A GIS-based Framework for Effective Landuse Planning: A Case Study of ETKA Organization, Tehran

Amir Hossein Fadaei Tehrani[1*], Narges Zaredar[2], Rouzbeh Forouzandeh

[1*] Researcher at Research & Development Centre, ETKA Organization, Tehran, Iran
[2]Department of Environmental Science, Collage of Environment and Energy, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran
3Master of science, Land surveying Department, Khaje Nasir Toosi University, Tehran, Iran

Abstract: Land use planning is an approach for sustainable use of land resources where different stakeholders have different interests. The present study presents a multi-objective GIS-based framework for land use planning of lands owned by ETKA Organization, Tehran. For this, capability of seven pieces of ETKA's lands was evaluated for agricultural, tourism, urbanization, and industrial development land uses. The land uses were allocated using MOLA (Multi Objective Land Allocation) module using IDRISI Software. 0.58% of the total study area has high suitability for agricultural land use. Steep slopes and highlands restrict suitable places for urbanization. As such, only a small patch, with an area of 835.7 ha (0.41% of study area) has a medium suitability for urban development. Approximately 4481 ha of the whole study area were recognized suitable for industrial development. Moreover, suitable places for outdoor and indoor recreation land uses comprise 4571.6 ha and 27495.9 ha of the study area, respectively. The research outcomes indicated that multi criteria decision-making methods are powerful tools in land capability evaluation and land allocation studies.

Keywords: Multi Objective Land Allocation, land use planning, urbanization, Land allocation, land capability evaluation, agricultural land use, recreational land use, urban development, industrial development

1. Introduction

Industrialization accelerates economic development, but has adverse impacts on environment [1]. The impacts of human activities on the natural environment are becoming more and more pronounced. Land use and land cover change is one of the most obvious areas of concern [2]. Different types of crises that currently threaten human societies are derived from human misuse of natural resources. In discriminate use of land resources causes water, soil, and air pollution, resource degradation, desertification, and so on. In such a situation, it is important to develop strategies for sustainable exploitation of resources. Land use planning is a strategy to modify any kind of human exploitation according to land capabilities in a way to meet sustainability principles. The assignment of multi-objective human resources is a very important phase of the decision-making process, particularly when performance strongly depends on capabilities of human resources [3]. A number of models have been proposed for the optimal allocation of different land uses [4]. Kheirkhah Zarkesh et al. (2010) presented a spatial decision support system for land use planning of Taleghan Watershed in Iran. They found Analytical Hierarchy Process (AHP) as a powerful decision support system in site selection and land allocation studies according to various environmental and socioeconomic factors [5]. Nizeyimana and Opadeyi in 2011 predicted that the use of GIS and GIS-based systems in land use planning activities will continue to increase in the future, as more detailed digital environmental datasets become available and the capability of computers to handle large volumes of data increases [6]. Qin and Jixian (2002) integrated RS and GIS for agricultural land use planning [7]. In 2011, Lewis overviewed land use and planning history in local governments of USA. He concluded that in spite of considerable ferment and dissatisfaction with the suitability of the dominant zoning approach to manage urban growth, major reforms to local land-use regulation are likely to be implemented only quite slowly [8]. Pilehforooshha et al. (2014) presented a two-stage model for crop allocation based on cellular automata, Markov chain, fuzzy rule-based system, goal programming, and GIS raster analysis in a logical framework. They found the advantageous of the model in determination of crops with highest suitability for a given area according to the desired objectives [9].

Appropriate allocation of different land uses based on land capabilities and socioeconomic considerations certainly lead to increased productivity and optimal use of existing resources. Accordingly, landowners, by adopting land use planning strategies maximize their own economic interest without harming natural resources. In this research, a multi-objective GIS-based framework for land use planning of lands owned by ETKA

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

Organization in Tehran. As one of the biggest and most reliable trading organizations in Iran, ETKA, with more than half a century experience in Macro and Micro producing and economic activities, has been launched since 1965 to gain an enormous share of the domestic market in Iran.

2. Materials

Study area

The present study is a land use planning research for appropriate allocation of different land uses in lands owned by ETKA Organization. These lands are in seven pieces scattered over an area of 782 ha in Tehran Province. The smallest piece has an area of 782 ha while the largest patch occupies an area of 127066 ha. Figure 1 illustrates situation of ETKA's lands in Tehran.

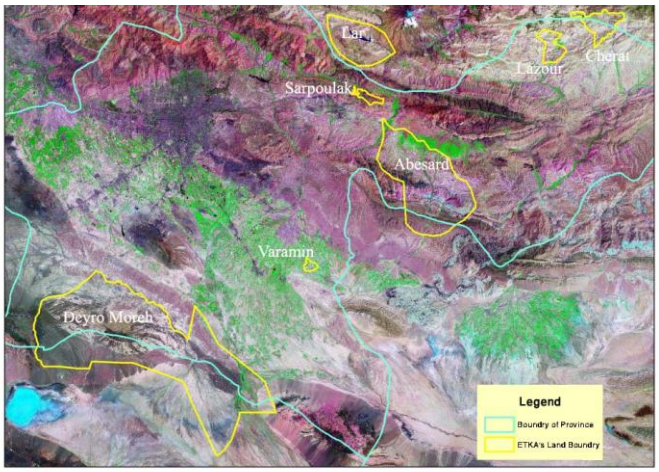


Fig. 1. Situation of ETKA's lands in Tehran

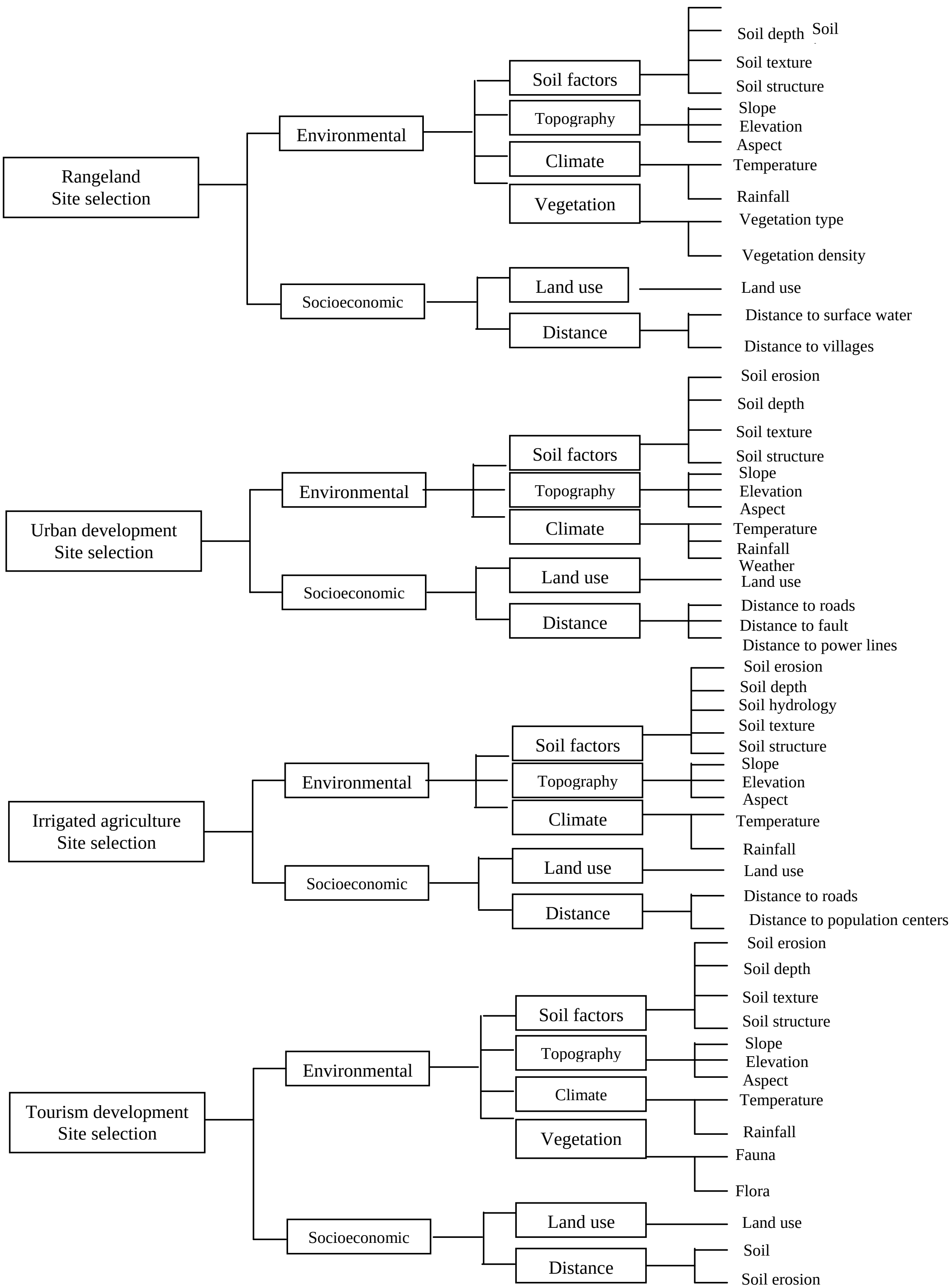
Research procedure

In order to determine capability of ETAKA's lands for agricultural (rain fed and irrigated), rangeland, urban development, and recreational land uses, Spatial Analytical Hierarchy Process (SAHP) was used. According to Siddipui *et al.*, (1996), SAHP process includes the following steps [10]:

i) Identification of criteria, ii) structuring the decision tree, iii) determination of relative importance of criteria,iv) overlaying criteria maps using Suitability Index (SI, and v) preparation of suitability maps using SI

In this research, decision criteria were selected according to literature reviews, interviewing with experts, and availability of data. Afterwards, Decision issue (land capability evaluation), was structured into a hierarchy (Figure 2).

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)



(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

Fig. 2. hierarchal structure for land capability evaluation of different land uses in Tehran

Values in the different criteria maps have different measurement scale (e.g. distance maps in meter, temperature in degrees centigrade, etc.). In order to compare criteria with each other, all values should be standardized and transformed to a same measurement unit (e.g. from 0 to 1) [5]. In this research, map layers were standardized using pair-wise comparison method (equation 1).

$$n_{i,j} = \frac{r_{i,j}}{\sum_{i=1}^{n} r_{i,j}} \qquad \text{(eq. 1)}$$

Where, the value of each criterion (r_{ij}) from decision matrix is divided in to the total values of rij, in each column.

As the next step, relative importance of criteriawas evaluated within each level of the hierarchy, between each pair of criteria and sub-criteriausing a nine-point scale. Table 1 shows the judgment scale for pair-wise comparisons.

Table 1. Judgment scale for pair-wise comparisons (Kheirkhah Zarkesh, 2010)

Preference	Equally preferred	Equally to moderately	Moderately preferred	Moderately to strongly	Strongly preferred	Strongly to very Strongly	Very Strongly preferred	Very Strongly to extremely	Extremely preferred
Scale	1	2	3	4	5	6	7	8	9

In order to ensure the accuracy of judgments, the consistency index (CI) was computed using equation (2). Based on the CI and random index (RI), the consistency ratio (CR) was calculated using equation (3) (Kheirkhah Zarkesh, 2010).

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \qquad \text{Eq. 2}$$

$$C.R. = \frac{C.I.}{R.I.} \qquad \text{Eq. 3}$$

Where, n is the number of items being compared in the matrix; $\lambda_{\max}$ is the largest Eigen value and RI is a random consistency index obtained from a large number of simulation runs and varies upon the order of matrix (Table 2).

Table 2. Random index

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

At final step, land suitability for different land uses were prepared by overlaying map layers based on SI values (equation 5).

$$SI = RI.A1 * \sum_{i=1}^{m} RI.Bi * RI.KBi + RI.A2 * \sum_{y=1}^{L} RICy * RIKCy + ...RIAN * \sum_{z=1}^{j} RIDz * RIKDz \qquad \text{(Eq. 5)}$$

Where, SI is the suitability index of each cells; N is the number of main criteria; RIA1, RIA2 …RIAN are the relative importance of the main criteria A1, A2 …AN, respectively; M, L and J are the number of sub criteria directly connected to the main criteria A1, A2 …AN, respectively; RIB, RIC and RID are the relative importance of sub criteria B, C and D directly connected to the main criteria A1, A2 …AN, respectively; RIKB, RIKC and RIKD are the relative importance of indicators category k of sub criteria B, C and D and main criteria A1, A2 …AN, respectively. This equation is suited for a four-level hierarchy; so it should be modified for decision hierarchies with more or fewer levels [5].

In this research, land capability evaluation was done separately for different land uses (agriculture, tourism, urban development, industrial development). At the end, it was found that particular patches of ETKA's lands highly suite for more than one land uses. As such, a piece of lands in northern Tehran has high suitability for either tourism or agricultural land uses. Therefore, it was required to adopt an appropriate mechanism for optimal land allocation. Land allocation addresses the process of designing an optimal mixture

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

of different land uses based on their suitability values [5]. In this study, Multi-Objective Land Allocation (MOLA) module in IDRISI Kilimanjaro software was used to allocate various land uses in the study area. The module undertakes the iterative procedure of allocating the best ranked cells for each objective according to the goals, looking for conflicts and resolving them based on the weighed minimum-distance-to-ideal-point logic [5].

Result and discussion

After standardization and weighting of criteria maps, they were overlaid based on SI values calculated. Figure 3 demonstrates suitability of ETKA's lands for rangeland and agricultural land uses. According to the obtained results, out of total area of 45724.4 ha in Abesard, approximately 18888.7 ha equal to 41.3% is not suitable for any of the agricultural landuses (rain-fed and irrigated). About 23.9% of ETKA's lands in Abesard has a high suitability for agricultural landuse. In Deyr o Moreh region with a total area of 127066.2 ha, 967258 ha equal to 76.1% of the entire study area was recognized unsuitable for agricultural land uses. Only a small piece of 0.43% was evaluated to have a second-degree suitability for farming. Moreover, 22.64% equal to 28769.1 ha and 0.79% equal to 1016.0 ha were categorized in 3 and 7 suitability classes for agricultural and rangeland purposes, respectively. No area was evaluated suitable for agricultural land use in Sarpoulak region. A large part of the region (94.32%) was classified in poor suitability class for rangeland land use. In Lar region, a vast area of 11737.5 ha was found unsuitable for agricultural land use. The smallest and largest site selected patches in this region were related to the class 1 (with an area of 57.1 ha) and class 7 (with an area of 3121.3 ha), respectively. Approximately, 878.3 ha of total area of Lazour region was classified in high suitability category while the rest area was recognized to be unsuitable for agricultural land use. According to the results, there was found no area suitable for agricultural land use in Varamin region. Only a small piece of land in Houmand was evaluated to be poorly suitable for rangeland land use (class 7). In overall, a large part of ETKA's lands (68.08%) is not suitable for agricultural land use.

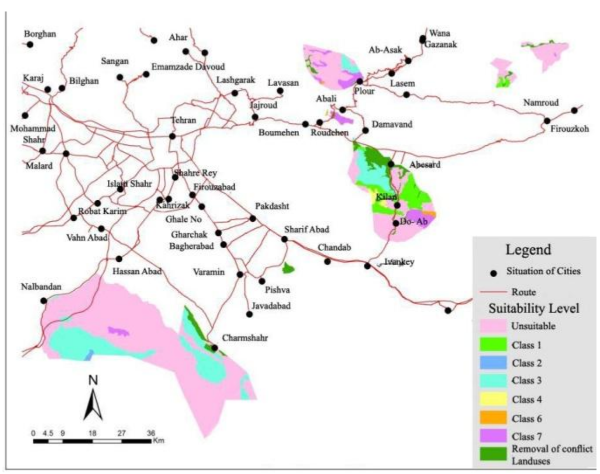


Fig. 3. suitability of ETKA's lands for rangeland and agricultural and rangeland land uses

Due to severe height restrictions and steep slopes, no area was recognized suitable for urban development except for a small patch with an area of 835.7 ha equal to 0.41% of total study area. An area of 4481 ha was found to be moderately suitable for industrial development. Figures 4 and 5 depict suitable areas for urban and industrial development.

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

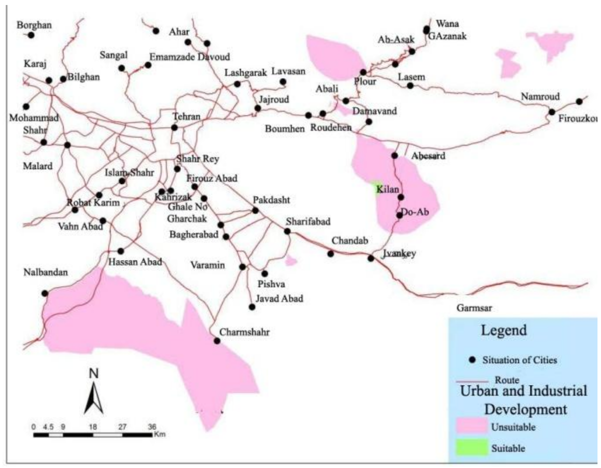


Fig. 4. suitability of ETKA's lands for urban development land use

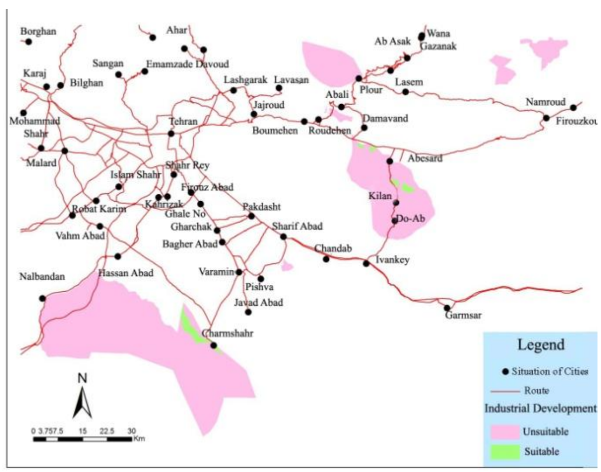


Fig. 5. suitability of ETKA's lands for industrial development land use

Decision criteria for indoor and outdoor recreational land uses were categorized into two main environmental and socioeconomic groups. The environmental criteria was divided into physical and biological sub-criteria. Physical criteria include climate, topography, geology, and pedology. Climate is comprises of tow sub-criteria of temperature and precipitation. Aspect, slope, and elevation substitute topographic criteria. Fauna and flora are two main components of biological criteria. As the obtained results suggest, out of total area of Abesard region (45724.4 ha), 21482.7 ha was recognized unsuitable for neither outdoor recreation nor indoor recreation land uses. Suitable areas for outdoor and indoor recreation land uses comprise 3678.7 ha and 17176.0 ha of total area in Abesard, respectively. About 117566.9 of total area of Deyr o Moreh (127066.2 ha) were found unsuitable for recreational land use. Sarpoulak region does not have suitability for indoor recreation however, tow patches with total areas of 84.6 ha and 1407.2 ha were categorized in classes 1 and 2 of outdoor recreation. No suitable area was found in Varamin region for recreational land use. Approximately, 6077.4 ha of Houmand and 3093.9 ha of Lazour were evaluated suitable for outdoor recreation. In overall, 5% of the entire study area equal to 9938.7 ha was found suitable for recreational land use while a large part of 9325.1 ha has no suitability for tourism development. Figure 6 illustrates suitability of ETKA's lands for indoor and outdoor recreational land use.

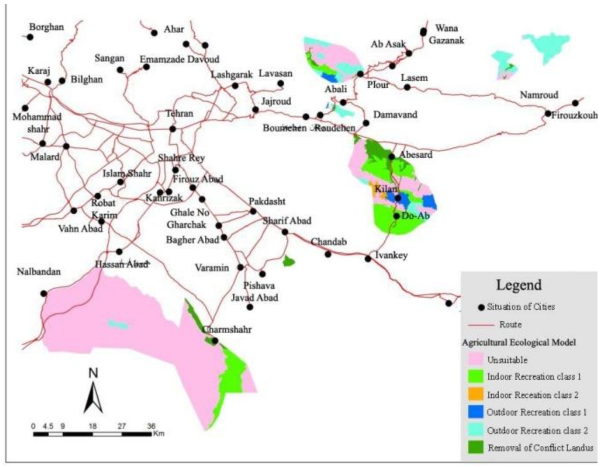


Fig. 6. Suitability of ETKA's lands for indoor and outdoor recreational land use

In this research, land capability evaluation was done separately for different land uses (agriculture, tourism, urban development, industrial development). At the end, it was found that particular patches of ETKA's lands highly suite for more than one land uses. Therefore, MOLA module was used to allocate various land uses in the study area. Before running the module, land capability map layers were prioritized using AHP method based upon ETKA's strategies. According to which, highest priorities were given to agricultural, urbanization, industrial development and tourism land uses in an ascending order. Table 3 gives the pair-wise comparison matrix for priority setting of different land uses.

Table 3. Pair wise comparison matrix for priority setting of different land uses in ETKA's lands

Land use	Agricultural land use	Urban development	Industrial development	Recreational development	Relative importance
Agricultural land use	1	6	7	9	0.514
Urban development	1/6	1	6	8	0.247
Industrial development	1/7	1/6	1	7	0.181
Recreational development	1/9	1/8	1/7	1	0.058

Following priority setting, different land uses were allocated in the study area. The obtained land use planning map is presented in Figure 7.

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

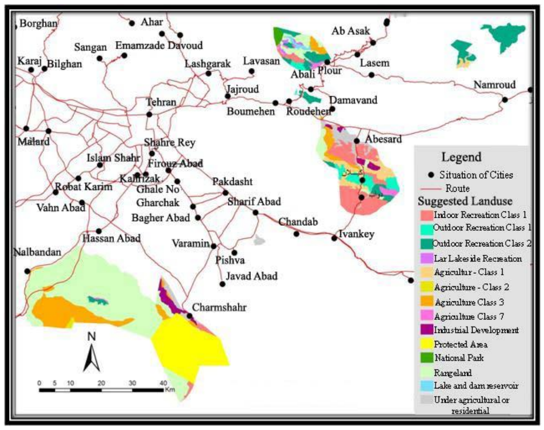


Fig. 7. land use planning map of ETKA's lands in Tehran

Conclusion

The present study presents a multi-objective GIS-based framework for land use planning of lands owned by ETKA Organization. For this, capability of seven pieces of ETKA's lands in Tehran was evaluated for agricultural, tourism, urbanization, and industrial development land uses. The land uses were allocated using MOLA (Multi Objective Land Allocation) module in IDRISI Software. According to the obtained results, 0.58% of the total study area has high suitability for agricultural land use. Steep slopes and highlands restrict suitable places for urbanization. As such, only a small patch, with an area of 835.7 ha (0.41% of entire study area) has a medium suitability for urban development. Around 4481 ha of the whole study area was recognized suitable for industrial development. Moreover, suitable places for outdoor and indoor recreation land uses comprise 4571.6 ha and 27495.9 ha of the study area. The research findings indicated that multi criteria decision-making methods are powerful tools in land capability evaluation and land allocation studies. A fundamental problem in land use planning process is to consider the interest of various stakeholders. SAHP involves stakeholders' viewpoints in priority setting and weighting process. Accordingly, decision-making will be done by participation of all stakeholders and their opposition can be prevented. As another advantage, SAHP has a mechanism to control team members' bias by consistency analysis of priority setting process. It provides the possibility of quantifying qualitative criteria. In overall, although S-AHP is a powerful method in land use planning studies, however, it is required to use other methods to compare the obtained results and choose those closer to the reality.

Acknowledgment

We would like to appreciate proofreading services rendered by **Ravian Danesh Mohit** Company.

(DOI: dx.doi.org/14.9831/1444-8939.2014/2-6/MAGNT.53)

References

1. Zhang J, Fu M, Zhang Zh, Tao J, Fu W. A trade-off approach of optimal land allocation between socio-economic development and ecological stability. Ecol Model 2014; 272: 175-187.

2. Wang SH, Huang ShL, Bud WW. Integrated ecosystem model for simulating land use allocation. Ecol Model 2012; 227: 46-55.

3. Mousa AA, Desoky IM. Stability of Pareto optimal allocation of land reclamation by multistage decision-based multipheromone ant colony optimization. Swarm Evol Comput 2013; 13: 13-21.

4. Liu X, Ou J, Li X, Ai B. Combining system dynamics and hybrid particle swarm optimization for land use allocation. Ecol Model 2013; 257: 11-24.

5. Kheirkhah Zarkesh MM, Ghoddusi J, Zaredar N, Soltani MJ, Jafari S, Ghadirpour A. Application of Spatial Analytical Hierarchy Process model in land use planning, Journal of Food, Agr Environ 2010; 8(2): 970-975.

6. Nizeyimana E, Opadeyi J. Geographic Information System (GIS): Land Use Planning. Enc Environ Manag 2011. DOI:10.1081/E-EEM-120002264.

7. Qin Y, Jixian Zh. Integrated application of RS and GIS to agriculture land use planning. Geo-spatial Inf Sci 2002; 5(2): 51-55.

8. Lewis PG. Land Use and Planning in Local Government. Encyclopedia of Public Administration and Public Policy, Second Edition, 2011. DOI:10.1081/E-EPAP2-120026191.

9. Pilehforooshha P, Karimi M, Taleai M. A GIS-based agricultural land-use allocation model coupling increase and decrease in land demand. Agr Syst 2014; 130: 116-125.

10. Siddiqui MZ, Everett JW, Vieux BE. Landfill siting using Geographic information systems: A demonstration. J Environ Eng 1996; 515-523.