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SEFIDROOD RIVER SUB-WATERSHED-DAM-ESTUARY AND DEGRADATION MODEL: A HOLISTIC APPROACH IN IRAN

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ABSTRACT: The major concern of this article is to address the shortcoming and outgoing effects of the human activities on the landscape patterns and their consequences in the Sefidrood River watershed in Iran. A flow of data includes three inputs; each of them belongs to one part of three zones of a fluvial system. The three parts of the Sefidrood River fluvial system include Zone 1, a sub-watershed as degradation modeling site, Zone 2, Sefidrood Dam as dam site, and Zone 3, 17km away from the Sefidrood River path to the Caspian Sea as ending point site. The degradation model in the Zone 1 provides a suitable mean for decision support system to decrease the human impacts on each small district. The maximum number for degradation coefficient belongs to the small district with the highest physiographic density, relatively cumulative activities, and a lower figure for the habitat vulnerability. The human degradation impact were not limited to the upstream. The investigation to the Sefidrood Dam and ending point of the Sefidrood River depicts that sedimentation continues as a significant visual impact in the Sefidrood Dam reservoir and the estuary.

KEY WORDS: degradation modeling; Sefidrood River watershed; Sefidrood Dam; Iran

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1 INTRODUCTION

In Iran, environmental landscape degradations have been increasing year after year (Department of Environment, 1992) while most of them are due to mismanagement and poor land use practices (MAKHDOUM, 1993). A few of studies reported the landscape degradation by using degradation model as a decision support system (MAKHDOUM, 2002). To detect the patterns of human impact on landscape development, a gradient of landscape modification has been observed (FORMAN and GORDON, 1986). NAKAGOSHI and OHTA (1992) and MANDER and JONGMAN (2000) emphasized that these are strongly related to socio-economic environment, which is a petrolium-agricultural base for Iran (Department of Environment, 1992).

Degradation model (DM) as a digested information model (MAKHDOUM, 1995) was introduced to address the ongoing problems of decision-making in Iran. The model provides the decision-makers with a set of quantitative measures to observe affected areas and simply distinguish between critical and non-critical areas for further development plans (ECCLESTON, 2000). However, most managers were uncertain about the meaning of computed degradation coefficients resulting from the DM, unless a paired comparison techniques (CANTER, 1996) were applied. A "hard uncertainity" (YOUNG, 2001) occurred, though most decision-makers believed that the application of DM would provide: 1) quantitative measures for decision-making; 2) digested information for resources allocation; 3) detailed information about population pressures on resources; 4) habitat vulnerability; and 5) ongoing cumulative environmental impact. However, mathematical analysis of the system to demonstrate the internal structure of the problem is not always possible. In this study authors managed to add GIS layers to quantify and calculate habitat vulnerability. We go beyond a specific site for degradation modeling and

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consider *holism* to reveal that human degradation activities in up stream may affect distant vicinities such as dam or estuary. A holistic concept provides us a way to find the origins of environmental deteriorations, and improve the idea of how to reduce the undesired impacts.

The purposes of this study are 1) to address the human effects on landscape degradation in the study area through degradation modeling—a decision-making support system (DSS) tool, and 2) to observe possible relationship amongst the sub-watershed, dam and the estuary in the Sefidrood River watershed by a holistic approach.

2 STUDY AREAS

In the three zones of a fluvial system (SCHUMM *et al.*, 1988), a sub-watershed in Zone 1 was selected to search the human activities in the Sefidrood River watershed. Then to control the possible consequences of the human degradation activities in the upstream in a holistic point of view (WALL, 1994; BEWS, 1935), Sefidrood Dam (in Zone 2) and Sefidrood River estuary (in Zone 3) were selected as the significant entities to be concerned.

2.1 Sub-watershed

The sub-watershed, with an area of 1179.2km^2, is located between 47°00′ to 47°33′E, and 35°41′ to 35° 49′N (Fig. 1). Pirmahmood Mountain (2642m a. s. l.) is the highest and the lowest elevation (1610m) is located in the northeast of the area. In this area, 47.35% and 52.65% of the total residents are living in the urban and rural areas in a hierarchy respectively and agriculture is the main socio-economic activity. There are 64 villages in the area and one city (Divandarreh). The average of the population density excluding the city was 10 persons/km^2 (Plan and Budget Organization, 1994b). The sub-watershed is divided into 11 sub-sub-watersheds (small districts) (Fig. 1) to prepare a suitable mean for comparison and calculations (Table 1).

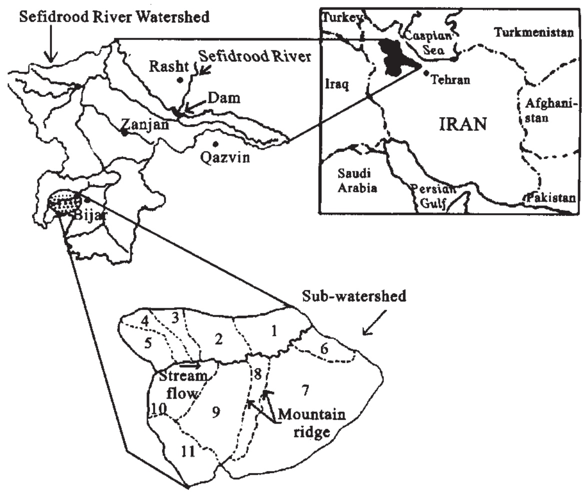

Fig. 1 Study area

Table 1 Population, agricultural land and area of each small district

Small district	Population	Agricultural land(km^2)	Total area (km^2)
1	740	52.0	89.6
2	1572	81.6	91.2
3	712	35.2	35.2
4	290	38.4	38.4
5	10775	54.4	54.4
6	168	25.3	44.8
7	2302	412.5	412.8
8	889	48.0	56.0
9	1694	149.5	155.2
10	1941	104.0	110.4
11	910	59.0	91.4
Total	21993	959.9	1179.4

2.2 Sefidrood Dam

Sefidrood dam is located at a distance of 260km from Tehran. The construction of the dam had taken seven years and finished in 1961. The dam lake area in maximum water level is 56km^2, the capacity of the reservoir is 1.8×10^9m^3, and 80m is the gap between the highest and the lowest water level (Plan and Budget Organization, 1968).

2.3 Sefidrood River Estuary

The Sefidrood River meets the Caspian Sea through Kiashahr Port. The estuary shape is similar to an "eagle head" (observed from the sky). Investigation site in the Zone 3 started from the Astaaneh Bridge to the Caspian Sea with a distance of 17km in both shorelines of the Sefidrood River.

3 METHODS

The degradation model was introduced in practice as a tool for environmental impact assessment of the past and present development projects of the country (MAKHDOUM *et al.*, 1997). The flow diagram of the degradation model components for the sub-watershed is shown in Fig. 2. The degradation model equation is: $H = (\sum I+DP)/V$, where H is degradation coefficient of the habitat, I is cumulative impact of human activities, DP is physiographic density of population, and V is habitat vulnerability (MAKHDOUM, 2002). Followings are the detailed explanations of each component.

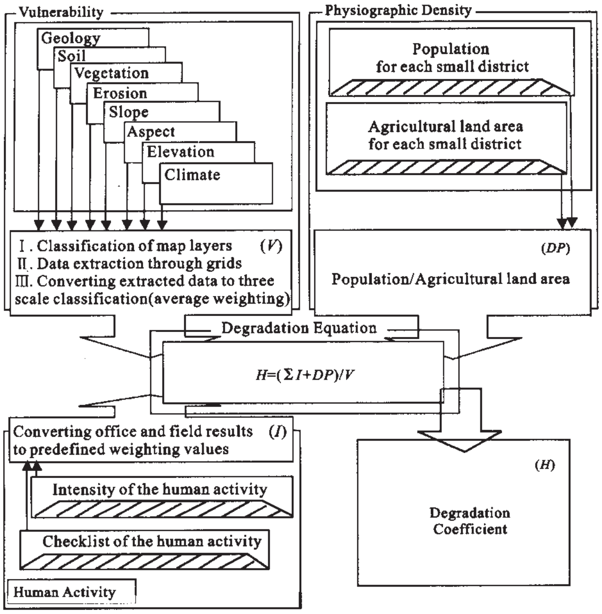

Fig. 2 Flow diagram of degradation model

3.1 Degradation Coefficient of Habitat

H or degradation coefficient of habitat is a decision-making tool. The unit area for degradation coefficient of the habitat may be a set of catchment areas, suburbs, factories, or arbitrary ecosystems (MAKHDOUM, 1992). The final coefficient numbers lead us to hierarchies in the units of the area.

3.2 Cumulative Activities

The estimation of the cumulative activities, or human degradation activities (I) was arranged through fieldwork. The checklist of the human degradation activities and their abbreviations for all the uses that causes land degradations are as the followings: poaching (H), conversion of rangelands to dry farmlands (XR), conversion of forests to ranch (XF), conversion of forests to dry farmlands (X), tree cutting for fuel (ZF), bush cutting for fuel (Z), poor mining practices (ZM), haphazard road construction (IR), use of wetland water for farming (W), conversion of farmlands to urban areas (T), overgrazing (OG), plowing along slopes (PS), poor land-use practices (IL), air pollution (YA), noise pollution (YN), water pollution (YW), soil pollution (YS), rubbish dumping (G), mismanagement (IM), reed cutting in wetlands (R), scenic disorder (YL), and petroleum dispersion at sea (YO) (MAKHDOUM, 2002). The cumulative activities are made up of human degradation activities (in the checklist) multiplied by the intensity of the activity that was investigated through field and office work. Pictures and the checklists of each small district were compared and each small district was scored for the observed activities. The predefined impact weighing values are: 1, 2, 3, and 4, which stand for "light", "medium", "severe", and "very severe" in a hierarchy (MAKHDOUM, 2002) that later multiplied each activities.

3.3 Physiographic Density

Physiographic density of the population, which provides a better index of human intensities and pressure than relative intensity (MILLER, 1979), was calculated after estimating the agricultural land area and the population for each small district.

3.4 Habitat Vulnerability

Based on the types of the ecosystem key variable weighs, vulnerability has three categories (CANTER, 1996). Roman numbers were used to show each category: Ⅰ stands for very vulnerable, Ⅱ vulnerable, and Ⅲ semi-vulnerable. The vulnerability determined by overlaying the eight layers of maps (1:250 000) including topography (elevation), erosion, aspect, climate, slope, geology, soil, and vegetation. The data of different maps were extracted through 737 grids (each grid 0.5cm×0.5cm) coordinated to the small districts borderlines (Fig. 3). Table 2 shows the classification

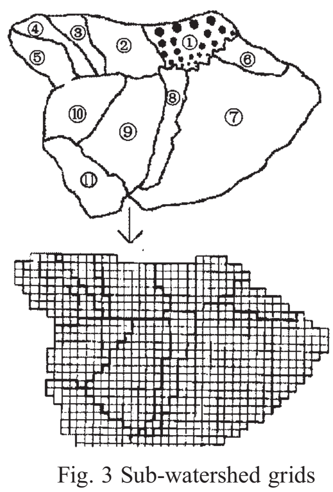

Fig. 3 Sub-watershed grids

Table 2 Classification of layers

Layer	Elevation(m)	Code	Slope(%)	Code	Aspect	Code	Erosion(t/ha)	Code
1	<1700	1	0–2	1	Plateaue	1	<5	1
2	1700–1800	2	2–5	2	South	2	5–20	2
3	1800–1900	3	5–8	3	West	2	20–100	3
4	1900–2000	4	8–12	4	North	3	100–200	4
5	2000–2100	5	12–15	5	East	3		
6	2100–2200	6	15–30	6				
7	2200–2300	7	30–65	7				
8	>2300	8	>65	8				
Layer	**Climate**	**Code**	**Vegetation(%)**	**Code**	**Soil(cm)**	**Code**	**Geology(stone)**	**Code**
1	Very humid	1	75–100	1	>180	1	Very resistant	1
2	Humid	2	50–75	2	120–180	2	Resistant	2
3	Semi-humid	3	25–50	3	60–120	3	Not resistant	3
4	Medium	4	0–25	4	30–60	4	Susceptible	4
5	Arid	5			<30	5	Very susceptible	5

of the layers for each map. The elevation, slope, and aspect were considered as 8, 8, and 5 layers of classification (MAKHDOUM, 1993) in a hierarchy. The climate, geology, soil, erosion and vegetation were considered as 5, 5, 5, 4, and 4 layers (Plan and Budget Organization, 1994 a, 1994b, 1994c, 1994d, 1994e). To each layer vulnerability code was added, and the higher number of the code stands for a more vulnerable layer than a smaller one. For example, slopes above 65% are more vulnerable than that of 2%–5%. The results of the classifications assigned weighted values were converted into a three-scaled category. Quatro Pro 6 (similar to Excel) did all of the calculations and data arrangement.

3.5 Dam and Estuary Observation

In 1997 the upstream, dam, and the estuary of the Sefidrood River were observed to address the possible relationship amongst them. Then the result of observed significant visual impacts was concerned to understand the role of the human degradation.

4 RESULTS

4.1 Degradation Model

Table 3 depicts the results of the fieldwork in the sub-watershed. The small district 11 has the highest number for the human degradation activities or the cumulative impact, while the numbers for the small districts 4 and 6 are the least. The total numbers for these cumulative impacts are shown in Table 4.

Physiographic density is the proportion of population to agricultural land area. Table 1 shows the population and area of different small districts. The physiographic densities are different amongst the small districts. The small district 5 has the highest physiographic density of the populations (198.07 persons/km^2), while the minimum of about 5.58 persons/km^2 belongs to the small district 7 (Table 4).

The ecological vulnerability was calculated by average weighting calculation for each small district in three-scales (CANTER, 1996), that are very vulnerable(2.0–3.0), vulnerable(1.0–2.0), and semi-vulnera-

Table 3 Results of fieldwork for human activities

Small district	Intensity and types of human degradation activities
1	$XR_3+OG_2+PS_3+H_2+Z_2$
2	$XR_3+OG_2+PS_3+Z_2+IR_2$
3	$XR_2+OG_3+PS_2+Z_2+IL_2$
4	$XR_2+OG_2+PS_2+H_2+Z_2$
5	$XR_3+OG_2+PS_3+H_2+Z_2+IL_2$
6	$XR_2+OG_2+PS_2+H_2+Z_2$
7	$XR_2+OG_2+PS_2+H_2+Z_2+IR_1+YW_1$
8	$XR_2+OG_1+PS_2+H_2+Z_2+IL_2+YW_1$
9	$XR_2+OG_2+PS_2+H_2+Z_2+IR_1+YW_2$
10	$XR_2+OG_3+PS_2+H_2+Z_2+IL_3$
11	$XR_3+OG_2+PS_3+H_2+Z_2+IL_3+IR_2$

Note: The lower marks of numbers stand for the code of human activities

Table 4 Degradation numbers and figures used for calculation

Small district	*I* (Human activity)	*DP* (Physiographic density)	*V* (Vulnerability)	*H* [$H=(\Sigma I+DP)/V$]
1	12	14.22	2.07	12.66
2	12	19.26	1.98	15.78
3	11	20.23	2.00	15.61
4	10	7.55	2.00	8.77
5	14	198.07	2.08	101.95
6	10	6.65	1.79	9.30
7	12	5.58	1.97	8.92
8	12	18.52	2.14	14.26
9	13	11.33	1.90	12.80
10	14	18.66	1.92	17.01
11	17	15.37	1.28	25.28

ble[0−1.0] categories (Table 4). Then to calculate the degradation coefficient ranking, the parameters in Table 4 were applied to computing degradation coefficients. The results demonstrate the degradation level of small districts by nominal figures. This calculation repeated 11 times for the 11 small districts, of which only small district 4 and 5 mentioned here:

$$H = (\sum I + DP)/V$$

$$H_4 = [XR_2+OG_2+PS_2+H_2+Z_2 + (7.55)]/\text{II} = (10+7.55)/2 = 8.77$$

$$H_5 = [XR_3+OG_2+PS_3+H_2+Z_2+IL_2+ (198.07)]/\text{II} = (14+198.07)/2.08 = 101.95$$

These figures were classified into categories and criteria to provide decision-makers with a quantitative set of measures for further development plans.

4.2 Sefidrood Dam

The investigation continued in the watershed to the Zone 2, the transferring zone. Sedimentation was the most conspicuous visual impact in the reservoir of the dam, which in a Ministry of Energy report (1976), figured out at 45 000m^3 per year. And the report mentioned "since the implementation of the dam, the capacity of the reservoir reduced to half within 17 years". In September very year, reservoir desedimentation of the dam has undertaken by draining off (a technique in which the gates of the dam is opened up suddenly). Therefore, due to high tail-water level, olive orchards across to the dam's toe were destroyed and the gates of the dam were damaged, the restoration of which, however, was expensive in the Sefidrood Dam management.

4.3 Sefidrood River Estuary

Sedimentation was still the major visual impact, hence Sefidrood Bridge (connects two sides of the Kiahshr Port) construction has been postponed for about 25 years.

5 CONCLUSIONS AND SUGGESTIONS

The results of degradation model, dam, and ending point observation reveal that small district 5 has the highest degradation coefficient (101.95) due to high physiographic density, while small district 4 has the minimum (8.77). These numbers were converted into the six classes for decision-making support system (DSS) to provide a quantified base (Table 5). Therefore, small district 5 is the critically impacted area that needs conservation but the other small districts are suitable for further development. Small district 11 is in a state that may pass the line and fall into the second category entitled as " noncritically impacted areas". The longest duration to reach the nonecritically impacted areas belongs to small district 4 as its degradation coefficient is only 8.77.

Table 5 Classes for decision-making

Class	Category of degradation coeffcient (H range)	Criterion for decision-making
1	8.77−24.3	Prone to further development
2	24.4−39.83	
3	38.84−55.36	Noncritically impacted areas
4	55.37−70.89	(need rehabilitation)
5	70.90−86.42	Critically impacted areas
6	86.43−101.95	(need conservation)

Fig. 4 shows how a holistic point of view can connect the three zones of the Sefidrood River fluvial system through understanding of human-origin degradation sources. From Fig. 4, it is implied that how specific human activities impact such as conversion of rangelands to dry farmlands (XR), overgrazing(OG), plowing along slopes (PS), bush cutting for fuel (Z), haphazard road construction (IR), and poor land use practices (IL) intensify the soil washing out in sediment-source area. The impact of these activities appear in the Sefidrood Dam and the estuary of the Sefidrood River as heavy sedimentation. In other words, landscape mismanagement in the upstream and negligence to the ecological resources management were not limited to the small districts, but continues to the Caspian Sea as well.

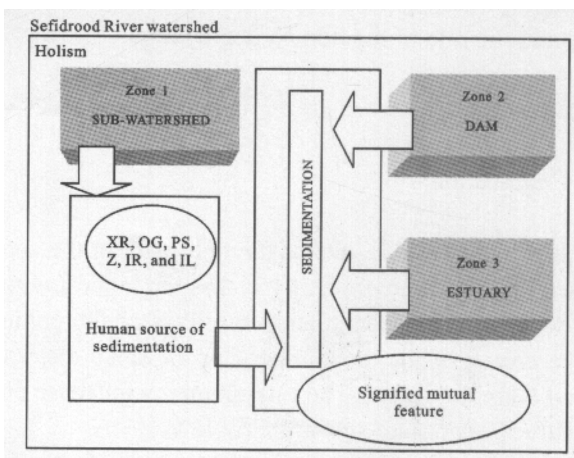

Fig. 4 Holistic approach in Sefidrood River watershed

These are some suggestions for reducing human impacts: converting plowing from along slopes to parallel to contour lines; 2) managing the population settlement in the area to gain a more sustainable land use toward small districts with lower degradation coefficient categories; and 3) reducing overgrazing and plowing along the slopes through mechanization of agriculture system and integration of husbandry. Table 5 includes six classes and six categories, but only three criteria for decision-making. That was to provide a suitable mean whenever uncertainity in decision-making occurs, for example the priority to donate agricultural facilities to small district 10 or 11.

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