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Forest landscape degradation assessment in Dokeh watershed, Iran

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Abstract: Degradation Model was introduced as an instrument of Environmental Impact Assessment (EIA) in Iran. Several methods are introduced in rapid environmental assessment, but none of them have evaluated landscape level. Thus, the main objective of this research is to introduce a new spatial method for EIA by using landscape metrics. A benefit of rapid assessment by using ecological landscape metrics is, understanding intensity of cumulative degrading activities in working units from past to present. The landscape degradation is $LD= \Sigma kI/Vi$. Where LD is equal to degradation coefficient of landscape compartments, ΣkI is the index of intensity of human activities in landscape working units, (I is the indicator of metrics and k is intensity of them) V stands for habitat vulnerability. The approach of this model is to emphasize on conservation of natural ecosystems (which their LD is low). Therefore, to introduce landscape degradation model, we considered Dokeh Watershed with 67600 ha, that is located in Gilan. Then, 13 sub watersheds were delineated as a measure for comparison between working units. The road and land use layers were overlaid to compute fragmentation. Then all landscape metrics were extracted for each working units. We arrangement these metrics as a total activity and number of patches (NumP) was considered as the habitat vulnerability in landscape degradation model. After computation of landscape degradation model, sub watershed 8, 9, 10 and 11 had the maximum number of degradation, which is suggested for development. In this study, we had correlated between satellite data, length of road, slope, number of patches, and data were extracted from landscape degradation model. These correlation were observed that red class in imaging data has the highest correlation with degradation (R^2= 0.61).

Keywords: Landscape Degradation Model, landscape Metrics, Rapid Environmental Impact Assessment, Dokeh, Gilan, Iran.

Introduction

Environmental Impact Assessment (EIA) is the critical appraisal of the likely effects of a policy, program, project, or activity on the environment. To assist the decision- making authority, assessments are carried out independently of the proponent, who may have prepared an environmental impact statement (EIS) (Erickson, 1994; Ndubisi, 2002). Sometimes impact assessing methods, proposed alternatives, plans and policy development are against to each other. Although EIA and environmental economic theories are useful facilities to measure the environmental capacities, but the results are not always effective due to the fact of quality measurement. A Decision Support Systems (DSS) as a useful instrument for solving these problems. One of Decision Support Systems that introduced in Iran is the Degradation Model (Makhdoum, 2002). Degradation Model has been applied first time by Makhdoum in 1993, to assess the environmental impact in East Azarbaijan. This method is one of the models of Iranian EIA that introduced in international level. Azari Dehkordi according to degradation model, after being applied in Sefidrod watershed case study (Azari Dehkordi *et.al*, 2003), Examined this model in Japan, for validation and modification degradation model in new scale and environment (Azari Dehkordi, 2005). The objective of applied this model, was to prevent repetitive review of degradation factors and intensity of degradation and ecosystem's

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vulnerability in addition to developing plan, predicting future degradation and preventing any likely occurrence in short time (Makhdoum, 2002).

Degradation model, overlap and check lists that uses in EIA are time consuming and expensive. Rapid Environmental Impact Assessment (REIA) is recommended when there is shortage in time and budget deficit. Rapid Environmental Impact Assessment (Anonim., 1999) studies the environmental limits and threats. One REIA model that introduced by Pastakia and Jensen (1998) proposes a Matrix for rapid impact assessment. Shueler (1994) rapid impact assessing model for sub-watershed in watershed that confirm upon man made impermeable layer. But except degradation model (Makhdoum, 2002; Azari Dehkordi, 2005) none of them has been taken in to consideration landscape degradation. In ecological landscape method spatial data are used to organize the hypotheses and evaluation procedure in landscape model and environmental management. There for a close relationship between types of current source data and this science, that recognition of their similarity and differences is one of principals in ecological landscape. A general model of landscape includes physical, biological, and cultural processes which are operating simultaneously in a region. On the other hand geological process, topography, soil, and land use, Cause to configure relation between landscape elements and distribution of species in landscape mosaic (Forman, 1995; Farina, 1998; Gergel & Turner, 2002). Consequently uses of these concepts for landscape evaluation, while time consuming and show a cumulative impact assessment.

There for the main aim of this paper is to introduce a technical method to measure the impact of human activities on Landscape and to identify the landscape degradation ratio per working units in study area and to provide the hierarchy between them.

Methodology

In this research, spatial data such as topography, hydrology network, roads network in 1:25000 scale and land use in the 1:50000 scale along with physical landscape metrics are used to execute the landscape degradation assessment model. The landscape metrics are used instead of degradation parameters and human activities intensity.

Degradation Model

One system (model) composed of input, procedure, and output. In degradation model human activities and ecological vulnerability are considered as an input, the procedure include the ratio of intensity activities & biological capacity. The out put is the number of degradation in landscape and ecosystem units. For a decision support system these numbers identify the hierarchy of degradation on working units. (Chamani *et.al,* 2005; Azari Dehkordi *et al*., 2003; Makhdoum, 2002). In this model working, units which possibly can be sub watershed, watershed, network or an environmental unit. Until now this model has applied in Iran and Japan.

Degradation model in Iran:

Degradation model is:

$$H_i = (\Sigma I + Dp_i)/V_i$$

In where H equals to degradation coefficient in working units (i), ΣI equals to cumulative impact of degradation factors in past and now, DP equals to density of population physiographic, V equals to habitat vulnerability per unit, and i is the working unit. In this model, all the degradation factors will be determined by field work in each working unit. Degradation factors in Iran are as follows:

Ploughed slope (PS), Irregular mining (ZM), Converting range to dry lands (XR), Converting fields to town (T), illegal land use (I L), Habitant degradation (HD), Converting forest to range (XF), Deforestation (X), soil degradation (SD), Soil contamination (YS), water contamination (YW), Air contamination (YA), Noise pollution (YN), illegal garbage discharge

garbage (G), taking fodder from wetlands (R), Impotent management (IM), Irregular grazing (OG), irrigation water supply from wetlands (W), illegal hunting (H), Oil pollution (YO), landscape pollution (YL) (Makhdoum, 2002).
In next step, DP will be calculated with this equation:

$$Dpi= Pi/Ari$$

Pi= number of population per unit
Ari= area of agricultural land in unit i.
And in next part ecological vulnerability will be evaluated based on ecological factors such as slope, elevation, climate, soil vulnerability and other factors (Makhdoum, 2002).

Degradation model in Japan:

This model was an amended type of Iranian one to make a suitable situation to compare one model in two entirely different environments (Azari Dehkordi, 2005). The equation of degradation in rural area in Japan is:

$$L_D = \sum kI / V$$

LD is equal to degradation coefficient of landscape compartments, ΣkI is the index of intensity of human activities in working units, (I is the indicator and k is intensity of them) V stands for habitat vulnerability. The list of degradation factors in Japan that made by (Azari Dehkordi, 2005):

forest cutting (FF), Deforestation (DF), Pesticide (PA), illegal garbage discharge (garbage) (G), car dumping in forest (SC), soil contamination (YS), converting fields to urban area (XF), constructional material factories (ZQ), Irregular road construction (IR), Physio-graphic Density (DP), Impermeable manmade layers (IP), collecting rare herbs (EC),

Ecological vulnerability is provided according to spacial maps such as slope, aspect, elevation, vegetation coverage density, soil and stone resistance in study area. Importance coefficient assigned based on information threshold because as factors reach the threshold environmental sensitivity changes as well (Azari Dehkordi, 2005).

Landscape degradation model:

The landscape degradation is

$$LD= \Sigma kI/Vi$$

Where LD is equal to degradation coefficient of landscape compartments, ΣkI is the index of intensity of human activities in landscape working units, (I is the indicator of metrics and k is intensity of them) V stands for habitat vulnerability .Picture 1 is Landscape Degradation diagram in Dokeh watershed.

List of activities in landscape degradation model

According to McGarigal and Marks (1995), the list activities in landscape degradation model is as follow:

Number of Patches in landscape (NumP), Median Patch Size (MedPS), Total Edge (TE), Edge Density (ED), Mean Patch Fractal Dimension (MPFD), Shannon's Diversity index (SDI) and Mean Shape Index (MSI)

Landscape ecological metrics are useful instrument to interference ecology in planning and they help to measure the quantity of landscape processes.

The process of landscape that concentrated in this study is fragmentation, which is one important process that effect function and structure of landscape and it can be a cause for landscape deviation into small pieces (Ahern and Andre, 2003).

Determination of activities intensity

At first, all the landscape metrics should be determined for each sub watershed and then the scope of each metric in each sub watershed will be categorized based on median. The median is a number, which divide data into equal part. In other word, it shows which part is the bigger 50%, and which part is the smaller 50%. To do this we use Excel program. In next step total of these metrics is considered as collection of landscape degradation activities. Activities are categorized then according to their quality in 4 classes based on Canter (1996) definition as follow: Code (1) Insignificant degradation, Code (2) Medium degradation, Code (3) Intense degradation, Code (4) high intense degradation. After comparing activities intensity (different metrics) with median scale, the intensity of each activity has been determined in working unit.

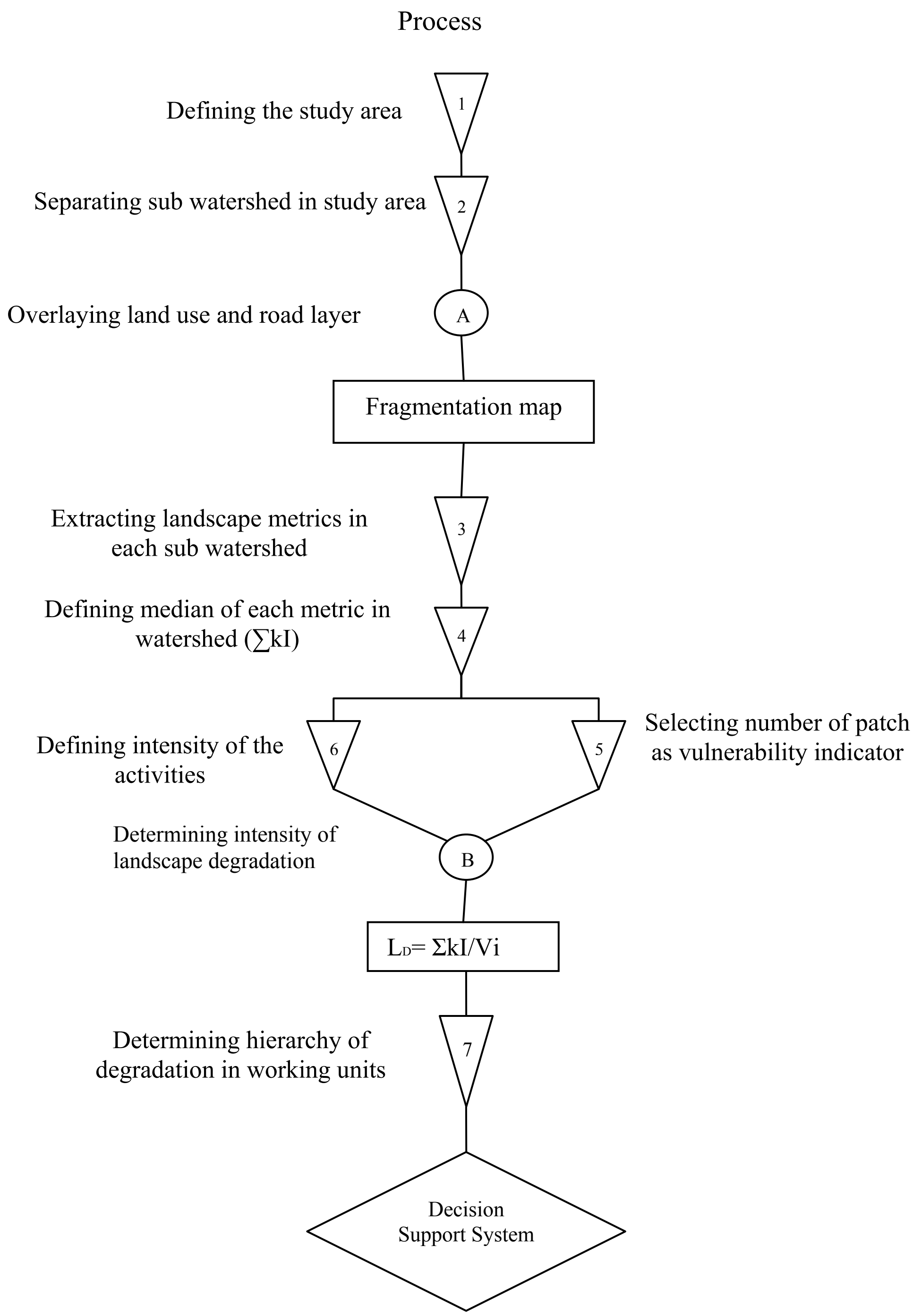

Figure 1. Fflow diagram of landscape degradation

Ecologic vulnerability in landscape model

Vulnerability is a degree that a system, sub system or its components will actually sustain damages and loss in case of being exposed to stimulant factors (Turner II et al, 2003). Some ways of vulnerability evaluation are as follows:

Vulnerability determination based on ranking of habitat (Rossi and Kuitunen, 1996), according to rapid watershed planning (Zeilinski, 2002) and using fuzzy logic expert system (Chenung *et al*., 2005)

One method to determine vulnerability is quantitative landscape by extracting, landscape metrics. Based on ecological landscape principals, when number of patches in ecosystem is fewer or in other word, when there is equal in land use in an ecosystem or sub watershed, that ecosystem is exposed to much less vulnerability (Gergel & Turner, 2002). The number of patches in landscape (Nump) is used to determine the ecological vulnerability.

Determination of scale to separate ecological vulnerability and activities intensity

This scale is based on median of data, explaining activities intensity in a form of quantity, first used by Azari Dehkordi (2005) in Japanese degradation model. Table No. 1 shows the level of vulnerability and table No. 3 shows scales attribute to each parameter in Dokeh watershed.

Table 1. Vulnerability level in Dokeh landscape

Vulnerability scope(NumP)	Vulnerability level
95>I1	Resistant
148 >I2≥95	Semi- critical
>I3≥148 296	Critical
I4 ≥296	vulnerable

Study Area

To apply the landscape degradation model we considered Dokeh watershed that is located in Gilan. Dokeh eastern longitudes are 48° 35' - 48° 55' and northern altitudes are 37° 36' - 37° 55'. (Figure 2)

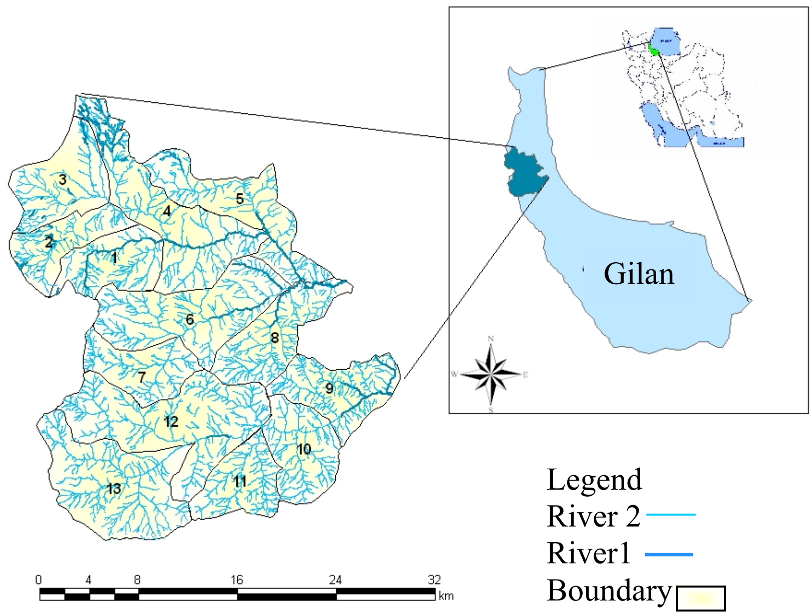

Figure 2. Map of study area

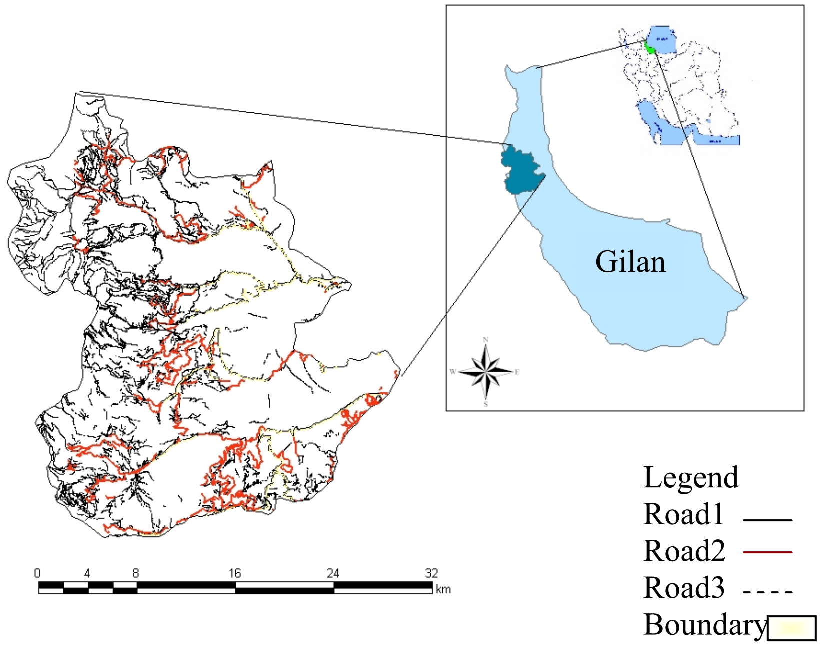

Figure 3. Roads of Dokeh watershed

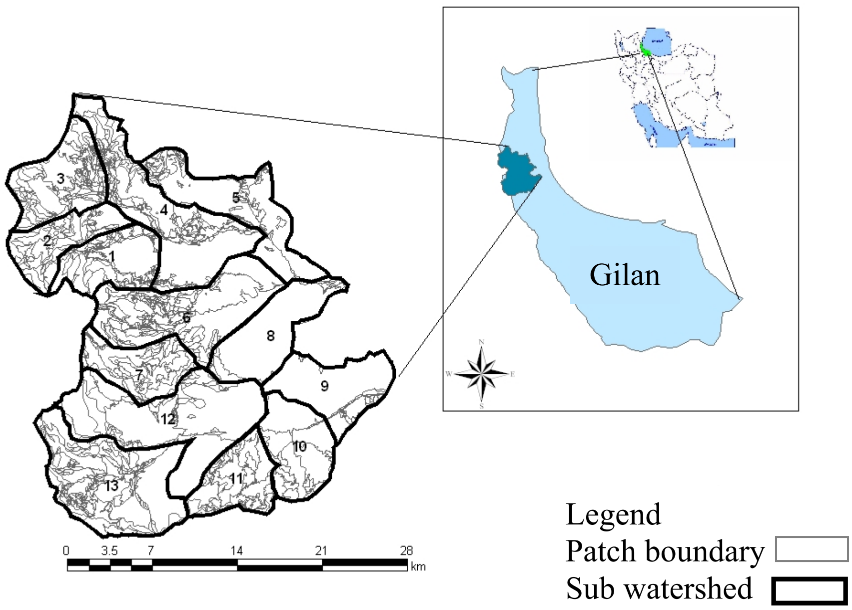

Figure 4- Landscape fragmentation of Dokeh watershed

After specifying watershed main boundary a number of 8 sub watershed has been identified by Strahler (1964) method, which is based on river classification system. In the next step the road (scale; 1:25,000), and land use (scale; 1:50,000) layers were overlaid to compute fragmentation.

Results

Figure 3 & 4 shown roads and landscape fragmentation maps in Dokeh watershed. Different metrics has been extracted by using figure 4. The results are shown in table No 2.

Table 2. Landscape metrics in each sub watershed of Dokeh watershed to extract degradation model

Composition				Configuration				**Num. sub watershed**
MPFD	**MSI**	**ED**	**TE**	**MEDPS**	**SD**	**MPS**	**NumP**	
1.42	1.71	0.009	33.9	1	5.05	13	285	**1**
1.34	1.64	0.008	25.9	5	4.21	27	119	**2**
1.39	1.69	0.009	41	3	4.98	17	254	**3**
1.39	1.6	0.008	58.1	2	5.38	17	443	**4**
1.38	1.65	0.006	34	2	4.54	24	222	**5**
1.39	1.69	0.008	58.4	1	5.22	18	400	**6**
1.35	1.76	0.009	30	5	4.32	25	136	**7**
1.41	1.73	0.003	11.2	3	2.88	90	49	**8**
0.98	2.46	0.003	12.7	3	3.22	73	57	**9**
1.33	1.8	0.004	16	9	3.18	97	41	**10**
1.17	4.82	0.008	27	5	3.9	35	94	**11**
1.43	1.73	0.004	34	4	4.14	61	148	**12**
1.34	1.72	0.007	56.4	6	5.01	32	248	**13**

In Table 3, Classification of landscape metrics separately in each sub watershed. Intensity of degradation for each of them has been extracted based on median of the data.

Table 3. Metrics classification in Dokeh

			Dokeh Subwatershed												
Metric scope	**Metric**	*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
I4≥296>I3≥148>I2≥95>I1	NUMP	Qt	285	119	254	440	222	400	136	49	57	41	94	148	248
		Int	13	12	13	14	13	14	12	11	11	11	11	13	13
I4≥62>I3≥27>I2≥20>I1	MPS	Qt	13	27	17	17	24	18	25	90	73	97	35	60	32
		Int	11	13	11	11	12	11	12	14	14	14	13	13	13
I4≥6>I3≥3>I2≥2>I1	MEDPS	Qt	1	5	3	2	2	1	5	3	3	9	5	4	6
		Int	11	13	13	12	12	11	13	13	13	14	13	13	14
I4≥46>I3≥34>I2≥22>I1	TE	Qt	34	26	41	59	34	58	30	11	13	16	27	34	56
		Int	13	12	13	14	13	14	12	11	11	11	12	13	14
I4≥0.009>I3≥0.008>I2≥0.005>I1	ED	Qt	0.009	0.008	0.009	0.008	0.006	0.008	0.009	0.003	0.003	0.004	0.008	0.004	0.007
		Int	14	13	14	13	13	13	14	11	11	11	13	11	12
I4≥3.27>I3≥1.72>I2≥1.66>I1	MSI	Qt	1.71	1.64	1.69	1.6	1.65	1.69	1.76	1.73	2.46	1.8	4.82	1.73	1.72
		Int	12	11	12	11	11	12	13	13	13	13	14	13	13
I4≥1.4>I3≥1.38>I2≥1.18>I1	MPFD	Qt	142	1.34	1.39	1.39	1.38	1.39	1.35	1.41	0.98	1.33	1.17	1,43	1.34
		Int	14	12	13	13	13	13	12	14	11	12	11	14	12
I4≥4.85>I3≥4.32>I2≥3.6>I1	SDI	Qt	5.05	4.21	4.98	5.38	4.54	5.22	4.32	2.88	3.22	3.18	3.9	4.14	5.01
		Int	14	12	14	14	13	14	13	11	11	11	12	12	14

*Qt.:**Quality,**Int.:**Intensity**

Table 4 shows intensity of activities, ecologic vulnerability, and number of landscape degradation separately.

Table4. Vulnerability and degradation number in sub watershed of Dokeh

Landscape Degradation LD=ΣkI/v	Vulnerability (v)	Intensity (ΣkI)	Number of Subwatershed
7.3	3	22	1
9	2	18	2
7.7	3	23	3
5.5	4	22	4
6.7	3	20	5
5.5	4	22	6
10.5	2	21	7
18	1	18	8
15	1	15	9
17	1	17	10
19	1	19	11
7.3	3	22	12
8.3	3	25	13

Table No. 5 shows degradation scope in Dokeh watershed based on development & protection ratio, which is according to fuzzy logic classification (Makhdoum,2002; Canter, 1996; Zadeh,1965;1975).

It aims to show those classes to which L_D belongs and to show the degradation which belongs to that special class. This method used for environmental impact assessment (EIA) first by Makhdoum (2002).

Table 5. degradation class in Dokeh watershed

Ratio for protection/development	Degradation Scope	Class
protect able	7>I1	L_{D1}
Needing landscape rehabilitation	8.3>I2 ≥7	L_{D2}
Protect able/ develop able	13.7> I3 ≥8.3	L_{D3}
develop able	I4 ≥13.7	L_{D4}

Conclusion

EIA studies have problems such as lack of time and information, therefore Rapid Impact assessment is recommended (e.g: Pastikia, and Jensen, 1998). But none of these methods include landscape cumulative assessment. One of the advantages of Rapid Impact assessment to determine environmental degradation is to access the state of environment rapidly. This method helps the classification of sub watersheds and also to identify the level of vulnerability and degradation in each sub watershed and to figure out their relation for future development. On the other hand it is possible to identify sub watersheds that suitable for restoration activities and to plan individually for each working unit. Planning should be done based on types of activities in each sub watershed (Zeilinski, 2002).

In Iranian degradation model, intensity of human activity's is determined based on field work and expert suggestions (Azari Dehkordi et al., 2003; Makhdoum, 2002; Chamani et,al. 2005). In that model physiographic density is separated from other parameters because the number of farmers working on fields is very important index in Iran (Makhdoum, 2002). This index in more industrialized countries like Japan, which has entirely mechanized agriculture, is not considered as an important index; rather it is just a factor among the others. (Azari Dehkordi, 2005). In rapid impact assessment model, we used ecological landscape metric as degradation factors, so the decision support system will be extracted separately in each working unit (Figure 5.)

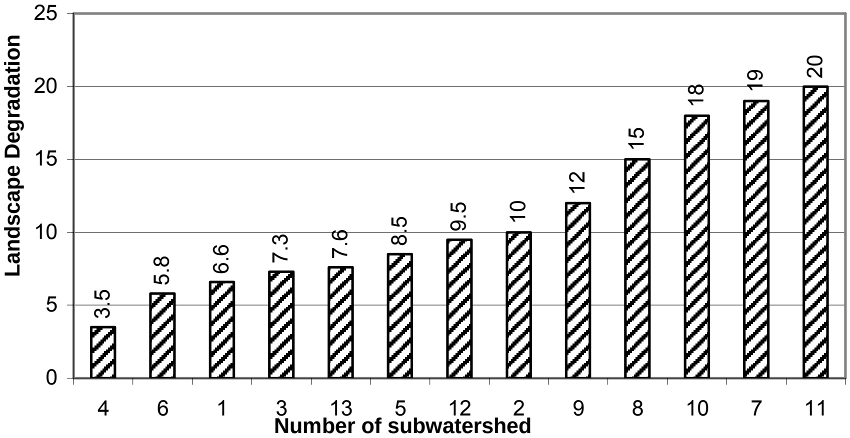

Figure 5. Hierarchy of degradation in each sub watershed

As illustrated in figure 5, sub watershed 8 to 11 in Dokeh watershed had the maximum number of degradation, which is suggested for development. Because recent new landscape degradation model for the purpose of maintaining current situation and develop the capacity in those previously developed units in order to prevent deforestation.

For validation of results we had correlated between satellite data (landsat1998) in near infrared spectrum and data were extracted from landscape degradation model.

According to this theory if region had maximum degradation, the redness is low, in other word that ecosystem being in the first succession (Steven et.al, 2003).

We had correlated between satellite data, length of road, slope, number of patches, and data were extracted from landscape degradation model (table 6).

Table 6. Results of regression between degradation and different parameter

Parameter	redness	slope	Road length	Number of patch
Degradation number	R^2=0.6	R^2= 0.6	R^2=0.5	R^2=0.6

One limitation of landscape degradation model in application is scale limitation. The best scale for watershed study is the landscape scale (Tress et.al, 2005). Study in landscape scale to cause integrates ecological, cultural and aesthetical values. We have environmental impact assessment in regional or local scale without integration (Tress et.al, 2005).

Some landscape metrics changes by changing scale, these metrics are number of patch (NumP), edge density (ED), and Shannon diversity index (SDI). Furthermore the expansion of study area is an effective factor. (Gergel and Turner,2002).

A benefit of using ecological landscape metrics in rapid environmental assessment is awareness about landscape degradation in a short time.

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