Int. J. Environ. Res., 4(4):701-712, Autumn 2010
ISSN: 1735-6865

A GIS Based Assessment Tool for Biodiversity Conservation

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Received 12 March 2008; Revised 15 April 2010; Accepted 25 April 2010

ABSTRACT: Infrastructure development often leads to considerable changes in the land use. These changes are major causes of habitat fragmentation and ecosystem loss. Moreover, decrease of the environmental impacts on biodiversity is among the most important objectives of sustainable development. For this purpose, Environmental Impact Assessment (EIA) along with the other appropriate tools can be applied to identify and predict the magnitude of such problems. Biodiversity Impact Assessment (BIA) as a specific disciplinary tool could be useful to identify the actual impacts on biodiversity within Environmental Impact Assessment. This tool with the assistance of Geographic Information system (GIS) techniques evaluates the data in a comprehensible way. In this paper, a brief case study dealing with the assessment of road alternatives has been carried out to demonstrate the efficiency of BIA. It is found that according to vegetation and wildlife maps, ecosystem loss and fragmentation score of proposed road are more than the existing one. On the basis of the assessment results, the authors also stated that application of BIA in Iran with an exclusive biodiversity is essentially needed.

Key words: Infrastructures, Biodiversity Impact Assessment, Environmental Impact assessment, Fragmen tation, Habitat loss

INTRODUCTION

In the recent years ample attention has been paid to various environmental pollution in Iran (Mehrdadi *et al.,* 2007a; Torkian *et al.,* 2007; Mehrdadi *et al.,* 2007b;); however the ecological studies are scanty.

One of the most significant anthropogenic modification of terrestrial habitats in the past century is the network of roads that has become a pervasive component of landscape worldwide (Trombulack and Frissel, 2000; Roe *et al.,* 2006). In fact, biodiversity loss is due to its potential impacts on ecosystem functioning (Bigg *et al.,* 2008; Irsen and Carpenter, 2007; Loreau *et al.,* 2002). Thus, establishment of GIS- based (Geographic Information System) ecological models as the prediction tool for biodiversity assessment has been considered. Numerous studies have addressed the importance of infrastructures development reduction in order to protect the wildlife habitat (Forman and Alexander, 1998; Nellemann *et al.,* 2003), but a few environmental impact statements (EIS), take advantage of biodiversity models. Furthermore, many planning decisions carried out in infrastructure and other development issues causes the fragmentation of natural habitats which result in both habitat loss and isolation, as well as habitat degradation (Opdam and Wein, 2002; Gontier *et al.,* 2006). Petroleum development and hydroelectric power dams form are some of the energy extraction (Kakonen, 1993; Mahonay and Schaefer, 2002), which expand network of roads, pipeline or power line. On the other hand, habitat loss and fragmentation are commonly associated with linear projects which, in turn, lead to considerable impacts on biodiversity at genetic, species and ecosystem levels. At these levels, Environmental Impact Assessment (EIA) should be essentially considered (Slootweg and Koholf, 2003). Generally, in this proceeding, there are often uncertainties and problems during the assessment of ecological impact. While, in initial stages of EIA, such as planning, design and construction phase of a new road way, the most important object is recognition of a wide range of ecological impacts. This has led to establishment of a specific disciplinary field namely Biodiversity Impact Assessment (BIA). The most important objective of BIA is development and application of strategies for performing the analysis of the impacts on biodiversity within EIA (Geneletti, 2003). Hence, the

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main objectives of this study can be classified as a) exploration of the impacts of two different scenarios of roads with BIA, and b) considering BIA in local government land use planning and regulatory activities as routine as the other commonly considered elements such as EIA.

MATERIAL & METHODS

Arjan-Parishan is a biosphere reserve located in Southern Iran (Fars province; Fig. 1). This area is well known for Persian lion at both national and international level. Parishan Lake and Arjan wetland with exclusive biodiversity level increase the importance of the situation. This region has a warm, dry climate in Parishan zone and a cold semi humid climate in Arjan zone. Annual temperature varies from 12 °c in the northwest part (Arjan zone) and is usually limited to 24.4 °c in southern part of Parishan zone. There is a freezing period from October to April and an annual precipitation level between 328 to 1263 mm. Geomorphogically, the study area is characterized by mountain with slope over 20 percent and appendage unit with slope from 1 to 15 percent and in some places more than 20 percent. Dominant land cover types are forest (the most part of area), rangeland and agriculture lands. Two options including construction of a new road namely Dashtearjan-Poleabgineh and no action (or widening the present road) are evaluated in this study. As shown in fig.2. the Dasht Arjan – Pol Abgineh road is placed in Fars province, between Shiraz and Kazerun which passes through Arjan- Parishan biosphere reserve.

Since this study reviews the ecosystem level of biodiversity, the first step of ecosystem mapping is to arrange a suitable map for each criterion. Generally, according to the type of the roads, the maps which have a suitable spatial resolution (with scale ranging from 1:5000 to 1: 25000), date and information content are more appropriate (Geneletti, 2002). The main objective is to work out a method like BIA to arrive at actions for decision makers, with regard to type and size of scheme. Considering the ecosystem as the best level to state the condition of biodiversity, therefore the most common method for mapping ecosystem consists of mapping the vegetation (Geneletti, 2003) and wildlife types. The road effect zone makes it difficult to display the transportation impacts. On the other hand, the buffer distance must be subject to the construction standards. The GIS allows to link database to spatial features such as roads, vegetation types, etc, using geographic space as the unifying factor. It also enables to visualize and analyze the data in an understandable way (Vanderhaegen and Mora, 2005). Thus, in different layers, the baseline study could be generated with vegetation, wildlife and road features. In this literature, several studies have been performed. For example, Sarrien et al. (2005) observed that despite the differences in road size and traffic density, environ-

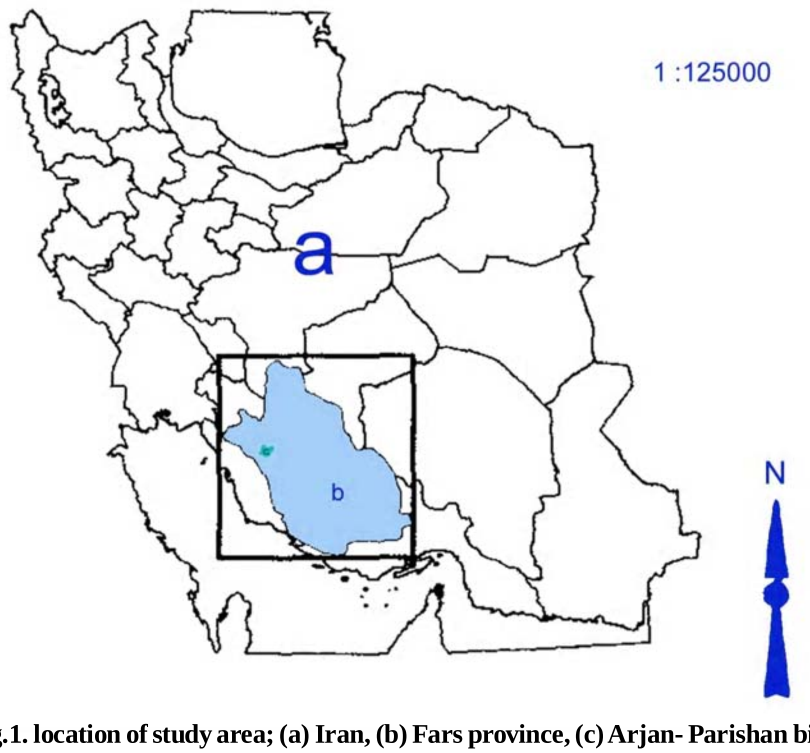

Fig.1. location of study area; (a) Iran, (b) Fars province, (c) Arjan- Parishan biosphere reserve

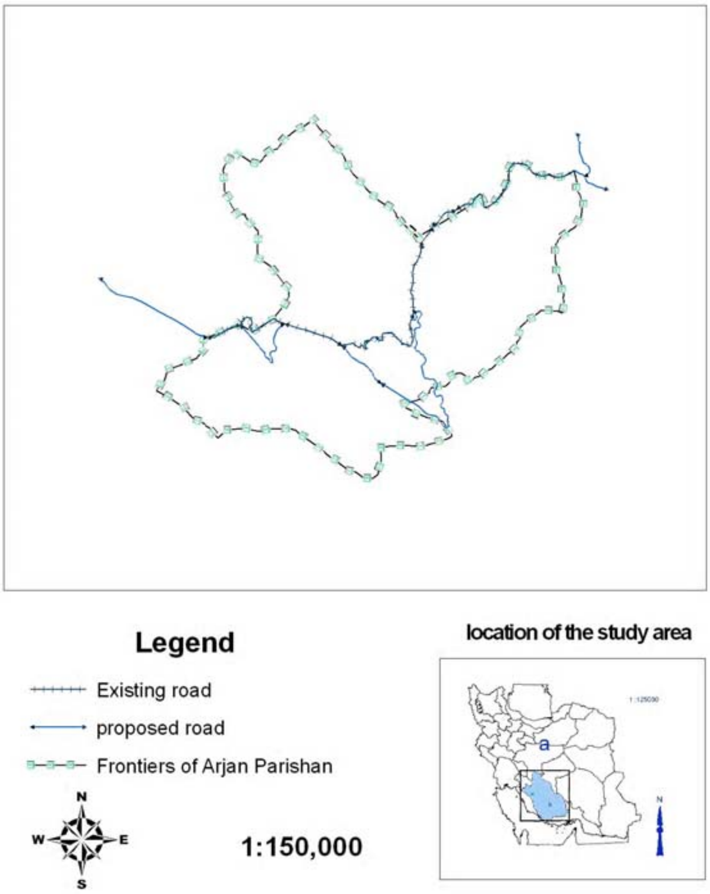

Fig. 2. The two different scenarios of roads

mental conditions were rather similar in the verges of highway, urban roads and rural roads, whereas to assess the potential widespread impacts of road development, a map of existing road with buffer is required. In addition, Biglin and Dupigny-Giroux (2006) concluded that the analysis of road effect used during the planning process is essentially needed in order to identify the environmental resources impacted by a road system (Danoff-Burgoff, 2007). In this study, since Dasht Arjan-Pol Abgineh road is a primary road with limited access; the appropriate distance was measured as 500 meter. Habitat loss is the broad scale removal of native vegetation, other plants or animal habitats resulting from human activity (Plieninger, 2006). For this stage, the map of natural ecosystems along with a map of the alternative road layouts proposed for the study area is the required data. At first, the rarity of natural ecosystem type with the remaining of related area in buffer road was estimated. Afterwards, multiplying these amounts and adding them up for each project alternative, the ecosystem loss impact could be measured. Rarity is the ratio of the actual cover to the potential cover of each natural ecosystem type. When the rarity has been measured for each type of the ecosystem in terms of percentage of potential remaining area, an assessor could indicate the actual assessment of such percentages. At the first step, the assessor transfers the values (actual assessment of the measured indicator) into a degree of relevance with respect to the preservation of natural biodiversity. Following this approach, the degree varies from 0 to 1.

In terms of the ecosystem type with nearly same score in potential and actual cover, there is the lowest chance to remain and corresponds value 1. Thus, protection of this ecosystem type contrary of the situation of zero value should be considered as the first preference. However, rarity can be meaningfully described only by referring to a scale of analysis (local, regional, etc.). In this survey, only the ratio of the actual cover to potential cover of each natural ecosystem was used because of the two following reasons:

1. consideration of regional scale
2. Non interference in the opinion of the assessor

Therefore, ecosystem loss impact would be calculated as follows:

$$\sum_{i=1}^{n} li = \sum (Aj * Rj)$$

where

$\sum li$ = ecosystem loss impact score of alternative j

Aj = predicted area loss for ecosystem type j

RJ = assessed rarity value of ecosystem type j

n = number of ecosystem types

The extent of habitat fragmentation is an important indicator of habitat quality because new road development may result in the reduction of habitat into smaller and more scattered patches (Kuo *et al.*, 2005). In order to predict the effects caused by fragmentation on each ecosystem patch, the ecosystem viability have to be assigned. On this basis, as presented in Geneletti (2004), three patch indicators (core area, isolation and disturbance) were described to predict the ecosystem viability through the above mentioned indicators. The core area was chosen because it simultaneously accounts for two fragmentation effects: the reduction in patch size and the increase in edge area.

Although this indicator can be computed with GIS but, the following equation which was carried out in Iran (Nejadi, 2008) is used.

Core area= S – (P * 72)

where

S: Spot area

P: spot perimeter

72: considered radius which is affected by external factors (this amount was taken in

View of forest ecosystem and expert knowledge)

Thus, by estimating the core area, in both the pre and post-project, the value of the region would be defined with respect to the total area of patch and the difference between the amounts. As shown in the following equation, such a score of each project by multiplying the rarity and their remaining area were computed.

$$\sum_{i=1}^{n} fi = \sum (VIj * Sj * Rj)$$

where

$\sum fi$ =ecosystem fragmentation impact score of alternative

VIj = assessed loss in viability of ecosystem patch j

Sj = area of ecosystem patch j

Rj = rarity value of ecosystem patch j

n = number of ecosystem patches affected by the project

The aggregation of the impacts maps into synthetic impact score is necessary for comparing the performance of the different alternatives. But, since this study only surveys one alternative, comparison of fragmentation impact score doesn't perform.

RESULTS & DISCUSSION

Since biodiversity has been used to locate important wildlife areas, transportation infrastructures and all above roads network are blamed for highly contributing to the decrease in both the quality and quantity of natural habitat (Geneletti, 2002). Based on this approach, the first survey was carried on vegetation and the patches of natural vegetation types are shown in Fig. 3. Different types of natural ecosystems of the study area can be seen in Tables 1 and 2. As it was mentioned, the rarity value of each ecosystem type is to be expressed by the ratio of the actual cover to the potential cover. Tables 3 and 4 express the rarity of different ecosystem types which are computed in different phases (pre and post-project). Then the comparison between the original ecosystem map and the other scenarios allowed the computation of the expected loss for each ecosystem type. The ecosystem loss value for pre-project ecosystem map was calculated as 318 while it was 594 for post-project. As it can be seen, the comparison between these scenarios expresses that the direct loss after the construction of the project is more than the existing one. Thus, the present road is more appropriate than the other one. Table 5 indicates the fragmentation impact score presented by aggregate of the impacts into a single score. This is particularly useful when the performance of several alternatives need to be computed. But, as in this study the value of different scenarios wasn't considered, the comparison of fragmentation has been not also performed. Therefore, the comparison of ecosystem loss for construction option and no-action was used. It is observed that for construction option the impact score was measured as 18. The assessment of the ecological value of animal species in the same way as vegetation type required BIA. The base line data are represented by a set of habitat maps which show the geographical range of distribution of the most significant animal species (Fig.5). The selected group of species was based on ecological value, conservation value, economical value, etc. The results presented in Tables 6, 7, 8 and 9 are similar to vegetation that show various condition of wildlife habitat.The ecosystem loss impact assessment comparable with vegetation types illustrated that impacts of road construction in this area are more than widening the existing one (Table 10). Fragmentation impact for wildlife was also evaluated, indicating that the post-project score is estimated as 11. The results of this process are shown in Table 11.

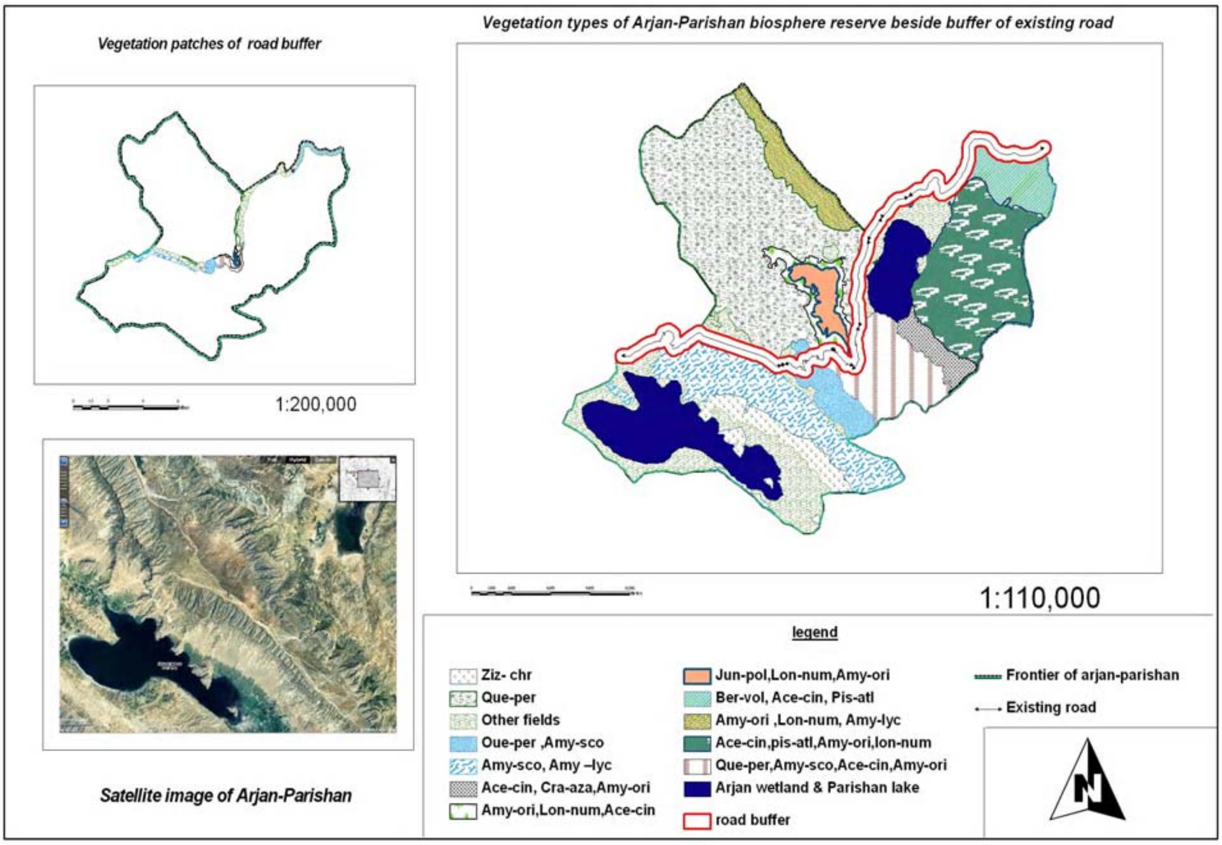

Fig. 3. Ecosystem map of the existing road (Vegetation)

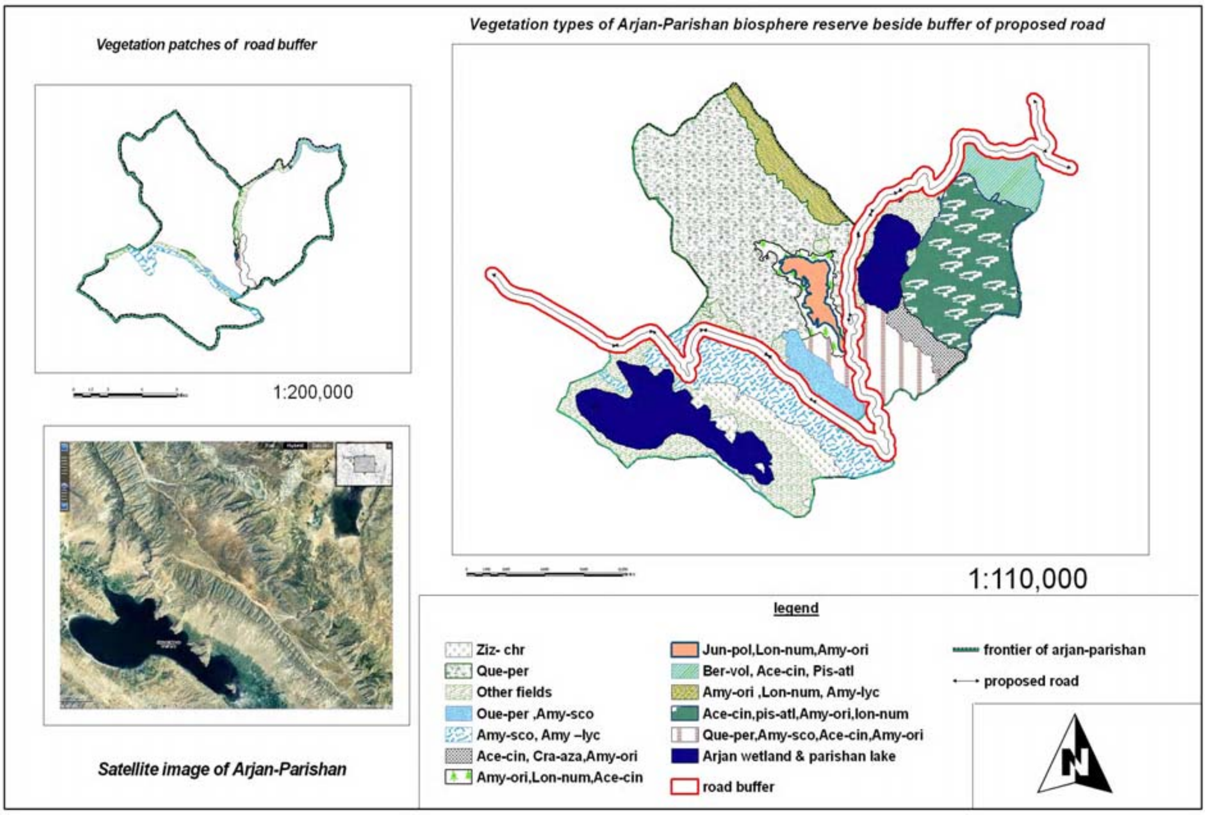

Fig. 4. Ecosystem map of the proposed road (Vegetation)

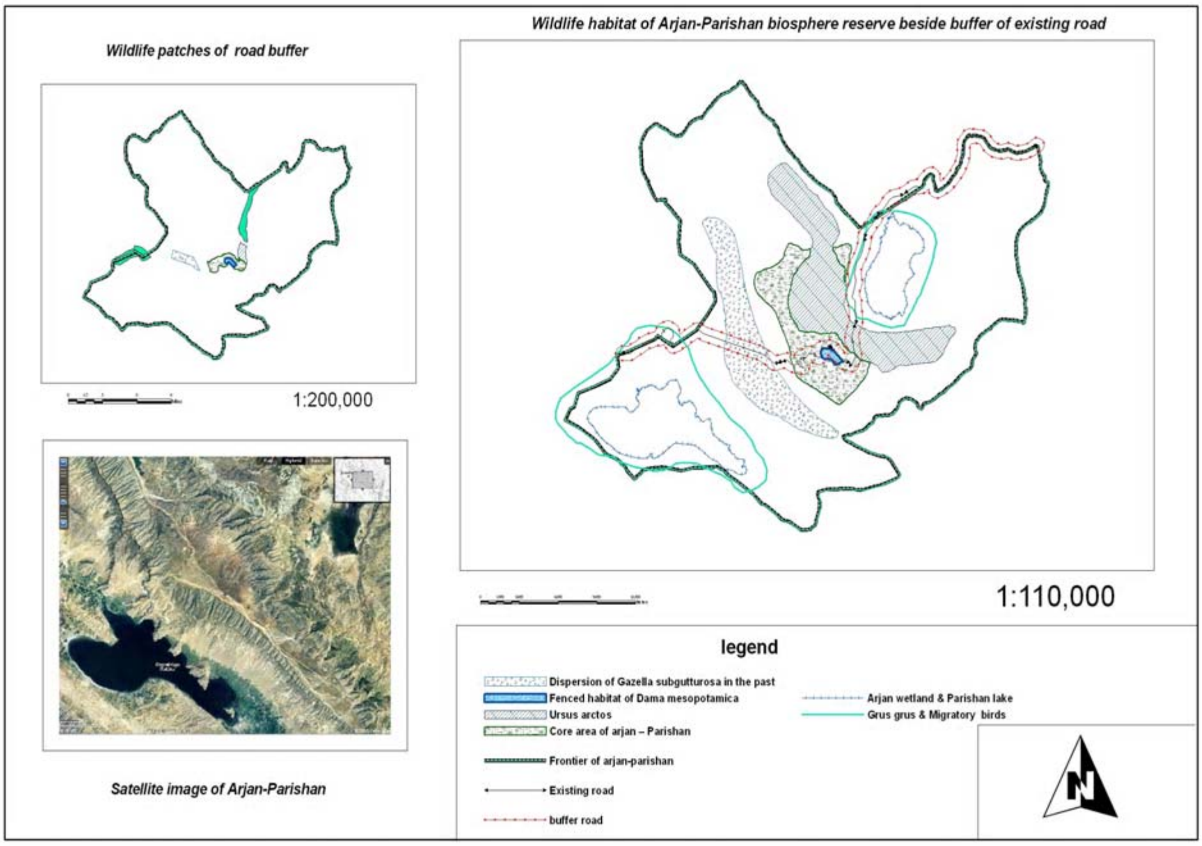

Fig. 5. Ecosystem map of the existing road (wildlife)

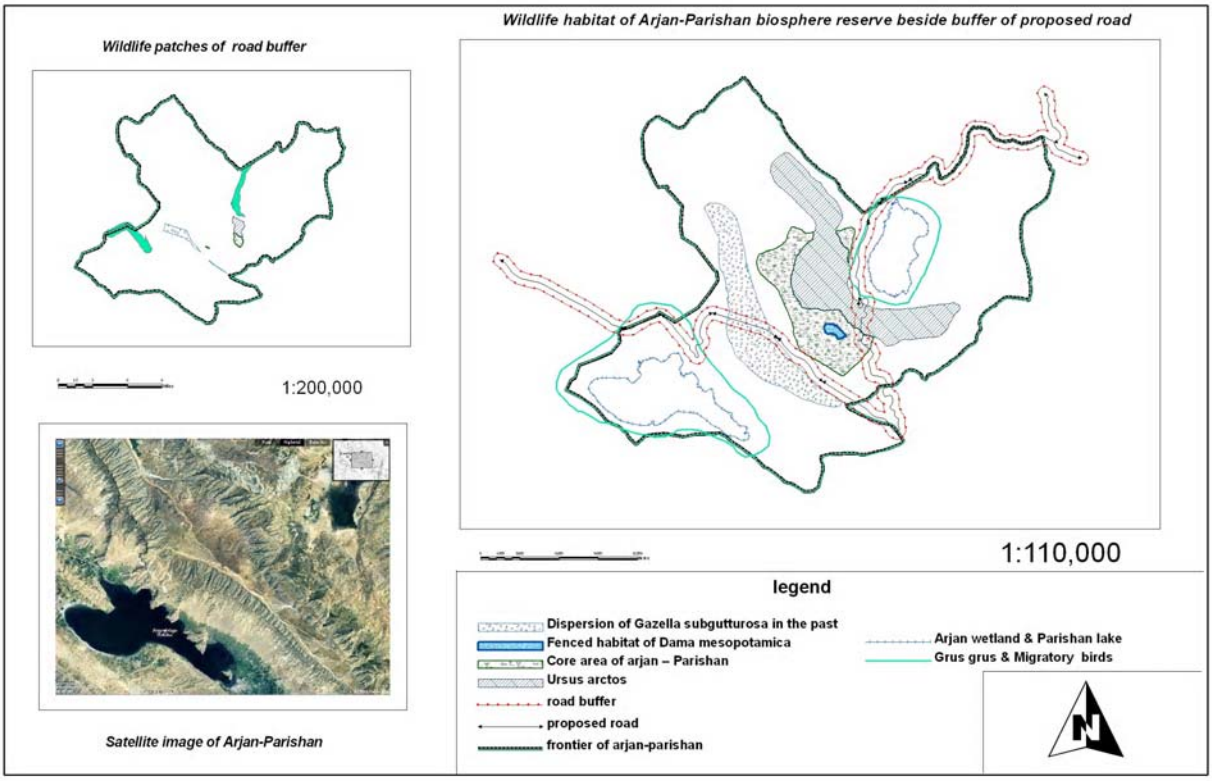

Fig. 6. Ecosystem map of the proposed road (wildlife)

Table 1. Condition of vegetation type in Arjan-Parishan before road construction

Vegetation type	Perimeter	Actual cover: Area in buffer (ha) S_1	Actual cover: Core area (ha)	Potential cover: Area in Arjan – Parishan (ha) S_2	$S_{1/}S_2$ (%)
Quercus Persica	24834	346	167	15197	2.27
Berberis Volgaris, Acer Cincrascens, Pistacia Atlantica	19706	486	344	2362	20.57
Acer Cincrascens, Pistacia Atlantica, Amygdalus Orientalis, Lonicera Numolaria	345	0.14	0	7781	0.001
	1058	7	0		0.09
	1408	5	0		0.06
	472	0.87	0		0.01
	514	2	0		0.02
Amygdalus Orientalis, Lonicera Numolaria, Acer Cincrascens	13861	182	82	1220	14.93
Juniperus Polycarpus, Lonicera Numolaria, Amygdalus Orientalis	4699	53	19	1137	4.65
Quercus Persica, Amygdalus Scoparia, Acer Cincrascens, Amygdalus Orientalis	18120	406	276	3963	10.25
Amygdalus Scoparia, Amygdalus Lycioides	24092	418	245	5973	7
Quercus Persica , Amygdalus Scoparia	8270	246	186	1688	14.56
	693	3	0		0.17
Other fields	35426	838	583	7888	10.6
	19614	515	373		6.52
	9364	162	95		2.05

Table 2. Condition of vegetation type in Arjan-Parishan after construction of road

Vegetation type	Perimeter	Actual cover: Area in buffer (ha) S_1	Actual cover: Core area (ha)	Potential cover: Area in Arjan – Parishan (ha) S_2	$S_{1/}S_2$ (%)
Quercus Persica	23234	336	169	15197	2.21
Berberis Volgaris, Acer Cincrascens, Pistacia Atlantica	19860	487	344	2362	20.6
Acer Cincrascens, Pistacia Atlantica, Amygdalus Orientalis, Lonicera Numolaria	345	0.14	0	7781	0.001
	1058	7	0		0.09
	1408	5	0		0.06
	473	0.87	0		0.01
	514	2	0		0.02
Amygdalus Orientalis, Lonicera Numolaria, Acer Cincrascens	5407	41	2	1220	3.32
Juniperus Polycarpus, Lonicera Numolaria, Amygdalus Orientalis	1609	11	0	1137	1
Quercus Persica, Amygdalus Scoparia, Acer Cincrascens, Amygdalus Orientalis	20162	796	651	3963	20.09
Amygdalus Scoparia, Amygdalus Lycioides	50879	1325	959	5973	22.18
Quercus Persica , Amygdalus Scoparia	14879	254	147	1688	15.05
Other fields	35757	841	583	7888	10.6
	24180	553	379		7.01
	9424	164	96		2.07
	659	2	0		0.01
	5263	54	16		0.68

Table 3. Rarity value of vegetation type in Arjan-Parishan before construction of road

Vegetation type	S_1/S_2 (%)	Rarity value
Quercus Persica	2.27	0.02
Berberis Volgaris, Acer Cincrascens, Pistacia Atlantica	20.57	0.2
Acer Cincrascens, Pistacia Atlantica, Amygdalus Orientalis, Lonicera Numolaria	0.18	0.001
Amygdalus Orientalis, Lonicera Numolaria, Acer Cincrascens	14.93	0.14
Juniperus Polycarpus, Lonicera Numolaria, Amygdalus Orientalis	4.65	0.04
Quercus Persica, Amygdalus Scoparia, Acer Cincrascens, Amygdalus Orientalis	10.25	0.1
Amygdalus Scoparia, Amygdalus Lycioides	7	0.07
Quercus Persica , Amygdalus Scoparia	14.73	0.14
Other fields	19.17	0.19

Table 4. Rarity value of vegetation type in Arjan-Parishan after construction of road

Vegetation type	S_1/S_2 (%)	Rarity value
Quercus Persica	2.21	0.02
Berberis Volgaris, Acer Cincrascens, Pistacia Atlantica	20.6	0.2
Acer Cincrascens, Pistacia Atlantica, Amygdalus Orientalis, Lonicera Numolaria	0.18	0.001
Amygdalus Orientalis, Lonicera Numolaria, Acer Cincrascens	3.32	0.03
Juniperus Polycarpus, Lonicera Numolaria, Amygdalus Orientalis	1	0.01
Quercus Persica, Amygdalus Scoparia, Acer Cincrascens, Amygdalus Orientalis	20.09	0.2
Amygdalus Scoparia, Amygdalus Lycioides	22.18	0.22
Quercus Persica , Amygdalus Scoparia	15.05	0.15
Other fields	20.37	0.2

Table 5. Ecosystem fragmentation score of vegetation type after construction of road

Vegetation type	Assessed loss in viability VL_j	Area of patch S_j	Rarity value R_j	VL_j* S_j*R_j
Quercus Persica	0	336.07	0.02	0
Berberis Volgaris, Acer Cincrascens, Pistacia Atlantica	0	486.7	0.2	0
Acer Cincrascens, Pistacia Atlantica, Amygdalus Orientalis, Lonicera Numolaria	0	14.81	0.001	0
Amygdalus Orientalis, Lonicera Numolaria, Acer Cincrascens	0.059	40.54	0.03	0.07
Juniperus Polycarpus, Lonicera Numolaria, Amygdalus Orientalis	0.01	11.41	0.01	0.001
Quercus Persica, Amygdalus Scoparia, Acer Cincrascens, Amygdalus Orientalis	-0.1	796.5	0.2	-10.92
Amygdalus Scoparia, Amygdalus Lycioides	-0.12	1325.09	0.22	-34.98
Quercus Persica , Amygdalus Scoparia	0.03	254.09	0.15	1.14
Total	-	-	-	-50

Table 6. Condition of wildlife habitat in Arjan-Parishan before road construction

	Actual cover			Potential cover	
Wildlife habitat	Perimeter	Area in buffer (ha) S_1	Core area (ha)	Area in Arjan – Parishan (ha) S_2	S_1/S_2 (%)
Capra aegagrus	2241	30	14	6027	0.5
	4853	69	34		1.15
Herpestes javanicus	9364	336	269	2449	13.73
Herpestes edwardsii	1686	15	2		0.59
Dama mesopotamica	5074	93	57	155	60.21
Ursus arctos	7935	234	177	5691	4.11
Dispersion of *Gazella subgutturosa* in the past	10339	377	302	4100	9.18
Branta ruficollis	18447	406	273	1497	27.1
Migratory birds *	18191	609	478	8797	6.92
	13298	598	502		6.79
Grus grus	18191	609	478	8797	6.92
	13298	598	502		6.79

* Vanellus vanellus, Tadorna ferruginea, Anser anser, Anser erythropus, Egretta garzetta, Aanser albifrons, Bbubulcus ibis

Table 7. Condition of wildlife habitat in Arjan-Parishan after construction of road

	Actual cover			Potential cover	
Wildlife habitat	Perimeter	Area in buffer (ha) S_1	Core area (ha)	Area in Arjan – Parishan (ha) S_2	S_1/S_2 (%)
Capra aegagrus	2596	26	7	6027	0.4
	3239	67	43		1.1
Herpestes javanicus	10523	423	347	2449	17.26
Herpestes edwardsii	1155	2	0		0.06
Ovis orientalis laristanica	1729	14	2	155	0.24
Ursus arctos	9020	294	229	5691	5.16
Dispersion of Gazella subgutturosa in the past	20173	437	291	4100	10.65
Branta ruficollis	19317	427	288	1497	28.5
Migratory birds *	19372	627	488	8797	7.1
	19541	856	715		9.7
Grus grus	19372	627	488	8797	7.1
	19541	856	715		9.7

* *Vanellus vanellus, Tadorna ferruginea, Anser anser, Anser erythropus, Egretta garzetta, Anser albifrons, Bubulcus ibis*

Table 8. Rarity value of wildlife habitat in Arjan-Parishan before construction of road

Wildlife habitat	**S_1/S_2 (%)**	**Rarity value**
Capra aegagrus	1.65	0.01
Herpestes javanicus *Herpestes edwardsii*	14.32	0.14
Dama mesopotamica	61.21	0.6
Ursus arctos	4.11	0.04
Dispersion of *Gazella subgutturosa* in the past	9.18	0.09
Branta ruficollis	27.1	0.27
Migratory birds	13.71	0.13
Grus grus	13.71	0.13

Table 9. Rarity value of wildlife habitat in Arjan-Parishan after construction of road

Wildlife habitat	S_1/S_2 (%)	Rarity value
Capra aegagrus	1.5	0.01
Herpestes javanicus *Herpestes edwardsii*	17.32	0.17
Ovis orientalis laristanica	0.24	0.002
Ursus arctos	5.16	0.05
Dispersion of *Gazella subgutturosa* in the past	10.65	0.1
Branta ruficollis	28.5	0.28
Migratory birds	16.8	0.16
Grus grus	16.8	0.16

Table 10. Ecosystem loss score of wildlife habitat in Arjan-Parishan

$\sum li$	Pre project	573
$\sum li$	Post project	725

Table 11. Ecosystem fragmentation score of wildlife habitat after construction of road

Wildlife habitat	Assessed loss in viability VL_j	Area of patch S_j	Rarity value R_j	VL_j* S_j*R_j
Capra aegagrus	-0.001	92.81	0.01	-0.0009
Herpestes javanicus *Herpestes edwardsii*	-0.03	424.4	0.14	-1.78
Ursus arctos	-0.01	293.76	0.04	-0.11
Dispersion of *Gazella subgutturosa* in the past	0	436.73	0.09	0
Branta ruficollis	-0.01	426.83	0.27	-1.15
Migratory birds	-0.02	1482.8	0.13	-3.8
Grus grus	-0.02	1482.8	0.13	-3.8
Total	-	-	-	-11

In the present condition, road construction, from the managers' point of view may be due to high economic profits while the lack of positive relationships between ecosystem and road activities would result in irretrievable effects on biodiversity loss. Transport infrastructure projects such as Dasht Arjan – Pol Abgineh road attempt to prompt economic development, but are also known to have undesirable impacts on unique areas. Hence, the failure to properly consider the importance of habitat may often result in significant road effects. Approval of the following literature is in the results of this study which demonstrates that the ecosystem loss impact score and the number of interference patches of post-project are more than the existing road. In other words, permanence of patches by widening existing road would be added.

EIS is needed for any project which affects the quality of the environment. In addition, biodiversity issues should play an important role throughout EIS. Thus, it is important to make use of clear tools for considering biodiversity in EIS. Although, a formal impact assessment stage is very often missing in EISs, which tend not to go beyond a mere description of the ecological features (Geneletti, 2006).

Byron et al (1999), by study of 40 recent UK road EISs illustrated that the explicit treatment of biodiversity impacts, in road EIA is often poor or non- existent. This confirms the results of Gontier et al. (2006), who reviewed a total of 38 EISs from four countries. They showed that, in many cases, the impact assessment often remained on a descriptive level and therefore considered only direct impacts, such as local habitat loss for some species, without considering indirect impacts linked to the overall habitat fragmentation on a landscape level. These considerations should be made during comprehensive habitat conservation planning and development of land use regulations which can limit such impacts (Crist *et al.*, 2000).However, using the guidance presented in Byron (2000) beside BIA tool ensures that the potential impacts on biodiversity are thoroughly addressed in road EIA. In this study with taking advantage of this guidance become clear that impacts of road in post-project would not be compensated.

The fragmentation approach of BIA tool is based on the results of landscape ecology. It also aims to assess the overall impact on ecosystem. This evaluation isn't same as the other models (Sluis 2001; Dale *et al.*, 1998; Foppen and Chardon 1998; White *et al.*, 1997) that are based on species and area requirement. This is because no target species were selected (Genelletti, 2004). In fact, limiting the evaluation to species that are formally protected still represents a rather common approach (Byron *et al.*, 2000).

In this way, to improve the management of biodiversity as part of the EIA process, the approach proposed for impact assessment along with the mentioned guidance could be applied for areas with a more vulnerable position. However, the use of BIA tool has certain shortcomings which have to be considered. For instance, the accuracy of assessment process could be affected (e.g. by the error in entered data and uncertainty analysis due to evaluation of the factors) (Nejadi, 2008). Thus, to enhance the clarity of the biodiversity, future studies should be done in the impact assessment procedure.This study also indicate that however, according to Noss and Cooperrider (1994) and Geneletti (2003), conservation, in many cases, is the most efficient when focuses directly on ecosystem but it is required to develop the studies of the impact on landscape, species and genes.

CONCLUSION

This study focuses on the assessment process which explores the interaction between infrastructure and biodiversity. Hence, BIA has been considered to estimate the impacts of Dasht Arjan – Pol Abgineh road on vegetation and wildlife. In terms of ecosystem preservation, the quantified data shows that the existing road is preferable to construction of a new road. The results also revealed that BIA could make the application of ecological assessment easier and more effective. Although there are different limitations in such tools, they could be used to eliminate the unclear aspects of current biodiversity assessment. Also application of BIA beside EIA in other linear infrastructures such as power lines, oil pipes, railway, monorail, etc can be considered of high importance.

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