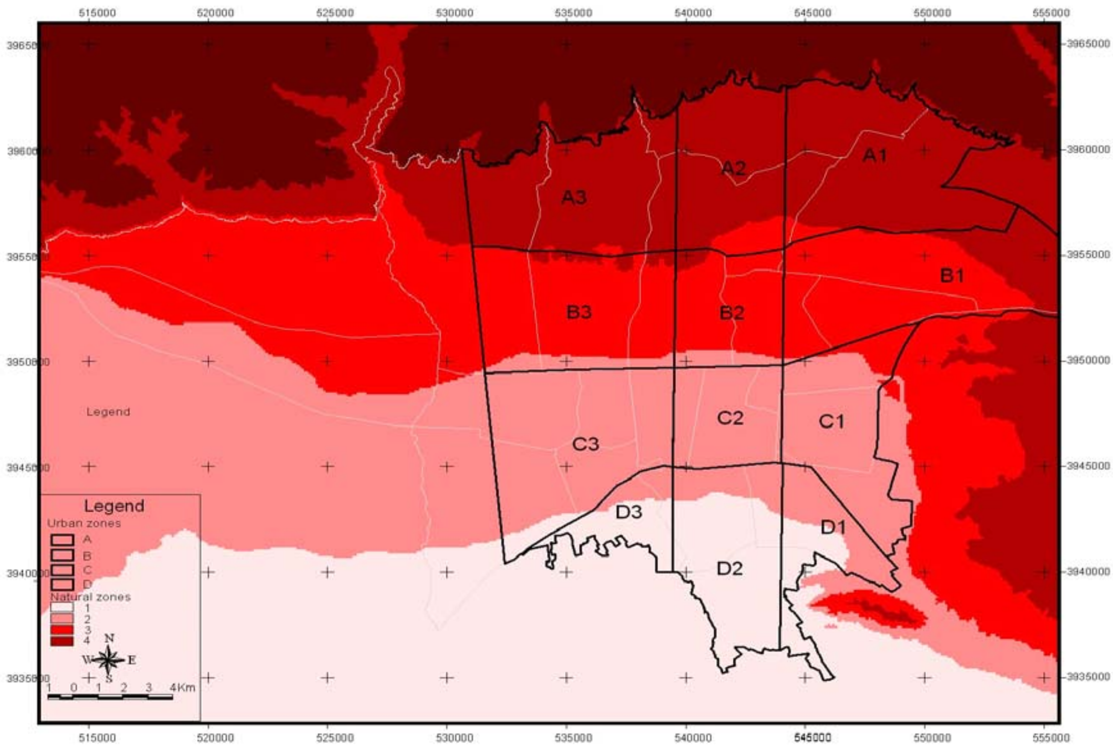

Fig. 9. Integration of natural (A; B; C; D) and urban (1; 2; 3) homogeneous landscapes

If waste water is appropriately allocated to these patches (reducing harms from inundation of urban facilities and health problems of rising water table) important green patch mosaic as urban forest is created that function as sink for air and water pollution and source of environmental services in addition to improvement of urban regions' remnant patch network connectedness.

- (C) C1; the present urban remnant patch mosaic network has both a low connectedness and a low class area proportion. Restorations are compulsory to obtain regional connectedness despite the fact that no particular advantageous potentials are available.

Regardless of their relative priority and despite the fact that both environmental resource capability and landscape structural features have been already considered for various parts of the urban region; an efficient restoration plan requires a conceptual and spatial design framework to integrate simultaneous or successive corrective measures at various scales.

CONCLUSION

A balanced combination of the urban network in respect to the underlying ecological pattern seems to be the best expression of the relationship between man and nature (Vrijlandt and Kerkstra, 1995). The vital presence of natural ecological functions and processes in urban regions may be achieved by the means of natural matrix connectivity throughout the city (Kendle and Forbes, 1997). In order to retain the necessary natural matrix connectivity; appropriate balance of remnant patch class area proportion with built land cover area is require. This is however; largely impossible to achieve in a city such as Tehran. Alternatively; a proper remnant patch mosaic class area proportion with appropriate connectedness also to the suburban natural matrix may provide; at least some of the principal missing natural services otherwise realized by natural matrix connectivity within the urban region. Considering that Tehran is surrounded by a valuable remnant natural matrix of protected areas and national parks with high natural values as source of natural services and as a life support system; then reduced natural matrix connectivity may be compensated by the remnant patch mosaic network connectedness to ensure the presence of nature in that urban region (Kendle and Forbes, 1997).

In fact when all different types of open and green patches are included in the computation of CAP for this patch class type; then about one fifth to one fourth of the area of Tehran still remain as semi-natural green and open land cover (Zovashtiaq, 1999). It seems then that the most significant drawback of the present remnant patch network mosaic of Tehran; at least at the regional urban level; is it's spatial distribution and configuration rather than its size. More specifically and at the urban region level; low connectedness between the remnant patches is the main hindrance to the efficient functioning of the remnant patch mosaic network. It is appropriate therefore; to undertake measures to enhance the frequency and intensity of the connections between these fragmented remnant patches; to ensure an acceptable level of urban environmental quality (Igegnoli, 2002). To integrate various corrective measures and simultaneous tasks at different scales; a conceptual framework and for effective implementation a spatial design frame work were needed. (Pickell *et al.*, 1994 in Makhzoumi & Puggetti, 1999).

Improving connectivity may be best obtained through creation of a network in harmony with spatial configuration of related natural structural elements and taking advantage of natural landforms. One of the main spatial design frameworks in ecological network design and restoration with in the Mediterranean region is the "Maquis-ravine" network whose restoration assures further development of many other ecological networks in altered urban landscapes. The physical characteristic of the ravine; namely its linearity and transverse position; allows it to link the remaining components and contribute towards the development of ecological networks (Nowicki, 1996 in Makhzoumi and Puggetti, 1999) within the framework of the regional model. In the case of Tehran; a river valley corridor network may be the most efficient alternative for improving connectivity at the landscape and urban region levels while increasing the natural matrix connectivity in the urban environment as well. River valleys allow for the introduction of nature to the city; and provide connectedness of remnant patch network as air and water flow paths at the urban region within the closed basin.

In many cases and particularly in arid zones; urban forestry development is planned in close relation to surface water (corridors) and within the framework of a process-oriented ecological approach (at the scale of watershed rather than urban limits). In that event; an adapted spatial design framework based on a solid conceptual framework would be successfully created by a process-oriented ecological discourse; known as a "Refuge Network" (Tjallingii, 2000). It provides a balancing mechanism for urban landscape and region by the sufficient presence of nature. River valleys possess the ecosystem capability and environmental resource suitability required at the finer scale. As a carrier of ecological functions in relation to both air and water (Tjallingii, 2000); such a refuge network encourages appropriate air and water resource allocation and provides opportunities for improving the proportion of remnant green patch area as well as its regional connectedness while also assuring the presence of nature and environmental livability in the city. A river valley corridor network may provide the needed spatial design closely adapted to ecological network layouts that also assure regional scale vertical connectivity within the upland-lowland context of the closed water basins continuum system of Tehran.

An adapted spatial design framework is also needed to ensure effective implementation of the restoration plan in tandem with the selected conceptual framework and in the specific urban region of Tehran. Specific spatial design conventions and general guidance instruments have been provided to secure the sufficient presence of nature and functional remnant patch networks in landscapes (Forman and Godron, 1986; Farina, 1999; Forman, 1999; Burel, 2003); based on the "Aggregate-with-outliers" model for all land use planning including sustainable urban development (Forman and Godron, 1986; Forman, 1995 a and b; Turner, 1989). For example; effort should be made to maintain large patches wide corridors; connectivity (first among larger patches); and heterogeneity and heterogeneous bits throughout areas under development. On the same basis; stepping stones and corridors have been suggested as a conceptual framework for the spatial planning strategy to help nature preservation in fragmented landscapes (Vrijlandt and Kerkstra, 1995). Such spatial design models and guidelines are proposed for improving various functions; including the improved functioning of air and water ecological processes in the urban environment.

Hills crossing the city from east to west in the form of a continuous row of core open remnant patches may be considered as the other main element of the prospective remnant patch or refuge network. Hills and terraces function as sources of natural resources and services such as oxygen; humidity; shade; air movement and ventilation; among others. They have sufficient surface area and have an interior value to provide ecological support for both the urban environment and its biota. Hills enjoy strategic locations in relation to the flow of air and water. They are located where natural air currents from and to the mountain meet the descending polluted air from both the northern and the southern core urban parts of Tehran. There is flowing water from the north that passes through them; and may be used for irrigation of trees and green spaces (the same waste and run off water that has created hydrological problems in the south of the city in the last decade) to function as a sink for air pollution and excess wastewaters. Hills and river valleys extending from north to south and from east to west respectively; also create and maintain the presence of a natural matrix inside the city.

In addition to the conceptual and spatial design frameworks mentioned above; for a successful implementation of restoration plan; appropriate planning unites (geared to a process-oriented ecological discourse of planning) would be required. Water (and air) sheds may be considered as alternative planning units. As such; increasing or decreasing consumption of water and other resources made available by river valleys in one location may provide conditions to resolve environmental problems in other locations as well. Decisions on land use without any arbitrary distinction between urban or natural purposes would then be guided by the position and spatial composition and configuration (design) of this network (Tjallingii, 2000) within the landscape (integration of natural and urban). But the execution of related tasks within this framework faces specific problems and constraints that will not be resolved unless planning units are integrated in the institutional and decision-making framework. Creative substitutions and alternative institutional arrangements would also be necessary.

The dispersal of responsibilities among several different planning institutions; and particularly the lack of any real decision making or enforcement capabilities in the office of Tehran's mayor generate numerous conflicts and create serious obstacles (Bourlon et al., 2002) for the implementation of any restoration plan. Each bureaucratic unit as well as service provider has its own agenda accompanied by a separate decoupage of territory in relation to its specific functioning and particular internal organization; determined with respect it its terms of reference. The end result is a paradoxical situation where despite viable technical competence and seriousness of purpose among several agencies; communication; regrouping and the crafting of common terms of reference have proven all but impossible. Even if and when mutual agreements are reached; the trans-disciplinary nature of ecologically oriented planning approaches demands the collaboration of several institutions within the conceptual and spatial frameworks of an integrated restoration plan - a requirement that is presently lacking. Restoration cannot be carried out in a piecemeal manner. The basic question of how and why plans and institutions have failed to realize their objectives concerns the capability of the institutions involved with environmental planning; and the suitability of their stated terms of reference; as well as coordination at the trans-institutional level. What are better solutions for planning and why does landscape ecology remain neglected; in spite of the promise it is believed to hold?

REFERENCES

Baschak, L. and Brown, R., (1998), River systems and Landscape networks; in: Mosaic landscape and ecological processes; edited by Hansson L.*et al.*, Chapman & Hall; London; U.K.

Beatley, T., (2000), Green Urbanism : Learning from European Cities. Island Press; Washington DC.

Botequilha, A. and Ahren, J., (2002). Applying landscape ecological concepts and metrics in sustainable landscape planning; in Landscape and Urban Planning; 59, 65-93; Elsevier Pub. Books Press; Montreal.

Bourlon, A. M., Beltrando, Y. and Bouregard, A., (2002), Rapport de Mission Tehran-Iran; Ministere Des Affairs Etrangeres; Republique Francaise.

Burel, F., (2003). Landscape Ecology: Concepts; Methods and Applications; Science Publishers; Inc.

USA Cutway, H. B.m (2005). Urban sprawl, Avaiable at: http://www.vtsprawl.org/

Darvish-zadeh, A., (1990). Geology of Iran; Amir Kabir Publisher; Tehran; Iran.

DOE, Department Of Environment, (2001). Urban environment report of the capital; Tehran; Iran.

Farina, A., (1999). Principles and Methods in Landscape Ecology; Chapman & Hall.

Cambridge History of Iran, (1968). On Vol. I; The land of Iran; Vols. IV; V; and VI History of Iran at different periods; Cambridge University Press; U.K

Forman, R. T. T. and Godron, M., (1986). Landscape Ecology; John Wiley & Sons; New York; N.Y; USA.

Forman, R. T. T., (1995 a). Some general principles of landscape and regional ecology; Land. Eco.; **10**, 133-142.

Forman, R. T. T., (1995 b). Land Mosaics; The ecology of landscape and regions" second edition; Cambridge University Press; USA.

Forman, R. T. T., (1999). Sustainable Development and Ecological Planning; Academic Pub. Bv. Amesterdam.

Gerrard, R., (1992). Mountain Environment; MIT Press; NY; USA.

Gordon, D., (1990). Green Cities: Approaches to Urban Space. N.Y. Black Rose.

Gustafson, E. J., (1998). Quantifying Landscape Pattern in Ecosystem 1/ 143-156.

Igegnoli, V., (2002). Landscape ecology a widening foundation Springer.

Kendle T. and Forbes S., (1997). Urban nature conservation; Chapman & Hall; Published by E and FN Spon Australia.

Kong, F. and Nakagoshi, N., (2005), Spatial-temporal gradient analysis of urban green spaces in Jinan; China; Landscape and Urban Planning.

Makhzoumi, J. & Pungetti, G. 1999 Ecological landscape design and planning Routledge NY; USA

Messerli, B., (1983). Upland-lowland interactive systems; International Sym. ICIMOD; University of Bern; Switzerland.

Naveh, Z. and Liberman, A. S., (1984). Landscape ecology; Springer-Verlag; New York; N.Y. U.S.A.

Naveh, Z., (2005). Epilogue: Towards a Trasdisciplinary Science of Ecological and Cultural Landscape Restoration; Restoration Ecology. **13** (1), 228-234.

Nilson, K. and Randrup, T. B., (1997). Proceedings of the Eleventh World Forestry Congress; Anatalya; Turkey; 13-22 October 1997.

Tjallingii, S. P., (2000). Ecology on the edge: Landscape ecology between town and country; Landscape and Urban Planning; **48**, 103-119.

Tricart, J., (1991). Le Models Des Regions Seches - in Persian by Sadighi & Kermani, 2000; Astan ghods press; Mashhad; Iran

Turner, M. G., (1998). Landscape ecology; The effect of pattern on process; in Annual Review Ecological Systems; **20**, 171-197.

Vrijlandt, P. and Kerkstra, K., (1995). A strategy for ecological and urban development.

Wiens, J. A., (1995). Landscape mosaic and ecological theory; Mosaic landscape and ecological processes; Chapman & Hall London.

Yavari, A. R., (2003). Land-use Planning in Arid Mountain Environment; First Seminar on Resource Utilization: Local Structure vs. Globalization; German Academic Exchange Service and The University of Tehran, Tehran, Iran.

Zonneveld, I. S., (1995). Landscape ecology and ecological networks.

Zovashtiaq, S., (1999). Tehran comprehensive plan; Pardazesh pub. Tehran, Iran.