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Original Research Paper

Evaluation of Wind Erosion Potential Using Empirical Method of IRIFR and GIS: A Case Study of Nishabur, Iran

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ABSTRACT

Erosion is a phenomenon during which soil and sediment materials are transferred by such damaging factors as water and wind. The type of erosion, of course, is different in various climates. As an example, in wet and semi-wet areas, water erosion is more likely than wind erosion. In turn, wind erosion is the main reason for damaging and transferring soil and sediment materials in arid and semi-arid zones, which can cover talented lands and bring about indispensable damage to land administrators. Wind erosion in arid zones is one of the most important processes of desertification, which is considered in different forms and in various models. Wind erosion status was investigated using the IRIFR method. In this method, nine parameters affecting wind erosion process including lithology, morphology and relief, wind velocity, soil characteristics, type and plant cover percentage, wind erosion features, soil moisture, type and distribution of sandy dune, land use and land management were considered. Ultimately, wind erosion index was classified in five classes. ArcGIS 9 was used to analyse and prepare the layers of quality maps to integrate the individual sub-indicator maps. Results show those areas classified under moderate category have a greater extent (61%) in the study area while areas under high and very high hazard cover 15% of lands.

INTRODUCTION

For the first time Bagnold (1941) introduced the wind erosion modelling through a series of empirical formulas to determine erosion threshold. Chepil (1957) began a vast research about wind erosion on the soil in farm conditions. In 1965 the first rather complete model of gray box type was proposed by Skidmore & Woodruff (1968) from USDA to evaluate the sediments of wind erosion. This method is called WEQ or Wind Erosion Equation. This model is used for soil management in cropping regions with agricultural features.

Another model called TEAM was introduced by Texas University researchers in 1999. In 1990s USDA researchers tried to propose a comprehensive computerized model of white box type which led to designing and introducing a model based on computer processes with physical basics and stronger capabilities called WEPS in 2000. The evaluation methods for wind erosion potential are performed through these three main ways:

1. The empirical methods (black box model): The evaluation of erosion and sediment amounts is done using some equations and empirical relations without analysing all relations and interactions influencing the erosion and sediment.

2. Direct measurement methods and the analysis of all relations in erosion and sediment (white box model): The application of this method is time consuming and expensive and all influential factors are not measurable by it, but it has a high accuracy.
3. Physical-empirical methods (gray box model): In this model a part of data is measured directly and another part is calculated through empirical formulas.

Despite the positive features of white and gray box models, these models require basic data and continuous measurement. Since there are not enough facilities of this type with proper continuity, the empirical and evaluation models should be used in soil loss estimation (Morgan 1986).

So for, meeting the needs of research projects in the country, a method like PSIAC model for water erosion was supposed to be introduced to evaluate wind erosion. This is an empirical model in which 9 factors influential in evaluating wind erosion were examined and finally by adding 9 scores in each facies of lands, erosion class and lands' eolian potential during the year was estimated (Ekhtessassi & Ahmadi 1995). Since most researches related to this method are performed with the cooperation of Iran Research Institute of Forest and Rangelands, the acronym IRIFR1[4] was introduced for this method. The advantages of IRIFR1 model which are offered for non-agricultural lands are as below:

1. Most of the current models for evaluating wind erosion sediment have coefficients which are accessed through a series of new researches and model calibration according to the region conditions.
2. The application of some models requires accessibility to basic data, statistic data and continuous measurements which makes their accessibility difficult or even impossible in short run.
3. Most introduced models in the world are offered for agricultural lands so they do not respond properly in non-agricultural lands.
4. The proposed model allows for rather quick and easy evaluation of wind erosion and soil loss in non-agricultural lands. Therefore, through the results, one not only evaluates the erosion and sediment potential of lands quantitatively, but also provides the proportional prioritizing of lands to the erosion.

MATERIALS AND METHODS

Study area: The study area, Fadishe plain, is located in the south of Neishabur in Khorassan Razavi Province (north eastern part of IRAN), 58°13' to 58°42' E and 35°41' to 36°7' N (Fig. 1). It covers an area of nearly 118643 ha. It has a minimum altitude of 1,040 m and maximum altitude of 1,625 m and comprises two geomorphologic main units: a mountain unit and a plain unit with 31 facies . The annual range of rainfall is 242 mm with a high inter-annual variability. In this arid environment, the hottest month is August and the coldest is February with mean monthly maximum and minimum temperatures of 21°C and 6°C, respectively. The wind is dry and generally cold and strong, blowing at great velocity sometimes reaching more than 45 km/h.

Methodology: Since there are not direct measuring facilities for wind erosion, the empirical methods should be used (cited from Morgan). For using the empirical models in evaluating erosion density and sediment potential, usually there should be a relation between the erosivity of the soil and its causing factor and the role of each factor should be evaluated.

In IRIFR1 method, like PSIAC model, the influence of 9 important and influential factors in wind erosion and the sediment amount resulted from that is evaluated and scored and depending on the weakness and strength of each factor and its influence on the sediment, a score was given to it.

Fig. 1: The map of studied region's location in Razavi Khorassan Province (Iran).

Total resulted figures for different factors will show the severity of the wind erosion. In this method the study of 9 factors related to IRIFR1 method along with related scores are presented and analysed. Nine factors, influential in wind erosion in IRIFR1 method, are given in Table 1.

For applying the mentioned method, first by adjusting the basic maps such as slope, land use, aspect of slope, geomorphology, geological factors and erosion facies, the smallest units with the same erosion potential (work-units) in the region were separated and after referring to the location and separating the scoring forms, severity of wind erosion and sediment potential resulting from the role of 9 factors influential in wind erosion in each work-unit and the whole studied region were determined.

Evaluation of sediment amount: The sediment amount in work-units and region was estimated by summing all scores related to different factors used in the model. This is done in GIS environment by overlaying different layers and preparing the required maps based on the resulted scores and each stage is saved in a database linked to maps. Table 2 can be used to determine the sediment potential from the last score derived from summing different scores of factors in each work-unit. For having more accuracy, the relation between sediment degree and the amount of sediment production can be also used. The recent relation in IRIFR1 method is:

$$Qs = 41\ e^{0.05R}$$

Qs: The annual sediment amount per ton in km^2 per year

R: Sediment degree (total scores of 9 factors influential in soil erosion by IRIFR1 method)

RESULTS AND DISCUSSION

Results from using IRIFR1 empirical model derived from total scores of 9 factors influential in wind erosion are shown in the form of different erosion classes in Fig. 2. Table 3 shows calculation method of wind erosion in some work units. The area of each erosion class is also given in Table 4.

As indicated, moderate erosion class with 71594.79 ha has the largest area and the mountainous regions and the regions without wind erosion or very low erosion class have the second place in area.

Table 1: The factors influential in soil erosion and sediment production with related scores in IRIFR1 model.

Row	The factors influential in wind erosion and sediment production	Score Range
1	Geology	0-10
2	Lands' shape and their ups and downs	0-10
3	The wind's speed and condition	0-20
4	Soil and its covering surface	-5-15
5	Vegetation density	-5-15
6	The erosion effects of soil surface	0-20
7	Soil moisture	0-10
8	The type and dispersion of wind hypothesis	0-10
9	Land use and management	-5-15

Table 2: Range of last score and sediment amount for wind erosion class in IRIFR model.

Score	Sediment amount (ton/ha per year)	Wind Erosion class
< 25	< 2.5	Very Low
25-50	2.5-5	Low
50-75	5-15	Moderate
75-100	15-60	High
> 100	> 60	Very High

Table 3. Calculation method of wind erosion in the southern region of Nishabur

Work unit	Score of the factors influential in wind erosion and sediment production												
	X1	X2	X3	X4	X5	X6	X7	X8	X9	Sum	Qs Ton/km2/yr	Area (km2)	Area (%)
1	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	2	4	3	2	3	0	0	0	3	17	96.633	2	0.14
11	7	7	6	7	5	3	4	2	7	48	452.221	3	0.25
12	7	7	6	7	5	3	4	2	7	48	452.334	3	0.26
13	9	7	10	10	3	5	5	2	2	53	580.024	2	0.19
14	9	7	10	10	3	5	5	2	2	53	580.228	5	0.39
15	1	4	3	2	3	0	0	0	3	16	91.247	2	0.15
17	1	4	4	2	5	0	2	0	3	21	117.375	4	0.3
18	7	4	4	2	5	1	2	1	2	28	165.956	1	0.05
19	9	7	6	7	5	5	4	2	7	52	552.012	0	0.03
20	1	4	3	2	3	0	0	0	3	16	91.247	1	0.11
21	7	4	4	2	5	1	2	1	2	28	165.931	1	0.12
22	1	4	3	2	3	0	0	0	3	16	91.247	2	0.13
23	1	4	3	2	3	0	0	0	3	16	91.247	0	0.03
24	1	5	5	0	2	0	2	0	3	18	100.844	0	0.03
25	1	4	3	2	3	0	0	0	3	16	91.247	1	0.07
26	7	4	4	2	5	1	2	1	2	28	166.263	1	0.05
27	4	4	4	2	5	1	2	1	2	25	143.872	9	0.76
28	1	4	3	2	3	0	0	0	3	16	91.247	15	1.25
29	1	4	3	2	3	0	0	0	3	16	91.613	2	0.2
30	1	4	4	2	5	0	2	0	3	21	117.199	4	0.34
31	.	.	.	.	.	.	.	.	.	.	.	.	.
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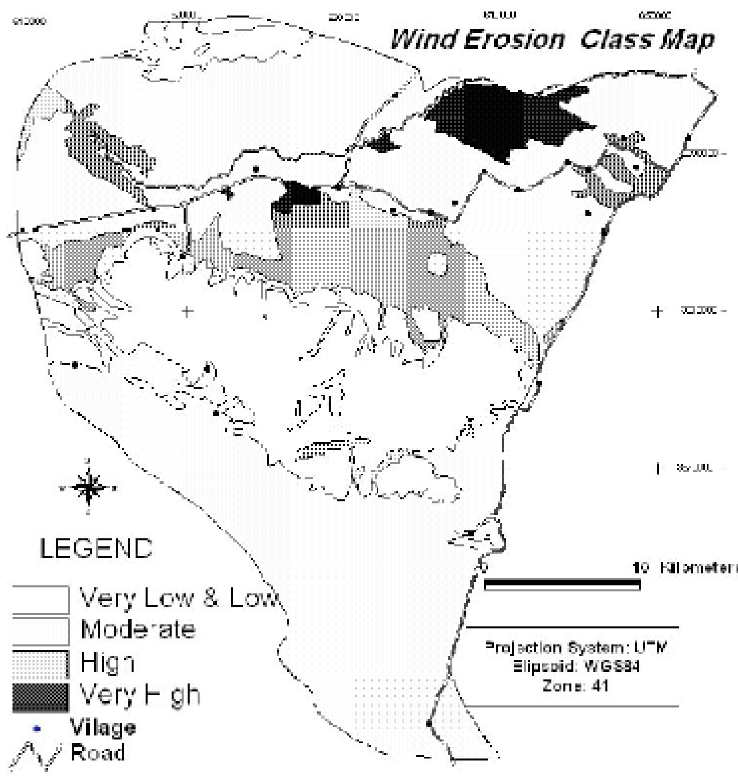

Fig. 2: Severity of wind erosion classes.

Table 4: The area of each wind erosion class in southern region of Nishabur.

Symbol	Severity of lands' erosion	Area (ha)	Area (%)
I0	Very low	18623.60	16
I	Low	10208.04	8
II	Moderate	71594.79	61
III	High	14514.21	12
IV	Very High	3703.18	3

Among studied work-units, 195, 209 and 210 with 3, 1 and 21 geomorphologic facies (Barkhan) in Erg area with 2600.79, 2597.29 and 2597.29 ton per km^2 per year have most scores. In other work-units, the wind erosion amount is highly reduced and is reducing toward one quarter and even more. Some areas in mountainous sections of the region, which are usually like regular slopes and one can see effects of carrying sand in the form of small nebkas formation and accumulation of the materials behind.

With due attention to the fact that part of the area has high and very high intensity of erosion and amount of sedimentation are very high and are part of active sand dune or coppice mound, so IRIFR method can be proved. The velocity of wind in the area approves such a phenomena and so Fadishe plain at the border of Kal-E-Shur located on the way of such winds which blow from Binalood and

Dizbad area towards west, so can say IRIFR method can be applied to prepare sensibility to erosion maps and classes of erosion which coincide with situation of such an area. So at down hills intensity of wind velocity decreases and bare stones could be found and the amount of wind erosion decreases.

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